Blockchain Enabled Demand Response Management in Internet of Vehicles

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Abstract

This dissertation investigates the integration of blockchain technology within the domain of Demand Response Management (DRM) in the Internet of Vehicles (IoV). The study is driven by the increasing integration of Electric Vehicles (EVs) into the energy ecosystem and a growing emphasis on decentralized energy resources. The aim of this study is to investigate the use of blockchain, as a technology for enhancing DRM in the IoV, addressing challenges related to energy management and secure data handling.

Electric vehicles have potential as decentralized energy storage systems, yet there are ongoing issues to be addressed, including DRM, managing the equilibrium of energy supply and coordinating the charging process. Centralized charging systems, currently in use, are limited in effectiveness and raise concerns about transparency and privacy. Blockchain technology emerges as a potential solution for these issues, yet its application in real-world IoV settings for privacy preservation and incentivizing participation is underexplored. Additionally, there is a notable absence of personalized EV charging strategies in existing studies, highlighting the need for empirical research on the effectiveness of blockchain-based DRM and personalized charging approaches in the IoV context.

To bridge this gap, a novel blockchain-based conceptual model for DRM in IoV is proposed. This model emphasizes tokenized incentives, user-centric profiles, adaptive charging schedules, bi-directional Peer-to-Peer (P2P) energy trading and privacy through blockchain capabilities.

The research adopts an interpretivist stance and a qualitative methodological approach, utilizing a multiple case study strategy to evaluate the proposed model. Four case studies, including organizations from both the academic and the industry area, provide rich empirical data.

While the empirical evidence supports the conceptual validity of the proposed model, it also reveals recommendations for further enhancement. Therefore, the proposed conceptual model is refined based on the empirical findings.

This research makes significant advancements, introducing a novel Blockchain-Enabled DRM Model for IoV, addressing key challenges in the field. This model is distinguished by its holistic approach, combining tokenized incentives, bi-directional P2P energy trading and user-centric profiles. The incorporation of blockchain not only enhances data security and transparency but also introduces a novel approach to incentivizing user participation through tokenized rewards. The model's emphasis on personalized EV charging strategies, based on user profiles, represents a significant leap in aligning DRM with individual user needs and behaviours. Additionally, the research introduces user-centric and blockchain-enabled DRM strategies. By centring the DRM process around the user, the study addresses a crucial gap in existing literature. Finally, the thesis incorporates environmental considerations into the DRM model, a novel aspect of the study. It addresses the energy consumption associated with blockchain technology and integrates renewable energy sources, aligning DRM practices with environmental sustainability goals.

In summary, this thesis extends the body of knowledge and contributes to the progress of blockchain technology in the context of IoV DRM, through a novel model development, empirical validation, user-centric approaches, and sustainability considerations.

Keywords: blockchain, internet of vehicles, demand response management, electric vehicles, energy, P2P energy trading, data privacy, tokenized incentives, user-centric approach, sustainability

Dedication

This dissertation is lovingly dedicated to Marios, my partner in life's journey. Marios, your support, insightful feedback, strength and love have been the guiding lights through the paths of this research endeavour. Your belief in me and constant encouragement were the forces that kept me moving forward, especially in moments when the goal seemed distant.

To my dear family, whose love and support know no bounds of distance or time. Despite the miles that separate us, your warmth and care have travelled across countries, bringing comfort and strength. Your ability to listen, empathize and uplift during times of uncertainty has been a testament to the enduring power of familial love.

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To all of you, I extend my deepest gratitude. This journey would not have been the same without your love, support and presence in my life.

With love, Evgenia

Αφιέρωση

Αυτή η διατριβή είναι αφιερωμένη με αγάπη στον σύντροφο μου Μάριο. Μάριε, η υποστήριξή σου, η βοήθεια, η δύναμη και η αγάπη σου ήταν οι οδηγοί μου κατά την διάρκεια αυτής της έρευνας. Η πίστη σου σε εμένα και η συνεχής παρότρυνση σου, ήταν οι δυνάμεις που με κράτησαν να προχωρώ μπροστά, ιδιαίτερα στις στιγμές που ο στόχος φαινόταν μακρινός.

Στην αγαπημένη μου οικογένεια, της οποίας η αγάπη και υποστήριξη δεν γνωρίζουν όρια απόστασης ή χρόνου. Παρά τα χιλιόμετρα που μας χωρίζουν, η ζεστασιά και η φροντίδα σας έχουν ταξιδέψει διαπερνώντας χώρες, φέρνοντας μου δύναμη. Η ικανότητά σας να ακούτε, να συμπάσχετε και να προσφέρατε αισιοδοξία σε περιόδους αβεβαιότητας, αποτελεί απόδειξη της δύναμης της οικογενειακής αγάπης.

Και τέλος, στην αγαπημένη μου γάτα, που μπήκε αναπάντεχα στην ζωή μου κατά το τελικό και πιο έντονο στάδιο της έρευνάς μου. Η ήρεμη παρουσία σου έχει αποτελέσει πηγή ψυχολογικής υποστήριξης, φέρνοντας φως και χαρά σε ατέλειωτες μέρες και νύχτες μελέτης. Έχεις αποτελέσει έναν σιωπηλό αλλά ισχυρό σύντροφο, υπενθυμίζοντάς μου τις απλές χαρές της ζωής.

Σε όλους εσάς, εκφράζω τη βαθύτερη ευγνωμοσύνη μου. Αυτό το ταξίδι δεν θα ήταν το ίδιο χωρίς την αγάπη, την υποστήριξη και την παρουσία σας στη ζωή μου.

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Finally, I extend my heartfelt thanks to my partner, family and friends for their emotional support throughout my PhD journey.

Thank you, Evgenia

Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Nicosia. This thesis has been composed solely by myself except where stated otherwise by reference or acknowledgment. It has not been previously submitted, in whole or in part, to this or any other institution for a degree, diploma or other qualifications.

Signed………………………… Date: 17 April 2024

Name/Surname: Evgenia Kapassa

List of Publications

This thesis documents the research journey undertaken by Evgenia Kapassa. Some of the material displayed herein has already been published or is under review in the form of the following publications:

Journal Articles:

- Borges, C.E., **Kapassa, E.,** Touloupou, M., Legarda Macón, J. and Casado-Mansilla, D., 2022. Blockchain application in P2P energy markets: Social and legal aspects. *Connection Science*, 34(1), pp.1066-1088.
- Strepparava, D., Nespoli, L., **Kapassa, E.,** Touloupou, M., Katelaris, L. and Medici, V., 2022. Deployment and analysis of a blockchain-based local energy market. *Energy Reports*, 8, pp.99-113.
- **Kapassa, E.** and Themistocleous, M., 2022. Blockchain technology applied in IoV demand response management: a systematic literature review. *Future Internet*, 14(5), p.136.
- Pressmair, G., Kapassa, E., Casado-Mansilla, D., Borges, C.E. and Themistocleous, M., 2021. Overcoming barriers for the adoption of Local Energy and Flexibility Markets: A user-centric and hybrid model. *Journal of Cleaner Production*, 317, p.128323.
- **Kapassa, E.,** Themistocleous, M., Christodoulou, K. and Iosif, E., 2021. Blockchain application in internet of vehicles: Challenges, contributions and current limitations. *Future Internet*, 13(12), p.313.

Book Chapters:

- **Kapassa, E.,** Themistocleous, M., Blockchain and the Internet of Vehicles: A Conceptual Model for Demand Response Management, in *Handbook of Blockchain Technology 2024,* Edward Elgar Publishing, UK, *In Press*
- **Kapassa, E.** and Touloupou, M., 2022. Local Energy Markets: A Market Transformation Survey Towards Segments of Interest. In: *European, Mediterranean and Middle Eastern Conference on Information Systems*, *EMCIS 2022,* Cham: Springer Nature Switzerland, pp.537-551.

- **Kapassa, E.,** Themistocleous, M., Quintanilla, J.R., Touloupos, M. and Papadaki, M., 2020. Blockchain in smart energy grids: a market analysis. In: *Information Systems: 17th European, Mediterranean and Middle Eastern Conference, EMCIS 2020, Dubai, United Arab Emirates, November 25–26, 2020, Proceedings 17*. Springer International Publishing, pp.113-124.
- **Kapassa, E.,** Touloupos, M., Kyriazis, D. and Themistocleous, M., 2020. A smart distributed marketplace. In: *Information Systems: 16th European, Mediterranean and Middle Eastern Conference, EMCIS 2019, Dubai, United Arab Emirates, December 9–10, 2019, Proceedings 16*. Springer International Publishing, pp.458-468.

Conference Articles:

- **Kapassa, E.,** Touloupou, M. and Christodoulou, K., 2022. A Blockchain Based Approach for Demand Response Management in Internet of Vehicles. In: *2022 7th International Conference on Smart and Sustainable Technologies (SpliTech)*, July 2022. IEEE, pp.1-6.
- **Kapassa, E.,** Touloupou, M. and Themistocleous, M., 2021. Local electricity and flexibility markets: Swot analysis and recommendations. In: *2021 6th International Conference on Smart and Sustainable Technologies (SpliTech)*, September 2021. IEEE, pp.1-6.
- Kalafatelis, A., Panagos, K., Giannopoulos, A.E., Spantideas, S.T., Kapsalis, N.C., Touloupou, M., **Kapassa, E.,** Katelaris, L., Christodoulou, P., Christodoulou, K. and Trakadas, P., 2021. ISLAND: An Interlinked Semantically-Enriched Blockchain Data Framework. In: *Economics of Grids, Clouds, Systems and Services: 18th International Conference, GECON 2021, Virtual Event, September 21–23, 2021, Proceedings 18*. Springer International Publishing, pp.207-214.
- Zabaleta, K., Casado-Mansilla, D., **Kapassa, E.,** Borges, C.E., Preßmair, G., Themistocleous, M. and López-de-Ipiña, D., 2020. Barriers to widespread the adoption of electric flexibility markets: A triangulation approach. In: *2020 5th International Conference on Smart and Sustainable Technologies (SpliTech)*, September 2020. IEEE, pp.1-7.

Table of Contents

List of Figures

List of Tables

List of Appendices

Abbreviation Index

ADMM	Alternating Direction Method of Multipliers
CC	Charging Coordinator
CPS	Cyber Physical System
CS	Charging Station
DAG	Directed Acyclic Graph
DeFi	Decentralized Finance
DER	Distributed Energy Recourse
DR	Demand Response
DRM	Demand Response Management
DSRC	Dedicated Short Range Communication
EV	Electric Vehicle
IoT	Internet of Things
IoV	Internet of Vehicles
ITS	Intelligent Transportation Systems
LP	Linear Programming
MILP	Mixed Integer Linear Programming
NLP	Non-Linear Programming
P2P	Peer-to-Peer
RES	Renewable Energy Sources
RSU	Road-Side Unit
SC	Smart Contract
SLR	Systematic Literature Review
SoC	State of Charge
SP	Service Provider
V2E	Vehicle-to-Everything
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Human
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VANET	Vehicular ad-hoc network
SSI	Self-Sovereign Identity
DID	Decentralized Identifier
VCs	Verifiable Credentials
PU	Publik Key
PK	Private Key
SLA	Service Level Agreement

1. INTRODUCTION

1.1 Summary

As decentralized renewable energy sources and energy storage devices, such as Electric Vehicles (EV), gain popularity, future energy systems are expected to utilize a significant number of decentralized components (Barman *et al.*, 2023). The factors driving this trend include among others (a) the increase in adoption of EVs, (b) government initiatives to reduce greenhouse gas emissions and (c) public opposition to centralized large-scale energy solutions (e.g. nuclear power and massive wind turbines) (EU Blockchain Observatory and Forum, 2022). In recent years, the emergence of the Internet of Vehicles (IoV) has significantly transformed the landscape of energy systems. The IoV integrates EVs equipped with Internet of Things (IoT) and AI technologies, resulting in a highly decentralized network (Arooj *et al.*, 2022; Hashem *et al.*, 2023). However, this decentralization poses challenges in effectively controlling energy demand response and ensuring secure information transmission.

To address this challenges, blockchain technology has emerged as a promising solution towards that direction (Wang *et al.*, 2023). By leveraging its inherent properties, such as immutability and tamper-proof data management, blockchain can play a crucial role in the management of demand response schemes within the IoV ecosystem. For instance, it can maintain anonymity among participants and provide incentives, while facilitating energy distribution, consumption, and trading over the IoV. This includes Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) energy trading (Samuel and Javaid, 2021). Consequently, the integration of blockchain technology with the IoV could offer significant prospects for creating a demand response management framework that is both efficient and secure.

Aligned with this context, the objectives of this chapter are to introduce the topic of this study, which focuses on the use of blockchain technology in managing energy demand response on the IoV and to elucidate the factors driving current research. By highlighting the potential benefits of integrating blockchain technology, this chapter aims to articulate the problem, research aim and objectives, providing a clear understanding of the purpose of this study and the organization of the thesis.

1.2 Introduction

Blockchain technology has risen as a promising solution for diverse applications, including areas such as energy and sustainability, IoT and smart mobility (Alladi *et al.*, 2019). This technology operates over a distributed ledger system, which removes the necessity for a central authority while it depends on collective agreement (i.e. consensus) for the verification of transactions. The resulting data structure is highly secure and transparent, with information stored and encrypted in blocks that are distributed across the network.

Recently, there's been an increasing focus on examining the capabilities of blockchain technology in smart energy systems, particularly in relation to the IoV. This interest stems from the compatibility of blockchain's features (i.e. security, transparency and decentralization) with IoV's needs, where the sharing of data among different stakeholders is essential. As a result, many studies have investigated the viability of blockchain-driven solutions for IoV-related applications, including V2G, V2V, management of charging infrastructure and Peer-to-Peer (P2P) energy trading (Dwivedi *et al.*, 2019; Khalid *et al.*, 2020; Wang *et al.*, 2020; Lin *et al.*, 2021, 2022; Samuel *et al*, 2022).

The energy management in IoV presents several challenges that need to be addressed to fully realize the potential of this technology (Ang *et al.*, 2019; Mollah *et al.*, 2021; Rimal *et al.*, 2022). These challenges include:

- **Scalability:** The number of connected devices in the IoV is constantly increasing, resulting in an exponential growth in data volumes. Managing this vast amount of data poses significant challenges in terms of scalability, processing power and storage.
- **Security:** The interconnected nature of IoV makes it vulnerable to cyber-attacks, which can have severe consequences for both the energy systems and the safety of the vehicles on the road.
- **Data Management:** In IoV, data is generated from multiple sources, such as energy storage systems, renewable energy sources and vehicles. Efficient management of this data is essential for accurate forecasting and effective decision-making.
- **Interoperability:** The integration of different devices and systems in IoV is often hindered by a lack of interoperability standards, making it challenging to exchange data and perform coordinated actions.

- **Regulation:** The regulatory framework for the IoV is still evolving and there is a need for clear guidelines on issues such as data privacy, cybersecurity and energy markets (Borges *et al.*, 2022).

Equally crucial is the challenge of managing Demand Response (DR). Demand Response management presents an opportunity for end-users to significantly contribute to grid management by reducing or shifting their electricity usage during peak hours, in reaction to time-based tariffs or various forms of incentives (Mohsenian-Rad *et al.*, 2010). The integration of DR with IoV, in particular, offers a promising approach to balance peak demand and reduce instability without the need for additional generators and storage devices (Zhou *et al.*, 2017). A network of connected EVs within the IoV ecosystem can be employed as a responsive load to absorb excess energy or serve as a backup energy source during peak times (Lazarou *et al.*, 2020; Hiesl *et al*, 2021).

The characteristics of blockchain technology, such as decentralization, immutability, transparency and security, present potential solutions to the ongoing challenges in energy management. Decentralization, for example, can enable more democratic control over energy resources, while immutability and transparency could improve auditing and compliance processes. Blockchain’s security features could protect against tampering and unauthorized access, critical in an environment where energy information should be controlled. Therefore, given the potential for these properties of blockchain to address the specific challenges in energy management, the researcher of this thesis investigates its application in the IoV field. The usage of blockchain technology might revolutionize energy demand response management in IoV by enabling a more decentralized, secure and transparent system for managing energy supply and demand.

Below, some potential benefits of using blockchain technology in energy demand response management are listed (Noor *et al.*, 2018; Nakayama *et al.*, 2019; Aggarwal and Kumar, 2021; Jamil *et al.*, 2021):

- **Decentralization:** Blockchain technology enables a distributed network of devices and systems to work together, without the need for a central authority or intermediary. This can enable more efficient and flexible energy management, as well as greater autonomy for energy users.
- **Security:** Blockchain technology provides a secure and tamper-proof platform for storing and sharing energy data. The decentralized nature of blockchain makes it

more resilient to cyber-attacks and hacking attempts, improving the overall security of the system.

- **Transparency:** Blockchain technology facilitates a transparent and auditable record of all energy transactions, offering enhanced visibility and accountability within the energy system. The latter assists in reducing fraud and ensuring adherence to regulatory requirements (Kamilaris *et al.*, 2020).
- **Smart Contracts:** Blockchain technology allows for the implementation of smart contracts, which are self-executing agreements that automatically carry out transactions when specified conditions are met. The latter enables efficient and automated energy transactions, decreasing the necessity for intermediaries and enhancing the overall efficiency of the system (Di Francesco Maesa *et al.*, 2020)
- **Tokenization:** Blockchain technology enables the use of tokens, which are digital assets that can represent energy credits, certificates, or other forms of value. Tokenization can enable more efficient and flexible energy trading, as well as the creation of tokenisation schemes (Lo and Medda, 2020).

In summary, blockchain technology has the potential to enable a more efficient, secure and transparent energy demand response management system by enabling decentralized energy transactions, smart contracts and tokenization.

However, while the theoretical potential of this application is clear, empirical study is necessary to test these claims and understand the practical implications. Scientific research in the field of IoV DRM is still in its early stage (Aggarwal *et al.*, 2019). Currently, the IoV is deficient in adequate security and privacy measures to mitigate the transfer of inaccurate and malicious information between EVs (Gill *et al.*, 2019; Suaib Akhter *et al.*, 2021). Such occurrences could lead to various accidents, posing risks to the lives of drivers, passengers, and pedestrians. Additionally, there is a shortage of incentive mechanisms that would motivate end users, such as EV drivers, to engage in DRM schemes (Kapassa *et al.*, 2021; Kapassa and Themistocleous, 2022). Due to the increased battery consumption and other associated costs of discharging, EV owners are reluctant to participate in large-scale decentralized energy trading systems without sufficient rewards (i.e., incentivization schemes) (Moniruzzaman *et al.*, 2019). Moreover, there are challenges to be addressed, including the scalability and interoperability of blockchain systems, and the establishment of regulatory frameworks that support blockchain-based energy systems (Patel *et al.*, 2019).

1.3 Research Aim and Objectives

1.3.1 Aim

The research on IoV-based DR has attracted the interest of both industry and academia. In order to overcome the challenges presented in Section 1.2, many authors suggest a distributed EV-based system for the effective management of charging and discharging activities in IoV (Boglou *et al.*, 2020; Sufyan *et al.*, 2020). While some studies investigate blockchain as a solution to the challenge of DR in EVs, optimizing the charging and discharging schedules of EVs to achieve energy balance, especially when considering drivers' profiles, continues to be a significant challenge. Moreover, current research often overlooks adequate incentive mechanisms to motivate EV drivers to engage in blockchain-enabled DR through optimal scheduling. The latter, could be the key to exploit blockchain-related activities in IoV and promote the use and its adoption. In this context, the aim of this thesis is:

Research Aim:

To investigate the use of blockchain technology for the demand response management on the Internet of Vehicles. In doing so, a conceptual model that studies the demand response management in this area, will be developed and empirically evaluated.

1.3.2 Objectives

In consideration of this thesis' aim, the achievement of the following objectives is essential:

- **Research Objective 1:** To conduct a systematic literature review on blockchain usage in IoV and the application of it in the demand response management, investigate current challenges and identify a research gap.
- **Research Objective 2:** To propose a blockchain-based conceptual model for demand response management in the IoV, in an attempt to address the identified research gap.
- **Research Objective 3:** To investigate established research methodologies and choose a suitable one for this study, aiming to assess the proposed conceptual model.
- **Research Objective 4:** To empirically test the proposed conceptual model, within a case-based setting.

- **Research Objective 5:** To extrapolate findings and contribute to the body of knowledge regarding blockchain-enabled DRM within the IoV context.

1.4 Research Methodology Overview

The selection of an appropriate research philosophy is an important and complicated task during the research process. As stated by Catterall (2000) five categories of research philosophies are identified, namely: (a) positivism, (b) critical realism, (c) interpretivism, (d) postmodernism and (e) pragmatism. Additionally, there are three main approaches to theory development: (a) deduction, (b) induction and (c) abduction (Catterall, 2000; Azungah, 2018; Woiceshyn and Daellenbach, 2018). This thesis adopts an interpretivist philosophical stance and abductive research approach to deeply understand the integration of blockchain technology on the IoV DRM. Interpretivism's focus on subjective experiences and the dynamic interplay between theory and data in abduction, aligns with the study's aim to investigate this evolving field. The main reasons for selecting the interpretivism philosophical stance and abductive research approach are summarized in Chapter 4.3.

Furthermore, this thesis utilizes a qualitative methodology to investigate blockchain technology's application in the IoV. Qualitative research, known for its flexibility and adaptability, is suitable for exploring this complex phenomenon and allows for ongoing evolution of the research hypothesis. This is particularly beneficial for the development and assessment of a conceptual framework for demand response management in the IoV. However, the limitations of qualitative research, including potential subjectivity, bias and challenges with generalizability, are noted. To address these, the researcher adopts a triangulation approach, integrating multiple data sources and collection methods to boost the credibility, reliability and validity of the findings. Justifications about the methodological approach selection are presented in Section 4.4.

Complementing the research objectives, a multiple case study approach has been selected to provide a comprehensive understanding of the phenomenon in its real-world context. Furthermore, it aligns with the study's philosophical stance and abductive research approach, facilitating hypothesis testing from empirical data, thus contributing to the knowledge around blockchain-based demand response management in the IoV. Justifications about the research strategy selection are presented in Section 4.5.

1.5 Layout of the Thesis

The structure of the thesis is based on Phillips and Pugh (1994) approach. That approach consists of four elements: (a) background theory, (b) focal theory, (c) data theory and (d) novel contribution. Background theory applies to the literature review undertaken to help the description of the background and better define the problem (Chapter 2). Focal theory refers to the production of the conceptual model (Chapter 3). The third part (i.e. data theory) consists of the research methodology, data collection techniques (Chapter 4), as well as the description of the empirical data analysis and research findings process (Chapter 5 and 6). The fourth part (i.e., novel contribution) of this dissertation in the research community (Chapter 7).

The thesis consists of seven chapters, who’s the overview is provided below and illustrated in Figure 1.1.

- **Chapter 1: Introduction -** In Chapter 1, the background and motivation of this PhD thesis is presented, also including the problem statement. Additionally, the research aim and objectives are provided as well as an overview of the research methodology.
- **Chapter 2: Systematic Literature Review** – In Chapter 2 the theoretical background around blockchain and demand response in IoV is provided. Additionally, an extensive Systematic Literature Review (SLR) is conducted (Research Objective 1).
- **Chapter 3: Conceptual Framework** – The conceptual model (Research Objective 2) of this research is developed by taking observations and research challenges from the literature review into account. Chapter 3 provides a detailed description of the proposed model, along with a list of its constituent variables.
- **Chapter 4: Research Methodology** – In Chapter 4, a comprehensive explanation of the chosen research methodology, including the qualitative approach and case study strategy, is provided. The chapter also discusses the justification for these choices, acknowledging the limitations of the qualitative approach and outlining measures taken to mitigate these, such as triangulation. This chapter also details the empirical research methodology and provides a comprehensive presentation of the case study protocol.
- **Chapter 5: Empirical Data and Research Findings** – In Chapter 5, empirical data from four case studies, including research and development organisations, a consulting firm and an industry startup, are examined in depth. The central focus of the chapter is a comprehensive investigation of the conceptual model proposed.

- **Chapter 6: Discussion and Revision –** Chapter 6 revises the conceptual model, addressing the case studies' insights and enhancing the model's applicability. Key modifications are made to the model's variables and relationships, improving its efficacy in real-world scenarios. This chapter serves as a bridge connecting empirical findings and theoretical advancements, resulting in a refined, evaluated and theoretically solid model.
- **Chapter 7: Conclusions and Future Work -** In Chapter 7, the dissertation concludes by summarizing its findings, presenting the research contributions and proposing future research directions. The chapter also acknowledges research limitations.

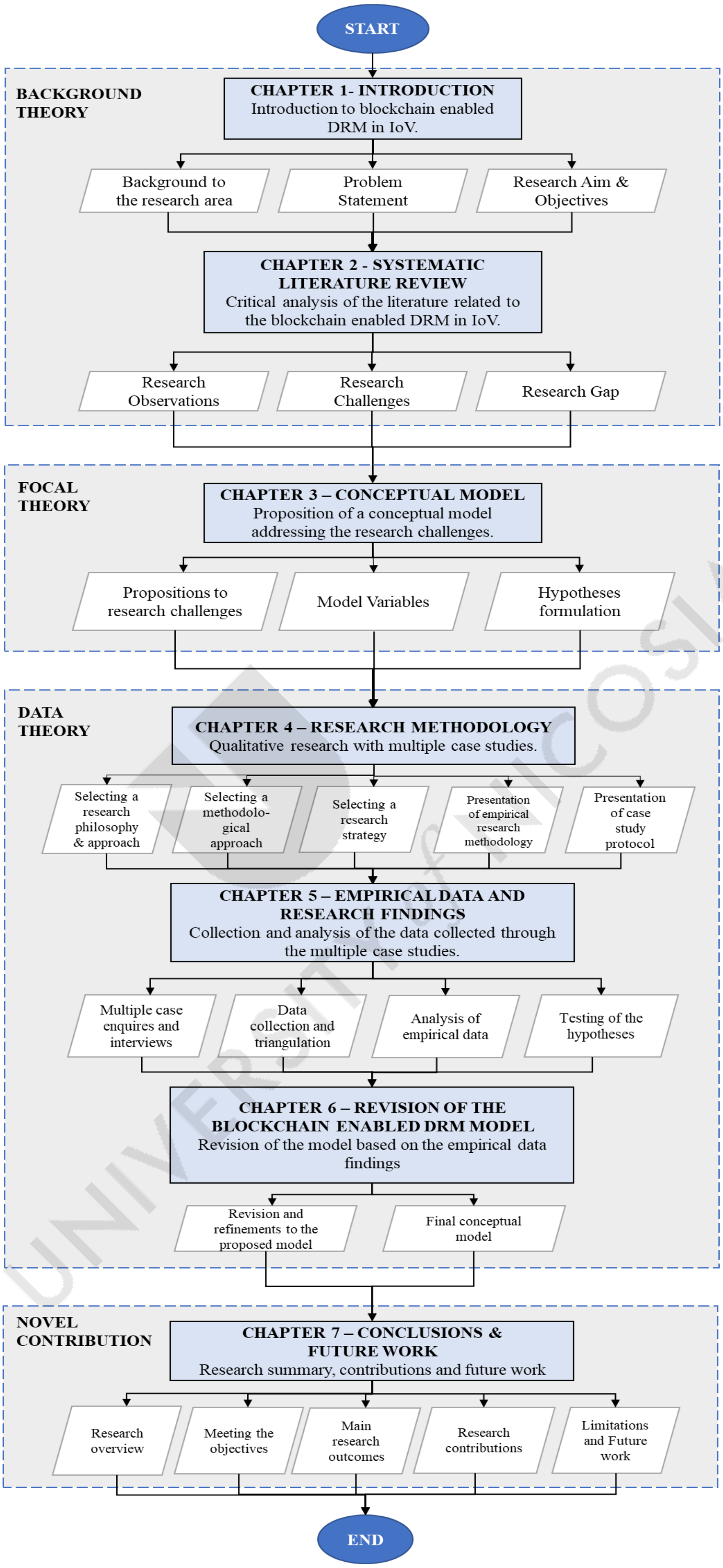


Figure 1.1: Thesis outline

2. SYSTEMATIC LITERATURE REVIEW

2.1 Summary

Chapter 2 offers a comprehensive overview and foundational knowledge pertaining to the specific field of study. Furthermore, a comprehensive systematic evaluation is now underway with the aim of identifying a research deficit within the domain of demand response management in the context of the IoV. The evaluation primarily centres on topics pertaining to secure energy trading, charging scheduling and the incentivization of EV participation. The literature review presents findings and identifies areas of ongoing study that are further elaborated upon in Section 2.3.5. The aforementioned observations and problems underscore the necessity for more research to effectively solve the highlighted gaps within the domain of demand response management in the context of IoV. The discussion presented in Section 2.3.6 offers significant contributions to the identification of prospective directions for future research and development, thereby furnishing a guide for scholars and professionals with an interest in this field.

2.2 Introduction

This section initiates with the theoretical foundation relevant to the research (Chapter 2.3). In presenting this theoretical background, the researcher defines concepts relevant to the identified research problem and explains key information for a deeper understanding of her study area. Subsequently, the researcher employs a systematic approach to review existing literature on blockchain usage in IoV demand response management (Chapter 2.4). The objective of this systematic literature review is to explore the application of blockchain in the aforementioned domain, identify, analyse and interpret all available data related to the specified research issue.

2.3 Background and Preliminaries

2.3.1 Blockchain and P2P Energy Transactions

Blockchain technology is a digital ledger system that has gained attention due to its ability to provide secure, transparent and decentralized transactions. The technology is best known for its application in cryptocurrencies such as Bitcoin (Nakamoto, 2008), but it also has potential applications in various fields such as finance, energy, healthcare, supply chain and more (Themistocleous, 2018; Themistocleous, Stefanou and Iosif, 2018; Duong-Trung *et al.*, 2020; Farooq, Khan and Abid, 2020). More specifically, blockchain technology is a decentralized ledger system that allows for secure and transparent transactions without the need for intermediaries. Each transaction is recorded as a block, which is then added to a chain of previous blocks, forming a chain of blocks, as depicted in Figure 2.1.

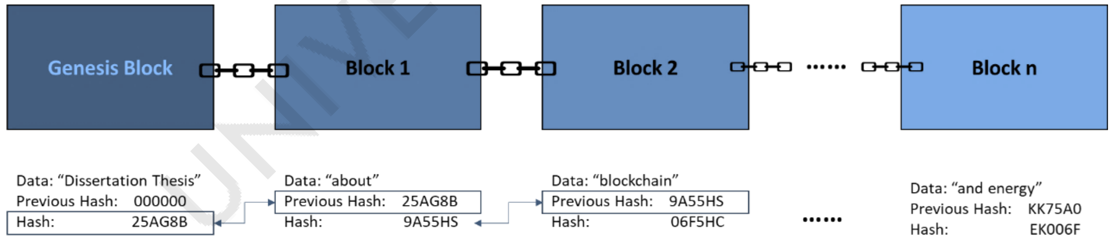


Figure 2.1:Blockchain - A chain of blocks

The blocks are validated by the network participants, using a consensus mechanism that ensures the authenticity and integrity of the transactions. Once a block is validated, it is added to the blockchain and the transaction becomes permanent and unalterable (Garfinkel and Drane, 2016).

One of the key characteristics of blockchain technology is its immutability (Xinyi, Yi and He, 2018; Viriyasitavat and Hoonsopon, 2019). Once a block has been added to the blockchain, it cannot be changed or deleted. This is because each block in the blockchain contains a hash, which is a unique identifier that is based on the contents of the block. Changing the contents of a block would change the hash, which would, in turn, change the hashes of all subsequent blocks. This would invalidate the entire chain, making it impossible to alter a single block without the consent of the network participants. Another characteristic of blockchain technology is its transparency (Xinyi, Yi and He, 2018; Viriyasitavat and Hoonsopon, 2019). All transactions on the blockchain are visible to all network participants, which means that it is a public ledger. This makes blockchain technology ideal for use in situations where transparency and accountability are essential, such as in energy demand response management or energy transactions.

P2P transactions on blockchain technology are conducted using public and private keys (Mohanta, Panda and Jena, 2018; Park *et al.*, 2019). Each user on the network has a public key, which is a unique identifier that is used to send and receive transactions. The public key is visible to all network participants and can be used to verify the authenticity of a transaction. Each user also has a private key, which is a secret code that is used to sign transactions. The private key is kept secret and is used to prove ownership of the assets being transferred (e.g., record of energy amount transmission). To conduct a P2P transaction on blockchain technology, the user initiates a transaction by creating a block that contains the details of the transaction, such as the amount of the transaction and the public key of the recipient. The user then signs the block using their private key, which creates a digital signature that verifies the authenticity of the transaction. The block is then broadcast to the network, where it is validated by the network participants using a consensus mechanism. Once the block is validated, it is added to the blockchain, and the transaction becomes permanent and unalterable.

Energy transactions over blockchain involve the use of the decentralized ledger technology to record and verify transactions involving the buying and selling of energy (Kirpes and Becker, 2018; Anoh *et al.*, 2020). Blockchain technology enables a secure and transparent system of tracking energy transactions, as it removes the need for intermediaries such as banks or energy brokers. In a blockchain-based energy transaction system, energy consumers can buy electricity directly from energy producers without the need for intermediaries. The transactions are recorded on a decentralized digital ledger that is publicly available for verification. The blockchain-based system uses smart contracts, which are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. These contracts automatically execute when the conditions specified in them are met (Liu *et al.*, 2019).

2.3.2 Internet of Vehicles

Within the Intelligent Transportation Systems, the Internet of Vehicles (IoV) stands out as a burgeoning technology that merges smart vehicles such as Electric Vehicles (EVs), IoT and AI methodologies, to facilitate intelligent vehicular networking. Smart vehicles in IoV are equipped with dedicated short-range communication technology and connect with other vehicles, drivers, passengers and road-side units through the internet. Additionally, the IoV ecosystem integrates Vehicle-to-Everything (V2X) communication, allowing for interactions between vehicles and various entities such as infrastructure, grid, pedestrians and more. This kind of communication is achieved via Vehicle-to-Vehicle (V2V) and Vehicle-to-Grid (V2G) communication technologies (Mahmood, 2020; Adnan Yusuf *et al.*, 2024).

- **Vehicle-to-Vehicle (V2V)** technology is a wireless communication system that allows vehicles to share information about their speed, position and other dynamics with each other. This technology is integral to intelligent transportation systems, aiming to enhance road safety and traffic efficiency by alerting drivers to potential hazards, such as imminent collisions or sudden braking by nearby vehicles. V2V is crucial for the development of autonomous and semi-autonomous vehicles, facilitating informed decision-making through real-time data sharing. While it primarily uses dedicated short-range communications and newer versions of cellular networks like 5G. Despite its benefits in improving driving safety and traffic flow, V2V technology faces challenges in ensuring data privacy and security (Rehman *et al.*, 2023; Adnan Yusuf *et al.*, 2024).
- **Vehicle-to-Grid (V2G)** technology is a system that enables Electric Vehicles (EVs) to interact with the power grid. This technology allows not only for the charging of EVs but also for the reverse flow of electricity from the vehicle’s battery, back to the grid. V2G can play a crucial role in stabilizing the grid, especially with the increasing

use of renewable energy sources. By acting as temporary energy storage, EVs can supply energy during peak demand times or when renewable sources are not generating enough power. This technology can potentially reduce the need for traditional energy storage solutions and optimize energy distribution. Additionally, V2G can provide financial benefits to EV owners, who can earn money by allowing their vehicle's battery to be used for grid services. However, the widespread adoption of V2G technology involves overcoming technical challenges and addressing concerns about the potential impact on the lifespan of vehicle batteries (Umair *et al.*, 2023; Adnan Yusuf *et al.*, 2024).

2.3.3 Demand Response in Internet of Vehicles

One of the key challenges in the IoV is to balance the energy demand and supply, especially during peak hours. Demand Response (DR) is a technology that can address this challenge by shifting the energy consumption from peak to off-peak hours. To that purpose, demand response is an economic management scheme for the provision of electric power that is facilitated by technologies. To better monitor consumption and identify peak demand periods, utility providers can offer smart meters and smart grid technologies. For example, DR can be achieved through various methods, such as dynamic pricing, load shedding and load shifting. In the IoV, DR can be implemented through the V2G technology, which allows EVs to provide grid services by charging and discharging their batteries in response to grid signals (Xin *et al.*, 2022).

For instance, through V2G vehicles can act as mobile energy storage devices that can help to balance the energy demand and supply in the IoV. During peak hours, when the demand for electricity is high, the network operator can request EVs to discharge their batteries to the grid. Similarly, during off-peak hours, when the demand for electricity is low, the operator can request EVs to charge their batteries from the grid. By doing so, the IoV operator can reduce the need for expensive peaking power plants and the EV owners can earn money by selling their surplus electricity back to the grid (Umair *et al.*, 2023; Adnan Yusuf *et al.*, 2024).

Within the IoV ecosystem, blockchain technology can facilitate P2P energy exchanges between EVs and the grid. EVs function as Distributed Energy Resources (DERs) and have the capability to sell energy they generate or store back to the grid, especially during peak demand times, as seen in V2G scenarios (Adnan Yusuf, Khan and Souissi, 2024). Blockchain aids in managing these V2G transactions by offering a secure and transparent method for recording them. Each transaction is documented on the blockchain, with a unique digital signature to confirm its authenticity, creating a tamper-proof ledger of all transactions accessible for audit by all system participants (Mehdinejad, Shayanfar and Mohammadi-Ivatloo, 2021). Furthermore, blockchain enables the use of smart contracts, which are automated contracts whose terms are encoded directly into the software. These smart contracts streamline V2G transactions by obviating the need for intermediaries like energy brokers or utilities, thereby reducing transaction costs and enhancing efficiency.

Overall, blockchain technology can help to enable secure, transparent and automated demand response management in the IoV (Wang *et al.*, 2023). By providing a tamper-proof record of all transactions and enabling smart contracts, blockchain can help to reduce transaction costs and increase efficiency, making it an attractive technology for managing energy transactions in the IoV.

2.4 Systematic Literature Review on Blockchain enabled Demand Response Management

For the purposes of this thesis, the researcher has adopted the approaches of (Harris M. Cooper, 1988; Brereton *et al.*, 2007; Kitchenham *et al.*, 2010; Briner and Denyer, 2012) to perform a Systematic Literature Review (SLR). A SLR is considered as an important tool to conduct a comprehensive and efficient literature analysis. A systematic review is conducted for a variety of reasons, including the need for theoretical background for ongoing or future research, deepening on a research topic of interest and providing research contribution on the research area.

A SLR is defined by (Kitchenham *et al.*, 2010) as follows:

> *A form of secondary study that uses a well-defined methodology to identify, analyse and interpret all available evidence related to a specific research question in a way that is unbiased and (to a degree) repeatable.*

Additionally, based on (Briner and Denyer, 2012),

> *Systematic simply means that reviewers follow an appropriate (but not standardized or rigid) design and that they communicate what they have done.*

The researcher of this thesis is following a specific SLR methodology based on three phases (i.e. planning, conducting and documenting the review) (Brereton *et al.*, 2007; Kitchenham *et al.*, 2010) as to be described in Section 2.4.1.

2.4.1 Phases of the Systematic Literature Review

The current thesis is based on the SLR methodology introduced by (Brereton *et al.*, 2007; Kitchenham *et al.*, 2010), to assure academic rigor, fairness and reproducibility. Performing a systematic review involves several discrete activities, which can be grouped into three main phases: planning the review, conducting the review and reporting the review. Figure 2.2 illustrates the phases of the SLR, as those presented below.

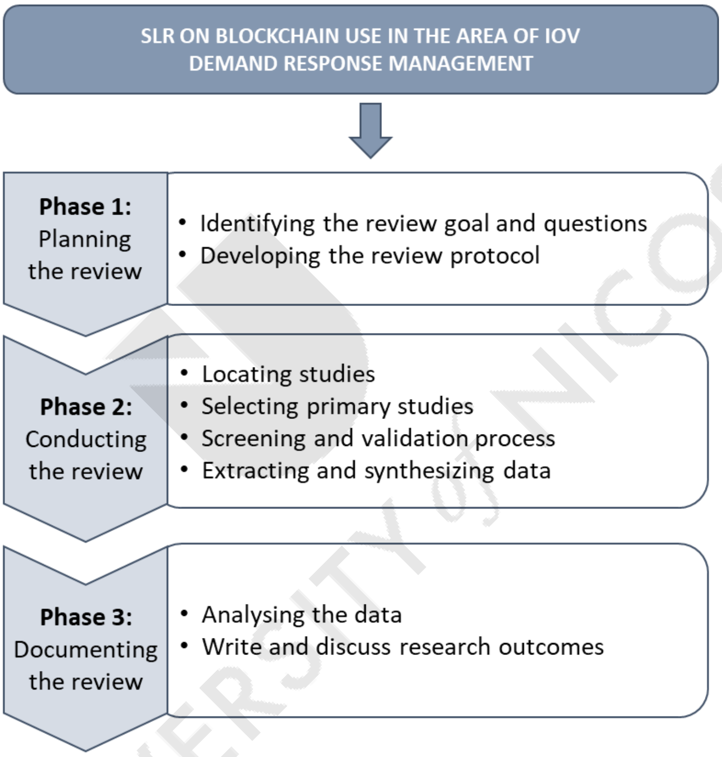


Figure 2.2 Systematic literature review plan

The three phases for the systematic review process are the following:

Phase 1 - Planning the Review:

- Goal of the review - Identify the literature review questions and goals.
- Develop the review protocol - Establish the methodology to be followed during the review (e.g., identifying search keywords and databases).

Phase 2 – Conducting the Review:

- Locate studies - Searching the literature to identify relevant studies for the review.
- Screening process - Assess studies' quality criteria for the selected studies to be included in the review.
- Extract and synthesize data - Obtain the necessary information about study characteristics and findings from the included studies.

Phase 3 – Documenting the Review:

- Analyse data - Explain how the data answer the identified research questions.
- Discuss research outcomes - Document the review outcomes in detail.

The outcomes of each phase are going to be provided in sections 2.4.2, 2.4.3 and 2.4.4.

2.4.2 Phase 1 - Planning the Review

The aim of this phase is to define the goal and the research question for the second stage of this literature review. To achieve the SLR goal, the researcher formulated the following systematic literature review question.

Systematic Literature Review Goal:

The goals which concern about the outcome of this research, extracted based on Harris M. Cooper (1988) taxonomy characteristics for the review and are: (a) identifying the main challenges and applications of demand response management in IoV, where blockchain technology is applied, (b) synthesizing past literature that is believed to be related to the same area and (c) discuss findings and provide future research directions.

Systematic Literature Review Research Question (SLR.RQ):

A systematic review is based on a pre-defined specific research question (Brereton *et al.*, 2007; Kitchenham *et al.*, 2010; Briner and Denyer, 2012). Several tools are available for developing a systematic review research question (Methley *et al.*, 2014; Gupta *et al.*, 2018). One of the most commonly used models for qualitative research is the *"SPIDER"* model (Cooke, Smith and Booth, 2012), which focuses the research investigation using the following parameters: (a) Sample, (b) Phenomenon of Interest, (c) Design, (d) Evaluation and (e) Research Type. The researcher specified the following parameters towards the identification of the systematic literature review question:

- Sample: use of blockchain
- Phenomenon of Interest: demand response management in IoV assisted smart grids
- Design: systematic literature review
- Evaluation: applications and challenges
- Research type: qualitative

The research question guides many aspects of this review process, including determining eligibility criteria, searching for studies, collecting data from included studies and presenting findings. Therefore, the present review initiated with the subsequent question:

Systematic Literature Review Research Question:

How blockchain can be used in different applications around demand response management in IoV and what are the challenges of its usage?

Review Protocol:

Another essential procedure of the literature review is the definition of the research protocol. The research protocol is described in a documented definition of the review process, based on Briner and Denyer (2012) approach to categorize literature reviews. Specifically, the researcher followed the following structure of systematic review protocol:

- **Selection Criteria:** which articles to include in the review, types of contexts, types of mechanisms, types of outcomes, types of studies (qualitative, quantitative, both), types of designs.
- **Search strategy for identification of studies:** databases and sources to be searched, included time-period, search terms and keywords, search queries, language restrictions.
- **Screening:** inclusion/exclusion criteria for studies.
- **Validation:** patterns recognition and taxonomy creation
- **Synthesis:** sort of synthesis to be used (e.g., aggregation, integration, interpretation, or both), representation of data to address review questions.

Apart from the review protocol, the researcher identified a set of search keywords and databases. The systematic literature search was conducted from 2017 onwards and conducted on Google Scholar (since it included a broad field of publications), IEEEXplore, ScienceDirect, SpringerLink and ACM Digital Library. As this particular study is focused on scientific information about blockchain applicability in the IoV, the researcher emphasized on literature published in academic journals and conference proceedings, which helped ensure quality.

Then, the researcher decided the keywords to be used in the study. Table 2-1 presents the search query used to identify the relevant studies for the review. Furthermore, a secondary search process was conducted, during which the researcher populated the literature collection through studying the references of the publications. Specifically, we used the "cited by" feature, to find relevant literature among the citing papers as well as create query alerts in the used databases, to retrieve relevant and updated studies.

Table 2.1: Systematic literature review - Keywords and search query

Keywords	Search Queries
Blockchain	blockchain AND "demand response" AND (IoV OR "Internet of Vehicles") AND (applications OR challenges)
IoV	
Internet of Vehicles	
Demand Response	
Applications	
Challenges	

2.4.3 Phase 2 – Conducting the Review

During the second phase, the researcher conducted the systematic literature review in a structured manner and synthesized the collected data.

Studies Location:

Even though the submission of the above search query in the electronic databases return thousands of results in one database (e.g., ScienceDirect), while fewer results return from others (e.g., ACM). Although, a problem was discovered in the databases' search engines, which are organized according to various models. The researcher was unable to apply the same set of search queries to each database due to the various database models. To extract relevant information from the research databases, the researcher created various queries based on the goal of the study. In doing so, the submitted queries for the different selected databases are presented in Table 2.2.

Table 2.2: Systematic literature review - Submitted queries (per database)

Database	Query	Initial Results
IEEE Xplore	(((“All Metadata”:blockchain) AND ((“All Metadata”:IoV) OR (“All Metadata”:”Internet of Vehicles”)) AND “All Metadata”:”demand response” AND (“All Metadata”:challenges OR “All Metadata”:applications)))	12
ScienceDirect	blockchain AND ((“Internet of Vehicles” OR (IoV)) AND “demand response” AND (challenges OR applications)	278
SpringerLink	‘blockchain AND “demand response” AND (“Internet of Vehicles” OR IoV) AND (applications OR challenges)’	163
ACM	[All: blockchain] AND [[All: “internet of vehicles”] OR [All: iov]] AND [All: “demand response”] AND [[All: challenges] OR [All: applications]]	13
Google Scholar	blockchain AND “demand response” AND (IoV OR “Internet of Vehicles”) AND (challenges OR applications)	788
Initial Results (before removing the duplicates)		1232

The location process resulted in an initial number of 1232 of publications. Before moving to the screening process, the researcher checked for possible duplicates within the union of the results of all databases. The results assessed for the screening, after removing the duplicates were 1086, as presented in Table 2.3.

Table 2.3: Systematic literature review - Initial results

Database	IEEE Xplore	ScienceDirect	SpringerLink	ACM	Google Scholar
Initial Results	12	278	163	13	788
Duplicates	0	14	4	0	4
Sum	12	264	159	13	784
Duplicates within the union	146				
Initial Results (after removing the duplicates)	1086				

Screening and Validation Process:

Moving to the screening process, the researcher evaluated the eligibility and quality of the selected literature based on a set of specified quality criteria for exclusion and inclusion, as presented in Table 2.4. Some exclusion criteria were used before introducing the literature in the bibliographic manager (i.e., the researcher used Mendeley in the current review), such as language, publication year and document type restrictions. Initially, the titles, keywords and abstracts of all research papers were assessed. Publications that met one of the exclusion parameters were omitted and sorted by exclusion.

Table 2.4: Systematic literature review - Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Peer-reviewed studies	Grey literature
Academic theoretical and empirical research	Full-text not available
Whitepapers	Written in non-English language
Published in 2017 onwards	Published before 2017
Relevant to blockchain and IoV concept	Diverged from the field of blockchain and IoV concept

Based on the specified inclusion and exclusion criteria, complying papers selected for further analysis. According to that:

- **Grey literature:** Grey literature stands for manifold document types produced on all levels of government, academics, business and industry in print and electronic formats where publishing is not the primary activity of the producing body. While the researcher avoided to include grey literature in the main SLR, she used it as supportive material for the introduction to the research domain of blockchain applied in IoV. The main reason for this decision was to enhance the completeness and reliability of the review, by providing a more comprehensive and diverse range of evidence.
- **White papers** - In the initial stages of the research, the researcher reviewed various sources, such as white papers, infographics, statistics and business reviews. Although the researcher refrained from incorporating whitepapers as primary sources in the SLR, she utilized them as secondary material towards the development of the conceptual framework. The decision to utilize whitepapers in this capacity was founded on the premise that their inclusion in a SLR can facilitate a more exhaustive

comprehension of a specific issue or subject matter, by enabling access to expert knowledge, current trends, recommendations and optimal practices.

- **Articles in non-English language** - Research material in different languages retrieved from electronic sources were not examined due to the lack of accurate translation excluded from literature review.
- **Diverged from the field of blockchain and IoV:** Regarding the focus of this literature review on specific area of blockchain use in IoV, papers with diverged research focus were not included in this review, but they were used as supportive papers for the introduction to the research domain.

After the location of the initial set of studies and the definition of the inclusion and exclusion criteria, the researcher carefully read the abstract, keywords and titles of the 1086 papers. In order a study to be considered as eligible for the review, it should meet all the inclusion criteria. Then, the researcher focused on two eligibility criteria during the abstract reading: Is the paper relevant to blockchain? Does the paper describe a concept/framework/study relevant to demand response management? Papers had to meet both criteria in order to be considered. Using this procedure, the researcher left with 326 papers.

Then, the researcher proceeded to the validation of the selected studies. The researcher excluded 216 studies there were not relevant with the thesis scope, resulting in 110 studies. Thus, the total considered papers are 110 and the researcher would study and derive findings and observations from them (the studies are presented in Appendix A: Considered Studies for the Systematic Literature Review). Table 2.5 presents the final studies to be considered in the literature review of this stage. At this point, the researcher would like to state that the decisions regarding inclusion and exclusion are relatively subjective.

Table 2.5: Systematic literature review - Considered results

Electronic Database	Results	Considered
IEEEXplore	11	4
ScienceDirect	191	36
SpringerLink	142	7
ACM	12	2
Google Scholar	730	277
Summary	1086	326
Excluded during validation	247	
Considered	110	

Data Extraction and Synthesis:

The goal of this process is to utilize data extraction forms to properly record the information gathered by the researcher from the primary study selection. For the data extraction process, a framework was formed by the researcher using Microsoft Excel. The data extracted from each study were the following:

- Study details including authorship, year, type of paper, publication location and digital object identifier.
- Evaluation of the study in terms of research knowledge including the identified problems, proposed solution/opportunities, study outcomes and study limitations and/or research directions.

The majority of the selected studies are journal articles and high-quality conference papers, although some book chapters were also analysed. A clear depiction of the types of publications identified is presented in Figure 2.5, while the distribution of them within the time range of the review is presented in Figure 2.6.

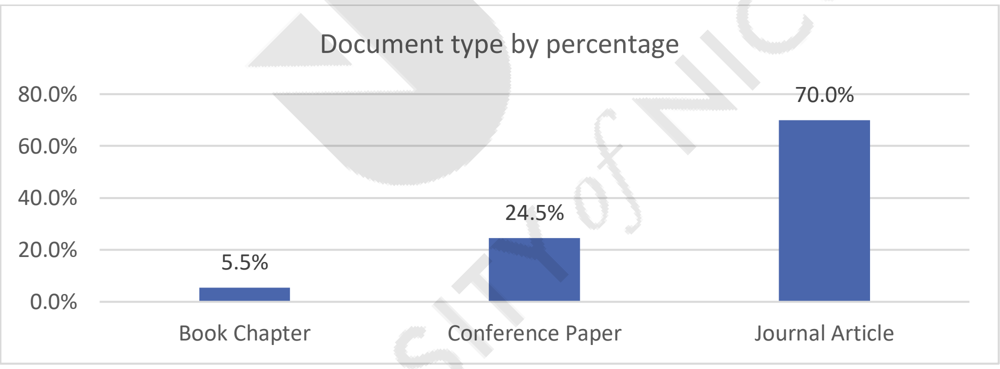
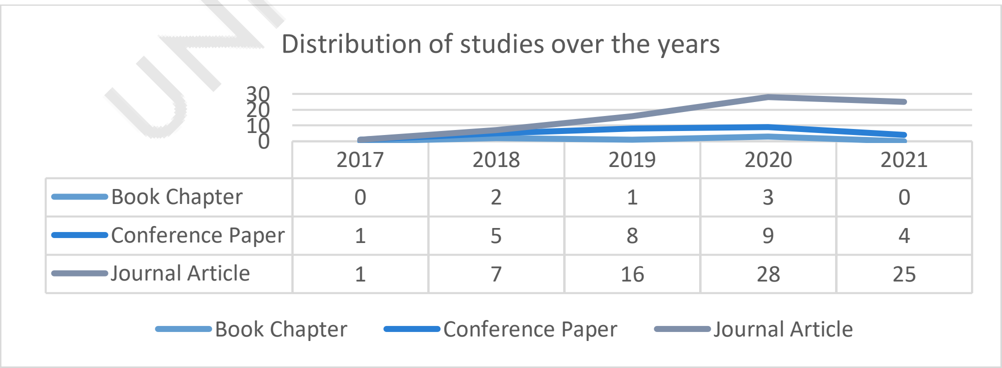


Figure 2.3: Studies type per percentage



	2017	2018	2019	2020	2021
Book Chapter	0	2	1	3	0
Conference Paper	1	5	8	9	4
Journal Article	1	7	16	28	25

Figure 2.4: Distribution of studies from 2017 to 2021

From the 110 considered studies, only 20 of them were selected after the quality assessment, in order to be considered in this thesis for highlighting the main current research trends and the gaps that have yet to be filled. The quality assessment was a critical part of this SLR, since it involved evaluating the quality of studies that have been identified during the literature search process and determining whether they are suitable for inclusion in the review. In the field of blockchain and energy, it is important to use rigorous quality assessment criteria to ensure that the studies included in the review are of high quality and provide reliable and valid results. Therefore, the quality criteria that were used included the study design, sample size, data collection methods, data analysis, reporting, confounding variables and generalizability of the article under assessment. These criteria considered as important for ensuring that the studies included in the review are of high quality and provide reliable and valid results.

As a result, Table 2.6 presents the problem statement of the selected studies.

Table 2.6: Systematic literature review - Selected studies and their corresponding problem statements

Author	Problem Statement
(Knirsch *et al.*, 2018)	The issue of varying pricing according to market demand and response is coupled with privacy concerns, as well as the challenge of accurately determining the locations of customers and their Electric Vehicles (EVs).
(Aggarwal *et al.*, 2021)	Uncoordinated utilization and unregulated energy consumption by Electric Vehicles (EVs) can potentially widen the demand-supply discrepancy between service providers and consumers.
(Tsao *et al.*, 2021)	. Researchers have not extensively explored sustainable microgrids that concurrently tackle economic benefits, environmental and social concerns.
(Zhang *et al.*, 2018)	The unpredictable dynamic nature of Electric Vehicle (EV) charging and routing presents challenges in managing EV load, potentially posing difficulties for power distribution operators and utility companies.
(Lazaroiu and Roscia, 2019)	As the demand for Electric Vehicles (EVs) grows, there will be a need to expand charging infrastructure to accommodate the increased absorption capacity of charging systems and to distribute energy demand more evenly.
(Jindal *et al.*, 2020)	Demand response protocols conveyed through communication infrastructure in smart cities can be vulnerable to various attacks, where malicious users might exploit security weaknesses in the network.
(Jiang *et al.*, 2020)	Existing research falls short in analyzing the interactions among prosumers during pricing, even though electricity trading is a crucial aspect of P2P trading.
(B *et al.*, 2021)	Every day, demand response systems generate a substantial volume of data from various sources, including energy production (such as wind turbines), transmission and distribution (like microgrids) and load management (for instance, smart meters and EVs).
(Danish *et al.*, 2021)	The centralized and potentially untrustworthy framework of energy markets and Electric Vehicle (EV) charging infrastructures poses several privacy and security risks, jeopardizing the personal information of EV users.
(Guo *et al.*, 2020)	The implementation of demand response requires a central agent, leading to issues related to security and trust. Additionally, the lack of consideration for disparities in user response cost characteristics during incentive pricing impacts the fair participation of users in demand response, subsequently escalating the costs.

(Karandikar *et al.*, 2021)	To align with the anticipated peak usage, energy operators must increase supply by over-provisioning generation capacity, which can incur significant costs.
(Lin *et al.*, 2021)	Smart vehicles possessing surplus computational power might be reluctant to participate in the trading process due to their inherent selfishness and distrust.
(Wen *et al.*, 2021)	The presence of diverse entities on the demand side presents a threat to the reliability and security of the power system.
(Karandikar *et al.*, 2021)	Peak demand periods pose a challenge for grid operators as they may require over-provisioning of grid capacity to maintain system stability, which leads to an increase in the marginal cost of energy.
(Pop *et al.*, 2018)	The inefficiency of centralized methods in smart grid management has led to a widespread recognition of the need for innovative decentralized approaches and designs.
(Zahid *et al.*, 2020)	Due to the shortcomings of centralized strategies in managing smart grids, there is a growing consensus on the importance of adopting novel decentralized techniques and designs.
(Pop *et al.*, 2020)	The acceptance of demand response programs remains limited due to consumers' insufficient comprehension, concerns about losing control and privacy of their energy data and various other factors.
(Zhou *et al.*, 2019)	The IoV faces challenges in providing incentive mechanisms and is susceptible to issues related to privacy breaches and security threats.
(Al-Obaidi *et al.*, 2021)	The widespread deployment of EVs can pose grid-related challenges if not adequately integrated.
(Kumari and Tanwar, 2020)	The rapid increase in energy demand necessitates an efficient DRM system to address service quality decline, customer satisfaction and data security concerns in Industry 4.0's smart grid.

By analysing the information presented in the selected studies, specific patterns of objectives and limitations identified, as those presented in Table 2.7 and Table 2.8.

Firstly, several studies focus on the development of blockchain-based demand response management systems. These systems aim to minimize peak energy usage, manage energy demand response and incentivize prosumers, electric cars and storage providers. Additionally, these studies propose the use of blockchain technology to ensure secure energy transactions between entities without trusted third-party intervention, addressing privacy and security concerns. However, these studies identify limitations such as the absence of real-time rescheduling based on unforeseen events, lack of dynamic pricing strategies and the absence of sufficient incentives to participate in the blockchain demand response network.

Secondly, other studies concentrate on the application of blockchain technology in real-time energy-based demand response programs. The proposed solutions leverage blockchain technology to provide real-time-based demand response programs, ensuring secure and anonymous transactions. However, the studies acknowledge limitations such as the need for energy scheduling algorithms, lack of incentives and the absence of blockchain-based smart contracts to ensure a fair deal for various stakeholders.

Lastly, some studies suggest also the use of blockchain technology to incentivize users to collectively charge their EVs with renewable energy-friendly schedules. These studies incorporate blockchain-based cryptocurrency components to incentivize users with monetary and non-monetary means in a flat-rate system. However, these studies identify limitations such as the lack of consideration for energy scheduling and the fact that the studies are designed based on a photovoltaic generation system, which is not evaluated in IoV scenarios.

In conclusion, the selected studies show that blockchain technology can address several challenges in demand response management, ensuring secure and anonymous transactions and incentivizing entities to collectively charge with renewable energy-friendly schedules. However, the studies acknowledge the need for further research and development in dynamic pricing strategies, energy scheduling algorithms and the use of blockchain-based smart contracts to ensure fair deals for various stakeholders.

Table 2.7: Systematic literature review - Selected studies and their corresponding objectives

Selected Studies	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**
Objectives																				
Secure Energy Transactions		X	X						X		X	X	X				X			
Blockchain-based Demand Response Management	X						X			X	X				X					X
Blockchain-based Smart Charging for Electric Vehicles					X						X								X	
Decentralized Energy Trading	X						X							X		X		X		
Demand Response Management	X					X		X						X						

Table 2.8: Systematic literature review - Selected studies and their corresponding limitations

Selected Studies	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**
Limitations																				
Lack of Real-Time Rescheduling	X										X								X	X
Energy Scheduling Not Considered		X	X		X	X						X	X							
Lack of Incentives				X						X					X					X
Lack of Analysis on Energy Profiles and Scheduling Algorithms							X	X								X		X		

Selected Studies	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**	**(Knirsch *et al.*, 2018)**
Lack of Dynamic Pricing Strategies	X								X											X
Lack of Market-Realistic Scenarios										X										
Lack of Blockchain Incentives				X	X		X				X			X				X		
Restricted Use of Dynamic Pricing									X											
Restricted Evaluation in IoV Scenarios				X			X								X					

2.4.4 Phase 3 – Documenting the Review

During the third phase, the researcher clearly documents the findings of the second stage of the systematic literature review. Based on her conducted analysis, the researcher provides a detailed presentation and research analysis regarding the following: (a) P2P energy trading using blockchain, (b) blockchain-based demand response programs and optimization models, (c) EVs charging scheduling using blockchain. This phase concludes by providing the research outcomes of the systematic literature review including significant observations.

Research on P2P trading and management in energy blockchain:

Distributed ledger technologies and blockchain are used in a range of applications related to the activities and business processes of smart energy grids. There are several studies in the literature that propose the use of blockchain technology for example in P2P energy trading. For instance, in (Jiang *et al.*, 2020), a game-theoretic approach for the demand side management model that incorporates a localized practical byzantine fault tolerance based-consortium blockchain is proposed, where both the interaction between sellers and buyers and the interaction among sellers constructed by Stackelberg game and non-cooperative static game were considered. Additionally, Brooklyn microgrid is one of the first applied engineering program of energy blockchain (Mengelkamp *et al.*, 2018). The whole project is based on P2P energy trading with blockchain and does not need a traditional and/or third-party energy supplier. Brooklyn microgrid proves blockchain can really be used in practical P2P electricity trading. Moreover, the authors of (Duan *et al.*, 2020) proposed an optimal scheduling and management smart city scheme, within the safe framework of blockchain. To do so, the authors proposed an improved Directed Acyclic Graph (DAG) approach in order to enhance the security of data transaction within the smart city and added and additional security layer to the blockchain which would prevent the cyber hackers' access to the system information. Additionally, the company LO3 P2P energy is a popular example of blockchain adoption in the energy market, introducing an energy supply scheme to the closest neighbours (Korkmaz *et al.*, 2021). More specifically, current literature dictates future distributed ledger implementations and mechanisms that could be concerned, as summarized below:

Based on the approaches proposed in recent studies (Long *et al.*, 2018; Durillon *et al.*, 2020; Tushar *et al.*, 2020; Zahid *et al.*, 2020), four techniques can be identified as the main contributors to the design of P2P energy trading systems that consider demand response aspects (Tushar *et al.*, 2020). These are (a) game theory, (b) auction theory, (c) constrained optimization and (d) blockchain. Game theory is a mathematical tool that analyses the strategic decision-making process of a number of players in a competitive situation, in which the decision of action taken by one player depends on and affects the actions of other players. A double auction involves a market of a number of buyers and sellers seeking to interact. In a double auction, which is usually a step-by-step process, potential buyers submit their bids to an auctioneer, while potential sellers simultaneously ask prices to the auctioneer. A number of constrained optimization techniques have been used to design P2P energy trading schemes. Examples of some techniques include linear programming, mixed integer linear programming, alternating direction method of multipliers and non-linear programming. A summary is presented in Table 2.9.

Table 2.9: Demand response techniques for energy trading

Technical approach	Focus of the approach	Main methods
Game theory	To comprehend the interplay of competition and cooperation among various participants in the P2P energy trading market and develop a solution that remains stable, occasionally reaches optimality and is mutually advantageous for all parties involved.	Stackelberg game, coalition formation game, canonical coalition game, noncooperative Nash game, generalized Nash game
Auction theory	To depict the interaction among multiple sellers and buyers within a P2P market, facilitating their ability to trade electricity in a systematic, step-by-step manner.	Double auction
Constrained optimization	To employ mathematical programming techniques to optimize the parameters of P2P trading while considering various hard and soft constraints imposed by both the market and the power system.	linear programming, mixed integer linear programming, alternating direction method of multipliers and non-linear programming
Blockchain	To offer a replicable data structure that allows secure, transparent and decentralized energy trading among members within a P2P network.	Smart contract, Consortium blockchain, Hyperledger, Ethereum

Research on blockchain based demand response programs and optimization models:

Demand response has been acknowledged as a strong technique for better balancing supply and demand in the electrical grid by affecting demand side behaviour. The demand to provide steady power supply continues to rise, owing to the unpredictability of renewable energy, electricity market pricing and the accumulation of forecast mistakes (Inayat and Hwang, 2018). When there is an electrical shortage, DR becomes an efficient alternate solution for absorbing the gap between supply and demand as well as controlling power consumption (Guo, Ji and Wang, 2020). Significant initiatives in blockchain based demand response programs and optimization models are presented below. To begin with, Aggarwal and Kumar, (2021) proposed a P2P energy trading scheme between EVs and the service providers, to manage the demand response in V2G environment, in an attempt to overcome the smart grid imbalances and to control the ever-growing energy demands from EVs. Moreover, Guo, Ji and Wang (2020) presented a blockchain-enabled DR scheme with an individualized incentive pricing mode is proposed. Fist the authors proposed a blockchain-enabled DR framework to promote the secure implementation of DR, while then they also designed a dual-incentive mechanism, based on the Stackelberg game model, to successfully implement the blockchain demand response management, consisting of a profit-based and a contribution-based model. Furthermore, in the area of IoV, there are also several studies which address the demand response problem and propose optimization solutions. Zhou *et als(2*019) a consortium blockchain-enabled secure energy trading framework for EVs with moderate cost is proposed, using a contract theory-based incentive mechanism to incentivize more EVs to participate in DR. The proposed optimization scheme falls into the category of difference of convex programming and is solved by using the iterative convex–concave procedure algorithm. Similarly, in Zhang *et al.* (2018) the authors are incorporating a blockchain-based cryptocurrency component, with which the system can incentivize users with monetary and non-monetary means in a flat-rate manner.

The design of DR programs in a smart grid context has undoubtedly attracted a lot of academic attention in recent years. The classification of these research endeavours is depicted in Figure 2.5, which was generated from the analysis of the systematic literature review, as well as other surveys and review articles in the literature. This categorization is based on the DR procedure’s control mechanism, customer motives to lower or move their expectations and the DR decision variable.

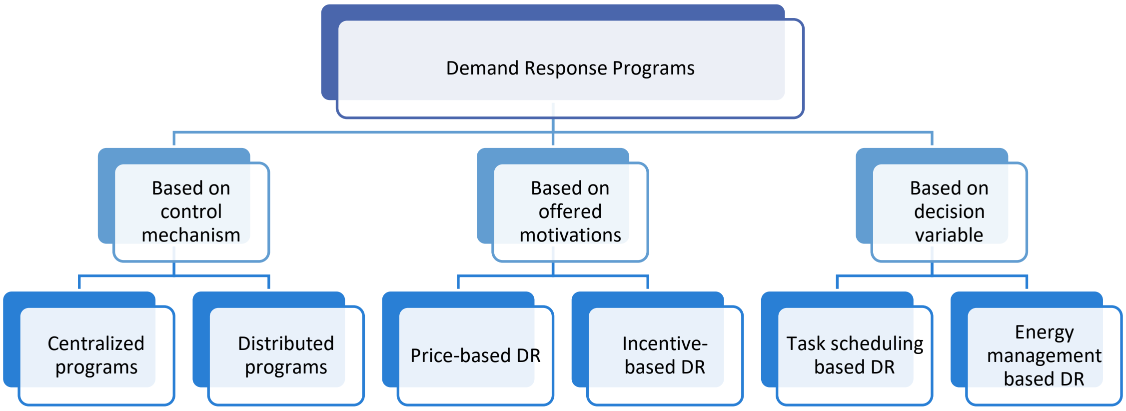


Figure 2.5: Demand response programs

The control mechanisms of DR schemes are categorized as centralized or distributed. Consumers communicate directly with the power utility in the centralized mode, without interacting with one another, while in the distributed mode, user interactions provide information to the utility about total consumption (Pinto *et al.*, 2020). The motivations offered to producers and consumers to decrease their energy usage are classified in the second category of DR schemes. These motivations are divided into two categories: time-based DR and incentive-based DR. Consumers are given time-varying prices that are defined based on the electricity cost in different time periods in the time-based DR. In incentive-based DR schemes, customers are offered either fixed or time-varying payments to reduce their electricity consumption during peak periods (Chen and Liu, 2017; Abidin *et al.*, 2018; Lei *et al.*, 2021). However, customers who do not participate in the program may face specific constraints or penalties. DR systems that use the decision variable to identify task-scheduling and energy-management based DR schemes, also known as energy or power scheduling DR schemes, belong to the third group (Veras *et al.*, 2018; Cruz *et al.*, 2020). The main feature of task scheduling DR is control over the desired load’s activation time, which may be moved to peak-demand periods (Golpîra and Bahramara, 2020; Kermani *et al.*, 2020). The energy-management-based DR solutions accomplish different power usage during peak-demand hours by decreasing the power consumption of certain loads (Samuel *et al.*, 2020; Ramos *et al.*, 2021).

Research on electric vehicles charging scheduling using blockchain:

Electric vehicles have gained significant popularity in recent years as a more sustainable mode of transportation, especially with the increasing focus on reducing greenhouse gas emissions. However, the increased usage of EVs also poses challenges to the power distribution system, particularly in terms of managing the charging load and its impact on the grid. Accurately modelling EV charging profiles is crucial for analysing the effects of increased EV load and charging mechanisms on the distribution system, including thermal limit violations, circuit losses, power quality and market price (Gilleran *et al.*, 2021).

Despite the importance of accurately modelling EV charging profiles, there are still gaps in the research regarding the realistic system behaviour of batteries during the charging process. Many studies consider EV battery loads as static, neglecting the dynamic nature of EV charging. Therefore, there is a need for research to address these gaps and develop more efficient and sustainable charging solutions. The conducted SLR, revealed that that current research aims to address these research gaps and answer questions such as (a) how can EV batteries be better integrated into the grid and used as energy storage devices? (b) how can smart charging systems be developed to lower the charging load and reduce the impact on the grid? (c) how can blockchain-based technologies be used to develop secure and efficient energy trading platforms for EVs? and (d) how can the energy trading in the Internet of Vehicles (IoV) be optimised for demand response management?

Wu *et al.* (2022) proposed a centralized control architecture for modelling and managing EV charging, which reduces peak demand and fulfils power network limitations. Wu *et al.* (2022) emphasised the potential for a bi-directional energy flow, allowing EV batteries to be utilised in the grid as energy storage devices. This approach enables demand management, such as peak shaving and provides additional storage during surplus renewable energy output. Smart charging systems that allow consumers to choose where, when and which EV to charge can help lower the charging load. Lazaroiu and Roscia (2019) developed a smart charging model using an adaptive EV charging flow chart, in which a software agent determines whether to load a unit, in what order, or whether it is better to sell energy to the market. The concept is built on blockchain, making transactions more trustworthy and verifiable and reducing the range of anxiety for EV drivers. Zhang *et al.* (2018) highlighted the challenges for power distribution operators and utilities due to the dynamic nature of EV charging and routing. SMERCOIN is a real-time system proposed by the authors that incentivises EV users to charge on a renewable energy-friendly schedule. It combines the concepts of priority and cryptocurrency, giving charge precedence to customers who have a longer history of using renewable energy. Zhou *et al.* (2019) developed a distributed, privacy-preserved and incentive-compatible demand responses mechanism for the IoV, employing blockchain technology to encourage more EVs to join the demand response program. Authors in Aggarwal and Kumar (2021) proposed a blockchain-based secure energy trading scheme for demand response management between EVs and service providers, maximising social welfare with privacy preservation. Similar examples can also be found in Lin et al. (2020) and Danish et al. (2021), where blockchain capabilities were used to optimise energy trading in IoV-assisted smart cities.

In conclusion, this paper has highlighted the importance of accurately modelling EV charging profiles and addressing the research gaps related to the dynamic behaviour of EV batteries during the charging process. The paper has also provided an overview of the existing literature on the integration of EVs into the grid, the development of smart charging systems and the use of blockchain-based technologies.

2.4.5 Critical Analysis of the Review

The review of the literature reported in Sections 2.3.1 - 2.3.4 led to several observations and research challenges, as presented in the following sub-chapters.

2.4.5.1 Observations

The review of the literature reported in Chapter 2.4.4 lead to the following observations as those illustrated in Figure 2-8.

- **Observation 1:** EVs can be charged through Grid-to-Vehicle (G2V) and discharge electricity towards the power grid through Vehicle-to-Grid (V2G) technology. Hence, EVs may considered as a distributed backup power enabling electricity storage.
- **Observation 2:** Variations in energy production, either surplus or deficit, may threaten the security of energy supply. The latter may lead to energy components overload and culminating with power outages or service disruptions, leading to the so-called Demand Response Problem (DRP).
- **Observation 3:** Specific areas of the IoV may increase the demand during specific time periods and/or locations. Thus, it is a challenge to optimally schedule the charging/discharging behaviour of EVs in order to realize energy balance in the grid.
- **Observation 4:** Existing charging coordination mechanisms suffer from several limitations (e.g. central charging coordination that jeopardizes its effectiveness, lack

of transparency, lack of privacy of the involved customers) while they rely on a single entity, namely Charging Coordinator (CC), to coordinate the charging requests. The CC though, may be an untrusted party which is not always honest in scheduling charging requests. CC also reveals private information about the owners of the EVs (e.g., patterns and drivers' profiles). Thus, it is observed that there is a need for a decentralized, transparent and privacy-preserving charging coordination mechanism to address the DRP in IoV-assisted smart grids.

- **Observation 5:** In most of the selected studies, it is observed that blockchain technology for ensuring the privacy of the EVs owners is considered. However, not many of them are considering incentive mechanisms for encouraging EV drivers to participate in this kind of blockchain-enabled DR framework. There are a couple of studies though, which state that the provision of incentives to the participants (e.g. EV drivers, energy providers, households etc) will be the key to exploit blockchain technology within smart grids and IoV.
- **Observation 6:** Energy demand forecasting helps to maintain the balance between electricity demand and supply in the IoV assisted smart grid. As a consequence, towards optimizing the electricity demand forecasting and planning, EV profiling should be considered.

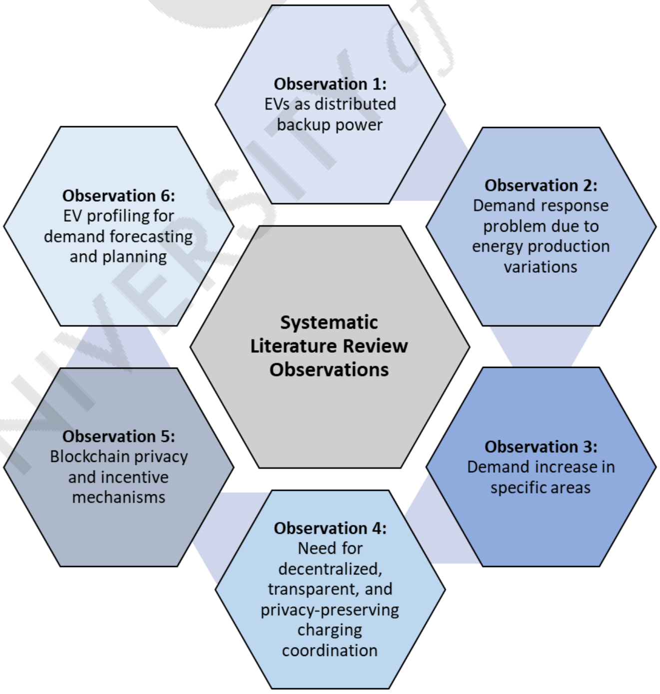


Figure 2.6: Systematic literature review observations

2.4.5.2 Similarities and Differences

This section provides a comparison of selected research studies on demand response management in smart grids with a focus on incorporating EVs. Similarities identified include the need for demand response management, the use of blockchain technology for optimized management and coordination of EV charging and the importance of considering human behaviour and preferences in creating EV profiles. Additionally, real-time energy demand is highlighted as an important aspect and the advantages of blockchain technology are recognized but incentivization schemes are lacking. Differences among the studies include the focus on sustainable microgrid design without incorporating EVs, the use of non-fungible tokens as a means of incentivization, the need for deep learning solutions in smart grids and the proposed data analytics scheme for security-aware DRM using blockchain to maintain grid stability and reduce peak energy consumption.

Overall, the following similarities and differences were identified:

Similarities:

- Optimal demand response management in smart grids is crucial and blockchain technology could establish security and privacy, especially to the drivers' related data and the exchange of information (Aggarwal and Kumar, 2021; Zhang *et al.,* 2018; Lazaroiu and Roscia, 2019; Jindal *et al.,* 2020; Guo *et al.,* 2020; Wen *et al.,* 2021; Karandikar *et al.,* 2021; Pop *et al.,* 2020).
- Blockchain technology can offer optimized management and coordination of EV charging (Knirsch *et al.,* 2018; Zhang *et al.,* 2018; Lazaroiu and Roscia, 2019; Al-Obaidi *et al.,* 2021).
- Human behaviour and preferences should be considered in creating EV profiles that will help the management of IoV assisted smart grids and emphasize different social aspects (Knirsch *et al.,* 2018; Aggarwal and Kumar, 2021; Zhang *et al.,* 2018).
- Real-time energy demand is not sufficiently analysed and explored, even though it is a vital aspect, considering the randomness of the EVs events and the unexpected events that may occur during everyday life (Zhang *et al.,* 2018; Lazaroiu and Roscia, 2019; Guo *et al.,* 2020; Wen *et al.,* 2021).
- Incentivization schemes that will provide relevant rewards to customers (i.e., EV drivers) to participate in a blockchain-based DR framework are lacking (Zhang et al., 2018; Lazaroiu and Roscia, 2019; Jindal *et al.,* 2020; Guo *et al.,* 2020; Wen *et al.,* 2021; Karandikar *et al.,* 2021).

Differences:

- Tsao *et al.*, (2021) focused on sustainable microgrid design problem by leveraging blockchain technology to provide real time-based demand response programs but did not couple it with the IoV or EVs in general.
- Karandikar *et al.*, (2021) focused on Non-Fungible Tokens (NFTs) as a mean for incentivization of the users, instead of price-based incentives.
- Farag *et al.*, (2021) reviewed electric load forecasting, state estimation, energy theft detection, energy sharing and trading and proposed a data analytics scheme for security-aware DRM using blockchain to maintain the grid stability and reduce peak energy consumption.
- Kumari and Tanwar (2020) proposed a data analytics scheme for security-aware DRM using blockchain to maintain the grid stability and reduce peak energy consumption and was motivated from the fact that current DRM solutions are not adequate in terms of peak loads reduction, consumer comfort and data security issues.

The rest of the studies have different approaches in addressing the problem of optimal demand response management in smart grids, such as: reliable, automated and privacy-preserving selection of charging stations based on pricing and the distance to the EV (Knirsch *et al.*, 2018), P2P energy trading scheme between EVs and the SPs to manage the demand response in V2G environment (Aggarwal and Kumar, 2021), blockchain-based approach for smart charging of EVs (Lazaroiu and Roscia, 2019), safe demand response management system based on blockchain (Jindal *et al.*, 2020), game-theory based pricing model in PBFT based-Consortium Blockchain (Jiang *et al.*, 2020), distributed ledger storage and management solution based on blockchain for energy data gathering from IoT and smart metering devices (Pop *et al.*, 2018), blockchain-enabled charging station selection mechanism for EVs (Danish *et al.*, 2021), blockchain-enabled demand response scheme with an individualized incentive pricing mode (Guo *et al.*, 2020), consortium blockchain approach for safe computing resources trading (Lin *et al.*, 2021), blockchain enhanced price incentive demand response (Wen *et al.*, 2021), unified blockchain-based energy asset transaction system for prosumers, electric cars, power companies and storage providers (Karandikar *et al.*, 2021), decentralized solution for demand response programs on top of a public blockchain (Pop *et al.*, 2020) and blockchain-enabled safe energy trading system for privacy and security in the internet of vehicles (Zhou *et al.*, 2019), blockchain-based smart contracts that allow decentralized energy trading among EVs (Al-Obaidi *et al.*, 2021) and a demand response management algorithm combined with a customer incentive system to minimize peak energy usage (Kumari and Tanwar, 2020).

2.4.6 Identification of the Research Challenges and Research Gap

2.4.6.1 Research Challenges

As discussed in earlier sections of Chapter 2, smart grids are now under strain as a result of substantial changes in production and the development of RES, particularly EV. Indeed, growing anomalies in power generation need the development of new paradigms. Demand Response is a well-studied approach in which EV customers actively alter their consumption in response to grid demands. Thus, smart energy management, which allows the optimal use of constrained energy resources, is required for the establishment of a smart, green and sustainable smart grid. However, the widespread use of unpredictable dispersed RES and uncoordinated EVs creates problems for smart energy management. To balance load and supply, a large number of centralized generators and energy storage devices should be placed, resulting in considerable capital expenditure and operational expense. Another option is to investigate the rapid spread of DR which may be used in smart cities to allow energy users to proactively change how and when they use (or create) energy based on the cost (or reward). Because IoV is a participatory data exchange and storage platform, the underlying information exchange system has to be safe, transparent and immutable in order to accomplish the desired objectives. In this regard, the use of blockchain as a system platform for addressing the IoV’s demands has been investigated. IoV applications enabled by blockchain are thought to offer a variety of desirable features, such as decentralization, security, transparency, immutability and automation, due to their decentralized and immutable nature.

Currently available research studies have several similarities as presented above, leading the way towards the integration of blockchain in the demand response management of IoV in smart cities in general. Although, as it is observed, there are still some limitations and open research challenges that need to be further investigated. The identified Research Challenges (RC) are described below and presented in Figure 2.7:

- **Research Challenge 1 (RC.1) -** Private information of the EVs are exposed resulting in privacy and security issues.
- **Research Challenge 2 (RC.2):** Energy generation and consumption in IoV affect the demand and response in IoV and should be further investigated.
- **Research Challenge 3 (RC.3):** EVs with surplus energy are not motivated to participate as energy sellers due to the lack of incentive mechanisms.
- **Research Challenge 4 (RC.4):** EV charging profiling from an EV user perspective is not investigated. This means that each EV user should be aware of and declare its charging preferences and also to update this information in a continuous manner. Charging strategies under a unified framework are not available.

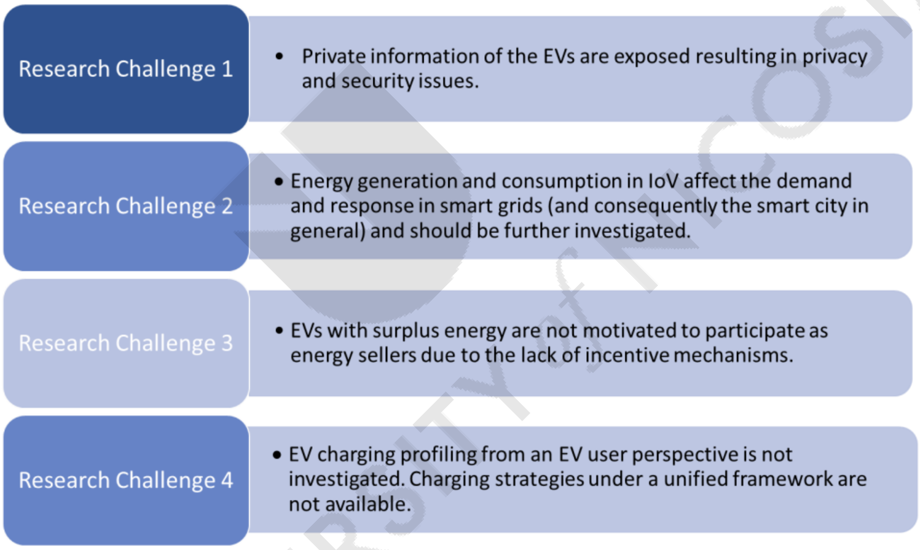


Figure 2.7: Research challenges extracted from the literature

2.4.6.2 Research Gap

Considering the observations presented in this chapter, it appears that the emerging era of the IoV brings the potential for numerous applications to improve quality of life. However, as illuminated by the observations and research challenges presented in this chapter, the full capacity of IoV in facilitating an efficient, reliable and sustainable energy management framework, particularly in relation to the increasing adoption EVs, is yet to be realized.

Observations from current studies reveal that EVs have the potential to act as distributed power storage units, with V2G and V2V technologies, enabling a bi-directional flow of energy. However, this new capability also introduces the issue of demand response management. The variability in energy generation and consumption threatens the balance of supply and demand in the grid, leading to potential overloads or service disruptions. Moreover, localized peaks in energy demand, based on specific time and location attributes in the IoV, further complicate the demand response problem. Another challenge lies in the domain of charging coordination for EVs. Current mechanisms largely rely on a central charging coordination, which has proven to bring limitations. The centralization compromises the effectiveness and further raises concerns over transparency and privacy. Privacy concerns related to the exposure of EV owners' private information, including charging patterns and driver profiles, come to the fore as well. Blockchain technology has emerged as a potential solution to address these challenges. Simultaneously, the role of energy demand forecasting has been identified as a critical factor in maintaining a balance between electricity demand and supply in the IoV. However, the individual EV user perspective has not been sufficiently considered, pointing to the need for each user to declare and continuously update their charging preferences. This requirement calls for personalized approaches to EV charging scheduling.

Concluding, current studies have not yet fully exploited the potential of blockchain technology in demand response management, particularly in terms of privacy preservation and incentivization of participants. Moreover, the need for personalized EV charging strategies and the challenges associated with charging coordination mechanisms are not adequately addressed. Therefore, the research gap lies in the lack of empirical evidence on the effectiveness of blockchain-based demand response management in real-world IoV settings.

To bridge this gap, Chapter 3 proposes a conceptual framework that integrates several innovative approaches, including tokenized incentives, personalized charging schedules and P2P energy trading, within a blockchain-based framework. This framework aims to effectively manage demand response. The proposed model's effectiveness will be further evaluated in Chapter 5, providing critical empirical insights.

2.5 Conclusions

Chapter 2 presented a critical review and analysis of the literature on blockchain use in the area of IoV demand response management. The researcher followed a systematic literature review approach to identify evidence related to the blockchain enabled demand response management. The researcher followed a SLR methodology as presented by Brereton *et al. (*2007) and Kitchenham *et al.*, (2010), as presented in Figure 2.2. Moreover, SLR research questions, based on which the systematic literature review is conducted and used in the development of search strings to extract data from sources, were presented. Moreover, Table 2.6 lists the selected studies that are considered as the main focus of this research. Finally, this chapter provided a critical analysis of the review, highlighting the researcher's main observations and research challenges.

Based on the latter, the researcher identified the following research gap. The literature review revealed that there is a need for further investigation into the impact of using blockchain-based demand response management in IoV for (a) reducing peak load and (b) improving grid stability, as to the best of the researcher's knowledge there is not sufficient empirical evidence that proves its effectiveness in real-world settings. This requires the identification of key variables that contribute to its success or failure and evaluating the impact of incentive mechanisms on user participation in demand response programs. The subsequent chapter centres on the results of the SLR, concerning blockchain utilization DRM within the IoV. This will guide the development of a conceptual model, aligning with Objective 2 of this study.

3. CONCEPTUAL MODEL

3.1 Summary

Chapter 2 laid the theoretical groundwork for the use of blockchain technology in DRM in the context of IoV. The SLR carried out has pinpointed a research gap, encompassing two primary issues. First, it highlighted the need for more profound exploration of the usage of blockchain in DRM in IoV, regarding peak load reduction and grid stability. Second, it underscored the shortage of empirical evidence demonstrating its effectiveness in practical environments. Chapter 3 tries to bridge this gap by proposing a conceptual blockchain-based model for DRM in the IoV.

Specifically, Chapter 3 presents the conceptual model that the researcher is proposing, aimed at enhancing DRM in IoV through the use of blockchain technology. The process began with a comprehensive examination of the identified research challenges and the introduction of proposals that aimed to address them. This analysis led the researcher to the proposition of a conceptual model, that integrates several variables, including tokenized incentives, user profiles, personalized charging schedules and P2P energy trading (among others). The model acknowledges also the role of energy generation, energy consumption, transparent distribution of the incentives and privacy. Additionally, nine hypotheses were formulated to support the proposed model, each one designed to measure the effectiveness of the blockchain-enabled DRM model.

The conceptual model developed in this chapter (Section 3.4) and visualised in Figure 3.2, aligns with the research aim and objectives, marking a significant step towards an enhanced, blockchain-enabled demand response management system in the IoV ecosystem.

3.2 Introduction

The previous chapter critically analysed the existing literature surrounding the application of blockchain technology in the IoV with a special focus on demand response management. This analysis revealed a gap in research, primarily due to a lack of empirical evidence supporting the effectiveness of blockchain-based demand response management in reducing peak load and improving grid stability within real-world IoV settings. The identified research gap is derived from four specific research challenges, as presented in Section 2.4.6.2.

Firstly, a crucial challenge is that EVs lack the motivation to participate as energy prosumers in energy trading due to an absence of effective incentive mechanisms. Secondly, a notable deficiency in research exists regarding profiling from the perspective of EV users, resulting in an absence of effective charging strategies within the current demand response management framework. Thirdly, there is a widespread concern surrounding the potential exposure of private information from EVs, culminating in significant privacy and security issues. Lastly, the influence of energy generation and consumption in the IoV on demand and response management within IoV needs to be thoroughly examined.

In response to these challenges, Chapter 3 presents a conceptual model which leverage tokenized incentives, personalized charging schedules based on users' profiles and bi-directional P2P energy trading, towards an efficient DRM system. The model aims to address the identified research gap and contribute to the broader understanding of the application and impact of blockchain technology in the IoV.

In order to effectively address the research challenges associated with the use of blockchain technology for demand response management in the IoV the researcher undertakes five key investigation actions, as illustrated in Figure 3.1.

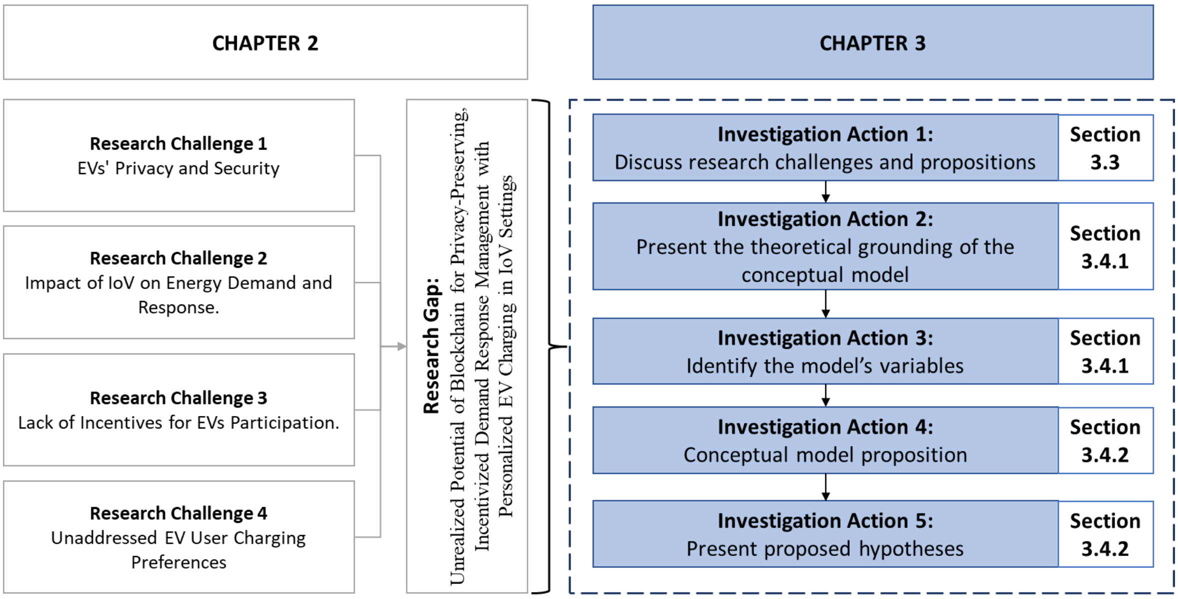


Figure 3.1: Correlating research challenges from chapter 2 with corresponding investigation actions in chapter 3

- **Investigation Action 1:** The researcher discusses the identified research challenges related to the use of blockchain technology for demand response management in IoV and introduce proposals towards addressing them.
- **Investigation Action 2:** This action provides the basis for the conceptual model, by presenting the theoretical grounding. It explains the importance of each proposition, setting the stage for understanding the proposed conceptual model. It also showcase the theoretical connections between the different elements of the model, providing a logical flow from one proposition to the next.
- **Investigation Action 3:** This action aims to identify the research variables involved in the conceptual model. Detailed descriptions of each variable, explaining their role and importance within the context of the conceptual model are also provided.
- **Investigation Action 4:** This action is devoted to the conceptual model presentation, explaining how the variables interact within the model.
- **Investigation Action 5:** During the final investigation action, the researcher proposes research hypothesis that provide testable predictions about how the variables may influence demand response management in the IoV.

3.3 Research Challenges and Propositions

The integration of blockchain technology with the IoV has the potential to revolutionize the management of energy demand and response in IoV. This section discusses the identified research challenges around blockchain enabled DRM, as those derived from Chapter 2. The research gap, uncovered in the literature and detailed in Section 2.4.6, is the primary focus of this chapter. Specifically, the researcher discusses four research challenges and introduces proposals towards addressing them. These challenges, as presented in detail in Section 2.4.6.1 and summarized below:

- RC.1: EV's privacy and security.
- RC.2: Impact of IoV in energy demand and response.
- RC.3: Lack of incentive mechanisms for EVs participation.
- RC.4: Unaddressed EV user charging preferences.

As highlighted by the identified research gap in Section 2.4.6.2, while many studies have discussed the potential benefits of using blockchain technology in DRM, further research is still needed to evaluate the impact of using blockchain-based demand response management and prove its effectiveness. Thus, the following sub-sections describe the current status and approaches of the identified research challenges and propose possible solutions to address them.

3.3.1 Challenge 1: EV's Privacy and Security

3.3.1.1 Challenge description and current approaches

As described in Chapter 2.3, when integrating blockchain within IoV, any transaction-related information, including senders/recipients records and value amounts, are publicly accessible and open. As a result, even if users employ pseudonyms, their identities may not be fully concealed, raising concerns over privacy and security (Theodouli *et al.*, 2020). Moreover, IoV-participants' actions and energy profiles, such as energy consumptions, productions, energy use patterns, driving profiles and other records, can be monitored and leaked by analysing the publicly available data on the blockchain.

Current approaches are mainly focusing on providing privacy and security to the exchanged data, rather than EV drivers themselves. For example, some proposals use consortium blockchain for energy transactions, while others use blockchain for validation and authentication. For instance, (Zhou *et al.*, 2019) proposed a consortium blockchain providing a secure energy trading mechanism, where all energy-related transactions are created, propagated and verified by authorized local energy aggregators (third party). Similarly, Kumari and Tanwar (2020) proposed a data analytics scheme for security-aware demand response management using blockchain, trying to maintain the smart grid stability, while (Lin *et al.*, 2021) proposed a consortium blockchain to ensure the energy transactions' security. Jindal et al. (2020) implemented and evaluated a validation scheme using blockchain to ensure blockchain transactions' security. On the contrary, Danish *et al.* (2021) emphasized the EV user's private information, proposing secure charging services and trusted reservation for EVs with the execution of smart contracts and proper authentication during the EV charging process. Ksnirsch, Unterweger and Engel (2018b) hid the identity and geographic position of the EV users during the selection of the optimal charging station. Pop et al. (2020) introduced a decentralized solution of demand response management on top of a public blockchain, which uses zero-knowledge proofs to protect the privacy of the prosumer's energy data and smart contracts to confirm the prosumer's activities. Finally, Abouyoussef and Ismail (2021) proposed a group signature to ensure the customer's anonymity and data unlikability, based on a private blockchain network. As supported by the SLR presented in Chapter 2, there is a lack of a solution that takes advantage of blockchain as a trust layer over the IoV. Currently, the available approaches mainly focus on decentralized privacy and security in on-chain transactions validation.

3.3.1.2 Proposition 1 – Blockchain as a trust layer

The transparent distribution of tokenized incentives, as well as the secure P2P energy trading facilitated by blockchain technology, plays a vital role in mitigating concerns surrounding privacy and security within the context of demand response management in the IoV. This transparent distribution is not only critical for fostering trust and user engagement but also instrumental in securing the personal information of EV users, thus addressing one of the major research challenges identified in Chapter 2.

By design, blockchain technology keeps an immutable record of all transactions that is transparently recorded and accessible to all network users. Users may independently check transactions, ensuring they are compensated fairly for their participation, which in turn results in an inherent amount of fairness in token distribution. With such levels of transparency, users are more likely to interact with the ecosystem, provide their data for the development of profiles and engage in P2P energy trading.

The participants’ privacy isn’t jeopardized by this transparency, though. While preserving the transparency of transactions, blockchain uses strong security measures to secure user identities. Identity management is an essential part of this.

Without disclosing personal information, the blockchain may identify and verify user identities. On the network, users are represented by pseudonyms, allowing for the tracking and verification of their activity without disclosing their real identities. Since it protects EV users’ personal information from potential exploitation while yet allowing for the tracking of token distribution and energy trading activities, pseudonymity effectively meets the challenge of privacy protection and security.

Additionally, the blockchain ecosystem’s usage of smart contracts is proposed, that might automate the token distribution process based on specified rules, assuring a trustworthy and fair distribution of rewards. Personalized charging schedules might also be established and enforced using smart contracts while still protecting user privacy.

3.3.2 Challenge 2: Demand Response Impact in IoV

3.3.2.1 Challenge description and current approaches

The widespread use of unpredictable dispersed RESs and uncoordinated EVs presents challenges for smart energy management, specifically in balancing the supply and demand of energy. One potential solution is to explore DR strategies that allow energy users to proactively adjust their energy usage based on cost or reward. However, the exponential expansion of energy consumption has led to increased demand-response gaps and lower service quality in the smart grid of Industry 4.0. While EVs can provide an efficient solution for balancing demand-supply mismatches through V2G energy trading, the growing popularity of EVs may place a significant load on V2G energy trading for demand response management. By 2025, it is estimated that there will be 8.4 million EVs on the road worldwide. While several studies focus on P2P energy trading in V2G and/or vehicle-to-vehicle (V2V) environments to handle the demand response problem, they do not efficiently consider the charging/discharging scheduling of EVs or the randomness of future events. For example, Aggarwal and Kumar, (2021) proposed a P2P energy trading system that maximizes social welfare for both EVs and service providers. Additionally, a blockchain-based model for distributed management, control and validation of DR events in low/medium voltage smart grids such as the IoV was presented by Pop *et al.* (2018). However, the selected studies lack two critical elements towards efficient demand response management. Firstly, they do not consider bi-directional charging capabilities, which involve two-way charging and discharging and can facilitate the energy transition. Secondly, they lack mechanisms that detect energy imbalances within a specific IoV area, which could potentially balance the demand and response. As a result, there is a need for a dependable solution to meet the future energy needs of industrial and residential customers while also supporting the charging and discharging requirements of EVs.

3.3.2.2 Proposition 2 – Bidirectional V2V/V2G Energy Trading

This fourth proposition centres on bi-directional P2P energy trading; a mechanism that makes it possible for the IoV energy market to be more effective. This proposition leverages the use of blockchain technology’s decentralized features to improve security, trust and transparency while enabling EV users to take an active role in the energy economy as both energy producers and consumers.

Traditional energy models often include one-way energy flow, with large-scale energy producers supplying energy to consumers. Such configuration reduces effectiveness and responsiveness to changes in the supply and demand of energy in real time. On the other hand, bi-directional energy trade greatly impacts this dynamic. EV owners may efficiently serve as distributed energy sources by using V2G technologies for supplying extra energy to the grid. By allowing EV users (i.e., peers) to sell surplus energy, a more efficient and balanced energy network is fostered. Blockchain offers an ideal environment for these transactions because of its decentralized structure, which guarantees their transparency and secure recording. In addition to promoting participant trust, this security tackles the noted research difficulty of protecting EV users’ private information. Furthermore, the transparency of the blockchain enables all parties to verify the energy transactions, which fosters confidence and promotes participation in the P2P energy market.

Finally, the introduction of tokenized incentives, as proposed in Section 3.3.3.2, which encourage EV users to actively participate in energy trading, is a crucial component of this argument. For each participant, the tokens they obtain are changed based on how much energy was traded. In addition to acting as a form of compensation, these tokens may also be applied to other IoV ecosystem services, adding still another incentive for proactive participation.

3.3.3 Challenge 3: Lack of Incentive Mechanisms For EVs Participation.

3.3.3.1 Challenge description and current approaches

As discussed in Section 2.3.5, creating effective and fair incentive mechanisms is crucial in incentivizing all participants to engage in blockchain-enabled demand response management. However, there is currently limited research focused on incentivization mechanisms, leading to a lack of motivation for EVs with surplus energy to participate as energy sellers. Some studies, such as Vishwakarma and Das (2022), propose blockchain-based incentive systems that promote social welfare and a scam-free transportation network. Similarly, Alquthami et al. (2021) suggest a load management and pricing calculation method based on dynamic incentives that consider load usage and changing patterns over time to determine electricity costs and incentives. Despite these efforts, most studies lack adequate incentives for encouraging EV drivers to participate in blockchain-enabled demand response management and the few that do exist are not mature enough. Price-based and time-of-use incentives are the primary focus of most studies, as seen in the outcomes of the SLR (Section 2.3.5). However, there is a small number of studies that consider incentives based on energy demand. To address this gap, it is essential to create effective and fair incentive mechanisms that encourage EV drivers to participate in blockchain-enabled demand response management, resulting in optimal energy management.

3.3.3.2 Proposition 3 – Tokenized Incentivization

Several of the research problems mentioned in Chapter 2 might be solved with the help of tokenization, especially the challenge of motivating EVs with excess energy to engage in energy trading. The approach of encouraging involvement, often referred to as tokenized incentivization, presents a strategy for promoting a more robust and effective DRM within the IoV.

Providing participants digital tokens in exchange for their engagement in the energy trading ecosystem is the essence of tokenized incentivization. This is a significant breakthrough since it redefines the participants' value offer. With this proposition, EV owners are potentially contributing to the energy supply as producers, acting at the same time as energy consumers as well. When they have extra energy, they might sell it to the grid and get rewarded in tokens. Thereby creating a financial incentive to actively participate in the energy market, these tokens may then be exchanged for other types of value (e.g., energy bill reduction).

Tokenization brings a novel proposition because it does not only offer a mechanism for incentivization but also enhances the system's level of trust and transparency. Blockchain is used to control how these tokens are distributed, giving a record of transactions that cannot be changed. This transparent record can raise user confidence and participation, further enhancing the system's efficacy.

3.3.4 Challenge 4: Unaddressed EV User Charging Preferences

3.3.4.1 Challenge description and current approaches

The literature review in Chapter 2, highlights a lack of investigation into EV charging profiling from the user's perspective. It is crucial for each EV user to declare their charging preferences and continuously update this information to successfully control the charging/discharging schedule in comparison to IoV metrics and stability. Factors such as the size and topology of the energy grid, the quantity and size of EVs, the time and location of charging, as well as the daily driving distance, significantly influence charging profiles. For instance, Chuan Wang *et al.* (2021) built a model to demonstrate the stochastic nature of each EV battery charging start time and first state-of-charge. Hussain et al. (2021) proposed a centralized control architecture to solve modelling and management of EV charging by reducing peak demand, raising the quantity of EVs charged at the same time and addressing other power network restriction. Furthermore, authors in Knirsch *et al.*, (2018a) provided a methodology for charging EVs with dynamic tariffs to identify the cheapest charging station in a previously selected location while maintaining the privacy of the EVs. Similarly, Jindal et al. (2020) proposed a blockchain-based Charging Station (CS) selection methodology for EVs that ensures EV user confidentiality and privacy, availability of booked time slots at CSs, good quality of service and improved EV user comfort. However, in many current approaches related to EV charging and discharging, the EV battery loads are mostly treated as a static load, with the actual system behaviour of the batteries during the charging process being largely neglected.

Despite the existing literature, the discussion above and the outcomes of the SLR (Section 2.4.5), the human factor (i.e., drivers' behaviour) during the charging scheduling is still not adequately considered. Although the preferences of EV users are investigated, driving patterns and EV profiles are not present during the scheduling, resulting in charging schedules that may not be compatible with real-life scenarios. Thus, to optimize DRM, it is crucial to take into account the human behaviour, driving patterns and EV profiles during the charging scheduling.

3.3.4.2 Proposition 4 – EV Profiling for charging scheduling

The third proposition acknowledges that EV users are more than just passive energy consumers; they can potentially supply extra energy to the grid. Due to their specific energy profiles, their charging and discharging behaviour can therefore have a big impact on total energy demand management. As a result, a method for EV profiling is proposed that uses connectivity to EV charging stations and/or directly to the EV through sensors, to extract and analyse data about the traits and behaviours of EVs. This method, which may be improved with AI/ML techniques, may identify patterns in this data to produce detailed and unique EV profiles. These profiles address one of the stated research challenges: the absence of personalized charging strategies. They not only include details about EVs, such as their battery status or charging history, but also about drivers' preferences and habits.

The proposed profiles might then be used to create customized charging and discharging schedules that optimize not only the individual EV's energy consumption and/or generation but also help the grid maintain a more efficient energy balance. These plans successfully balance energy demand and supply by considering the preferences and driving habits of individual drivers, reducing peak loads and improving grid stability.

3.4 Introducing a Novel Conceptual Model for Blockchain Enabled Demand Response Management in IoV

3.4.1 Theoretical Grounding of the Conceptual Model

Building upon the discussion from Section 3.2, this section provides the theoretical grounding, focusing on the application of blockchain technology within the IoV to enhance demand response management efficiency. Specifically, the theoretical grounding of the proposed model, incorporates various variables such as tokenized incentives, transparent distribution, user profiles, personalized charging schedules, bi-directional P2P energy trading, energy consumption/generation, privacy and primary energy generation. These variables interact to effectively manage demand response.

Tokenized incentives serve as an innovative strategy to motivate user participation in DRM actions and facilitate the creation of user profiles. The latter is important due to the fact that user engagement is the backbone of a successful DRM system and incentives can significantly increase this engagement. Furthermore, by using blockchain technology, which is noted for its immutable and secure properties, these incentives will be transparently distributed, fostering user confidence in the system’s fairness and effectively addressing privacy and security concerns.

The model also leverages user profiles enriched with data reflecting each user’s driving and charging habits. These profiles inform the development of personalized charging schedules, which subsequently enable users to participate effectively in bi-directional P2P energy trading. The importance of these profiles cannot be overstated as they inform the development of personalized charging schedules. Personalization is key in creating an efficient DRM system as it considers the individual energy needs and consumption patterns of users, thus enhancing overall system efficiency.

Furthermore, the proposed model underlines the interconnection between energy generation and consumption in bi-directional P2P trading, with a particular emphasis on EV energy generation. In this context, EVs transform into distributed energy sources, injecting surplus energy back into the grid. The integration of EVs into the energy grid (i.e. turning consumers into prosumers), increases grid flexibility and enhances the overall robustness and resilience of the IoV. Participating actively in P2P energy trading may result in more energy-efficient consumption habits as well as increased energy production.

When necessary, energy production from various renewable sources like photovoltaics, wind turbines and other green energy systems could also be established. The quantity and time of energy production from these primary sources, provide an additional supply that can support effective DRM when the energy generated from the EVs is not sufficient. The integration of other (renewable) sources could enhance the sustainability of the energy system, reduce dependency on EVs solely and contributes to environmental protection.

The theoretical grounding presented above, lead the researcher to the identification of ten variables as part of the proposed conceptual model.

- **Variable 1 - Tokenized Incentives:** The tokens provided to users for active participation in the demand response framework.
- **Variable 2 - Transparent Distribution:** The fairness and transparency of token distribution over the blockchain.
- **Variable 3 - User Profiles:** The anonymized preferences of EV users recorded on the blockchain.
- **Variable 4 - Personalized Charging Schedules:** The individual charging schedules developed for each user, based on their profile.

- **Variable 5 - Bi-directional P2P Energy Trading:** The amount of energy traded (both consumed and produced) by each user in the P2P energy market facilitated by the blockchain.
- **Variable 6 - Primary Energy Generation:** The energy generated from primary sources like photovoltaics, wind turbines, or other resources that can contribute energy to the grid.
- **Variable 7 - EV Energy Generation:** The amount of energy generated by EVs who are participating in the bi-directional energy trading, including the energy contributed back to the grid by the EVs.
- **Variable 8 - Energy Consumption:** The amount of energy used by each EV user.
- **Variable 9 - Privacy:** The extent to which the exchanged information is protected.
- **Variable 10 - Demand Response Management:** The effectiveness of the overall DRM framework.

Variables 1 to 9 are the independent variables, and it is hypothesized that they affect the dependent variable (i.e., Variable 10 - Demand Response Management).

3.4.2 Conceptual Model Proposition

In an effort to provide a cohesive and integrated perspective on blockchain-enabled Demand Response Management in the context of the IoV the following conceptual model has been developed, based on the discussion carried out throughout Section 3.3. and 3.3.1. This model endeavours to encapsulate the interactions between variables identified in this research (Section and 3.3.1).

A visual representation of the conceptual model is provided in Figure 3.2 highlighting the theoretical basis previously discussed. Each link represents a potential impact an independent variable can have on demand response management.

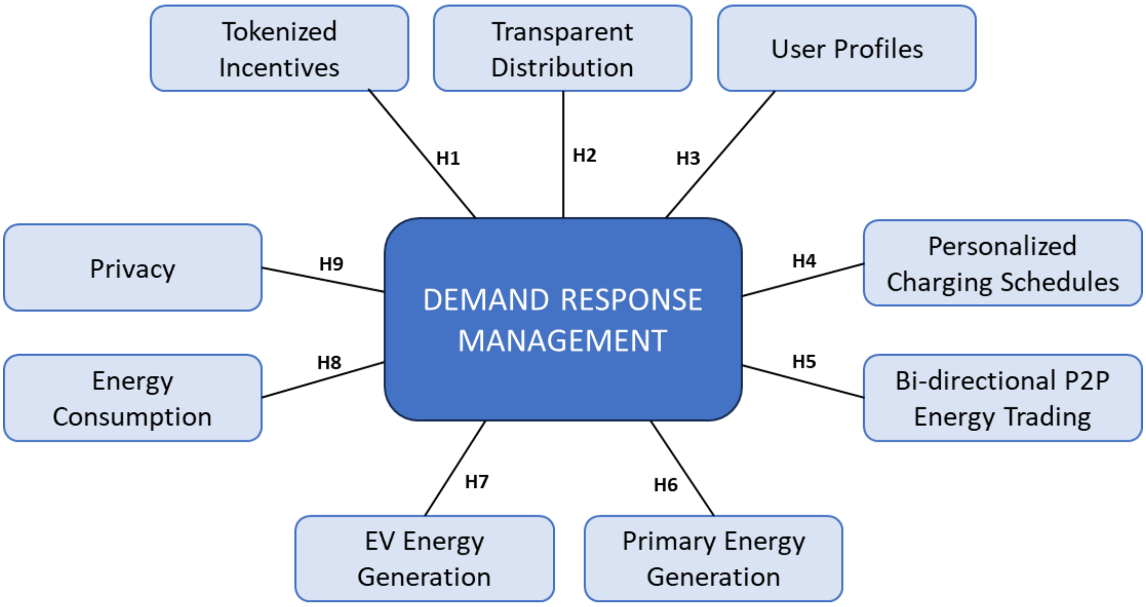


Figure 3.2: Proposed conceptual model

Nine hypotheses connect the variables and form the conceptual model's foundation. These hypotheses lend depth to the model's structure and test its significance in demand response management in the IoV:

- **Hypothesis H1 (H1): Tokenized incentives could potentially influence users' willingness to participate in the demand response program.**
  - Description: This hypothesis proposes that users' willingness to actively participate in the demand response program may be positively influenced by tokenized incentives, which serve as a type of reward for users. The hypothesis is that incentives could promote actions that are advantageous to demand response management as a whole.
- **Hypothesis H2 (H2): Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation.**
  - Description: It is anticipated that transparency, especially in the token distribution process, will enhance demand response management performance. Users are more likely to actively engage in the program and increase its overall efficacy when they have faith in the system's fairness and honesty.

- **Hypothesis H3 (H3): Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules.**
    - Description: This hypothesis suggests that accurate and comprehensive user profiles could increase demand response management effectiveness. The underlying assumption is that customized charging schedules produced from user profiles may result in more effective patterns of energy production and consumption.
- **Hypothesis H4 (H4): Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management.**
    - Description: This hypothesis suggests that personalized charging schedules may have an impact on the extent of bi-directional P2P energy trading. It is hypothesized that users are more likely to engage in energy trading and improve demand response management when charging schedules are customized to their unique needs and behaviours.
- **Hypothesis H5 (H5): Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance.**
    - Description: According to this hypothesis, actively engaging in bi-directional P2P energy trading may have an influence on the balance between energy generation and consumption. The hypothesis is that when consumers both use and produce energy, it may result in a more effective balancing of energy resources, which would help Demand Response Management succeed.
- **Hypothesis H6 (H6): Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand.**
    - Description: The hypothesis is that primary energy production might be essential for assisting demand response management. The rationale behind such energy sources is that they offer a consistent supply to satisfy energy demand, hence enhancing grid stability and the efficiency of Demand Response Management.
- **Hypothesis H7 (H7): Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management.**

    - Description: According to this hypothesis, the energy produced by EVs could enhance the efficiency of Demand Response Management. The underlying idea is that EVs, as prospective energy sources, might help keep supply and demand in balance, improving the effectiveness of demand response management.
- **Hypothesis H8 (H8): The level of energy consumption could potentially influence the overall load on the grid and effectiveness of demand response management.**
    - Description: According to this hypothesis, the amount of energy consumed could have an impact on the grid’s total load and the efficiency of demand response management.
- **Hypothesis H9 (H9): Privacy measures could potentially influence user trust and willingness to participate in the demand response program.**
    - Description: This hypothesis argues that privacy measures might affect prosumers’ confidence in the system and readiness to take part in the demand response program. The rationale behind this is that participants are more likely to trust the system and actively participate in demand response activities when their data and transactions are effectively protected.

In conclusion, the proposed conceptual model combines crucial aspects like tokenized incentives, transparent distribution, user profiles, personalized charging schedules, bidirectional P2P energy trading and optimal energy generation and consumption. Each component plays a vital role. Thus, the integration of these aspects with blockchain technology presents a novel approach to managing demand response in the IoV. The model addresses key issues like user privacy, energy imbalance and user participation deficiency, potentially bridging the identified research gap.

3.5 Conclusions

In this chapter, the researcher has proposed a novel conceptual model aimed at enhancing DRM in IoV, via blockchain technology utilization. This model directly responds to the research challenges pinpointed in Chapter 2 (Section 2.4.6) by providing targeted solutions.

Blockchain technology's features empower the model to streamline the processes of energy generation, consumption and trading, thereby enhancing the efficiency of DRM. This chapter thoroughly describes the researcher's proposition, from tokenized incentives to user profiles, personalized charging schedules and bi-directional P2P energy trading, illuminating the multifaceted benefits of blockchain solutions in the DRM of IoV.

In the process of creating this conceptual model, ten variables were defined and analysed. Each variable plays a unique role, affecting different aspects of the DRM process. The theoretical relationships between these variables were examined, forming nine foundational hypotheses that underpin the model. These hypotheses provide a conceptual model, laying the groundwork for examining potential impacts on DRM effectiveness.

Having presented the theoretical framework of the proposed conceptual model, the subsequent chapter (Chapter 4) will outline the research methodology to test this proposition empirically. The methodological approach will be explained and justified, setting the stage for testing the proposed hypotheses.

4. RESEARCH METHODOLOGY

4.1 Summary

Chapter 4 provides a comprehensive overview of the methodological approach taken in this study to investigate the use of a blockchain-based DRM model within the IoV context. The chapter begins by detailing the research's philosophical stance, taking an interpretivism approach which aligns with the abductive research approach adopted in this study.

The chapter also explains the qualitative methodological approach taken, which is deemed appropriate given the exploratory and in-depth nature of this research. The case study strategy is selected due to its potential to provide rich, contextual insights into the research topic under investigation.

The methods of data collection are also outlined, which include semi-structured interviews, document analysis and the review of archival records. Each of these methods is justified and detailed, providing an understanding of how they contribute to the data completeness and quality.

Additionally, the interview's procedure is thoroughly detailed, including the aspects of ensuring participant comfort, gaining informed consent and ensuring data confidentiality. The purpose of the semi-structured interviews is also discussed and an interview agenda is presented to guide the process.

Then, the chapter highlights the critical process of data analysis, underlining the need of maintaining consistency during this phase. Data triangulation is also discussed, with the researcher intending to apply it to ensure the validity and reliability of her findings.

Finally, the chapter provides an outline of the case study protocol that is followed, detailing the overview of the study, field procedures, questions addressed by the research and guidelines for reporting the research findings.

4.2 Introduction

The research onion model proposed by Saunders et al. (2011) provides a comprehensive model for conducting research by defining the various stages involved in the process. The model comprises of six layers that are interdependent, with each layer building upon the previous one (Figure 4.1). These layers include research philosophy, research approach, research strategy, time horizon, data collection methods and data analysis methods. Each layer will be described an analysed in the following sections.

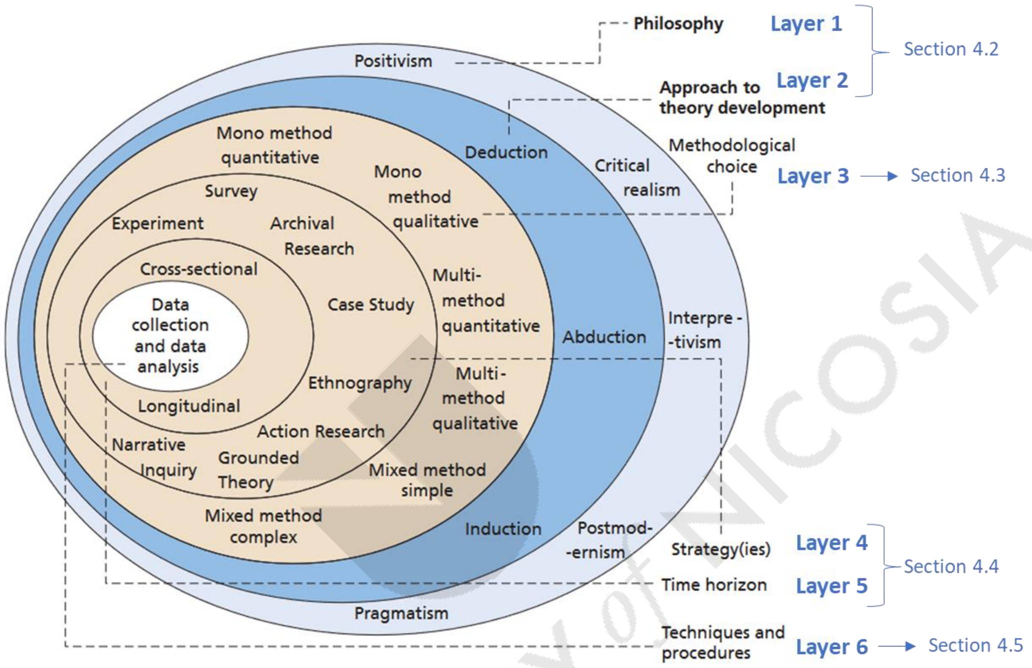


Figure 4.1: The 'research onion' model

(Adopted from Saunders et al., 2011)

The research onion approach involves six layers that guide the research process. The first layer involves selecting the research philosophy, which is explained and justified in Section 4.3. The second layer focuses on the research approach, which is justified in Section 4.3 also. The third layer covers the available methodological choices and the adopted approach, which is explained and justified in Section 4.4. The fourth and fifth layers pertain to the research strategy and time horizon, respectively, which are also justified in Section 4.5. Finally, the last layer involves the techniques and procedures for data collection and analysis. In Section 4.6, the empirical research methodology is introduced, including the research design. This section offers insights into the research design, related data, methods of data collection, and the approach for interpreting and reporting the outcomes. Finally. Section 4.7 presents the case study protocol of this thesis.

4.3 Selecting a Research Philosophy and Approach

The research on blockchain use in demand response management of IoV is classified under computer science. Considering the advancing nature of blockchain technology and the complexities of the IoV, choosing an appropriate research methodology is of paramount importance. This guarantees that the study is not just rigorous but also captures the field’s complexities. To select the appropriate research strategy for this dissertation thesis, it is decided to first dive into the different research philosophies and approaches, in order to (a) provide deep knowledge and understanding of the multidisciplinary nature of computer science and (b) justify the rationale behind the chosen philosophical stance in this research.

4.3.1 Philosophical Perspectives

The selection of an appropriate research philosophy is an important and complicated task during the research process, since the research paradigm is a set of beliefs which direct the research, as Guba and Yvonna state (1994). Based on (Catterall, 2000) and (Saunders, 2015), there are five main philosophies: (a) positivism, (b) critical realism, (c) interpretivism, (d) postmodernism and (e) pragmatism. The philosophical perspectives mentioned above are briefly outlined below, to provide the reader with a clearer comprehension of the basis for selecting the stance of this thesis.

- **Positivism:** Scientists who are part of the positivism philosophy view the world as being real and existing independently from the human existence. The world is seen as an ordered, structured place that is governed by physical laws. Studying the world from this position can be done objectively and without concern for how people create meaning (Comte, 2009). Additionally, positivism assumes the previous existence of structured relationships in the phenomena under investigation (Comte, 2009). The positivist philosophical stance also places a strong emphasis on precise measurement and hypothesis testing and assumes that science is objective. The basic principle of this paradigm is the verification theory of meaning, which asserts that assertions or arguments are significant only if they can be empirically/experimentally proved (Clark, 1998). This model is primarily distinguished by the inductive statistical method of research (Brown *et al.*,1987).

- **Post-modernism:** Postmodernism emphasizes the importance on the function of language and power dynamics in an effort to challenge accepted thinking and bring clarity to unfavoured, alternative viewpoints. They contend that any impression of order is illusory and without substance and can only be created by the categories and classifications of our language (Clark, 1998). In order to find instabilities inside these realities' commonly held truths and for what has not been explored - absences and silences produced in the shadow of such facts (Derrida, 2019).

- **Critical Realism:** According to the critical realism philosophy, an occurrence is caused by actual, pre-existing mechanisms. A detailed grasp of the otherwise non - observable mechanism using qualitative and quantitative methodologies also has predictive but explanatory potential. The critical stance, more particularly, emphasizes the social and historical contexts and sources of meaning (Ambert *et al.*, 1995). The critical approach looks closely at the process of knowledge acquisition. As a result, information is not discovered by unbiased research but rather through discussion and critical disclosure (Ambert *et al.*, 1995).
- **Interpretivism (selected):** The interpretive philosophy is founded on the idea that since science is subjective, other models of reality are acceptable. In many ways, it is the antithesis of positivism and emphasizes the creative side of science. The interpretive perspective emphasizes the significance of such aspects for an understanding of how scientific knowledge develops (Alharahsheh, 2020). In contrast, the positivist model, disregards factors like social interaction and influence among researchers, the quirks of the individual researchers and the researchers' subjective interpretations (Peter and Olson, 1983). In fact, observations are always understood in the context of the researcher's knowledge and models, as pointed out by both Kuhn (1971) and Popper (1972).
- **Pragmatism:** According to pragmatism, the significance of ideas lies in their ability to facilitate action, as discussed by Kelemen and Rumens (2011). Pragmatism strives to strike a balance between subjectivism and objectivism, values and knowledge, precision and rigor and the multitude of contextualized experiences. This equilibrium is achieved by assessing theories, concepts, ideas, hypotheses and research findings in terms of their utility as tools for both thought and action, considering their practical implications in specific situations rather than in abstract terms. Pragmatists emphasize the importance of reality, as it directly influences the practical application of ideas and they hold knowledge in high regard, recognizing its role in enabling actions. Pragmatist approaches research from the perspective of addressing a problem and aims to provide valuable solutions that have a tangible impact on current practices. When faced with uncertainty or a sense of discord, the reflective investigative process is set in motion,

ultimately reinforcing belief once the problem has been resolved (Elkjaer and Simpson, 2011).

It is evident that a research philosophy is the choice of the researcher, on how to pursue her research. Even though the aforementioned stances have identified as the five main research philosophies in academia, choosing one is a matter of the researcher's viewpoint and perspective. In an attempt to make the decision easier, in Table 4.1, the researcher presents a comparison of the philosophical perspectives (Catterall, 2000).

4.3.2 Research Approaches

There are three main approaches to theory development: deduction, induction and abduction (Catterall, 2000; Azungah, 2018; Woiceshyn and Daellenbach, 2018). As stated in Catterall (2000) the deductive method is employed when research commences with a hypothesis, often derived from an examination of academic literature. Subsequently, the researcher constructs a research strategy to test this hypothesis. On the other hand, an inductive approach is chosen when the research initiates with the collection of data to explore a phenomenon and generate or construct a theory, typically in the form of a conceptual framework. The abductive method is utilized when data are gathered to examine a phenomenon, uncover themes and extract patterns, with the aim of formulating a new hypothesis or revising an existing one, which is subsequently assessed through additional data collection. The research approaches mentioned above are detailed below, to enhance the reader's understanding of the researcher's chosen methodology.

- **Deductive Approach:** A theory and hypothesis (or hypotheses) are formed through deduction, to test an idea. It entails the construction of a theory that is then put into practice using a number of premises in a rigorous manner. As a result, it is the predominant study methodology in the natural sciences, where laws serve as the basis for explanation, enable the prediction of events, forecast their occurrence and afterwards enable their management. Furthermore, in a deductive inference, if the assumptions are true, the conclusions should be true as well. Deductive studies would also employ a highly structured methodology to aid replication. Generalization is another characteristic (Catterall, 2000).

Table 4.1: Comparison of philosophical perspectives

	Positivism	Critical realism	Interpreti-vism	Post-modernism	Pragmatism
Overview	Positivism focuses on the observable reality and aims to produce law-like generalizations.	Supporters of critical realism claim that reality is much more than our senses allow us to see, preferring to focus on the bigger picture.	Interpretivism is a subjectivist philosophy that focuses on studying the people and the meanings they create.	Postmodernism is a subjectivist philosophy, that emphasizes the role of language and aims to give voice to alternative or deprecated views.	Pragmatism focuses on making scientific progress using a variety of methods.
Acceptable knowledge	Scientific methods Observable and measurable facts Causal explanations	Relativism Knowledge historically situated. Facts are social constructions. Historical causal explanations	Theories and concepts too simplistic Focus on perceptions and interpretations. New understandings and worldviews as contribution	Dominant ideologies Focus on absences, silences and oppressed/repressed meanings. Interpretations and voices Exposure of power relations and challenge of dominant views as contribution	Practical meaning of knowledge in specific contexts Focus on problems & practices. Problem solving & informed future practice as contribution
Typical methods	Deductive Large samples Highly structured Quantitative methods	Retroductive In-depth historically situated analysis of pre-existing structures. Range of methods and data types	Inductive. Small samples In-depth investigations Qualitative methods of analysis	Deconstructive In-depth investigations of anomalies and absences Range of data types Qualitative methods of analysis	Following research problem and research question Range of methods: qualitative, quantitative, action research Emphasis on practical solutions and outcomes

- **Inductive Approach:** With induction, data are gathered and after data analysis, a theory is created. Deduction originated in natural science study, as we already mentioned. Deduction, however, has become a source of concern for social science researchers in the twentieth century. They criticized a method of reasoning that made it possible to establish a cause-and-effect relationship between certain factors without considering how people interpret their social environment. The strength of an inductive approach is to develop such an understanding. The context in which such events occur is likely to be of particular interest to research that employs an inductive approach of thinking. As a result, a study of a small sample of people rather than a large one, as with the deductive technique, may be more appropriate in inductive process. In order to build various perspectives on phenomena, researchers in this approach are more likely to deal with qualitative data and a variety of approaches to acquire it.

- **Abductive Approach (selected):** In the case of abduction, data are used to study a phenomenon, discover patterns and explain them to develop a new or change an existing hypothesis that is then put under test. An abductive approach swings back and forth, effectively integrating deduction and induction, Abductive approach opposes deduction which is moving from theory to data and inductions which is moving from data to theory (Griffin and Hustad, 2003). Abduction starts with the observation of a "fact," and then it develops a reasonable explanation for how it could have happened. Deduction and induction are complementary to abduction as logics for testing plausible theories, according to (Van Maanen, Sørensen and Mitchell, 2007).

A brief comparison between the three research approaches is presented in Table 4.2.

Table 4.2: Research approaches comparison

Approach	Criteria	Description	Application
Deductive	Logical reasoning from general to specific.	Begins with theory and tests hypotheses against data.	Ideal for hypothesis testing with extensive knowledge on a topic.
Inductive	Observational to general theory.	Builds theories from patterns in collected data.	Best for new theories from empirical observations.
Abductive	Pattern recognition to plausible explanation.	Infers likely explanations for incomplete observations.	Suited for case studies needing initial explanatory hypotheses.

4.3.3 Justifying the Selection of Interpretivism Philosophical Stance and Abductive Research Approach

The aim of this research is to investigate the use of blockchain technology for the demand response management on the Internet of Vehicles. The research objectives include conducting a systematic literature review on blockchain use in IoV and the application of it in the demand response management, proposing a blockchain-based conceptual framework for demand response management and evaluating the proposed framework towards contribution to knowledge.

To determine the most suitable philosophical stance for this PhD thesis, the five main philosophies were considered: positivism, critical realism, interpretivism, postmodernism and pragmatism. After thorough consideration, it was concluded that the most fitting philosophical stance for this thesis is interpretivism. Interpretivism is based on the belief that our knowledge of reality is a social construct and therefore, is subjective. It emphasizes understanding the depth and complexity of human experiences, rather than simply looking for causality. This perspective resonates with the goals of this research, as the researcher not just seeking to identify a causal relationship between blockchain use and improved demand response management in IoV. Instead, the researcher aims to understand the nuances, challenges and potential opportunities associated with this integration. This requires a detailed exploration of diverse stakeholders' perspectives, understanding their interpretations and gathering rich insights that are often neglected in more positivist research.

Additionally, this research adopts an abductive research approach. Unlike deduction, which starts with a theory and tests it, or induction, which starts with data and builds a theory, abduction is a dynamic interplay between theory and data. The abductive approach allows for the exploration of observed data "anomalies", leading to the refinement or development of new theories. Given that the application of blockchain in the IoV for demand response management is a relatively new and evolving field, it is likely that the research will encounter unexpected findings. The abductive approach is particularly suited for such scenarios, allowing the researcher to derive new or modified theories that can then be further tested and refined.

In the context of this thesis, the initial insights from the literature about demand response management, blockchain technology and the IoV will guide the early stages of the research and the proposition of a conceptual model. As empirical data is gathered, the abductive approach will enable the researcher to revisit and potentially modify the proposed model, ensuring that the research remains grounded and relevant.

4.4 Selecting a Methodological Approach

This section presents the different methodological approaches, as a form to explore the underlying work. While several methodologies exist, the most dominant ones are the quantitative and qualitative research methodologies (Wilson, 1978).

4.4.1 Qualitative Research

Exploratory research makes up most of the qualitative research. It is employed to comprehend the underlying causes, viewpoints and motivations. It offers understanding of the issue or helps formulating concepts or theories for possible quantitative studies (Ambert *et al.*, 1995; Moriarty, 2011). To further investigate the issue and identify trends in attitudes and cognition, qualitative research is also employed. The typical questions asked in qualitative research include "what," "how" and "why" of a phenomenon (Guba and Yvonna, 1994; Clark BA RN, 1998). Creswell (2000) gives a brief description of qualitative research. He claims that:

> *"Qualitative researchers routinely employ member checking, triangulation, thick description, peer reviews and external audits. Researchers engage in one or more of these procedures and report results in their investigations."*
>
> *Creswell (2000, page 124)*

The most common qualitative research methods include ethnography which offers an immersion into cultural or social groups; phenomenology, focusing on the lived experiences of individuals; and grounded theory, which seeks to develop theory rooted in data. Additionally, there is case study research, which stands out as am in-depth approach, allowing researchers to investigate a specific phenomenon within its real-life context (Creswell, 2000). Within these methods, popular data collection techniques are interviews, focus groups, observations and document analysis (Lewis, 2015). These techniques entail direct communication (either in person or online) with a participant. It is mostly used to investigate attitudes and opinions on particular subjects. These techniques, particularly when employed in case studies, often encompass structured and semi-structured interviews, facilitating direct communication with participants.

4.4.2 Quantitative Research

Quantitative research methods are concerned with collecting and analysing data that is structured and can be represented numerically (Clark, 1998; Franklin, 2008; Goertzen, 2017). Quantitative research utilizes quantifiable data to establish facts and detect patterns within a study. The methods employed for collecting quantitative data are notably more structured compared to those used for gathering qualitative data. Various formats, including surveys, face-to-face and telephone interviews, longitudinal studies, online polls, as well as systematic observations and experiments, are employed to acquire quantitative data (Franklin, 2008). Common quantitative methods include experiments, observations recorded as numbers and surveys with closed-ended questions (Denzin *et al.*, 2008; Franklin, 2008; Goertzen, 2017). Furthermore, in quantitative research, surveys consist of lists of open-ended or multiple-choice questions that are administered to a sample, whether online, in person, or over the phone. On the other hand, observations involve the act of observing participants in a natural setting where variables cannot be controlled. As previously mentioned, quantitative data relies on numerical values. To identify patterns or commonalities within the data, researchers employ either basic mathematical calculations or more advanced statistical analyses. The presentation of results often involves the use of tables and graphs. The outcomes may encompass average scores, the frequency of specific responses, correlations or causal relationships between two or more variables, as well as an evaluation of the validity and reliability of the findings.

4.4.3 Justifying Qualitative Research as Chosen Methodological Approach

In essence, qualitative and quantitative research methodologies allow you to address many types of research questions by collecting data in various ways. Their differences are presented in Table 4.3, below.

Table 4.3: Comparison between qualitative and quantitative research methods

Criteria	Quantitative Research	Qualitative Research
Basis of Analysis	Statistical, mathematical; Objective data analysis.	Interpretative; Subjective meaning from data.
Expression of Results	Numerical form (e.g., numbers, graphs, tables).	Descriptive form (e.g. words, images, narratives).
Sample Size	Large for generalization; Usually more than 100 samples; Sample has a statistical significance.	Smaller sample but more in-depth; Focused on context.
Key Terms	Testing, measurement, objectivity, replicability.	Understanding, context, complexity, subjectivity.

Qualitative research has several advantages that make it a suitable approach for the current thesis.

- First, qualitative research is well-suited to examining complex phenomena and understanding the meanings and interpretations that individuals attach to these phenomena. As this study aims to explore the use of blockchain technology in the context of the IoV, a qualitative approach can provide insight into the various factors that shape the use and acceptance of this technology. This can include social, cultural and institutional factors that are not easily quantifiable but are nonetheless important for understanding the complex nature of technology adoption and innovation.

- Second, qualitative research is flexible and adaptable, which allows for the exploration of the refinement of research hypothesis as the study progresses. This is particularly relevant for this study, which involves the development and evaluation of a conceptual framework for demand response management in the IoV. The iterative and reflexive nature of qualitative research can help to ensure that the proposed framework is grounded in empirical evidence and reflects the perspectives and needs of relevant stakeholders.

However, qualitative research approach presents a number of drawbacks, which should be taken into consideration when adopting such a research approach. One of the main drawbacks is the potential for subjectivity and bias in data collection and analysis. In the context of the current thesis, using a qualitative approach may limit the ability to make broad generalizations about the effectiveness of blockchain technology in demand response management in IoV. Additionally, the small sample size and non-random sampling techniques used in qualitative research may limit the ability to generalize findings to a larger population, which may be problematic when aiming to make recommendations or provide insights for industry or policy makers.

To overcome the aforementioned limitations, the researcher will use triangulation by providing multiple perspectives on the same phenomenon. In the context of the current thesis, the researcher will use multiple sources of data, to provide a more comprehensive understanding of the use of blockchain technology for demand response management in the IoV. By using multiple methods of data collection, the researcher will increase the credibility and reliability of her findings, as well as enhance the validity of her research. Triangulation can also help to identify any inconsistencies or discrepancies in the data and allow for a more thorough analysis of the results.

Overall, the advantages of qualitative research make it a suitable approach for this thesis, as it can provide a rich and detailed understanding of the complex phenomena under investigation, while also allowing for flexibility, adaptability and reflexivity in the research process.

4.5 Selecting a Research Strategy

4.5.1 Qualitative Research Strategies

After establishing positivism as the philosophical stance and qualitative research as the methodology for this thesis, this section introduces the research strategies applicable in a qualitative approach, guiding towards the selection of the most suitable one. A research strategy is a plan or method for carrying out a research project that outlines the general approach to be used in achieving the research objectives. It involves making decisions about how to collect and analyse data, what methods and techniques will be used and how to ensure that the research is valid, reliable and ethical.

The most commonly used strategies in qualitative research include the following:

- **Case Study:** A case study is an in-depth examination of a particular phenomenon or event, usually focusing on a single individual, group, organization, or community. Case studies often involve multiple sources of data collection, including interviews, observations and document analysis (Yin, 1994; Yin, 2013).

- **Grounded Theory:** Grounded theory is a research strategy that seeks to develop a theory based on the data collected. It involves the systematic collection and analysis of data, with the aim of identifying patterns and themes that can be used to develop a theory that explains the observed phenomenon (Strauss, 1990).

- **Phenomenology:** Phenomenology is a research strategy that focuses on the lived experiences of individuals or groups. It involves the exploration of subjective experiences, perceptions and meanings attributed to a particular phenomenon (Polkinghorne, 1989).
- **Ethnography:** Ethnography is a research strategy that involves the immersion of the researcher in a particular culture or social group, with the aim of understanding the culture and social practices of that group. It often involves the use of participant observation, interviews and document analysis (Stebbins, Hammersley and Atkinson, 1985).
- **Narrative Analysis:** Narrative analysis is a research strategy that involves the study of stories or narratives, with the aim of understanding the ways in which individuals construct their experiences and identities through the use of stories (Patterson, 2008).
- **Content Analysis:** Content analysis is a research strategy that involves the systematic analysis of written, oral, or visual communication, with the aim of identifying patterns, themes and meanings that emerge from the data (Downe-Wamboldt, 1992).

4.5.2 Justifying the Use of Multiple Case Studies

The case study is a common qualitative research strategy that has been used in various fields, including business, social sciences and education. In this strategy, the researcher focuses on multiple case studies, investigating them in depth to gain a comprehensive understanding of a phenomenon. In the context of the current thesis, which investigates the use of blockchain technology for demand response management on the IoV, a multiple case study approach is the most suitable research strategy.

- Firstly, considering that the objectives of this thesis as described in Section 1.3.2, a case study approach allows to investigate the phenomenon in its natural context. The latter is crucial in developing a conceptual framework that is grounded in reality. By selecting targeted and multiple case studies, the researcher can gain an in-depth understanding of the complexities of the phenomenon, which would be difficult to achieve through a survey or experiment.

- Secondly, the identified research hypotheses, as described in Section 3.4, are centred around the effectiveness of the proposed model in reducing peak load, enhancing grid stability and improving DRM. These are complex phenomena that are influenced by a range of factors, including technological, environmental and social factors. A multiple case study approach allows the researcher to investigate these factors in-depth, identifying the specific factors that contribute to the effectiveness of the proposed framework.

- Thirdly, one of the objectives of this thesis is to contribute to knowledge around blockchain-enabled DRM in the IoV. A case study approach allows to generate rich, detailed data that can provide insights into the phenomenon, that may not be captured through other research strategies. By selecting multiple cases, the researcher can compare and contrast the findings, identifying commonalities and differences that may inform the development of a more comprehensive understanding of the phenomenon.

- Fourthly, multiple case studies would allow the researcher to use also triangulation, to employ various data collection methods, including interviews and document analysis from multiple cases, to overcome the limitations of qualitative research. Additionally, by comparing and contrasting the findings from different cases, the researcher can enhance the validity and reliability of the findings, thus contributing to the rigor of the research.

- Lastly, the case study approach is compatible with the positivist philosophical stance and deductive research approach chosen for this thesis. It allows for the testing of the proposed hypotheses and the evaluation of the conceptual model through the collection and analysis of empirical data. Additionally, a case study approach is suitable for generating theory from data, which can contribute to the advancement of knowledge in the field of blockchain-based DRM in the IoV.

4.5.3 Justifying the Cases Selection

When implementing a multiple case study approach, the rationale behind selecting specific cases holds significant importance. In the context of the research outlined in this dissertation, four case organizations, namely Hypertech, E7, SUPSI and Hive Power, were examined. The primary motivations for selecting them are as follows:

- **European Reputation**: All four organizations boast a notable European reputation in the area of blockchain and energy services. Their impact and contribution in this space are recognized and respected across the continent, making them invaluable subjects for this research.

- **Experience with Blockchain & Energy Services**: Each of these organizations not only adopts but also has hands-on experience with blockchain technology. This, combined with their expertise in energy-related services (i.e., including EVs) and demand response management, positions them as beacons of knowledge and experience, essential for the depth and breadth this research aims for.

- **Diverse Domains:** Incorporating views from R&D, academia, policy-making and industry ensures that the research captures a holistic understanding of the subject. Each case study acts as a piece of the puzzle, with its unique challenges, opportunities and insights. Together, they provide a comprehensive picture, ensuring that the research findings are not only grounded in theory but are also relevant and applicable across various real-world scenarios.

Upon further examination of the distinctive characteristics of each organization, it becomes apparent how each entity contributes and enhances the current study:

Hypertech (R&D, Greece): As an SME rooted in digital transformation, Hypertech' s specialization in smart homes and smart grids offers a unique perspective from the research and development domain. The insights from two interviewees (Appendix C), both of whom have extensive experience with DRM and blockchain technologies, provide a detailed view of the research and technological intricacies related to the proposed conceptual model.

E7 (Consulting/Policy-Making, Austria): E7's reputation in sustainable energy and building management systems ensures a policy and consultancy-driven viewpoint. Given their role in the energy transition not just in Austria but globally, the insights from the E7 interviewee (Appendix C), an expert in energy economics, shed light on policy implications, market dynamics and the practical aspects of integrating blockchain in DRM and IoV from a policy and advisory lens.

SUPSI (Academia, Switzerland): SUPSI's blend of academic rigor and its application in real-world scenarios provides an academic perspective. The insights from the SUPSI interviewee (Appendix C), who bridges computer science with energy optimization, enrich the research with an academic view on the challenges and opportunities of using blockchain in energy systems.

Hive Power (Industry, Switzerland): Operating at the industry forefront, Hive Power brings a hands-on, industry-driven perspective. Hive Power's interviewee (Appendix C), journey from academia to leading an industry change, presents a pragmatic view of the challenges, limitations and potentials of blockchain in the energy sector, especially in IoV.

In conclusion, the selection of these multi-faceted case studies ensures that the research is enhanced with theoretical understanding and practical insights. As the study advances, the acquired knowledge from the distinct case studies will be of great value in (a) addressing the research objectives of this thesis, (b) evaluating and revising the proposed conceptual model and (c) contributing to knowledge around the area of blockchain in the IoV.

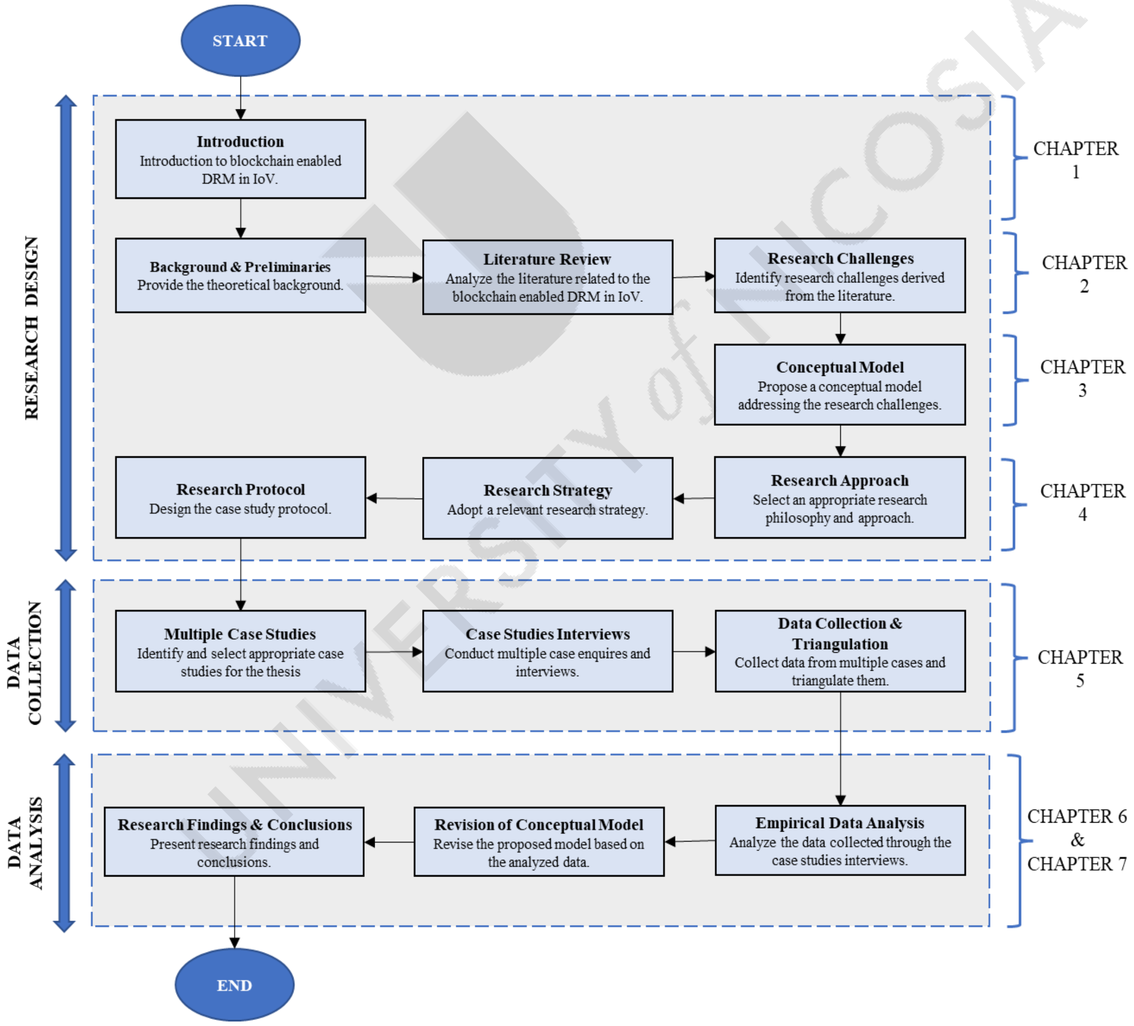


Figure 4.2: Empirical research methodology of the current study

4.6 Empirical Research Methodology

Empirical research is a type of research methodology that involves obtaining evidence using empirical data, which come from either direct observation or experimentation. Empirical research is used to answer questions about the world in a systematic and scientific manner. Based on Themistocleous (2002), empirical research methodology includes three stages:

- **Research Design:** This step involves determining how the researcher will gather the empirical data, what type of data will be collected and how to analyse it.
- **Data Collection:** This step involves using data collection methods (e.g., interviews) to gather information about the phenomenon under investigation.
- **Data Analysis:** This step involves interpreting the details and patterns within the data gathered to provide insights, establish meanings and develop empirical knowledge.

Each stage builds on the previous one, leading to a comprehensive investigation of the research problem. The empirical methodology will allow this research to provide substantial, data-driven insights into the application of blockchain technology in demand response management within the IoV. The above-mentioned steps are presented and analysed in this section. The following sections present and analyse these steps as also depicted in Figure 4.2.

4.6.1 Data Collection

The data collection represents the second stage of the empirical research methodology, as depicted in Figure 4.2. This stage involves the collection of information from which insights will be derived. As this thesis adopts a qualitative approach, data collection entails gathering non-numerical data to understand concepts, opinions, experiences and behaviours around the proposed conceptual model. Specifically, the data collection stage involves:

- Identifies and selects the appropriate case studies for the current thesis, as justified in Section 4.5.3. The selected cases named Hypertech, E7, SUPSI and Hive Power, are presented and analysed in Chapter 5.
- Collects empirical data using interviews and documents as data collection methods (as those described in Section 4.6.1.1).
- • Implements data triangulation methods, like those outlined in Section 4.6.2.3 to mitigate the risk of systemic biases.

4.6.1.1 Data Collection Methods in Qualitative Research

Various qualitative data collection methods exist, each with their own strengths and limitations. Among others, most common data collection methods include: (a) interviews, (b) observation, (c) focus groups and (d) document and content analysis, as referred in the literature (Waterman, 2008; Sutton, 2015).

- **Interviews:** Interviews can be structured, semi-structured, or unstructured. They provide detailed insights into a participant's experiences, emotions, opinions and perceptions. In-depth, one-on-one interviews can uncover rich, detailed data that might not emerge in a group setting.
- **Focus Groups**: These involve a moderated discussion among a group of participants. They can be particularly useful for exploring consensus and diversity among participants and triggering discussions that might not arise in individual interviews.
- **Observations**: Observational data collection involves recording participant behaviours or occurrences in their natural settings. This method can provide context-rich data and direct information about people's behaviour rather than reported or interpreted behaviour.
- **Document and Content Analysis**: This involves analysing existing documents, records, or artifacts relevant to the research topic. It could range from analysing social media posts to government policies, company records, or historical documents.

Table 4.4, presents the data collection methods adopted in the current thesis.

Table 4.4: Data collection methods applied in this study

Data Collection Method	Application in this PhD Thesis
Interviews	Semi-structured interviews with experts who specialize in the fields of blockchain technology, energy demand response management and the Internet of Vehicles, are the man data collection method of this thesis.
Document and Content Analysis	Technical reports, policy documents and whitepapers with related systems are some examples of the documentation and artifacts that the researcher analyses. This offers crucial information for evaluating the suggested model.

4.6.1.2 Interviews

Interviews are selected as the primary data collection method for this research due to their flexibility, depth and adaptability. By utilizing semi-structured interviews, the research benefits from a combination of consistent questioning based on an interview agenda and the opportunity to explore unexpected findings further, in a spontaneous way. This approach not only ensures depth by allowing interviewees to elaborate on their experiences but also gives the researcher the flexibility to clarify, rephrase, or request elaborations. Such a dynamic interaction ensures a thorough comprehension of the participants’ perspectives, including delicate information that could be missed in a more formal interview structure.

4.6.1.3 Semi-structured Interviews

As mentioned before, participants’ data are collected primarily through semi-structured interviews. These interviews are flexible, owing to the predetermined interview questions, which allow participants the liberty to disclose specific details and personal experiences. Due to the open-ended nature of the questions, participants are encouraged to provide thoughtful, in-depth responses that draw upon their personal experiences, sentiments and knowledge to foster a greater understanding of the phenomenon. The interview process is dynamic, as the interviewer is at liberty to explore alternate paths and ideas that emerge, while still adhering to the interview agenda.

4.6.1.4 Interview Procedure

Before the interviews, participants are briefed about the aim of the research, the nature of their involvement and the confidentiality of their responses. They are provided with an opportunity to ask questions and are asked for their informed consent to participate. Additionally, the interviews are recorded for accuracy and transcribed verbatim. As interviews rely on the willingness and openness of the participants to share their experiences and insights, establishing trust with them is crucial. However, during the current research and data collection phase, all participants consent and permit to publish their names and organizational details. Specifically, information about the participants themselves can be found in Annex E. This method of data collection allows for an in-depth understanding of the participants’ views, motivations and experiences and provides rich qualitative data that informs and supports the research objectives.

4.6.1.5 Interview Agenda

Regarding the format of the semi-structured interviews conducted by the researcher, every section includes a set of open-ended questions. This method allows interviewees to express their views openly, minimizing the potential for eliciting biased responses. The interview agenda is oriented towards gathering data from specific segments, as analysed below and the questions within each segment are detailed in Table 4.5.

- **Segment A: Introduction**: The purpose of the introduction is to establish a common understanding with the participant, provide them with necessary information about the study, ensure their consent to participate and set the overall tone for the interview.
- **Segment B: General Organization Data:** The objective of this section is to gather data referring to the organization under research. This includes information such as (a) the organization's nature, (b) its key objectives and (c) the size of its workforce, among other relevant details.
- **Segment C: Brief Description of the Study:** The purpose of this section is to introduce the interviewee to the research context, present the aim and objectives and present the proposed conceptual model under investigation.
- **Segment D: Background Information**: This section is designed to gain understanding about the interviewee's level of knowledge, experience and expertise in the area of IoV and blockchain technology, which could influence the depth and relevance of their responses.
- **Segment E: Blockchain and IoV**: The purpose of this segment is to investigate the participant's thoughts, experiences and insights about the utilization of blockchain technology within the IoV. This segment will provide firsthand information about the possibilities and challenges of blockchain-enabled DRM in IoV.
- **Segment F: Incentive Mechanisms and Transparent Distribution**: This part of the interview focuses on understanding the participant's perspective on the use of tokenized incentives within the DRM framework. It helps in assessing the potential effectiveness of such incentives and their role in increasing user engagement.
- **Segment G: User Profiles and Charging Scheduling**: The purpose here is to understand the complexities of EV charging coordination and scheduling within the DRM context. This section seeks to understand the challenges, needs and potential solutions related to personalized charging schedules and coordination mechanisms.

- **Segment H: Energy Generation and Consumption**: This section seeks to understand how EVs could be utilized as distributed energy sources and how the balance of energy generation and consumption could be managed within the IoV. This will shed light on the practical aspects of energy management in DRM.

- **Segment I: Privacy and Security**: The aim of this section is to explore the participant's views on privacy and security issues within the context of blockchain technology and the IoV. Their insights could reveal new considerations or solutions for privacy and security concerns in DRM.

- **Segment J: Blockchain enabled Demand Response Management Model**: During this segment the researcher aims to collect data related to the model's various components, as well as the suitability of the proposed model.

- **Segment K: Additional Comments**: This section serves as a conclusion to the interview. It provides the participant with an opportunity to add any thoughts or insights that may not have been covered during the interview.

- **Segment L: Participants Data**: The aim of this section is to gather data concerning the participant.

It is noted that the complete interview agenda for this study is presented in Appendix B.

Table 4.5: Interview agenda overview

Segment	Segment Title	Interview Questions
A	Introduction	A.1 - A.5
B	General Organization Data	B.1 – B.4
C	Brief Description of the Study	C.1 – C.3
D	Background Information	D.1 – D.3
E	Blockchain and IoV	E.1 – E.3
F	Incentive Mechanisms and Transparent Distribution	F.1 – F.7
G	User Profiles and Charging Scheduling	G.1 – G.5
H	Energy Generation and Consumption	H.1 – H.6
I	Privacy and Security	I.1 – I.3
J	Blockchain Enabled Demand Response Management Model	J.1 - J.6
K	Additional Comments	K.1 – K.2
L	Participant Data	L.1 – L.2

4.6.2 Data Analysis

4.6.2.1 Data Analysis Steps

The final phase of the empirical research methodology involves the data analysis, as depicted in Figure 4.2. This step entails interpreting the collected empirical data. Key activities undertaken during this stage include:

- **Empirical Data Analysis:** After data collection, which encompasses both recorded interviews and document/content analyses, the initial step involves transcribing the recorded interviews and analysing the gathered documents for relevant content. This is followed by promptly collating field notes. These transcripts and document analyses are then systematically re-arranged to serve the objectives of the research study. For example, responses referring to the same aspect of the proposed conceptual model are clustered together, ensuring the overall coherence of the data. The qualitative nature of this research approach renders the analysis and comparison of raw data quite challenging. Nevertheless, to guarantee the validity of the data and the reliability of the study's findings, it is essential to systematically organize the data in a standardized way.
- **Revising the Conceptual Model:** The interpretation of empirical data paves the way for the introduction of new guidelines and modifications to the proposed conceptual model. These updates are covered in detail in Chapter 6.
- **Extrapolation of Findings:** The concluding phase of the empirical research methodology encompasses the extrapolation of the research findings from this study. In Chapter 7, the main outcomes, contributions and recommendations for future research are presented.

By executing these steps, the researcher aims to understand and test the effectiveness and potential use of the proposed blockchain enabled DRM model in the context of IoV, thereby contributing significantly to the existing body of knowledge in this domain.

4.6.2.2 Data Saturation

In qualitative research, data saturation is reached when additional data no longer contribute new or contradictory insights. This study employs data saturation as a guiding principle to determine the extent of case study interviews. The primary aim is to evaluate each hypothesis of the proposed DRM model within the context of IoV. Saturation is identified when a consensus among all interview participants is reached on the evaluation of each hypothesis, indicating a uniform understanding and agreement across different cases. The process involves close monitoring of each hypothesis evaluation during the interviews. Data gathering is considered to be finished when repeated interviews consistently support previous findings without introducing new or divergent opinions on the hypothesis. The consistent recurrence and agreement observed in various interviews and case studies indicate that conducting further data collection is unlikely to provide any additional insights for evaluating the hypotheses. The uniformity observed among diverse viewpoints provides a valid basis for asserting that data saturation has been achieved. achieving data saturation according to these criteria guarantees that the results made are based on a thorough and coherent understanding of the model's hypotheses as observed in various case studies.

4.6.2.3 Data Triangulation

Data triangulation is a crucial part of the analysis process, enhancing the credibility, reliability and validity of the research findings. Through data triangulation, this research analyses findings by examining information from multiple sources and applying various analytical techniques. The following sections outline the different types of triangulation employed in this research:

- **Source Triangulation**: This research emphasizes the use of multiple (i.e., four) case studies, as those presented in Section 5.6, Section 5.5, Section 5.4 and Section 5.3. These case studies represent diverse sectors: research and development, academia, policy/advisory and industry. By gathering data from semi-structured interviews with insights from these case studies, the research gains a multi-faceted understanding of the phenomena. Additionally, the cross-verification, through a comparative analysis between the four case studies (Section 5.7) provides a broader understanding of the phenomena, allowing for a comprehensive evaluation of the impact and potential of blockchain technology in the IoV within the DRM context.
- **Theoretical Triangulation**: Besides semi-structured interviews, the researcher compares the findings of the study with existing theories and models around blockchain and DRM literature (Section 5.2). This process helps identify potential gaps or discrepancies, contributing to the development of new insights and the refinement of the proposed conceptual model.
- **Investigator Triangulation**: While the research primarily involves one researcher, it mitigates potential bias and subjectivity by including academic supervisors during the analysis process. Comparing and cross-checking interpretations and conclusions

minimize potential biases or blind spots from single-investigator analysis (Section 5.2).

By leveraging data triangulation, this research seeks to provide a robust and reliable understanding of the role and impact of blockchain technology in DRM within the IoV. The use of multiple data sources, methods, investigators and theoretical frameworks allow for a comprehensive and trustworthy exploration of this research domain.

4.7 Case Study Protocol

In qualitative research, case study methodologies have been widely employed across various disciplines, allowing for an in-depth exploration of complex phenomena within real-life contexts (Yin, 1994; Yin and Yin, 2013). Among the various components contributing to the robustness and reliability of case study research, the case study protocol holds a central position. According to Yin (1994) a case study protocol serves as a major reliability procedure akin to an execution plan for the researcher. The protocol articulates the procedure to be followed, ensuring that the researcher maintains a consistent approach throughout the research process. This consistency is crucial in minimizing biases, enhancing reliability and providing a reference point for other researchers aiming to replicate the study.

The structure of a case study protocol generally includes (a) an overview of the study, (b) field procedures, (c) questions that the study should address and (d) a guide for the final report. Recent studies have started to incorporate additional elements such as ethical considerations within the protocol (Cassell and Symon, 2012). As such, this thesis will adopt the combined case study protocol outline suggested by Yin, Cassel and Symon.

4.7.1 Overview of the Study

The primary aim of this study is to evaluate the effectiveness of a blockchain-based DRM model within the IoV context. This case study will critically analyse the proposed conceptual model's practical aspects, focusing on how various components like tokenized incentives, privacy measures, energy generation from primary sources and EVs and personalized charging schedules, among others, could potentially contribute to the efficacy of DRM.

Additionally, the issues under investigation are detailed, to assist the researcher in focusing on the main questions that need to be studied. These are factors that the author needs to focus on, to generate data that is required to investigate the use and evaluation of the blockchain-based DRM model. The consideration of these issues is crucial, to retain focus during the interviews.

These issues are the following:

- Investigate how tokenized incentives can influence the willingness and motivation of users to participate in the DRM program.
- Examine whether the transparency in the token distribution process influences trust in the system, thereby affecting participation levels and the overall effectiveness of DRM.
- Investigate how user profiles and personalized charging schedules could lead to more efficient DRM.
- Investigate the role and impact of bi-directional P2P energy trading on the balance of energy generation and consumption.
- Investigate how the level of energy consumption could potentially influence the overall load and how energy generation influences supply-demand balance and overall grid stability.
- Understanding whether privacy measures influence users' trust and their willingness to participate in the DRM program will be crucial.
- Obtain feedback and insights into the overall proposed model. Understanding its perceived benefits, potential drawbacks and areas for improvement will be critical for refining and improving the model.

Each of these issues presents its unique set of challenges and opportunities that will need careful exploration and understanding. By focusing on these issues, the researcher is able to generate the necessary data to evaluate the proposed blockchain-based DRM model and further enhance it.

4.7.2 Field Procedures

When conducting case study research, it is common to encounter "unforeseen" occurrences, such as difficulties in reaching interviewees or accessing data documentation. To address these challenges, a carefully delineated set of field procedures was established for the investigation of case studies. These procedures encompassed the following actions:

- **Define organizations and key persons for interview:** The selection of organizations and key persons for interviews is a critical step in the data collection process. Organizations are ideally chosen based on their involvement with IoV and DRM initiatives. In this study, the researcher targets organizations familiar with blockchain technology in these areas. Furthermore, organizations from diverse areas such as industry, academia, policy and research are actively sought. Engaging with a wide spectrum of organizations ensures a comprehensive understanding of the topic, as each sector offers unique insights, challenges and perspectives that enrich the overall research narrative. The size, sector and geographical location of organizations are considered to ensure a diverse and representative sample. Key persons for the interview are individuals who hold strategic or operational roles in these organizations and are familiar with blockchain and DRM practices. This includes, but is not limited to, executives, managers, technical experts and frontline employees.

- **Interview appointments and documents requests:** Interview appointments are scheduled in advance, respecting the interviewees' time and commitments. For efficiency, requests for relevant documents are made when scheduling the interview. This approach gives interviewees enough time to gather the necessary materials. While rescheduling might occasionally occur due to unforeseen circumstances, it doesn't impede data collection progress and alternate arrangements are made promptly.
- **Define a clear procedure for data collection:** A detailed interview agenda (provided in Appendix B) serves as the primary tool for data collection through the semi-structured interviews. This agenda ensures a structured approach to the conversation while allowing interviewees the flexibility to express their thoughts and experiences freely. Besides interviews, organization documents, interview transcription and recording, reports and website data serve as additional data sources. This triangulation of data sources enriches the collected information and deepens the understanding of the investigated issues.
- **Define confidentiality between involved parties:** Confidentiality holds utmost importance in this research. All participants receive information about their confidentiality and provide their consent accordingly, at the beginning of the interview. They are assured that their data remains exclusive to this research and is not shared with third parties unless they give explicit permission. Furthermore, the identities of both the organizations and participants are not anonymized and are available in Annex E, as all participants grant permission for this disclosure.

4.7.3 Topics Investigated by the Empirical Research

To maintain focus during data collection, a set of guiding pillars under investigation was identified. These research pillars act as a foundation for the researcher, from which specific questions are derived to ensure the necessary data is collected. While interviewees are not directly exposed to these, they were instrumental in informing the development of interview questions (i.e., as presented in the Interview Agenda). This approach ensures that the research remains structured and focused during the interview process. The primary goal of these guiding topics is to keep the researcher on track during data collection. The research seeks to investigate these topics related to the adoption and potential benefits of a blockchain-based DRM model within the IoV context. These guiding topics are presented in Table 4.6.

Table 4.6: Research pillars investigated by the empirical research

Topic	Topic Description
Blockchain as a Trust Layer	Investigate the potential of blockchain technology as a trust layer in IoV and DRM (mainly under the scope of transparency and privacy)
Tokenized Incentives	Investigate how tokenized incentives could potentially enhance participants' willingness and motivation to engage in the DRM.
User Profiles and Charging Scheduling	Investigate the dynamics of user profiles and charging scheduling in the context of DRM in IoV.
Demand Response through P2P Energy Trading	Investigate the landscape of demand response through P2P energy trading (under the scope of balancing energy production and consumption).

4.7.4 Ethical Considerations

Research ethics are a vital component of every study. This research is undertaken with respect, responsibility, honesty and transparency as guiding principles. All participants and their right to privacy, confidentiality and informed consent are respected. Participants are informed of the goal of the study and the intended use of their data. Their participation is completely voluntary and they can withdraw from the research at any time. Additionally, no damage is caused to participants and every effort is taken to ensure their comfort during the interviews. In terms of accountability and honesty, the research adheres to the principles of good research practice. The collected data is used only for this study and any findings are published honestly and correctly. Any potential conflicts of interest are disclosed in advance and the research process remains open and transparent.

4.7.5 Guidelines for Reporting the Research Findings

Chapter 5 describes the empirical data analysis and the format of the empirical investigation’s result. The study findings are presented in a way that is clear and indicative of the collected data. Chapter 5 offers a systematic presentation of the data and a additional information from document analysis, based on the conceptual model and the literature explored in preceding chapters.

The key results are organized according to the research’s primary aim and objectives. This organization makes it simple for readers to follow the route of inquiry and understand how the research objectives are met. Moreover, to confirm the findings, interpretations are reinforced with exact quotes from the interview transcripts when applicable. In addition to a critical review of the data, the research recognizes limitations identified. In conclusion, the ramifications of the findings for both theory and practice are discussed, along with suggestions for further study.

4.8 Conclusions

This chapter offers a foundation for the subsequent empirical work and is the methodological backbone of this research. It outlines in detail how the study is conducted, the instruments that are employed and the tactics that are implemented to evaluate the acquired data. By detailing the technique, the research procedure is made public and responsible, hence enhancing its trustworthiness and validity.

The chapter opens with verifying the philosophical attitude and methodology of the investigation. In accordance with the interpretivism philosophical stance and abductive research methodology, the study aims to go from conceptual ideas to particular hypotheses. This alignment provides an organized, hypothesis-driven environment that is essential to the research's growth.

In addition, the use of a qualitative technique supported by a multiple case study approach is regarded appropriate for the research aim. This technique and strategy permit an in-depth comprehension of the study situation and its intricate interrelationships.

The chapter proceeds to present the data collection methods. A comprehensive guide is developed for conducting semi-structured interviews, a technique that permits the discovery of novel ideas while preserving consistency among interviews. In addition, the chapter highlights the value of document analysis as sources of rich, context-specific information.

The significance of data analysis is also emphasized throughout the chapter. To assure the accuracy of the analysis, a strict approach is outlined. The notion of triangulation is presented as an effective tool for improving the validity and reliability of the study findings, hence strengthening the methodological framework.

The chapter concludes with the development of a comprehensive case study protocol. This protocol acts as a guide for the empirical research, encouraging organization, systematic execution and ethical behaviour. It is intended to give explicit principles for maintaining uniformity and dependability throughout the research process.

5. EMPIRICAL DATA AND RESEARCH FINDINGS

5.1 Summary

Chapter 5 goes into the collection of empirical data and the evaluation of the conceptual model proposed in Chapter 3. This chapter discusses and analyses the empirical data derived from four distinct case studies in a systematic manner. The empirical evaluation is based on the conceptual model depicted in Figure 3.2.

Diverse case studies were chosen to provide this evaluation with depth and multi-faceted insights. The selected case studies covered a wide range of domain participants, including research and development organisations like Hypertech and academia like SUPSI. In addition, the consulting expertise of E7 and the real-world industry application of a company, Hive Power, were utilised.

Collecting and methodically analysing empirical data contributed to support various aspects of the proposed conceptual model. It became clear that the alignment of blockchain with the IoV has enormous promise and the proposed model is supported. Finally, the empirical data reveal additional findings that need to be taken under consideration towards the refinement of the model in the subsequent chapter (Chapter 6).

5.2 Introduction

The normative literature, as outlined in Chapter 2 of this thesis, demonstrates the unrealized potential of blockchain as the foundation for DRM in the IoV ecosystem. The investigation of this potential reveals the lack of a model that effectively integrates blockchain and DRM to enable it in the IoV domain.

Chapter 3 focuses on the development of the proposed conceptual model that the researcher is proposing, aiming to enhance DRM in IoV using blockchain technology. The proposed model is a combination of ten variables orchestrated by nine hypotheses. That seeks to enhance the DRM in IoV by incorporating tokenized incentives, user profiling, charging scheduling and blockchain.

Chapter 4 has resulted in the identification of a suitable research methodology. In doing so, the thesis adopts the interpretivism qualitative research methodology and multiple case study research strategy as being more appropriate to test the proposed conceptual model.

With Chapter 5, this research reaches a crucial phase: the empirical data collection from four case organizations and the empirical testing of the proposed conceptual model. Based on the case study protocol stated in Section 4.7, the researcher identifies and chooses four eligible case organizations (Hive Power, SUPSI, E7 and Hypertech) to explore DRM in IoV in order to test and assess the proposed conceptual model. The Hive Power case study is described in Section 5.3, SUPSI in Section 5.4, E7 in Section 5.5 and Hypertech in Section 5.6.

During the case study protocol identification, the researcher specifies particular research pillars under investigation, that are aimed to enable full comprehension and analysis of the conceptual model (as presented in Section 3.3). A summary of these pillars is essential for aligning the empirical findings with the general context of this research. The following research pillars were presented in the interview participants to describe the high-level context of this study:

- **Blockchain as a Trust Layer**: Investigating the potential of blockchain technology as a trust layer in IoV and DRM (mainly under the scope of transparency and privacy).
- **Tokenized Incentives**: Investigating how tokenized incentives could potentially enhance participants' willingness and motivation to engage in the DRM.
- **User Profiles and Charging Scheduling**: Investigating the dynamics of user profiles and charging scheduling in the context of DRM in IoV.

- **Demand Response through P2P Energy Trading**: Investigating the landscape of demand response through P2P energy trading (under the scope of balancing energy production and consumption).

Based on these topics, the theoretical grounding of the proposed conceptual model incorporates various variables such as tokenized incentives, transparent distribution, user profiles, personalized charging schedules, bi-directional P2P energy trading, energy consumption/generation, privacy and primary energy generation. Following the description of the study and its aim and objectives, the proposed conceptual model, as shown in Figure 5.1, was presented to the interviewees. Every variable and hypotheses that is present in this model was explained to them. The additional benefits of using the proposed blockchain-based model for DRM in the IoV were also highlighted.

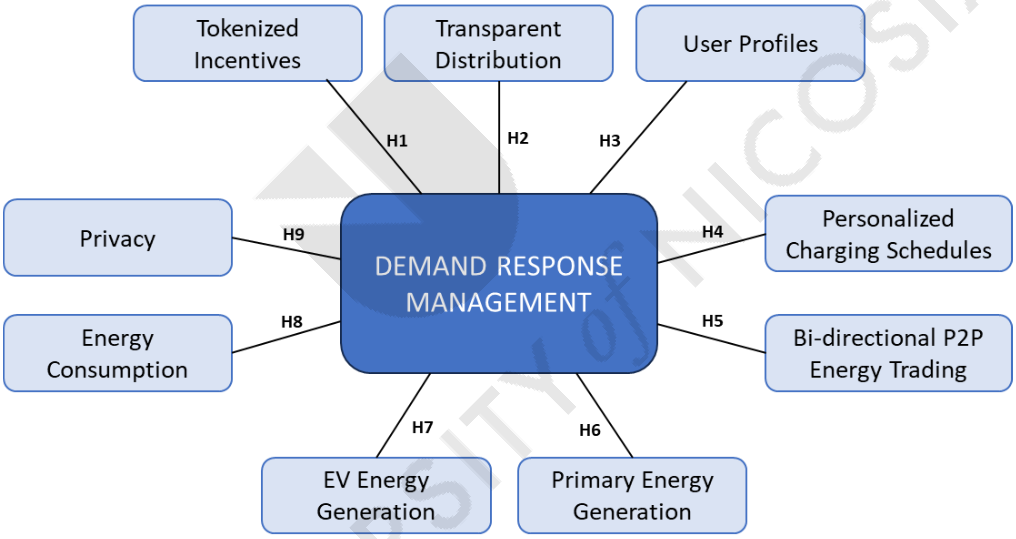


Figure 5.1: Proposed conceptual model (same as Figure 3.2)

The nine hypotheses (i.e., H1 – H9) that support the researcher’s investigation and are part of the proposed model are summarized below (discussed in detail in Section 3.4).

- **H1**: Tokenized incentives could potentially influence users’ willingness to participate in the demand response program.
- **H2**: Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation.
- **H3**: Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules.

- **H4**: Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management.
- **H5**: Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance.
- **H6**: Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand.
- **H7**: Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management.
- **H8**: The level of energy consumption could potentially influence the overall load on the grid and effectiveness of demand response management.
- **H9**: Privacy measures could potentially influence user trust and willingness to participate in the demand response program.

Within the context of data collection, the researcher follows a specific procedure to ensure the accuracy and reliability of the collected data. The procedure utilizes several digital tools to enhance the efficiency of data collection and processing. For example, online interviews are done through Microsoft Teams (Microsoft, 2024), a reliable and interactive platform that facilitates effective contact with the participants. The interviews conducted during these meetings are documented using integrated recording mechanisms inside the platform, guaranteeing a comprehensive and precise record of the interactions. Furthermore, the process of recording transcription is conducted using a transcription tool known as Cockatoo (Cockatoo, 2023) , which is powered by AI. This data collection flow consists of the following steps:

- **Interview and Recording:** The interview process follows a structured approach outlined in the Interview Agenda (Annex D), with the recording serving as a key tool for capturing the content of the discussion.
- **Interview Transcription:** The interview is transcribed by utilizing the cockatoo transcription software, which accurately and efficiently converts the recorded audio into written text, maintaining a verbatim representation of the original content.
- **Sharing the Transcription and Main Outcomes with the Interviewee:** The transcriptions and main conclusions of the interview are shared with the interviewees to validate the information and eliminate the possibility of any misunderstandings.

- **Validation of the Main Outcomes and Transcription**: Participants are requested to verify the precision of the transcriptions and the main outcomes and to offer any remarks, if applicable. This process enables the researcher to resolve any inconsistencies and establish the credibility of the documented data.

The selection of digital tools used in this study is based on their demonstrated reliability and user-friendly nature. In addition to utilizing Microsoft Teams and Cockatoo, the researcher also incorporates ChatGPT from OpenAI (OpenAI, 2024). Its utilization was two-fold: firstly, ChatGPT assisted in managing and consolidating qualitative data. This included organizing and synthesizing information from interview transcripts and integrating insights from various sources (i.e., archive records from the case study organizations) to form a coherent analysis. Secondly, ChatGPT helped to process large volumes of text data expedited the analysis process, ensuring thoroughness and accuracy in understanding the empirical findings.

In addition to the individual case study analyses, a comparative analysis is introduced (Section 5.7). This section aims to present the insights and evidence gathered from each case study against each hypothesis, thereby facilitating a holistic view of the conceptual model's applicability and robustness across the investigated case studies.

Furthermore, as discussed in Section 4.6.2.3, this thesis undertakes theoretical triangulation to enhance the empirical findings of this chapter. The study's results are compared with theories and models in the blockchain and IoV DRM literature, to assess alignment and identify potential imbalance. Such comparison not only validates the empirical methods used but also aims in identifying areas for further investigation and contributes to the ongoing development of the conceptual model. Moreover, throughout this study, discussions with blockchain and energy experts and academics have been a regular part of the research process. These discussions offer a way for assessing the research findings in light of existing theoretical knowledge. The feedback and perspectives gained from these engagements have been crucial to ensure academic integrity. The impact of these discussions is evident in the proposed modifications detailed in Chapter 6. The insights from these expert interactions are critical, shaping the revisions to the BBF. By doing so, the revised framework not only responds to the empirical data but also aligns with the broader academic discourse.

The following sections present the empirical data and research findings obtained from the four case studies, in accordance with the aforementioned data analysis flow. For all case studies the following aspects will be explored: (a) present the case study organizations' and the reviewers' background, (b) analyse the empirical data revealed from the interviews, shedding light on the interplay of blockchain and DRM in IoV, (c) evaluate the hypotheses based on the empirical data gathered and (e) conclude with a summary of the most important findings that emerge from this investigation. The four case studies aim to evaluate the effectiveness of the conceptual model depicted in Figure 3.2, particularly focusing on the aforementioned research pillars and seek to deepen the researcher's understanding in these areas.

Last but not least, it is worth mentioning that in conducting qualitative research, particularly when it involves human responses, it becomes essential to ensure that the communication of ideas is both clear and effective. With this objective, the researcher has taken the decision to rephrase certain quotes from the case study interviews. Rephrasing specific interview quotes enhances clarity, ensuring that the participants' intended messages are conveyed without ambiguity. It also contributes to conciseness, stripping away any circumlocutory elements. Additionally, correcting any grammatical or syntactical errors that naturally occur in informal speech aids in maintaining the academic standard of this thesis. Aligning quotes with the context of the narrative is also crucial; it ensures that the participants' insights are directly relevant to the research questions and hypotheses and the data analysis flow. It is worth mentioning that the rephrasing is done to preserve the original meaning and integrity of the participants' statements, allowing the research to be presented with rigor and accessibility.

5.3 Case Study 1: HIVE Power

This section focuses on the first case study investigated during this thesis, which is Hive Power.

5.3.1 Introduction to Case Study 1

Hive Power, founded in 2017 in the heart of Switzerland, has established itself as an industry leader in smart grid solutions. By combining its dedication to advanced research with real-world pilot projects on decentralised energy management, the company demonstrates a pioneering spirit in the ever-changing energy sector. This dedication to innovation, led by a team with expertise in smart grids, data analytics and optimization, positions Hive Power at the forefront of attempts to transform the energy industry.

Participant A, Chief Operating Officer (COO) and co-founder, is essential to Hive Power's development. Participant A, a graduate of the École Polytechnique Fédérale de Lausanne

(EPFL), has an interdisciplinary approach to problem-solving, as seen by his fundamental background in micro-engineering and subsequent move into energy. His experience with industrial automation, operation of complex robotics and crossover into the field of local energy optimization demonstrate his versatility. Significant experiences, particularly managing a research team at SUPSI (a university of applied sciences in southern Ticino), enriched Participant A's path. As a visionary, he realised blockchain's potential and guided the establishment of Hive Power. Initially, the firm intended to utilise the blockchain for energy communities, but as the adventure progressed, practical considerations gained precedence. Hive Power's software solutions, particularly the FLEXO platform, offer an impressive suite of tools to manage energy communities and smart homes, sans blockchain. Their mode of operation, operating within a business-to-business-to-customer paradigm, emphasises collaboration and the pursuit of standards, despite the fact that such standards remain elusive in the industry landscape.

Case Study 1 holds a distinctive place within this dissertation. While the other case studies focused on research-oriented perspectives, this one provides a practical, industry-driven approach. It is essential to note that the insights gained from this case study offer a relatively distinct perspective. Participant A's significant experience with Hive Power provides credibility to his perspective, which emphasises the hurdles and limitations of the immediate adoption of blockchain technology in the energy sector and especially the IoV. The purpose of the upcoming empirical data analysis is not only to test or contradict the proposed model, but to embrace the multidimensionality of perspectives, recognising that each contributes to constructing a holistic image of the future of IoV.

5.3.2 Empirical Data Analysis from Case Study 1

This section, the researcher analyses the empirical data collected from Case Study 1, which consists of an interview with a key player in the field of blockchain and energy: Participant A. This section's aim is to analyse critically the proposed conceptual model and test its hypotheses from an industry perspective. The subsequent discussion integrates these findings, their ramifications and their compatibility with the hypotheses underlying the proposed conceptual model.

5.3.2.1 Findings on Blockchain as a Trust Layer

Participant A's views provide the researcher with a comprehensive understanding of blockchain's potential as a trust layer and its practical application limitations, particularly in domains that are primarily associated with the real world and the industry ecosystem. His insights are relevant to the proposed conceptual model, which integrates blockchain technology for enhancing DRM in IoV.

Reflecting on his transition from academia to industry, Participant A states: *"If I had remained purely in the research area, my outlook might have been more optimistic. In that academic setting, my focus wouldn't be on selling a product and I'd have the freedom to explore blockchain technology in depth, which I find incredibly intriguing"*. This perspective is essential in understanding the gap between theoretical blockchain applications and their practical implementation.

To begin with, Participant A's analysis of blockchain in energy sectors highlights the sensitive balance between technological advancement and real-world implementation. He observes that, *"the computational intensity and networking demands of blockchain pose practical challenges, especially when real-time operations are essential".* This statement underlines the difficulty blockchain faces in real-time, data-intensive environments, such as IoT and IoV. While the theoretical appeal of blockchain in energy sectors is undeniable, Participant A's insights draw attention to the pragmatic challenges that arise in real-time, data-intensive environments such as IoV. This observation is particularly relevant to the proposed conceptual model, which envisions the use of blockchain for enhancing DRM in IoV. The computational challenges highlighted by Participant A underscore a significant consideration for the model, particularly in its application to real-time operational demands.

Furthermore, he highlights the challenge of data validation, noting that *"the challenge lies in accurately validating real-world measurements and data on the blockchain."* This comment reflects the difficulty of integrating blockchain's digital trust with physical world data. The aforementioned remark underscores the fact that incorporating blockchain technology into IoV necessitates not only advanced technological knowledge but also a deep comprehension of how digital trust and the integrity of physical data can be harmoniously integrated. This aspect is crucial within the proposed model, as reliable data is indispensable for charging schedules and user profiles.

Participant A also touches on the regulatory landscape, revealing the complexity of integrating blockchain within regulated sectors. His remark, *"It exists a tension between the transparent nature of blockchain and privacy regulations like GDPR",* underscores the conflict between blockchain's transparency and privacy norms mandated by regulations. He then brings in the perspective of regulated sectors, adding that *"Highly regulated sectors, such as energy, often come with established standards and trusted entities".* This insight suggests a potential redundancy or conflict between blockchain’s decentralization and existing trust structures in sectors like energy. Participant A’s analysis of the regulatory landscape highlights the tension between blockchain’s transparency and privacy mandates like GDPR. This is relevant to the proposed model for integrating blockchain in DRM within IoV. Balancing the transparency of blockchain with stringent privacy requirements is crucial for successful implementation, especially in consumer data protection contexts. While the proposed model already considers privacy, it also needs to consider the existing trust structures in highly regulated sectors like energy, addressing potential redundancy or conflict between blockchain’s decentralization and established trust entities. Therefore, the proposed conceptual model must navigate regulatory compliance and established trust mechanisms while embracing blockchain’s innovative capabilities. Participant A’s insights shed light on the dynamic intersection of blockchain technology and regulated industries. He suggests a hybrid approach, combining blockchain’s trust-establishing capabilities (as already proposed in the conceptual model) with traditional systems, which is crucial in environments like the IoV.

Furthermore, he highlights the complexity of blockchain in real-time operations, especially in the IoV, where accurate vehicular data is essential. The oracle problem in blockchain underlines the challenge of validating real-world data in a digital trust environment. Ensuring the accuracy of information and promoting smooth cooperation among various stakeholders, such as energy suppliers and EV manufacturers, is a critical aspect of the blockchain’s function in establishing a trustworthy IoV ecosystem. The challenge of consistently adding accurate real-world data to the blockchain, known as the "oracle problem", becomes crucial to guaranteeing that the digital trust created by blockchain corresponds with the validity of real-world data. This problem is also faced in the context of the IoV where decision-making systems depend heavily on accurate data. Participant A’s point about the necessity of smooth cooperation among various stakeholders, including energy suppliers and EV manufacturers, underscores the need for a holistic approach in the proposed model. It suggests that it should not only address the technical aspects of blockchain integration but also foster collaborative mechanisms among key players in the IoV ecosystem.

To summarize, Participant A provides a comprehensive analysis that balances the innovative aspects of blockchain with the practicalities and regulatory requirements of its implementation in the energy sector and particularly in the IoV. His insights are invaluable for understanding the nuanced challenges and opportunities blockchain technology presents in real-world applications, especially in regulated industries.

The following table (Table 5.1) serves as a summary of the key findings gained from the interview with Participant A on the topic of blockchain as a trust layer.

Table 5.1: Case study 1 - Findings on blockchain as a trust layer

Topic	Sub-Topic	Finding	Implication
Blockchain as a Trust Layer	Transition from Academia to Industry	Blockchain holds promise from a research perspective but faces real-world application challenges.	The application of blockchain might be more complex than academic theories suggest.
	Blockchain with Edge Computing	High computing intensity and networking needs limit blockchain's usability where real-time activities are critical.	Immediate real-time operations with blockchain in certain fields, like energy, might face hurdles.
	Regulatory Landscape	There is conflict between the transparency of blockchain and privacy requirements such as GDPR.	Maintaining blockchain's ethos while guaranteeing compliance is a challenging task.
	Trust in Regulated Sectors	Regulated sectors, such as energy, have established trust infrastructures that may diminish the need for blockchain.	The need for blockchain in sectors with inherent trust systems might be questionable.
	Significance of Precise IoV-oriented Data	Emphasis on the oracle challenge shows the need for precise data for the IoV.	Blockchain can enhance data validation and trust within the IoV ecosystem.
	Evolving Regulations	Changing vehicle operations and energy regulations necessitate platforms that provide trust and compliance.	Blockchain might offer a flexible platform balancing both trust and evolving compliance needs.

Table 5-20 provides an overview of Participant A's insights around the role of blockchain technology in the energy and IoV particularly. The findings highlight a disparity that exists between the anticipated outcomes and the actual execution of blockchain technology. Participant A's concerns revolve on the substantial processing requirements of blockchain for real-time operations, its potential incompatibility with privacy regulations such as GDPR and its redundancy in industries where trust networks are already established (e.g., energy networks).

5.3.2.2 Findings on Tokenized Incentives, User Profiles, Charging Scheduling and Demand Response

The researcher discovers a crucial link between theoretical enthusiasm and practical applications when analyzing Participant A’s contributions. Participant A is a positivist who is intrigued by the possibilities presented by blockchain technology. However, his direct involvement in his own business solidifies his viewpoint and lead him to adopt a more realistic stance. This shift in perspective is not only theoretical; rather, it is directly related to the real-world difficulties and realizations he has gained from his work in the field. These insights are extremely helpful in this dissertation and the study of the empirical data because they give a realistic counterweight to academic ideas and provide an accurate representation of the intricacies involved.

While Participant A recognizes that blockchain technology may eventually be more smoothly incorporated into the energy industry, he also highlights a number of current obstacles. It’s important to note that his worries are more focused on the short-term feasibility of blockchain technology than its long-term potential. This contrast points to the need for a gradual approach to blockchain adoption in the energy sector, solving immediate issues while retaining hope for potential applications down the road.

This has an important impact on the current research. This grounded perspective from the industry gives the research a sense of direction and guarantees that the conceptual model revision (Chapter 6) takes practical feasibility into account. The research acquires depth by integrating these ideas from the industry, which successfully establish a balance between theoretical academic theories and practical applicability.

Given this context, the interview took an unexpected yet insightful route that was unanticipated. In that sense, a discussion was made around tokenized incentives, user profiling, charging scheduling and DRM as presented below:

- **Tokenized Incentives:** Participant A briefly mentioned tokenized incentives, a disruptive concept in theory. Given his broad perspective on blockchain’s lack of preparation for energy sector integration, the examination of incentives was condensed. The difficulties associated with valuing, maintaining and actualizing tokens in real-world circumstances, particularly when evaluated from Participant A's point of view, need a cautious approach. Participant A suggests a cautious approach to integrating tokenized incentives into a blockchain-based DRM model in the IoV, considering practical aspects like token valuation and operational feasibility in the energy sector, to ensure the model effectively captures innovative potential and addresses practical challenges.

- **User Profiles:** While the user profile dimension of the IoV is clearly crucial, the discussion remained at a high level due to the broader perspective. Combining blockchain-based user profiles with data privacy issues and producing universally resonant profiles in an environment that is dynamically evolving provide challenges that Participant A finds complex and unsolved at this time. Participant A highlights the challenge of creating universally resonant profiles in the IoV ecosystem, balancing data privacy concerns with the dynamic nature of user behaviors. This requires careful consideration of ethical data management and privacy regulations in blockchain technology.
- **Charging Scheduling and Demand Response:** Given the importance of these factors in the IoV-blockchain matrix, the brief mention of them reflected the discussion's overarching theme. The combination of user needs, energy resource optimization and practical scheduling remains a question, the complexities of which, in light of Participant A's perspective, require further investigation. Thus, Participant A highlights the importance of charging scheduling and demand response in the IoV ecosystem, which are crucial for managing energy resources and meeting user needs, supporting also the relevant variables in the proposed conceptual model.

While the interview with Participant A took a different turn than the researcher had anticipated, but it nevertheless helps to frame this case study as a link between theoretical and practical application. It brings to light the discrepancy between practice and academic curiosity. The most important lessons from this case study are the understanding of the practical challenges and the prospects of blockchain in the energy sector, even though Participant A's overall cynicism hindered the in-depth analysis of pillars like tokenization, user profiles and demand response.

5.3.3 Hypothesis Evaluation for Case Study 1

In order to bridge the gap between theoretical assumptions and empirical reality of DRM in IoV, a set of hypotheses was established during conceptual model development. This sub-section will evaluate those hypotheses against Case Study 1, enabling the researcher to methodically test the suggested conceptual model, resulting in a more in-depth and detailed understanding of her area of study, as well as the revision of the conceptual model. Table 5.2 presents the hypotheses evaluation based on Case Study 1.

Table 5.2: Case study 1 - Detailed hypothesis evaluation

#	Hypothesis Statement	Findings Summary	Result
H1	Tokenized incentives could potentially influence users' willingness to participate in the demand response program.	Participant A's skepticism about blockchain technology led to a lack of exploration into tokenized incentives. This neutral stance suggests a need for further investigation into the effectiveness of tokenized incentives, separate from blockchain technology, in driving user participation in DRM.	Neutral
H2	Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation.	Participant A's insights into the balance between blockchain's transparency and privacy regulations provide an indirect support to the hypothesis, highlighting the intricate yet constructive challenges of aligning transparency with privacy norms. This underscores the potential for creating a trust-building framework that is both transparent and compliant.	Indirectly Supported
H3	Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules.	While the potential of user profiles in enhancing DRM efficiency is acknowledged by Participant A, the current state reflects a gap between theoretical possibilities and practical implementation. This suggests that while there is inherent value in detailed user profiles for DRM, the practical challenges and privacy concerns need to be addressed to fully realize this potential.	Indirectly Supported
H4	Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management.	The lack of direct discussion on personalized charging schedules points to an exciting research opportunity in this domain. Understanding their impact on P2P energy trading can significantly contribute to the advancement of DRM strategies.	Neutral
H5	Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance.	The absence of a detailed discussion on bi-directional P2P energy trading indicates a promising area for future research, with the potential to significantly impact energy consumption and generation balance in DRM.	Neutral

H6	Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand.	Participant A's broader focus on blockchain, rather than on primary energy sources, suggests a fertile ground for further research to explore how these energy sources can be effectively integrated into DRM.	Neutral
H7	Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management.	The neutral findings regarding EVs' contribution to energy generation in DRM highlight a prospective area for further exploration, particularly in enhancing the flexibility and efficiency of energy management.	Neutral
H8	The level of energy consumption could potentially influence the overall load on the grid and the effectiveness of demand response management.	The relationship between energy consumption, grid load and DRM effectiveness remains an intriguing topic for further research, offering potential insights for optimizing energy management systems.	Neutral
H9	Privacy measures could potentially influence user trust and willingness to participate in the demand response program.	Participant A's concerns regarding the balance between blockchain's transparency and privacy regulations shed light on the complexities of DRM, offering an opportunity to develop more nuanced and user-centric privacy strategies that	Indirectly Supported

5.3.4 Summary of Key Findings from Case Study 1

In Case Study 1, with Participant A as interviewee, a series of remarkable insights was presented about the viability and practical obstacles of using blockchain in the energy sector. Participant A’s comments provide a crucial industry viewpoint, grounded in real-world experience, which adds a layer of realism to this research’s findings.

The primary focus of Case Study 1 was the perceived difficulty of blockchain integration into the energy sector and IoV. Participant A emphasized that while the blockchain concept is intriguing and may have long-term value, its immediate deployment comes with obstacles. Among these include the conflict between the transparent nature of blockchain and strict data protection rules like GDPR, as well as the significant energy consumption associated with blockchain operations. These findings are not merely theoretical; they are based on the difficulties his company encountered in actual situations. Such opinions highlight the gap between the theoretical attractiveness of blockchain and its applicational obstacles.

Participant D identified the fundamental scalability problem of blockchain as a significant constraint. As the energy sector (including the field of DRM in IoV) is large and requires real-time data management, current blockchain implementations may not be able to effectively meet these requirements. The incompatibility between the transparent nature of blockchain and the requirements of rules such as GDPR poses a potential barrier to the protection of personal information.

Table 5.3 presents an overview of the hypotheses’ evaluation through the discussion with Participant’s D. It is noted that the symbol of a checkmark (✓) is used to signify agreement or support for the hypothesis by the participant, whereas a question mark (?) is used to indicate uncertainty or insufficient data to either support or contradict the hypothesis.

Although Participant A’s views occasionally clash with the more optimistic thoughts on blockchain, they offer a vital reality check. This guarantees that the research is anchored in both theory and the practical realities of the energy landscape. Participant A’s contributions are a strong reminder of the importance of combining academic theory with practical knowledge. Through the combination of these diverse viewpoints, a deep understanding of the topic under research emerged. Therefore, it becomes essential to compare these practical findings to the conceptual model and revise it accordingly, to ensure the model’s robustness and applicability in real-world applications.

Table 5.3: Overview of case study 1 hypotheses evaluation

Hypothesis	Participant A
H1	?
H2	✓
H3	✓
H4	?
H5	?
H6	?
H7	?
H8	?
H9	✓

5.4 Case Study 2: SUPSI

This section presents the findings of the second case study investigated during in this thesis. The second case study organisation is University of Applied Sciences and Arts of Southern Switzerland, commonly known as SUPSI.

5.4.1 Introduction to Case Study 2

The University of Applied Sciences and Arts of Southern Switzerland, known by its acronym SUPSI and its Italian name, Scuola Universitaria Professionale della Svizzera Italiana, is situated in southern Switzerland. SUPSI represents a rich blend of practical education and real-world applications and is a regional leader in academic and research excellence. SUPSI, which employs over one thousand people, focuses on the applied aspects of education in an effort to develop students into professionals who can effortlessly adjust to industry issues after graduation. The Institute of Applied Sustainability to the Built Environment (ISAAC) is an important part of SUPSI committed to promoting environmental sustainability. Under the Department for Environment Constructions and Design (DACD), ISAAC focuses on crucial sectors such as photovoltaics, energy optimization in constructions, sustainable development in the field of energy planning and the complex interaction between sustainability and society. Two competence centres strengthen ISAAC's portfolio: the Centre for development and cooperation and the Radon competence centre. Embedded within a complex network of associations that includes universities, government bodies, non-governmental organisations and industry conglomerates, the institute's endeavours rely on interdisciplinarity.

The second case study featured an interview with Participant B of SUPSI and the ISAAC Institute (information can be found in (Appendix C). Participant B is a software developer and researcher at SUPSI. Participant B's computer science experience compliments his research endeavours at SUPSI since 2015. Participant B's academic history goes back to the Polytechnic of Milano. During his time at SUPSI, he was involved in a multitude of initiatives revolving around the intersection of energy optimization, blockchain applications in the energy spectrum and the development of machine-learning algorithms for demand response and energy trading. Over the past five years, Participant B's expertise has benefited a variety of European projects, including PARITY.

After establishing the context and setting of Case Study 2 with SUPSI, as well as outlining Participant B background, it is necessary to go into the empirical data analysis gained through the interview. Section 5.4.2 analyses the findings supplied by Participant B throughout our discussion in order to evaluate the conceptual model proposed in this thesis.

5.4.2 Empirical Data Analysis from Case Study 2

This section investigates the empirical findings from Case Study 2. It features an interview with Participant B, who is an expert in the domain of blockchain and DRM.

5.4.2.1 Findings on Blockchain as a Trust Layer

This section explores the insights provided by Participant B, regarding the use of blockchain as a trust layer in the context of DRM in IoV.

Transitioning to decentralized energy systems demands a paradigm shift in terms of trust establishment methods. In the IoV, it is anticipated that blockchain's unique characteristics will play a crucial role in this transformation. Participant B's observations on this topic provide a deep comprehension of how blockchain might facilitate trust.

Transparency and security are central to the discussion of blockchain because of its intrinsic capacity to offer them. As Participant B observes: *"Blockchain provides a decentralized and transparent ledger system, where each transaction is traceable and verifiable, inherently fostering trust".* His statement that blockchain provides a transparent, decentralised ledger system where transactions are traceable and verifiable directly bolsters the tenet of the suggested model, which is to build confidence within the Internet of Vehicles ecosystem. The intrinsic traceability and transparency of blockchain transactions support the security element and also play a major role in building trust, which is necessary for the efficient DRM in the IoV.

Furthermore, Participant B's discussion on the tokenization of incentives highlights and supports a key component of the proposed model. His support for blockchain's ability to tokenize behaviours and actions supports the model's use of tokenized incentives to encourage individual engagement in DRM activities. Participant B's remark that *"Tokenization of incentives is a process that, once established or annually updated on the blockchain, becomes immutable and incurs no additional cost", is particularly insightful.* From the above statement it is evident also that based on Participant B, tokenizing the incentives over the blockchain, ensures equitable rewards for participants, fostering a sense of trust and engagement. In that sense, Participant B emphasizes the significance of a system in which: *"Trust is embedded".*

On another note, Participant B also discusses the relationship between anonymity and transparency in the context of blockchain technology. He specifically addresses the challenges posed by the General Data Protection Regulation (GDPR), highlighting that *"it's essential to go beyond merely claiming GDPR compliance; we should clearly communicate to participants exactly how their data is protected and managed under these regulations"*. This statement reflects a deep understanding of the intricacies involved in managing sensitive user data within blockchain frameworks. Participant B emphasizes the importance of not only ensuring GDPR compliance but also transparently conveying these processes to participants to maintain their trust. The proposed conceptual model, therefore, should incorporate mechanisms that are compliant with GDPR and also effectively communicate these compliance measures to users, reinforcing confidence in the system.

The following table (Table 5.4) serves as a summary of the key findings gained from the interview with Participant B on the topic of blockchain as a trust layer.

Table 5.4: Case study 2 - Findings on blockchain as a trust layer

Topic	Sub-Topic	Finding	Implication
Blockchain as a Trust Enabler	Transparency and Security	Blockchain provides an immutable record of transactions.	Builds trust through transparency in the IoV ecosystem.
	Tokenization and Incentives	Blockchain can tokenize actions and behaviors as incentives.	Encourages active participation and rewards in the network.
	Decentralization	Blockchain operates without a single point of control.	Fosters trust as no entity has undue control.
	Privacy Concerns	Blockchain should ensure GDPR compliance and privacy.	Ensures data protection and trust among European users.

Table 5-14 highlights the role of blockchain as a trust layer in the IoV, under the scope of Case Study 2. It highlights four key aspects: transparency, security, tokenization, decentralization and privacy. Transparency and security are crucial for trust in the IoV ecosystem, as blockchain provides an immutable record of transactions, reducing fraud and manipulation. Based on Participant B, tokenization encourages active participation and engagement, creating a dynamic IoV environment. Furthermore, decentralization promotes a more democratic culture by preventing one organization from having excessive authority. Then, based on Participant B, privacy concerns, particularly in Europe, are addressed by ensuring GDPR compliance and protecting user privacy. Overall, Table 5-14 emphasizes the importance of blockchain in building trust in the IoV ecosystem, fostering a trustworthy and reliable environment.

5.4.2.2 Findings on Tokenized Incentives

In exploring the domain of DRM in IoV, Participant B highlights the transformative potential of tokenized incentives in decentralized energy systems. His exploration of DRM in IoV, supports the use of tokenized incentives as outlined in the researcher's proposed model, particularly for their role in increasing user participation and facilitating data exchange. He raises a pivotal question though: *"Can the process of tokenization indeed enhance users' willingness to engage?"* This insight supports the proposed conceptual model but also points to the need for more refinement, particularly in figuring out how tokenization affects behavior and psychological aspects. Based on participant B's findings, it appears that how users perceive and engage with tokenized rewards could have a significant impact on the DRM system's effectiveness. Therefore, while supporting the current model's approach, Participant B's observations suggest further improvements to more effectively leverage the behavioral aspects of tokenization for the development of ideal user profiles and customized charging schedules in the context of the Internet of Vehicles.

Moreover, Participant B turns also the conversation around by emphasizing the importance of privacy in DRM systems, particularly with regard to the obligations of GDPR compliance. He asserts, *"Privacy is of the utmost importance and must be guaranteed; compliance with the GDPR is crucial for the system,"* thereby weaving the narrative of privacy into the fabric of DRM and tokenized incentives. Participant B highlights the importance of balancing the need for transparency and traceability of transactions and incentives with maintaining high standards of privacy and data protection. This balance is crucial for building user confidence and ensuring their personal information remains secure. The model should incorporate blockchain technology for tokenization, system transparency and compliance with GDPR. This approach ensures the DRM system is efficient, transparent and respects user privacy, enhancing its effectiveness and user acceptance. By incorporating Participant B's insights, the proposed model can create a DRM system that is efficient, transparent and respectful of user privacy.

Moreover, Participant B's insights reveal the diversity of participants within the blockchain-powered DRM system. From "tech enthusiasts" deeply engaged with every aspect of their energy consumption to the broader public favoring simplicity, he acknowledges the spectrum of user involvement. *"We can have many layers,"* he suggests, indicating the need for multi-faceted communication and token allocation strategies. This multi-layered approach is not just about token distribution; it's equally about understanding user behavior, ensuring privacy and customizing the communication of benefits across various user segments, thus ensuring the DRM system's relevance and efficacy for a wide range of users. This approach necessitates a deep understanding of different user segments, ensuring privacy for all while also customizing the communication of benefits to resonate with each group uniquely.

The following table (Table 5.5) serves as a summary of the key findings gained from the interview with Participant B on the topic of tokenized incentives.

Table 5.5: Case study 2 - Findings on tokenized incentives

Topic	Sub-Topic	Finding	Implication
Tokenized Incentives	Value Exchange in Decentralized Ecosystem	Tokenized incentives are an exchange of value and can encourage people to take part in DRM activities.	Enhances user engagement and trust in the system.
	Transparency & Trust	Combining the transparency of blockchain with tokenized incentives builds trust and gets more people involved in energy trading.	Builds confidence in the fairness and transparency of the system.
	Adaptability of Tokenized Incentives	Tokenized incentives can be adjusted to accommodate the needs and habits of different users. This makes them flexible and dynamic.	Helps the DRM system work better by considering different user habits and preferences.
	Influence of Tokenized Incentives	Tokenized incentives can motivate users to provide data.	Using rewards to get more users involved and improve the accuracy of the data in the system.
	Psychological and Behavioral Impact of Tokenization	Participant B discusses the potential of tokenized incentives in decentralized energy systems but questions its impact on user engagement and psychological aspects.	Suggests further refinement of the DRM model to leverage the behavioral aspects of tokenization more effectively, ensuring user engagement and trust.

Table 5-15 is based on the insights from Participant B. Based on those insights the use of tokenized incentives in a DRM system can significantly enhance participation and trust. These incentives act as a form of value exchange, motivating users to engage more actively in DRM activities. The transparency offered by blockchain technology and the application of tokenized incentives create a robust method for building trust among participants. Also, the adaptability and flexibility of tokenized incentives make the DRM system more responsive and dynamic, catering to the unique preferences and behaviors of users. Additionally, based on Participant B’s findings, tokenized incentives can motivate users to provide more accurate and comprehensive data, which is crucial for optimizing energy management and trading activities.

5.4.2.3 Findings on User Profiles and Charging Scheduling

This section explores the User Profiles and Charging Scheduling insights offered by Participant B. The field of user profiling and charging scheduling, particularly in the context of electric vehicles (EVs), has emerged as a central theme in energy management. Participant B provides several insights on this aspect emphasizing the value of individualized user profiles. Specifically, he believes that *"customized user profiles are proved to be extremely beneficial".* By collecting the individual energy use and charging behaviors of users, these profiles provide the foundation for optimizing energy distribution. However, as Participant B points out, that *"the problem is to the data acquisition*". Participant B's observation about the challenge in data acquisition presents an important area for consideration in the proposed model. This consideration is twofold: firstly, it involves the technical aspect of gathering detailed and accurate user data in a manner that is both efficient and respects user privacy. Secondly, it concerns the willingness of users to share their data, which is essential for creating these detailed profiles. This challenge highlights the need for the proposed model to incorporate effective data collection methods that are transparent and secure, fostering user trust and willingness to participate.

Moving forward, Participant B suggested that EVs have a tangible impact on energy grids and IoV, stating that *"EVs could be charged through the household battery charging stations".* Therefore, it is crucial to comprehend the charging patterns of EVs. This insight, in turn, can drive energy storage and subsequent distribution plans. Participant B's observation that EVs can be charged through household battery charging stations and the consequent impact on energy grids and IoV is a vital component of the proposed conceptual model. His emphasis on understanding the charging patterns of EVs is crucial for developing effective energy storage and distribution strategies within the DRM system. This understanding is not only about managing energy load but also about optimizing the use of renewable energy sources and enhancing grid stability.

Moreover, relating back to the concept of tokenized incentives, these incentives have the ability to operate as drivers. By rewarding users with tokens for their data, the system may see increased involvement and data accuracy. This leads Participant B to reflect, saying that *"Tailoring user profiles is particularly vital, especially for electric vehicles, where it's of utmost importance".* Thus, by incentivizing users with tokens for sharing their data, particularly regarding their EV charging behaviors, the DRM system can potentially see increased user involvement and data accuracy.

Similarly, charging scheduling, especially for EVs, appears as a crucial aspect of effective DRM. An efficient schedule that balances the IoV increases at the same time its efficiency. Participant B discusses the issues, highlighting the complexities of actual implementation, as he emphasizes the practical aspects. Participant B's observations clarify the interconnected nature of user profile, charging scheduling and the broader context of energy management.

The following table (Table 5.6) serves as a summary of the key findings gained from the interview with Participant B on the topic of user profiling and charging scheduling. Specifically, Table 5-16 highlights that customized user profiles are crucial for efficient energy management, as understanding individual user patterns allows for diverse management strategies. Based on Participant B, accurate user profiles are essential for optimizing EV dispatching and energy trading. The table also emphasizes the need for robust and reliable data collection to ensure accurate user profiling. Strategic planning and optimized scheduling are key requirements for managing peak charging times, balancing the grid's load and ensuring efficient energy distribution. Furthermore, privacy concerns and GDPR compliance are also emphasized, with blockchain technology playing a vital role in enhancing data security and privacy. Similar to previous findings from case study 1 and 2, Participant B from Case Study 2 also supports that accurate data collection is essential for aligning charging schedules with user needs and grid requirements, ensuring efficient grid management and optimizing energy consumption patterns.

Table 5.6: Case study 2 - Findings on user profiling and charging scheduling

Topic	Sub-Topic	Finding	Implication
User Profiles and Charging Scheduling	Tailored User Profiles	Customization of user profiles is vital for energy management	Efficient energy use stems from pattern understanding
		Varied user patterns necessitate distinct management approaches	Diverse management strategies are required for different behaviors
		Challenges in data collection are present	Robust data collection is critical for accurate profiling
	EVs and User Profiles	EVs impact the energy grid	Strategic planning is needed for peak charging times
	Privacy Concerns	Privacy assurance is important	Data protection boosts user confidence
		Necessity for GDPR compliance	Open communication about data compliance is essential
		Blockchain enhances data security	Blockchain use can alleviate privacy issues
	Charging Scheduling	Optimized schedules are crucial for DRM	Efficient grid management requires coordinated schedules
		Accuracy in data is vital for charging schedules	Precise data is key for user- and grid-aligned schedules

5.4.2.4 Findings on the Demand Response through P2P Energy Trading

Participant B discusses the transforming effects of IoV in the area of DRM through P2P energy trading. He perceives EVs primarily as energy storage devices within the trading system. His observation that *"the energy trading process could potentially be bi-directional"* supports the relevant part of the proposed conceptual model, where EVs are not just energy consumers but also contributors to the energy grid. This bi-directional nature of energy trading, where EVs can absorb excess energy and release it during peak demand, adds a layer of flexibility and efficiency to the energy management system within the IoV. However, Participant B highlights a crucial factor: *"The issue with EVs is that their impact largely depends on the user's profile".* This insight supports the proposed conceptual model but also points to the need for more refinement, particularly in figuring out how tokenization affects behaviour and psychological aspects. Based on participant B's findings, it appears that how users perceive and engage with tokenized rewards could have a significant impact on the DRM system's effectiveness. Therefore, while supporting the current model's approach, Participant B's observations suggest further improvements to more effectively leverage the behavioral aspects of tokenization for the development of ideal user profiles and customized charging schedules in the context of the Internet of Vehicles.

Discussing energy balance, Participant B emphasizes also the self-consumption model, particularly relevant in solar energy-rich regions like Switzerland and Cyprus. He proposes, *"EVs could be harnessed to absorb this excess energy, shaving off production peaks",* suggesting a strategy for using EVs to stabilize energy production and consumption patterns. In addition to using EVs as energy storage devices, this strategy supports the overarching objective of stabilizing patterns of energy production and consumption. EVs can decrease the problem of production peaks by absorbing excess solar energy, which will help create a more efficient and balanced energy system. However, he advises, *"You need an energy producer, either from your local energy community or from an external source".* This statement underscores the necessity for reliable energy sources to support the model, highlighting the interplay between local and centralized energy solutions.

Further, Participant B touches on blockchain's role in P2P energy trading. While acknowledging that P2P trading can occur without blockchain, he notes its value in adding transparency and decentralization. He explains, *"Tokenization is fundamentally linked to blockchain technology",* indicating blockchain's fit with the decentralized nature of P2P trading. While he acknowledges that P2P energy trading can technically occur without blockchain, he highlights the significant value that blockchain adds in terms of transparency and decentralization. This insight is crucial for the proposed conceptual model, as it underscores the role of blockchain not just as a technological tool, but to enhance the principles of P2P trading in the IoV ecosystem.

The following table (Table 5.7) serves as a summary of the key findings gained from the interview with Participant B on the topic of DRM through P2P energy trading.

Table 5.7: Case study 2 - Findings on demand response through P2P energy trading

Topic	Sub-Topic	Finding	Implication
Demand Response Management through P2P Energy Trading	EVs as Storage Systems	EVs act as energy storage, capable of feeding back to the grid	Enables the Vehicle-to-Grid (V2G) concept, offering bi-directional energy flow
	Balancing Energy Generation and Consumption	Energy balance is vital in an energy community, with EVs playing a role in energy storage	EVs help shave off production peaks and aid in optimizing consumption patterns
	Role of User Profiles	User profiles are essential for determining the availability of EVs for energy storage or trading	Effective energy management strategies can be devised based on these profiles
	Blockchain and Energy Trading	P2P energy trading can integrate with blockchain for transparency and decentralization	Blockchain offers a platform for both tokenized incentives and decentralized P2P trading

Based on the abovementioned findings, Participant B mentions that EVs play a crucial role in energy trading, particularly in DRM through P2P trading. EVs can serve as energy storage systems, allowing them to feed energy back into the grid, enabling the V2G concept. This bi-directional flow of energy is essential for a dynamic and responsive energy management system. EVs can absorb excess energy during production peaks and release it during high-demand periods, optimizing consumption patterns and stabilizing the energy grid.

Additional Findings

In addition to the central insights of our discussion, the interview with Participant B at SUPSI revealed several other crucial aspects that significantly enrich the overall landscape of IoV, DRM and the potential role of blockchain within this context.

Participant B looked deeply into a proposed scenario illustrating the practical difficulties and complexities of integrating blockchain into the IoV and DRM:

> *"In our institute, which has around 40 to 45 employees, the future scenario might involve everyone owning an Electric Vehicle (EV). While this is not the case yet, it's a possibility we consider. Our department is already equipped with 32 chargers and we have photovoltaic (PV) panels installed on our roof. The concept I'm considering involves creating incentives for employees who use their EVs in a way that aligns with our energy management goals. These*

> *incentives would be tokenized on the blockchain. The idea is to use the PV energy produced during the day to charge the EVs when they are connected to the chargers, helping to reduce peak demand on the grid. The more an employee contributes to this effort by aligning the charging of their EV with PV production times, the more they would be rewarded, as per the terms set out in blockchain contracts (i.e., smart contract). This process wouldn't just be about energy trading; it's more about efficiently storing PV production in the EV batteries. This whole system would be recorded on the blockchain. Additionally, this setup could provide valuable data for studying user profiles, although gaining access to this data from the chargers might present a challenge."*

Participant B's proposed scenario at SUPSI, envisioning a future where every employee owns an EV and participates in an energy management system, offers a practical and innovative application of blockchain within the IoV and DRM context. This scenario, involving the use of photovoltaic (PV) panels and EVs as energy storage systems, aligns with the proposed conceptual model's emphasis on optimizing energy consumption patterns and efficient energy management. The idea of using blockchain to create tokenized incentives for employees who align their EV charging with PV production times is a compelling example of how blockchain can facilitate decentralized energy systems.

However, as Participant B points out, this scenario also presents several challenges. Tokenizing incentives for energy balancing raises technical feasibility, fairness and compliance issues, while blockchain offers transparency but introduces complexity in data management and GDPR regulations. Additionally, Participant B's comment on the difficulties in acquiring data from chargers highlights a significant obstacle in implementing such a system. Reliable and comprehensive data are essential for optimizing energy distribution and consumption patterns, as well as for establishing accurate user profiles.

5.4.3 Hypotheses Evaluation for Case Study 2

In order to bridge the gap between theoretical assumptions and empirical reality of DRM in IoV, a set of hypotheses was established during conceptual model development. This sub-section will evaluate those hypotheses against Case Study 2, enabling the researcher to methodically test the suggested conceptual model, resulting in a more in-depth and detailed understanding of her area of study, as well as the revision of the conceptual model. Table 5.8 presents the hypotheses evaluation based on Case Study 2.

Table 5.8: Case Study 2 - Detailed hypothesis evaluation

#	Hypothesis Statement	Findings Summary	Result
H1	Tokenized incentives could potentially influence users' willingness to participate in the demand response program	Participant B highlighted the effectiveness of tokenized rewards in motivating employees to participate in DRM, particularly for electric vehicle users, with blockchain ensuring transparency. These insights demonstrate the significant impact of tangible, blockchain-based incentives on human-centric engagement in DRM	Supported
H2	Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation	Participant B underscored blockchain's role in providing a transparent and decentralized platform for tokenized rewards and P2P trading. This emphasis on transparency is crucial in enhancing participant confidence and the overall effectiveness of DRM initiatives	Supported
H3	Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules	The significance of detailed user profiles was stressed by Participant B, particularly in the context of EV availability and data challenges from chargers. This knowledge is critical for developing effective DRM strategies, highlighting the need for comprehensive user understanding	Supported
H4	Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management	Participant B highlights the role of EVs in P2P energy trading, suggesting they can absorb excess energy in solar-rich areas. He emphasizes blockchain's transparency and decentralization. However, he suggests further exploration to link personalized charging schedules with increased participation in P2P trading, considering privacy, behavioral aspects and user involvement	Partially Supported
H5	Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance	The characterization of EVs as energy storage systems capable of bidirectional energy flow by Participant B supports their crucial role in balancing energy consumption and generation through active participation in P2P energy trading	Supported

H6	Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand	Participant B emphasized the essential role of primary energy sources in DRM, highlighting their importance in ensuring grid stability and seamless management. This emphasizes the irreplaceable role of primary sources in DRM maintenance	Supported
H7	Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management	The exploration of EVs as potential storage media capable of feeding energy back into the grid aligns with the Vehicle-to-Grid (V2G) concept, indicating significant opportunities for enhancing DRM effectiveness	Supported
H8	The level of energy consumption could potentially influence the overall load on the grid and the effectiveness of demand response management	Participant B discusses the bidirectional nature of energy trading in the IoV, with EVs acting as both consumers and suppliers. They can influence grid load and enhance DRM effectiveness, but individual energy consumption levels' impact on grid load and DRM effectiveness is not explicitly addressed	Partially Supported
H9	Privacy measures could potentially influence user trust and willingness to participate in the demand response program	Participant B focused on the challenges of GDPR compliance in utilizing blockchain, emphasizing the need for effective privacy protections in DRM. This highlights how crucial privacy safeguards are in fostering user trust and active participation in DRM	Supported

5.4.4 Summary of Key Findings from Case Study 2

Case Study 2 revealed significant future DRM landscape implications. The insights gained from the interview with Participant B, contribute significantly to the researcher’s understanding on this research area.

The proposed reinterpretation of the purpose of EVs was a particularly noteworthy conclusion. Rather than simply being viewed as vehicles, EVs also hold promise as potential energy storage devices. This deep comprehension could enable EVs to dynamically participate in energy flows, embodying the V2G concept, in which vehicles collect energy during excess times and release it during peak needs.

Moreover, tokenized incentives have emerged as an effective tool for engaging and motivating users. In addition to their monetary value, tokens can act as contribution certificates or rewards, giving a psychological incentive as well. Such a method, when clearly recorded on technologies like the blockchain, could inspire a deeper engagement from users in DRM initiatives.

Despite the advantages of personalized user profiles, which promise major improvements in DRM efficiency, the associated difficulties cannot be overstated. To realise the full potential of personalised DRM approaches, the obstacles in data collecting, storage and processing should be overcome.

The analysis also stressed the need for a broader energy landscape perspective. Strategies for a complete and sustainable approach to energy consumption and distribution can be developed by incorporating both primary and renewable energy sources. Such a holistic perspective is essential for building flexible and effective DRM schemes.

Moreover, privacy and data protection concerns are of the utmost importance. This case study re-assured the hypothesis that trust, supported by robust privacy protections, is vital for maintaining widespread user engagement, particularly in a blockchain environment. Effective communication regarding these technologies can serve to further dispel any confusion surrounding them, fostering confidence and engagement among prospective users and stakeholders.

Based on the above overview, Table 5.9 presents an overview of the hypothesis evaluation for Case Study 2, in which the symbol of a checkmark (✓) is used to signify agreement or support for the hypothesis by the participant, whereas a question mark (?) is used to indicate uncertainty or insufficient data to either support or contradict the hypothesis.

Table 5.9: Overview of Case Study 2 hypotheses evaluation

Hypothesis	Participant B
H1	✓
H2	✓
H3	✓
H4	✓
H5	✓
H6	✓
H7	✓
H8	✓
H9	✓

A proposition for strengthening the suggested model emerged from these findings. It is necessary to reframe the function of EVs to emphasise their significance as energy storage systems. This emphasis could provide a deeper comprehension of their role in DRM. Tokens can also evolve to serve as indicators of community participation, so potentially increasing user engagement. The model should also solve the practical issues associated with personalised user profiles, maybe by integrating user-friendly interfaces or automated data collection techniques. In addition, the model should prioritise effective security measures and transparently communicate the processing of user data in order to bolster confidence. , fostering comprehension and confidence among users and stakeholders. The encouragement and regulation of P2P energy trading, which might considerably enhance the model's holistic approach to energy management, is an extra aspect worth incorporating, according to Participant B's observations. In conclusion, Case Study 2 has significantly enriched the researcher's understanding of the DRM landscape, suggesting possible areas for model improvement and refinement.

5.5 Case Study 3: Energy Innovation & Engineering

This section focuses on the second case study investigated during this thesis, through Energy Innovation & Engineering (E7).

5.5.1 Introduction to Case Study 3

Austria-based Energy Innovation & Engineering (E7) is known for its sustainable energy and building management systems. It was formed with a focus on energy efficiency, renewables and sustainability and it operates at the intersection of innovation, engineering and environmental stewardship. E7, with over 25 people, helps companies optimise their energy use, reduce their carbon footprint and move to more sustainable operations. E7's primary competencies include energy consultancy, project creation, monitoring and verification and policy advising, among others. The company provides comprehensive energy and sustainability solutions, assisting a wide spectrum of clients, from private businesses to government agencies, on their path to a greener future. The company has a strong reputation for its technical expertise and forward-thinking approach, playing a crucial part in the energy transition in Austria and worldwide.

The second case study encompassed an interview with Participant C from E7 (information available in Appendix C). Participant C, a graduate of the University of Natural Resources and Applied Life Sciences in Vienna, has been working as a project manager and junior consultant at E7 since 2016. He gained professional experience in 2015 at the Blue Minds Company, where he learned about the Austrian Energy Efficiency Act. Participant C's expertise lies in energy economics, particularly in flexibility in electricity markets and the e-mobility transition. He is also pursuing a PhD at the same university, focusing on demand response business models. Pressmair's insights shed light on various critical aspects, from the role of blockchain in the IoV to the importance of user profiles in DRM. The data presented in the following sub-sections encapsulates the core responses and observations drawn from the in-depth interview with him.

5.5.2 Empirical Data Analysis from Case Study 3

In this section, the analysis focuses on the empirical data gathered from Case Study 3. This involves a detailed interview with a specialist in demand response management (Participant C).

5.5.2.1 Findings on Blockchain as a Trust Layer

This section explores the insights provided by Participant C regarding the use of blockchain as a trust layer in the context of DRM in IoV.

While the proposed model is supported from Participant C in terms of trust, it is also highlighted that it may enhanced by Participant C's observations regarding the relationship between user comprehension and blockchain transparency in the IoV DRM system. Drawing attention to a significant issue, he compares the complexities of blockchain to those of an energy bill, highlighting how daunting the technology may seem to those who are not familiar with it. Some consumers may become alienated from blockchain due to its complexity, even though its immutable and transparent ledger is essential for security and transparency. According to this insight, a DRM system must strike a compromise between accessibility and transparency in order to make the system simple to use and comprehend.

Furthermore, Participant C emphasises the value of consistent financial incentives—a concept that aligns with the proposed model's objective of promoting user involvement and trust. The incentives' structure and distribution must be predictable and equitable in order for them to be viewed as rational and fair. This emphasises how crucial it is to provide tokenized incentives in a way that is clear and fair to all users, in addition to simply incorporating them into our model. This strategy will improve the model's ability to captivate users and build DRM system confidence.

Participant C additionally emphasises the significance of maintaining consistency in tokenized rewards. In an IoV demand response management scenario, token rewards that are dispersed erratically could undermine user trust in the system. "*Participants may begin to question the system's dependability if they receive inconsistent token rewards—receiving a substantial quantity one day and none the next for similar actions",* he emphasises. His concern that inconsistent token distribution can undermine user confidence is especially relevant. He correctly points out that participants may begin to doubt the system's dependability if they consistently receive token rewards for comparable efforts, such as receiving a substantial amount one day and none the next. This issue is critical to our model because it implies that the administration of rewards has a larger role in a tokenized incentive system's performance than the rewards alone.

While Participant C's primary emphasis is on data management, his observations provide opportunities to investigate the potential of blockchain technology in augmenting security and privacy in interconnected systems such as the IoV. He also recognises the inherent capability of blockchain to securely store and transmit data, extrapolating on a future in which blockchain could fundamentally transform methods of safeguarding data in complicated systems.

Participant C presents an observational viewpoint that effectively reconciles the pragmatic ramifications of blockchain technology with its technical capabilities, as it pertains to the user experience. This highlights the significance of simplicity, predictability and dependability in blockchain-based systems aimed at strengthening trust in the IoV.

The following table (Table 5.10) serves as a summary of the key findings gained from the interview with Participant C on the topic of blockchain as a trust layer.

Table 5.10: Case study 3 – Findings on blockchain as a trust layer

Topic	Sub-Topic	Finding	Implication
Blockchain as a Trust Layer	Transparency vs. Complexity	Full transparency can be overwhelming; it should be balanced with simplicity.	There's a need to keep the system trustworthy without overwhelming the user with excessive details.
	Tokenized Incentive Systems	Inconsistent rewards can erode trust in the system.	The algorithm for rewards should be robust and transparent to ensure predictability and trustworthiness.
	Blockchain's Potential and Security	Blockchain holds promise for data security in interconnected systems.	Blockchain may revolutionize data security in complex systems like IoV.

Table 5.10 addresses the balance between transparency and complexity in blockchain systems. The findings suggest that while full transparency is beneficial, it can also be overwhelming and should be balanced with simplicity. This indicates the need to design blockchain systems that are trustworthy yet user-friendly, without inundating users with excessive details. Additionally, the table discusses tokenized incentive systems, noting that inconsistency in rewards can erode trust in the system. These findings underline the importance of having a robust and transparent algorithm for rewards to ensure their

predictability and reliability, thereby maintaining user trust and engagement in the DRM system. Lastly, the table examines blockchain's potential in enhancing data security, especially in interconnected systems like IoV. The main insight gained from these findings is that blockchain technology holds promise for revolutionizing data security in IoV systems, potentially leading to significant improvements in how data integrity and confidentiality are managed.

5.5.2.2 Findings on Tokenized Incentives

Moving on to the second pillar of the conceptual model, which was thoroughly discussed with Participant C, it is essential to emphasise that the effect of incentives in influencing user behaviour is fundamental of any system, especially in the changing environment of the IoV and blockchain technology. Participant C gave a balanced perspective on the difficulties and promise of tokenized incentives.

One important finding, according to participant C, is that incentives need to have a real market value. This viewpoint puts the model to the test to make sure that any tokenized system put into place has real-world financial relevance in addition to operating efficiently within the IoV ecosystem. He questions the feasibility of the business models that leverage vehicle flexibility, underlining a need for financial balance: *"The critical consideration for me is whether a viable business model exists that capitalizes on the flexibility provided by these vehicles. Is the revenue generated from these markets sufficient to justify the investments?"*. This perspective highlights the need for an ecosystem that maintains tokenized systems, guaranteeing their real value and hence fostering user trust. The perceived value and market viability of a tokenized incentive system are just as important as its technical implementation when it comes to determining its success. In addition, Participant C's recognition of the connection between detailed user profiles and the effective distribution of incentives highlights how crucial it is to employ a variety of user data for appropriate reward distribution.

Additionally, his emphasis on the significance of accurate forecasting in energy trading and vehicle dispatching highlights a critical aspect of system functionality. Inaccurate forecasts have the potential to cause systemic disruptions and influence the fair distribution of incentives, which in turn can impair user confidence and the DRM system's overall efficacy. Therefore, the researcher is driven by Participant C's observations to examine the economic and market facts that support the viability of tokenized incentives in the context of IoV. The following table (Table 5.11) serves as a comprehensive summary of the key insights gleaned from the interview with Participant C on the topic of tokenized incentives.

Table 5.11: Case study 3 - Insights on tokenized incentives

Topic	Sub-Topic	Finding	Implication
Tokenized Incentives	Motivation and Value	The value of tokens should be rooted in a "physical" market.	Establishing a solid ecosystem for tokenized systems to boost user trust and engagement.
	Quality of User Profiles	Accurate user profiles could lead to more effective incentives.	Using well-maintained, comprehensive user profiles to improve the effectiveness of personalized charging schedules in IoV
	Forecasting Accuracy	Accurate forecasting is crucial for successful tokenized incentives and DRM.	Having a dependable forecasting system to prevent performance issues caused by inaccurate predictions.

Table 5.11 emphasizes the importance of grounding token values in "physical" markets for a robust ecosystem and enhancing user trust and engagement. Accurate user profiles are crucial for effective incentive distribution, as well as accurate forecasting for the success of tokenized incentives and DRM in the IoV context. A reliable forecasting system is essential to avoid performance issues and ensure the efficiency and effectiveness of the DRM system. These insights are crucial for designing effective DRM systems that motivate user participation and ensure operational efficiency.

5.5.2.3 Findings on User Profiles and Charging Scheduling

The convergence of IoV and blockchain technology has opened a new era of energy management and vehicle dispatching possibilities. An essential aspect of this integration is the significance of user profiles and billing schedules. Participant C demonstrated a comprehensive understanding of how these parameters could be utilised to maximise energy trading and demand response management.

Participant C's insight on the critical role of accurate predictions for effective user profiling in the IoV context is a key element for enhancing the researcher's conceptual model. He emphasizes the need for reliable data to optimize EV dispatch and energy trading, stating: *"The essence of profiling lies in achieving an accurate forecast […] Without a reliable forecast, the outcomes are compromised".* This statement underscores the importance of high-quality, data-driven forecasting in the proposed model. However, prioritizing accurate forecasts brings up issues related to data quality, privacy and the capacity to manage complex data analytics in real-time. Ensuring that the data used for profiling and forecasting is both accurate and handled securely is vital for maintaining user privacy, which in turn is crucial for the system's credibility and operational efficiency.

Furthermore, Participant C points out that the depth and precision of user profiles have a direct impact on the effectiveness of incentives. He notes, *"Profiling is integral to generating accurate forecasts, which are essential for optimizing electric vehicle dispatch and trading".* This perspective directly supports the proposed conceptual model and highlights the importance of having detailed and accurate user profiles, as they contribute to tailored market offers and appropriate incentive schemes. Therefore, the model should strive to balance the advantages of using detailed user data for market optimization with strict privacy and data protection protocols.

Participant C identifies central fleet management, such as car-sharing services and delivery fleets, as key areas where user profiling and charging scheduling can significantly enhance DRM efficiency. He points out the potential benefits for these sectors, stating, "Central fleets, preferably business fleets, that are making use of that. If that's a use case that can really make profits or can make incentives". This perspective suggests that business fleets have structured usage patterns and can benefit from sophisticated profiling techniques, potentially leading to increased profits.

The following table (Table 5.12) serves as a summary of the key insights gained from the interview with Participant C on the topic of tokenized user profiling and charging scheduling.

Table 5.12: Case study 3 - Insights on user profiles and charging scheduling

Topic	Sub-Topic	Finding	Implication
User Profiles and Charging Scheduling	Importance of Accurate Forecasting	Accurate prediction is foundational for effective user profiling.	Without realistic forecasts, the optimization of vehicle dispatching and energy trading is compromised.
	Data Collection for Forecasts	Profiling and data collection are crucial for reliable forecasts in EV dispatching and energy trading.	Reliable forecasts improve the optimization and overall efficiency of the system.
	Quality of User Profiles & Incentives	The number of incentives offered is connected to the quality of user profiles.	Precise user data enables companies to provide better market offers and thus justify larger incentives, creating a cycle of accuracy and reward.
	Centralized Fleet Management	The ideal use case might be in fleets with a central manager.	Central fleet management may be a more efficient model for leveraging incentives and optimizing energy management.

Table 5.12 highlights the importance of user profiles and charging scheduling in DRM and IoV. It emphasizes the need for accurate forecasting and data collection for user profiling, which is crucial for optimizing vehicle dispatching and energy trading. The table also highlights the role of robust data collection methods in creating reliable forecasts, which enhance the overall efficiency of DRM systems. The quality of user profiles also influences the allocation of incentives, with more precise data leading to better market offers and larger incentives. The efficiency of centralized fleet management is also discussed, highlighting its potential for leveraging incentives and optimizing energy management. These insights are crucial for designing user-centric and efficient DRM systems within the IoV ecosystem.

5.5.2.4 Findings on Demand Response through P2P Energy Trading

Towards efficient DRM, Participant C provided a multifaceted perspective on the problems and potential at the junction of energy generation, consumption and P2P trading.

Regarding P2P energy trading, Participant C presents a viewpoint that underscores the ever-changing characteristics of these systems. He emphasises that P2P trading involves utilising flexibility to respond to market price fluctuations in addition to designating energy quantities. This approach requires sophisticated algorithms capable of real-time market analysis, as Participant C states: *"If we think about P2P trading, that's just assigning entry quantities to different parties. But what we want is to leverage flexibility with it, so we need to react to these prices on this local peer-to-peer market".* His insights on P2P trading's adaptability to market fluctuations, suggest a need for a highly responsive and intelligent system. His focus on flexibility rather than mere energy quantity allocation underlines the evolving nature of energy markets, implying a requirement for continuous adaptation and innovation in DRM strategies. By incorporating these observations, the proposed model should incorporate also the analytical understanding to capitalise on market adaptability. This entails developing systems that are smart in their response to market fluctuations as well as effective in managing energy. By leveraging the cyclical nature of energy prices and needs, these systems could optimise the energy supply and generate profits for IoV ecosystem participants.

Furthermore, in the context of DRM systems, Participant C highlights the increasingly critical role of EVs, not merely as energy consumers but also as key contributors to energy production and storage. This dual functionality of EVs brings a new layer of complexity as well as opportunity to our conceptual model. The technical and financial implications of integrating EVs into DRM strategies are significant, as they can effectively bridge the gap between energy supply and demand. He specifically states that *"This involves the integration of battery storage systems and diverse demand response mechanisms, which encompass the utilization of electric vehicles for smart charging or bidirectional charging*". This strategy, as mentioned by Participant C, encompasses smart charging techniques that optimize charging times based on energy availability and pricing, as well as bidirectional charging that allows EVs to feed energy back into the grid during peak demand periods. The integration of these mechanisms into the proposed DRM model implies a more dynamic and interactive energy management system. It suggests a model where EVs are not passive participants but active players in balancing energy needs, contributing to the overall efficiency and sustainability of the IoV ecosystem.

Furthermore, Participant C emphasizes the evolving role of EVs, which are increasingly important not just as consumers of energy but also as contributors to energy production and storage. This multifaceted functionality of EVs introduces both complexity and opportunity to the proposed conceptual model. He notes the importance of incorporating EVs into DRM strategies, stating, *"This involves the integration of battery storage systems and diverse demand response mechanisms, which encompass the utilization of electric vehicles for smart charging or bidirectional charging".* This approach includes smart charging methods to optimize charging schedules based on energy availability and cost, as well as bidirectional charging, enabling EVs to supply energy back to the grid during peak times. These insights, significantly support the demand response through P2P energy trading, as proposed in the conceptual model, signifying a shift towards a more dynamic and interactive energy management system in the proposed DRM model.

In addition, Participant C emphasises the significance of preserving the system's energy balance. The level of significance that Participant C attributes to energy balance maintenance is indicative of the intricate nature of integrating diverse energy sources and consumption patterns. In addition to a technical challenge, his observations indicate that attaining equilibrium in P2P trading necessitates knowledge of market dynamics and consumer behaviour.

Moreover, he discusses that the efficacy of these tokens in encouraging user participation and bolstering confidence in the DRM ecosystem is contingent on their value being tied to a real market. This approach would likely increase user trust in the DRM system, as participants can see a direct correlation between their energy trading activities and the rewards they receive. In the proposed conceptual model, Participant C agreed that there is significant potential in using tokenized incentives to promote engagement in P2P energy trading and that this means designing a tokenization system where the incentives are not only a tool for engagement but also a representation of real-world value.

Finally, Participant C's observations demonstrate a thorough comprehension of the complexities associated with P2P energy trading within the DRM framework. They emphasise the importance of advanced market-responsive mechanisms and the distinct contribution of EVs to improving the efficiency and equilibrium of the system.

The following table (Table 5.13) serves as a summary of the key insights gained from the interview with Participant C on the topic of energy generation and consumption.

Table 5.13: Case Study 3 - Insights on demand response through P2P energy trading

Topic	Sub-Topic	Finding	Implication
Demand Response through P2P Energy Trading	Core Strength of P2P	The real power of P2P trading lies in dynamically reacting to market price changes.	The future of energy trading is deeply intertwined with the development of algorithms capable of real-time market analysis and adaptability to market shifts.
	EVs as Unique Assets	EVs can both consume and generate energy, differentiating them from other assets.	Their dual capacity allows for diverse use cases, each with unique technical and financial requirements.
	Bidirectional P2P Energy Trading	Energy balance is crucial for efficient DRM and bidirectional P2P energy trading helps establish this balance.	Successful energy balance involves a complex interplay of factors, including energy generation, consumption patterns and market prices.
	Role of Primary Energy Sources	Primary energy sources, such as solar and wind, play a role in ensuring a consistent energy supply.	These sources contribute to grid stability and overall DRM efficiency.
	Tokenized Incentives in P2P	Tokens can incentivize P2P energy trading participation.	The effectiveness of these tokens depends on their perceived value, which should be rooted in a tangible market.

Table 5.13 highlights the role of P2P energy trading in DRM, under the scope of Case Study 3. Based on Participant C, P2P trading's core strength lies in its ability to react dynamically to market price changes, requiring advanced algorithms for real-time market analysis. EVs are unique assets in the DRM system, capable of both consuming and generating energy. Bidirectional P2P energy trading is crucial for establishing energy balance in efficient DRM, involving factors like energy generation, consumption patterns and market prices. Additionally, primary energy sources like solar and wind are essential for consistent and reliable energy supply, contributing to grid stability and DRM system efficiency. Concluding, based on Participant C, the effectiveness of tokenized incentives in P2P energy trading depends on their perceived value, which should be closely tied to a "physical" market.

5.5.2.5 Additional Findings:

During Participant C's interview, perspectives that imply further areas of investigation were also explored. These potential research directions are outlined as follows:

Market Behaviour: Participant C emphasized the importance of tokens possessing tangible, market-driven value. Consequently, the economic aspect of these systems' success complements their technological value. In particular, the observation made by Participant C emphasises the necessity for the incorporation of token economics into IoV to be pragmatic and relevant to everyday situations. Incentives for energy efficiency, transactional mechanisms, or instruments in energy trading markets are all ways in which tokens have the potential to change the energy sector. In addition to technological robustness, market considerations including demand, utility and regulatory approval significantly influence their worth. This requires an in-depth examination of market dynamics, encompassing fluctuations in supply and demand, which have a direct influence on the value and stability of the tokens. Furthermore, the economic motivations provided by tokens play a crucial role in influencing customer conduct within the IoV. These incentives may encourage the adoption of more energy-efficient practises and increase participation in energy-saving programmes. Nevertheless, the efficacy of these incentive frameworks is dependent on how the market perceives the worth of the tokens, necessitating a balance between technological and economic advancement at the same time.

User Psychology and Behaviour: Given the emphasis placed on predictability and trust, understanding human behaviour and psychology is crucial to the success of these systems. Although not explicitly stated, the need for predictability and transparency shows that user participation is contingent not only on monetary incentives, but also on psychological comfort and confidence.

5.5.3 Hypothesis Evaluation for Case Study 3

In order to bridge the gap between theoretical assumptions DRM in IoV practice, a set of hypotheses was established during conceptual model development, as reported in Section 3.4. This sub-section will evaluate those hypotheses against Case Study 3, enabling the researcher to methodically test the suggested conceptual model, resulting in a more in-depth and detailed understanding of her area of study, as well as the revision of the conceptual model. Table 5-14 presents the hypotheses evaluation based on Case Study 3.

Table 5.14: Case Study 3 - Detailed hypothesis evaluation

#	Hypothesis Statement	Findings Summary	Result
H1	Tokenized incentives could potentially influence users' willingness to participate in the demand response program.	Participant C suggests that tokenized incentives encourage users to provide more accurate data, leading to increased participation in demand response programs. This effectiveness in user engagement through tokenized incentives aligns with market strategies for motivating active participation.	Supported
H2	Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation.	The crucial role of transparency in token distribution is emphasized by Participant C, with a focus on blockchain technology for ensuring this transparency and security. This aspect is fundamental in building trust and is a decisive factor in encouraging active participation in DRM.	Supported
H3	Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules.	Participant C highlights the importance of precise forecasting based on detailed user profiling, enabling optimized vehicle dispatching and energy trading. This accuracy in user profiles is essential for efficient DRM and supports more tailored charging schedules.	Supported
H4	Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management.	The advantages of EVs in P2P energy trading, especially in relation to customizable charging, are examined by Participant C. Customized charging schedules responsive to market demands can boost participation in P2P energy trading, enhancing the effectiveness of DRM.	Indirectly supported
H5	Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance.	Participant C underscores the dual role of EVs in energy trading, noting their potential to both generate and consume energy. This active participation in bi-directional energy trading is key to balancing energy consumption and generation, which is crucial for efficient DRM management.	Supported

H6	Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand.	The significance of primary energy sources like solar and wind for a reliable energy supply is emphasized by Participant C. These sources contribute to grid stability and overall DRM effectiveness, highlighting their pivotal role in DRM success.	Supported
H7	Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management.	Participant C discusses the unique capacity of EVs to both consume and generate energy, presenting a special opportunity in the energy ecosystem. This dual capability of EVs is crucial for balancing energy dynamics and enhancing DRM effectiveness.	Supported
H8	The level of energy consumption could potentially influence the overall load on the grid and the effectiveness of demand response management.	Participant C discusses the role of EVs in DRM systems, particularly in P2P energy trading. He suggests smart charging and bidirectional charging can balance energy needs and influence grid load. However, a direct correlation between consumption levels and grid load is not explicitly addressed.	Indirectly Supported
H9	Privacy measures could potentially influence user trust and willingness to participate in the demand response program.	Participant C's focus on blockchain technology for establishing trust in IoV and DRM indirectly supports the idea that privacy measures are important. While specific privacy safeguards are not emphasized, the broader concept of trust, enhanced by blockchain, is key to motivating user participation in DRM.	Indirectly supported

5.5.4 Summary of Key Findings from Case Study 3

Case Study 3 undertook a comprehensive investigation into the interconnected areas of blockchain, IoV and DRM. Case Study 3 was based on a revealing conversation with Participant C, from E7. His observations offered a window into the complex world of energy trading, particularly in a decentralised setting and the effects it has on demand response and the broader energy market.

Participant C emphasised how important blockchain is as a trust anchor for both IoV and DRM. In this situation, trust isn't just an abstract characteristic; it's built on the solid bedrock of transparency, verifiability and an impenetrable security blanket. This trust foundation casts a long shadow over tokenized incentives. Participant C's vision is that tokens are not just digital objects, but strong carriers of real-world value. By bridging the gap between the virtual and the physical world, these tokens can encourage users to get more involved and make proactive contributions to the energy network. This brings up a point that isn't often talked about: even though the technology is promising, the success of these systems is deeply tied to their ability to make profit. As we look deeper into the user-centric dynamics, we see that detailed user profiles are a key to getting better DRM results. The more detailed and accurate these profiles are, the more likely it is that charging schedules can be made to fit the needs of each person. However, P2P energy trading is necessary for the energy ecosystem to be complete. As Participant C revealed its complexity, a vivid image emerged in which individuals transform from mere consumers to essential players who balance the weights of energy use and production.

However, there was more to the interview than originally caught the eye. The subtle market dynamics of tokens and the deep fabric of human behaviour and psychology hid beneath the overt themes. Meaningful understanding and integration of these aspects can result in a model that is not only technologically proficient but also fundamentally human-centric.

To that end, the hypothesis evaluation for Case Study 3 is provided in Table 5.15, in which the symbol of a checkmark (✓) is used to signify agreement or support for the hypothesis by the participant, whereas a question mark (?) is used to indicate uncertainty or insufficient data to either support or contradict the hypothesis.

Table 5.15: Overview of case study 3 hypotheses evaluation

Hypothesis	Participant C
H1	✓
H2	✓
H3	✓
H4	✓
H5	✓
H6	✓
H7	✓
H8	✓
H9	✓

The results were insightful but also highlighted areas for improvement. To fully utilize DRM's potential, its underlying business model should be integrated. It's essential to consider profitability aspects, like the benefits from battery storage and EVs, for a comprehensive understanding. It's also vital to understand how different factors of the model interact. For instance, the balance between personalized charging times and privacy, or the relationship between EV energy production and usage, should be clarified. Incentives are key motivators and can also become essential tools for gathering data. Businesses may be more inclined to offer rewards if they receive valuable data in return. This data exchange can lead to more market-responsive products. Finally, when examining P2P trading, it's important to differentiate between its true form and the more detailed allocation of flexible resources based on market values. This highlights the importance of accurate scheduling.

In summary, this case study confirmed many initial hypothesis and assumptions and highlighted the complex aspects of DRM. It revealed the untapped potential of blockchain and tokenization in this area.

5.6 Case Study 4: Hypertech

5.6.1 Introduction to Case Study 4

Hypertech is a 1997-founded, Greece-based Small and Medium-Sized Enterprise (SME) with over 40 employees who specialize in digital transformation, innovation and communication. Energy, Fintech, Artificial Intelligence, Internet of Things, Augmented and Virtual Reality and Digital Communication are among the many domains in which Hypertech excels.

A specialty of Hypertech is their Energy Labs unit, which excels in delivering ICT solutions for Smart Homes and Smart Grids. This unit’s principal aim is to provide tailored solutions for small and medium-sized consumers, alongside holistic solutions for utilities and energy service providers in demand-side management.

Participant D1 and Participant D2 which participated in Case Study 4 are presented in Appendix C. Participant D1 and Participant D2 were interviewed in order to gain an understanding of the complexities of Hypertech’s operations and their alignment with the research objectives. Participant D1 plays a crucial role in the Energy Labs division, concentrating on the deployment of blockchain technology in energy management systems. She has a master’s in electrical engineering with a concentration in Renewable Energy Systems. Throughout her almost a decade-long career, she has worked on numerous DRM and blockchain-related initiatives. Her thoughts are especially important for understanding the actual obstacles and opportunities involved in implementing blockchain for DRM. Participant D2 on the other hand, is a technical lead in the same department and has a plethora of experience with IoT and energy trading platforms. He possesses a Ph.D. in Computer Science with an emphasis on IoT and has participated in multiple research projects examining the convergence of DRM, IoV and blockchain technologies. His opinions provide a detailed grasp of the suggested conceptual model’s technical characteristics and viability.

5.6.2 Empirical Data Analysis from Case Study 4

This section, the researcher analyses the empirical data collected from Case Study 4, which consists of in-depth interviews with two key stakeholders in the field of demand response management in the IoV: Participant D1 and Participant D2.

5.6.2.1 Findings on Blockchain as a Trust Layer

This section explores the insights provided by Participant D1 and Participant D2 regarding the use of blockchain as a trust layer in the context of DRM in IoV.

Participant D1 provides a comprehensive analysis of the role blockchain plays in promoting confidence in energy trading systems. She brings out its ability for transparent and immutable record-keeping that guarantees building participant confidence. Her emphasis on blockchain's capability for transparent and immutable record-keeping underlines its fundamental role in building trust among participants, supporting the use of blockchain as a trust layer in the proposed conceptual model. This transparency ensures that every transaction within the energy trading system is verifiable and tamper-proof, which is crucial in establishing a reliable and credible trading environment.

Regarding verifiable transactions, Participant D1 explains the effect of blockchain on privacy and security by saying, *"The elimination of potentially untrustworthy intermediaries... greatly contributes to the system's effectiveness"*. Her statement, on the one hand, it enhances privacy by allowing direct P2P interactions without the need for intermediaries and on the other hand, it improves the overall security of the system. This dual benefit is integral to the effectiveness and attractiveness of blockchain-based DRM systems. This perspective ensures that the proposed model addresses the technical capabilities of blockchain while also considering its broader implications on participant confidence and system credibility. Participant D1's focus on the privacy and security benefits of blockchain acknowledge that blockchain aspects in the proposed model enhance transparent and efficient but also secure and respectful user privacy. Participant D2 elaborates on decentralization, referring to the scenarios in which communication between users within IoV is made through a central server or fully decentralized. His observation that *"In a decentralized scenario, users interact directly within the blockchain network"* highlights the fundamental shift from traditional centralized communication models to a more direct P2P approach. This decentralization is significant as it allows users to interact and transact directly with each other on the blockchain, bypassing the need for a central server or intermediary. Integrating Participant D2's insights into the proposed conceptual model, it is evident that Participant D sees the importance of developing a DRM system that leverages the decentralized nature of blockchain.

Shifting the focus to economic aspects, Participant D2 sheds light on the economic dynamics of the DRM system, emphasizing the aggregator's crucial role in orchestrating the energy contributions from EV users. for Participant D2, the aggregator has a critical role. The aggregator can make contracts with the EV users and brings the required energy from these vehicles as per the requirements. He says in this economic model a “win-win” philosophy is followed and the DRM aggregator has an important role. Especially, Participant D2 proposes a practical scenario:

> *“These business models are beneficial for all parties involved. For example, the aggregator operates the system, ensuring protection and deriving income from it—imagine a scenario where the system earns 1,000 euros. Out of this, the aggregator might take 300 euros, while individual users could gain 20 euros each. This is advantageous because managing the system without a demand response mechanism would incur significantly higher costs. The specifics of these costs are complex, but the overarching point is that demand response leads to savings for everyone”.*

The example provided by participant D2 highlights the advantages of the suggested conceptual approach. In his example, individual users benefit monetarily as well; the system as a whole makes a specific amount and the aggregator keeps a percentage of the earnings. This case demonstrates the economic feasibility of a DRM system in which the aggregator enables energy trading and distribution, resulting in financial gains and cost reductions for all participants.

Finally, Participant D1 foresees a future where EVs automatically manage storage and trade of energy among themselves by using blockchain, indicating proper integration with smart contracts and efforts being made towards designing an automated IoV. Finally, Participant D1 highlights how, through the use of blockchain, tamper-resistant data integrity, in the face of huge volumes of data generated from IoV, is assured.

Table 5.16 summarizes insights specifically related to the potential of Blockchain as a trust layer in IoV and DRM. As discussed, both Participant D1 and Participant D2 offer perspectives on the role of transparency and privacy in this context.

Table 5.16: Case study 4 - Findings on blockchain as a trust layer

Topic	Sub-Topic	Finding	Implication	Participant
Blockchain as a Trust Layer	Role of Blockchain	Acts as a foundational layer for IoV and DRM	Enables transparent and tamper-proof data sharing	Both
	Anonymity	Anonymity ensured	Adds a layer of privacy and trust	D2
	Security & Privacy	Blockchain ensures data integrity & confidentiality	Enhances trust among participants and ensures user data privacy	Both
	Decentralization	Blockchain facilitates decentralized operations	Reduces reliance on centralized entities; Empowers individuals	D1
	Transparency in P2P interactions	P2P interactions become more transparent	Builds user trust in the system	D2

In Case Study 4, as presented in Table 5.1, blockchain technology is explored as a foundational trust layer for the Internet of Vehicles (IoV) and Demand Response Management (DRM). Both participants agree that blockchain acts as a crucial enabler for transparent and tamper-proof data sharing, which is central to IoV and DRM operations. Participant D2 specifically points out that blockchain facilitates anonymity, adding a significant layer of privacy and trust to the system. The technology is also recognized for ensuring data integrity and confidentiality, which in turn enhances trust among participants while safeguarding user data privacy. Participant D1 emphasizes the role of blockchain in decentralization, which reduces the reliance on centralized entities and empowers individual users. Furthermore, blockchain's capacity to make P2P interactions more transparent is noted to increase user trust within the system, especially by Participant D2.

5.6.2.2 Findings on Tokenized Incentives

This section explores the insights provided by the two participants (D1 and D2) regarding the use of tokenized incentives in the context of DRM in IoV.

Participant D1 offers a detailed view on the role of tokenized incentives in engaging users in IoV-based DRM, particularly emphasizing their motivational value. In an ecosystem where vehicles serve as both energy consumers and suppliers, she notes the special relevance of the incentives for EV owners. She underscores the importance of transparency in the process of tokenizing rewards, stating, *"Blockchain's role is to tokenize these incentives... adding a transparent layer to existing incentives".* Her insight highlights the significance of these incentives in encouraging EV owners to participate actively in the DRM system. In a scenario where EVs are integral to both consuming and supplying energy, the incentivization of their owners becomes a key factor in the overall system's success. Integrating Participant D1's insights into the researcher's conceptual model, it supports the need for a tokenization system that is both effective in motivating user participation and transparent in its operation. To that end, Participant D1, supports that the proposed model leverage blockchain technology to create a clear and transparent mechanism for distributing incentives, thus enhancing user engagement and trust in the system.

Additionally, Participant D1 addresses the need to carefully balance these incentives against the costs associated with battery degradation in EVs. She points out, *"Engaging in demand response management... accelerates the wear and tear on my battery",* highlighting the necessity for significant incentives to compensate for any potential reduction in battery lifespan, thereby ensuring that participants see a net benefit. This insight brings to light a key challenge in designing incentive schemes within an IoV-based DRM system. The incentives must be substantial enough to ensure that participants perceive a net benefit, despite the increased usage of their EV batteries. Participant D1's point highlights that while incentivization is crucial for user engagement, it should also take into account the long-term costs to users, such as battery degradation. Integrating this perspective into the proposed conceptual model involves creating a balanced and equitable incentive structure. This structure should not only motivate users to participate in the DRM system but also adequately compensate them for any additional "wear and tear" on their vehicles.

Despite Participant D1's positive mention of the role of tokenized incentives as motivation for user participation, this carries complications. Her emphasis on the balance between incentives and battery wear, highlights a crucial trade-off. This raises the question: *How can DRM systems encourage participation without adversely affecting the lifespan of EVs?* The tension between short-term rewards and long-term sustainability is a key consideration for the proposed conceptual model.

Moreover, Participant D1's insights on how blockchain's decentralization can transform the process of incentivization within a DRM system are pivotal. She points out that the secure and transparent nature of blockchain transactions can significantly enhance trust among participants, thereby simplifying and streamlining the reward process.

Additionally, Participant D2’s suggestion of a flexible incentivization system, which adjusts rewards based on market conditions or contractual agreements, brings a dynamic and responsive element to the proposed DRM model. He introduces the concept of ‘stand-by’ users in DRM, explaining, *“These ‘stand-by’ participants are called upon in emergencies... compensated appropriately for stepping in”.* This approach adds flexibility to demand response schemes, allowing for efficient responses to unexpected conditions. However, Participant D2’s approach also raises important questions about fairness and the equitable distribution of rewards within the DRM system. The challenge of ensuring fair compensation for all participants, including those on ‘stand-by’, is crucial for the integrity and sustainability of the system. Integrating this concept into the proposed conceptual model, necessitates a transparent, equitable incentivization framework that values all participants’ contributions and ensures fair compensation for those not actively engaged.

The following table (Table 5.17) serves as a comprehensive summary of the key findings gained from the interviews with Participant D1 and Participant D2 on the topic of tokenized incentivization.

Table 5.17: Case study 4 - Findings on tokenized incentives

Topic	Sub-Topic	Finding	Implication	Participant
Tokenized Incentives	Tokenization	Introduction of a token-based incentive system	Potentially higher engagement and participation in DRM activities	Both
	Behavioral Shift	Tokens can motivate users to change energy behaviors	Enhanced energy management and grid efficiency	D1
	Economic Impact	Token-based systems might lead to cost savings	Users are financially motivated to participate and adhere to DRM schedules	D2
	Trust Layer	Tokens on a blockchain ensure transparency	Increased trust in the incentive system; minimized fraudulent activities	Both
	Adoption Barriers	Concerns over token value stability	Need for regulatory frameworks and mechanisms to ensure token stability	D1
	Community Building	Token incentives can foster community energy exchanges	More localized energy exchanges, potentially reducing energy transportation costs	D2

Table 5.2 of Case Study 4 explores the impact of tokenized incentives on Demand Response Management (DRM). Participants agree that tokens can boost engagement, promote behavioural change and reduce energy costs. Blockchain-based tokens offer transparency, reducing fraudulent activities. However, concerns about token value stability suggest the need for regulatory frameworks. The table highlights the potential for community-building and reduced energy transportation costs.

5.6.2.3 Findings on User Profiles and Charging Scheduling

This section investigates the insights provided by Participant D1 and Participant D2 on the topic of User Profiles and Charging Scheduling.

Participant D1 emphasizes the critical need to understand individual user behaviors for creating effective charging schedules, underlining the significance of tailored solutions in DRM. In a system where vehicles are both energy consumers and potential suppliers, this approach is key. She also stresses the importance of maintaining privacy and security in user profiles, particularly in a decentralized blockchain system.

Participant D1 advocates for a user-centric approach in DRM systems, focusing on IoT and blockchain technologies to simplify daily lives. She emphasizes the importance of convenience in technology adoption, aiming for an intuitive, easy-to-interact system that seamlessly integrates into users' daily routines. She also highlights that users are often more concerned with the financial implications of energy consumption than the consumption itself. This suggests that financial factors, such as cost savings or monetary rewards, are key motivators for DRM participation.

In line with Participant D1's focus on user-centric solutions, Participant D2 supports the use of more accurate and approachable terminology when discussing DRM systems. He proposes terms like "Charging Profiles" or "Driving/Discharging Profiles," which are more intuitive and reflective of the users' actual experiences and expectations. This shift towards language that more accurately reflects user experiences and expectations plays a vital role in making DRM systems more approachable for the average user. By using terms that resonate with users' daily experiences, the proposed model can bridge the gap between complex technical concepts and user comprehension, thereby enhancing the system's accessibility and appeal.

Additionally, Participant D2 draws attention to the important link between battery degradation and user profiles. He underscores the necessity of developing charging patterns that are mindful of battery health, emphasizing that DRM systems should not only focus on energy efficiency and cost-effectiveness but also on the longevity and sustainability of the vehicle's battery. This approach is essential for ensuring that DRM solutions are holistic, considering the long-term implications on both the vehicle and the user. His further explanation likely delves into the specifics of how such charging patterns can be optimized to balance energy needs with battery preservation.

> *"Imagine you own an electric vehicle, like a Nissan Leaf... The compensation should reflect the extent of current drawn from your vehicle because significant draw can substantially affect the battery's health and that should be economically recognized".*

Participant D2's example, illustrates the importance of compensating users not just for the energy provided but also for the potential impact on their vehicle's battery. The idea that significant energy draw from the vehicle could affect the battery's health and should be economically recognized, introduces a layer of complexity in the incentive structure. Integrating this insight into the proposed conceptual model involves creating a compensation mechanism that factors in the degree of battery usage and its potential degradation.

The following table (Table 5.18) serves as a summary of the key findings gained from the interviews with Participant D1 and Participant D2 on the topic of user profiling and charging scheduling.

Table 5.18: Case study 4 - Findings on user profiles and charging scheduling

Topic	Sub-Topic	Finding	Implication	Participant
User Profiles and Charging Scheduling	User Profiles	Different users have varied energy consumption patterns	Need for flexible DRM schedules to accommodate diverse user behaviors	Both
	Charging Scheduling	Optimal charging times differ for users	Efficient energy consumption and reduced grid congestion	D2
	Impact of Profiles on DRM	User profiles greatly affect demand response	DRM strategies need to be adaptive and customizable to individual user profiles	D1
	Profiles & P2P Energy Exchange	Users can trade based on their consumption/charging profiles	Enhanced P2P trading efficiency and satisfaction among users	Both
	Profile-driven Incentives	Tailored incentives can be offered based on user profiles	Increased engagement in DRM activities; users feel their unique needs are recognized and rewarded	D1
	Evolution Over Time	User profiles may change over time	Need for continuous monitoring and updating of user profiles to keep DRM strategies relevant	D2

Table 5.3 examines the significance of user profiles and charging scheduling in enhancing DRM. The findings underscore the diversity in energy consumption patterns among users, emphasizing the need for DRM schedules to be flexible enough to accommodate this variety. Both participants agree that user profiles have a profound impact on DRM, with Participant D1 stressing that DRM strategies must be adaptive and tailored to individual behaviours.

Participant D2 adds that optimal charging times for users can lead to more efficient energy consumption and lessen grid congestion. The table also touches on the potential of profile-driven incentives, suggesting that such personalized rewards can boost user engagement by acknowledging their unique needs. Moreover, the ability for users to engage in P2P energy exchanges based on their consumption and charging profiles is seen as a way to enhance the efficiency and satisfaction of such trades. The participants highlight the dynamic nature of user profiles and the consequent necessity for DRM strategies to evolve over time, advocating for continuous monitoring and updating to ensure relevancy. Overall, this table summarises the significance of adaptability in user profile management as it relates to DRM, the potential for incentivization and the vital role that personalised user data plays in formulating effective DRM solutions.

5.6.2.4 Findings on Demand Response through P2P Energy Trading:

This section aims to provide a comprehensive overview of the insights gathered from Participant D1 and Participant D2 in the area of demand response through P2P energy trading.

Participant D1 highlights the need of Service Level Agreements (SLAs) in establishing explicit terms of participation in demand response. She is an advocate of the necessity of strong incentives to offset the additional degradation on the batteries of EV. Participant D1 argues that the incentive must be significant, emphasising the importance of clear contractual terms. In addition, she advocates for bidirectional trade due to its effectiveness in IoV. However, she acknowledges that smart charging alone can efficiently handle demand response. The focus placed by Participant D1 on SLAs highlights the significance of having well-defined responsibilities and expectations in a P2P energy trading system. Her position on providing significant incentives to offset the degradation of electric vehicle batteries highlights a crucial element of sustainability in the energy trading sector. The aforementioned insights reveal that the proposed conceptual model should also provide contractual terms through SLAs and substantial incentives that consider the sustainability of participants’ resources.

Participant D1 also expresses concern about the integration of EVs into the current energy grid, highlighting the possibility of sudden increases in demand and emphasising the crucial role of demand response. In addition, she acknowledges the possibility of people misusing the network and emphasises the importance of implementing appropriate safeguards to prevent such usage. The user’s worries regarding the incorporation of EVs into current electricity grids highlight the necessity of modifying infrastructure to accommodate emerging technology. The possibility of users manipulating the system for personal benefit, leading to network misuse, highlights a significant vulnerability that needs to be resolved in order to uphold the system's integrity and fairness.

However, Participant D2 emphasises the need of effectively managing battery management. He proposes implementing collaborative discharging as a means to reduce battery degradation. *"According to our research, we recommend releasing all of them simultaneously",* Participant D2 remarks, highlighting the advantages in terms of longevity. Participant D2's emphasis on managing battery degradation through collaborative discharging strategies in a P2P energy trading network introduces a significant approach to enhancing the sustainability of EVs within the DRM system. His suggestion, based on research, to coordinate the release of energy from EVs in response to grid demand signals presents an innovative method to reduce the wear and tear on individual batteries. This collective approach to discharging within a P2P network can potentially extend the overall lifespan of EV batteries, as it optimally balances energy demand and supply across the grid. In addition, he emphasises the economic benefits of utilising reduced off-peak rates for charging and discharging during high-demand periods.

Participant D2 further emphasises the crucial significance of aggregators in overseeing extensive energy transactions. *"The primary authority rests with an Aggregator,"* he elucidates, *"delineating their role in orchestrating energy allocation among multiple consumers to optimise demand response management".* His insights into the economic benefits of utilizing time-of-use tariffs for charging and discharging during different demand periods bring to light a key economic aspect of P2P energy trading. By capitalizing on reduced off-peak rates for charging and opting to discharge during high-demand periods when rates are higher, users can achieve financial benefits while actively participating in demand response initiatives. This approach not only offers economic incentives for users but also aligns individual gains with overall grid efficiency through smart P2P energy exchanges.

Finally, Participant D2 emphasises the role of EVs at the distribution level, where they can function as loads during transportation and as batteries (i.e., V2G) when parked. Specifically, he mentions that EV owners can participate in DRM by signing flexibility SLAs with Aggregators and getting compensation for every kilowatt-hour of delivered flexibility. As he explained in detail, this is advantageous not only for the grid but also for EV owners.

> *"Managing demand response for a single car has negligible impact. The real power lies with an Aggregator, an entity that doesn't just manage one car, but potentially a thousand. This means it has established agreements with a thousand individual users. When the network faces peak load conditions and needs, for example, an extra 10 kW of energy, it's the Aggregator that responds. The Aggregator, having a portfolio of a thousand cars, each with a battery capacity to spare—let's say 30-40% of a small 20 kW battery—coordinates this energy capacity. It's a systematic process; the network doesn't deal with each car owner individually. Instead, it's the Aggregator who acts as an intermediary, managing contracts and orchestrating the energy distribution according to the agreed terms with the participants."*

The role of the aggregator, as outlined by Participant D2, is pivotal within the context of P2P energy trading. He explains that managing the demand response for a single car has a negligible impact, but the true power lies in the collective management of more than one vehicle. Integrating Participant D2's insights into the proposed conceptual model requires the incorporation of mechanisms for managing aggregator-user relationships in a P2P energy trading environment and the efficient coordination of energy resources from multiple EVs. The model should support the establishment of flexible SLAs that are mutually beneficial for both EV owners and aggregators within a decentralized energy market. Additionally, it should facilitate the systematic process of energy distribution management by aggregators, ensuring that the energy capacity from EVs is utilized optimally during peak demand periods and enabling effective participation in P2P energy trading.

In summary, the insights provided by both Participant D1 and Participant D2 offer a comprehensive understanding of the complexities involved in energy generation and consumption. While Participant D1 provides a more systemic and contractual viewpoint, Participant D2 offers practical considerations, especially concerning battery degradation. Their collective insights are invaluable for any research or model aiming to explore this intricate landscape further.

The following table (Table 5.19) serves as a comprehensive summary of the key insights gleaned from the interviews with Participant D1 and Participant D2 on the topic of demand response through P2P energy trading.

Table 5.19: Case study 4 - Findings on demand response through p2p energy trading

Topic	Sub-Topic	Finding	Implication	Participant
Demand Response through P2P Energy Trading	Peer-to-Peer Trading	Bi-directional Trading allows for decentralized energy distribution	More flexible and decentralized energy distribution	Both
	Role in Demand Response	P2P trading enhances energy management	More efficient energy consumption and response to demand	Both
	Local Market	Addresses local energy congestion	Improved grid stability and energy efficiency at a local level	D1
	Battery Management in P2P	The role of batteries is critical in P2P energy management	Ensuring battery longevity and efficiency is crucial for effective P2P energy trading	Both
	Time Zones & Tariffs in P2P	Time zones can lead to cost savings in P2P trading	Encourages users to engage in P2P trade, leading to more efficient energy usage	D2
	Demand Response Mechanisms	Service Level Agreements set clear participation expectations	Clarifies responsibilities and benefits for all involved parties in DRM	D1
	Aggregators in P2P	Aggregators can streamline energy requests and fulfillments	Facilitates large-scale energy exchanges and balances demand across numerous users	D2

Table 5.4 highlights the benefits of bi-directional trading, such as a more decentralized energy distribution, in addressing local energy congestion and improving grid stability. The table also emphasizes the importance of batteries, time zones, tariffs, clear SLAs and aggregators in streamlining energy requests and fulfilling demands. These elements contribute to efficient energy use, cost savings and user participation in energy trading. The table highlights the interconnected nature of P2P energy trading and its impact on effective DRM.

5.6.2.5 Additional Findings

While the interviews with Participant D1 and Participant D2 primarily touched upon the pillars of the conceptual model, their insights implied additional considerations that could be extrapolated for further study. These are presented below.

Expansion of Stakeholders:

In the dynamic environment of energy management, especially in the context of demand response, the roles of numerous stakeholders are becoming more complex and interrelated.

Participant D2 introduces the concept of the aggregator (as discussed in detail in Annex D). The aggregator is identified as a key stakeholder who manages a vast network of EVs, by collecting and analysing extensive mobility data from these vehicles. The primary function of the Aggregator is to optimize EV operations, enhance user experiences and potentially influence EV charging and driving patterns based on the analysed data. This role underscores the importance of data in managing large fleets of electric vehicles and highlights the potential influence such stakeholders have in shaping EV usage and policies. According to Participant D2, the Aggregator is responsible for signing contracts with users and collecting the necessary energy from these cars when it is required. This offers a business model in which the Aggregator plays a substantial part in demand response management, which is mutually beneficial.

The Participant D2 specifies that the aggregator responds directly to the energy demands of the network. For example, if the network wants 10 kW of energy, the Aggregator can obtain this from the fleet of cars it manages. He also says that the contracts between the Aggregator and the users can alter based on a variety of factors, including the deterioration of the automobile batteries.

Environmental Considerations:

In the context of P2P energy trading, environmental concerns, specifically the reduction of carbon emissions, have arisen as a major concern. Participant D2 examines the environmental advantages of P2P energy exchange, highlighting its potential to alleviate climate change.

Participant D2 explores the concept of P2P energy exchange and its environmental benefits, in particular the reduction of carbon emissions. He argues that electric vehicles can be charged overnight, when network demand is low and discharged during peak demand hours. This method not only optimises energy consumption, but it also minimises the demand for fossil fuel-derived energy generation during peaks.

Participant D2 underlines the broader implications of this method, specifically its effect on climate change mitigation. P2P energy exchange can considerably contribute to reduce carbon emissions by decreasing dependency on fossil fuel-based energy sources during peak demand periods. This connects nicely with global efforts to mitigate climate change and offers a feasible, community- or even individual-level solution that can be applied immediately.

The insights of Participant D2 highlight the environmental benefits of P2P energy exchange, with a particular emphasis on carbon emission reduction and climate change mitigation. By charging electric vehicles during off-peak hours and discharging them during peak demand, the energy ecosystem can reduce its dependency on fossil fuels by a significant amount. This contributes to worldwide efforts to cut carbon emissions and battle climate change, in addition to its economic benefits.

Table 5.20 serves as a summary of the key findings of Case Study 4. It provides an overview regarding the role of P2P energy trading in enhancing DRM, highlighting its bi-directional nature, decentralized distribution and flexibility. It emphasizes the importance of batteries, time zones, tariffs, user participation and clear SLAs. Aggregators are examined for streamlining energy requests, fulfilling demands and facilitating large-scale energy exchanges. This enhances energy management, addresses local energy congestion, improves grid stability and enhances community efficiency.

Table 5.20: Case study 4 - Additional insights outside the topics under investigation

Additional Insight	Finding	Implication	Participant
Expansion of Stakeholders	Inclusion of the aggregator in P2P energy trading.	Enhanced stakeholder involvement in DRM.	Both
Aggregator Role	Aggregators control energy from thousands of vehicles.	Enables large-scale energy exchange and demand fulfilment.	D2
Environmental Considerations	P2P trading can reduce carbon emissions.	Connects to global efforts to mitigate climate change.	D2
Peak Demand & Fossil Fuels	Off-peak charging can reduce fossil fuel reliance.	Direct environmental benefits and cost savings.	D2

5.6.3 Hypothesis Evaluation for Case Study 4

In order to bridge the gap between theoretical assumptions and empirical reality of DRM in IoV, a set of hypotheses was established during conceptual model development. This sub-section will evaluate those hypotheses against Case Study 4, enabling the researcher to test the suggested conceptual model, resulting in a more in-depth and detailed understanding of her area of study, as well as the revision of the conceptual model. Table 5.21 presents the hypotheses evaluation based on Case Study 4.

Table 5.21: Case study 4 - Detailed hypothesis evaluation

#	Hypothesis Statement	Findings Summary	Result
H1	Tokenized incentives could potentially influence users' willingness to participate in the demand response program.	Participants D1 and D2 expressed strong support for tokenized incentives, noting their potential to build trust and interest and motivate participation in DRM. This suggests that integrating such incentives can substantially increase user participation, aligning with the effectiveness of rewards in digital ecosystems.	Supported
H2	Greater transparency in token distribution might contribute to more effective Demand Response Management by building trust and promoting active participation.	Both participants highlighted the importance of transparency in token distribution for building trust. This clarity in processes is viewed as critical for participant engagement in DRM, underscoring the need for DRM systems to prioritize transparency in their reward systems.	Supported
H3	Detailed and accurate user profiles may lead to more efficient Demand Response Management through better personalized charging schedules.	Participant D1 and D2 acknowledged the significance of accurate user profiles for anticipating user needs, especially in tailoring charging schedules. This accuracy in profiles is instrumental in enhancing the efficiency of DRM through more tailored and effective charging schedules.	Supported
H4	Personalized charging schedules might affect the level of participation in the bi-directional P2P energy trading market, thus enhancing the effectiveness of the Demand Response Management.	The feedback from both participants suggested that personalized charging schedules could significantly enhance participation in P2P energy trading, thereby improving DRM effectiveness by offering a tailored experience that optimizes energy distribution and consumption.	Supported
H5	Active participation in bi-directional P2P energy trading could impact energy consumption and generation balance.	Participants perceived active participation in P2P energy trading as beneficial for the energy community, especially for balancing energy in the grid. This view aligns with the idea that active P2P trading is key to achieving a sustainable and efficient energy grid.	Supported

H6	Energy generation from primary sources could support demand response management by ensuring adequate supply to meet energy demand.	Both participants emphasized the crucial role of primary energy sources in providing a stable foundation for the grid, especially during high-demand periods. This stability is essential for effective DRM, ensuring a predictable supply to meet IoV energy needs.	Supported
H7	Energy generation from EVs could contribute to the balance of supply and demand, thus enhancing the effectiveness of Demand Response Management.	Discussions around EVs highlighted their dual role as both consumers and suppliers of energy, suggesting their significant contribution to a flexible and efficient IoV ecosystem. This capability of EVs is pivotal for balanced energy management.	Supported
H8	The level of energy consumption could potentially influence the overall load on the grid and the effectiveness of demand response management.	Participant D1 and D2’s concerns about energy consumption and its impact on IoV load underscore the importance of monitoring and managing energy usage. Effective DRM relies on anticipating these patterns to maintain an efficient, balanced grid.	Supported
H9	Privacy measures could potentially influence user trust and willingness to participate in the demand response program.	The emphasis on strict privacy measures by both participants indicates its importance in building trust and encouraging user participation in DRM activities. Protecting user data emerges as a key factor in user adoption and use of DRM services.	Supported

5.6.4 Summary of Key Findings from Case Study 4

The in-depth interviews with Participants D1 and D2 provided light on the complexity of the field of DRM. Despite their individual perspectives, both interviews emphasized the need for trust, transparency and user-centric approaches to maximize the efficacy of DRM in IoV. Participant D1 highlighted blockchain's potential as a trust layer, citing its openness and robustness in maintaining data integrity. This transparency was viewed as essential to promote equity and fairness in the proposed model. She, along with Participant D2, highlighted the good impact tokenized incentives have on user engagement. Both interviewees acknowledged the serious significance of personalized charging schedules, obtained from comprehensive user profiles. Regarding energy trading, Participant D1 observed that the environment of demand response poses both obstacles and opportunities for achieving a balance between energy consumption and production. Participant D2 concurred, recognizing P2P energy trading as a possible game-changer for demand response.

The findings from Case Study 4, provided support for all the hypotheses, as summarized in Table 5.22 , in particular with regard to the role of tokenized incentives, transparency in token distribution, user profiling and the positive effects of P2P energy trading. In addition, their combined views highlighted the significance of energy sources and consumption levels in grid stability, as well as the importance of privacy safeguards for user confidence and engagement. It is noted that in the following table the symbol of a checkmark (✓) is used to signify agreement or support for the hypothesis by the participant, whereas a question mark (?) is used to indicate uncertainty or insufficient data to either support or contradict the hypothesis.

Table 5.22: Overview of case study 4 hypotheses evaluation

Hypothesis	Participant D1	Participant D2
H1	✓	✓
H2	✓	✓
H3	✓	✓
H4	✓	✓
H5	✓	✓
H6	✓	✓
H7	✓	✓
H8	✓	✓
H9	✓	✓

As a result of the empirical data analysis and research findings of Case Study 4, several useful inputs for enhancing the proposed model were identified. Participant D1’s model enhancement insights were observant and actionable. She emphasized the need of security inside the blockchain architecture, not only from the perspective of data protection but also in preserving the integrity of transactions. These conclusions are consistent with the increasing significance of trust in decentralized systems, where security methods are of fundamental importance. Exploring the complexities of EVs, I.D emphasized the significance of battery degradation. She stated that while participation in demand response events offers various advantages, it shouldn’t come at the cost of the battery’s longevity. Consequently, the model would benefit from methods that monitor and restrict the frequency and magnitude of demand response events for individual EVs. She proposed that SLAs could serve as a mechanism for establishing explicit expectations between EV owners and demand response coordinators. Such agreements would not only describe the specifics of participation, but also ensure that EVs are not overloaded. Participant D1 also emphasized the significance of expanding the model’s stakeholder landscape. In particular, she highlighted the roles of the CPO and the Network Operator, indicating that their inclusion might provide useful insights into energy consumption trends, grid stability and charging availability. On the other hand, Participant D2 made both general and detailed propositions. He appreciated the novel nature of the suggested model and identified application possibilities, particularly for implicit demand response. He suggested clarifying key terms, such as replacing “energy” with “power”, “tokenized” with “incentive by tokens” and “user profiles” with a more precise term. In addition, he emphasized the contrast between P2P energy exchange and P2P information exchange, emphasizing the need of further clarification in the conceptual model.

The combination of these insights and the evaluation of hypotheses provides a solid foundation for improving the proposed conceptual model and comprehending the complexities of demand response management. By incorporating both Participant D1 and Participant D2’s opinions and suggestions, it is possible to revise and optimize accordingly the model.

5.7 Comparative Analysis

The purpose of the comparative analysis presented in this section is to compare the conclusions derived from the four case studies, namely Hypertech, E7, SUPSI and Hive Power. The primary objective of this analysis is to enhance comprehension regarding the testing of the proposed conceptual model for enhancing Demand Response Management (DRM) in the context of the Internet of Vehicles (IoV) through the utilization of blockchain technology. This section aims to enhance the reader's understanding of the proposed hypotheses across all four case studies, by examining their evaluation. Therefore, the focus of this comparative analysis centres on evaluating the level of support or contradiction for each of the nine hypotheses within each case study. The comparison of the hypothesis evaluation across the four case studies is presented in Table 5.23.

The presented comparative table provides a summary of the assessment conducted on nine hypotheses within the context of four case studies, encompassing diverse viewpoints from various participants. The analysis of each hypothesis is conducted considering the insights provided by the participants in each respective case study (Section 5.6 - Section 5.3). The symbol of a checkmark (✓) is used to signify agreement or support for the hypothesis by the participant, whereas a question mark (?) is used to indicate uncertainty or insufficient data to either support or contradict the hypothesis.

Table 5.23: Comparative analysis of the research findings

	Case Study 1	**Case Study 2**	**Case Study 3**	**Case Study 4**	
Hypothesis	Participant A	Participant B	Participant C	Participant D1	Participant D2
H1	?	✓	✓	✓	✓
H2	✓	✓	✓	✓	✓
H3	✓	✓	✓	✓	✓
H4	?	✓	✓	✓	✓
H5	?	✓	✓	✓	✓
H6	?	✓	✓	✓	✓
H7	?	✓	✓	✓	✓
H8	?	✓	✓	✓	✓
H9	✓	✓	✓	✓	✓

The comparative analysis of the research findings provides a concise overview of the general agreement among the case studies regarding the support for each hypothesis, as presented in Table 5.23. The analysis in this section underscores the consensus reached in all the hypotheses while recognizing areas that could benefit from further exploration, as highlighted by Case Study 1. The diversity of participants, particularly Participant A's industry-oriented perspective, enriches the comparative analysis, providing a well-rounded view of blockchain's application in DRM within IoV.

The pattern observed in case study 1, involving Participant A, is particularly notable. His industry perspective offers an insight into the real world and emphasizes the importance of applicability in industrial settings. This variance is instrumental in critically assessing the model's practicality, ensuring it meets the requirements of real-world applications. Participant A's scepticism about certain hypotheses, especially H1, H4, H5, H6, H7 and H8, indicates a cautious approach to the adoption of blockchain in industrial settings, emphasizing the need for empirical validation. This divergence is not a drawback but a valuable addition, ensuring that the model's practical implications are thoroughly examined. It is critical to clarify that the contributions of Participant A provide an essential balance to the study.

In contrast, the outcomes obtained from case studies 2, 3 and 4 show a complete level of agreement with the hypotheses. Participants from these studies consistently validate the theoretical underpinnings of the model, underscoring its strengths particularly in terms of blockchain functionality and user engagement strategies. The support for all hypotheses by the participants in these cases, reaffirms the fundamental role of blockchain technology and the efficacy of user engagement strategies, such as tokenized incentives and accurate profiling, in DRM, the role of both EVs and primary energy sources in energy management and the importance of privacy measures in user trust and participation.

Concluding, such uniformity in the responses highlights the model's validity and applicability across various operational scenarios within IoV. This understanding is key in driving forward the adaptation of the proposed conceptual model to suit the findings of the four case studies.

5.8 Conclusions

This chapter provides a detailed presentation of the data collection, analysis and interpretation by systematically approaching the empirical data acquired from the four case studies. The primary focus is the evaluation of the conceptual model described in Section 3.4, with particular attention paid to each research pillar (i.e. pillar 1: blockchain as a trust enabler, pillar 2: enabling bidirectional P2P energy trading, pillar 3: tokenized incentivization and pillar 4: customized EV charging schedules through profiling), the underlying variables and the related hypotheses. The research confirms that the model's proposed variables have a significant impact on DRM in the IoV. Nonetheless, the empirical research uncovers other elements influencing the DRM in IoV, indicating that the initially proposed model requires refining (Chapter 6). Focusing on the empirical findings, the conclusions can be organized around the following topics that describe the high-level context of the model:

Blockchain as a Trust Layer:

- The decentralized, tamper-proof nature of Blockchain places it as a foundation for creating confidence inside the IoV by preventing fraud and boosting transparency.
- Scalability and energy consumption were exposed as obstacles by practical deployments. Integrating blockchain, particularly in varying IoV environments, highlighted the necessity for refined solutions.

Tokenized Incentives:

- Tokens emerged as a two-fold asset: a user engagement incentive and a method for exchanging value.
- Concerns were expressed over the valuation of tokens on volatile markets and their real-world applications, mostly due to legislative and technological factors.

User Profiles and Charging Scheduling:

- Emphasis was placed on customizing charging schedules based on user profiles, hence increasing energy efficiency inside the IoV.
- Data security was a significant concern. Unprotected user data creates misuse risks, particularly in decentralized environments.

Demand Response through P2P Energy Trading:

- P2P energy trading developed a foundation for efficient and local energy trading.

- Broader-scale P2P adoption poses obstacles ranging from technological maturity to regulatory compliance.

The empirical findings from the four case studies have deepened the researcher's understanding of the integration of blockchain within IoV. The theoretical potential of blockchain in IoV is substantial, but its practical deployment, as highlighted especially in Case Study 1, is recommended to researched more. These insights pave the way for Chapter 6, where a refined version of the conceptual model is developed, considering these empirical findings and aiming to bridge the gap between theory and practice.

6. REVISION OF THE BLOCKCHAIN ENABLED DEMAND RESPONSE MANAGEMENT MODEL

6.1 Summary

The empirical findings from Chapter 5 highlight the significance of the proposed Blockchain-enabled Demand Response Management Model within the IoV. These findings are based on observations from four case studies. Specifically, the findings indicate not only the usefulness of the model but also areas that require refinement and further investigation. The four investigated case studies, namely Hypertech, SUPSI, E7 and Hive Power, provide valuable feedback and insights, pointing to specific modifications that can enhance the model's quality. The purpose of the model revision, as outlined in Chapter 6, is to enhance the strength of this research. This aligns with the primary objective of this study, which is to create a model that effectively combines blockchain technology with DRM in IoV.

6.2 Introduction

With the advent of IoT and, more specifically, the IoV, the necessity for effective and reliable DRM systems becomes imperative. The literature, as outlined in Chapter 2 of this thesis, presents the unrealized potential of blockchain as the foundation for DRM in the IoV ecosystem. However, the investigation of this potential, reveals the lack of a model that effectively integrates blockchain for DRM in the IoV domain. This study introduces a model for DRM that incorporates blockchain technology, as outlined in Chapter 3, in an attempt to address the identified challenges and limitations, as those outlined in Section 3.3. In Chapter 4, a thorough research methodology is outlined, using four case studies to evaluate the proposed model. Then, Chapter 5 dives deeply into the empirical evaluation of the proposed model by analysing data from the four case studies, which include one university and three companies. While the empirical evidence supports the conceptual validity of the proposed model, it also reveals certain challenges and insufficiently addressed aspects. Therefore, the purpose of Chapter 6 is to extrapolate the empirical findings detailed in Chapter 5 and revise the conceptual model, in order to address the identified challenges.

6.3 Lessons Learnt from the Case Studies

During Chapter 5, empirical data from Hypertech, E7, SUPSI and Hive Power were collected, evaluating the pillars (i.e. pillar 1: blockchain as a trust enabler, pillar 2: enabling bidirectional P2P energy trading, pillar 3: tokenized incentivization and pillar 4: customized EV charging schedules through profiling) of the proposed conceptual model. Through this process, valuable lessons have been derived, with the objective of enhancing comprehension of blockchain-based Demand Response Management (DRM) within the context of the Internet of Vehicles (IoV). The lessons learned from the four case studies are as follows:

Lesson 1 – Ensuring data privacy and protection in a blockchain network is crucial, as it involves balancing transparency with the complexity of managing user profiles while also maintaining trust:

- Data privacy and protection are significant considerations in the field of blockchain implementation within the DRM in IoV. Although blockchain technology provides a level of trust, transparency could make managing user data more complex. Participants in this research’s case studies emphasised the significance of protecting user data within blockchain networks. Participant A emphasised the difficulties faced when applying blockchain technology in real-world scenarios, emphasising the need to balance the transparency of blockchain with practical privacy considerations.

Similarly, Participants B, C, D1 and D2 all recognised the necessary balance between the transparency of blockchain and the imperative to safeguard confidential user data. They proposed that although the transparency of blockchain is crucial for establishing confidence and guaranteeing the accuracy of data, it should not jeopardise user confidentiality. This necessitates DRM solutions that exhibit not only efficiency and transparency, but also robustness in their approach to safeguarding user data, guaranteeing adherence to privacy requirements such as GDPR and upholding user confidence in the system.

Lesson 2 – Effective DRM frameworks need to scale and manage real-time data from IoV participants efficiently:

- The ability of DRM frameworks to efficiently process large amounts of real-time data is essential, particularly in the context of P2P energy trading within the IoV. Participant A’s observations specifically emphasise the constraints of existing blockchain technologies in handling the significant amount of data produced by participants in the IoV. This highlights the requirement for DRM systems that are not just technologically advanced but also capable of scaling up to meet the increasing data requirements of such ecosystems. In order for P2P energy trading to be successful, it is essential that these systems have the ability to analyse data in real-time. Lesson 2 indicates that future advancements in blockchain enabled DRM frameworks should prioritise improving data processing capabilities, guaranteeing scalability and upholding system efficiency, even with the growth in data volume and the number of IoV participants.

Lesson 3 – In DRM, stable token pricing is crucial for incentivizing consistent user participation:

- The dynamics of tokenized incentives play a pivotal role in influencing user behaviour and participation in demand response within the IoV. Participants B, C, D1 and D2 all emphasize the motivational power of tokens. However, they also point out a significant challenge: the unpredictability of token value can act as a barrier to user participation. Unstable token prices may lead to hesitancy or reluctance among users to engage actively in the system, as the perceived value of their rewards fluctuates. This uncertainty can undermine the trust and interest in the DRM system. Therefore, ensuring the stability of token prices emerges as a critical factor. By maintaining a consistent value, tokens can effectively motivate users to participate in demand response activities, making these incentives more reliable and appealing. This calls for DRM systems to not only integrate tokenized rewards but also to establish mechanisms or partnerships that stabilize token value, ensuring they align with real-world market dynamics.

Lesson 4 – A balance between personalization and user privacy is needed to enhance efficiency and minimize data privacy risks.

- Personalising billing and charging schedules based on user profiles is essential for improving the efficiency of DRM systems in the IoV. Participants B, D1 and D2 endorse the idea that personalisation leads to enhanced energy management efficiency. Nevertheless, they also raise a significant concern: as the degree of personalisation increases, risks linked to data privacy also grow. Designing DRM solutions that are simultaneously efficient and respectful of user privacy presents a significant problem. Extensive user data is necessary for highly customised systems, but if not adequately protected, it could be vulnerable to unauthorised access and misuse. Hence, the participants' findings underscore the necessity for DRM systems to utilise advanced security methods and comply with privacy regulations such as GDPR. This method guarantees that while the systems make use of personal data to improve operational efficiency, they also protect the privacy and confidence of the users, maintaining a delicate equilibrium between personalised efficiency and privacy concerns.

Lesson 5 - User profiles in IoV enhance the accuracy of energy demand forecasting and contribute to more effective energy management strategies.

- User profiles play a crucial role in the IoV, particularly in DRM, as emphasized by Participants B, D1 and D2. These profiles, containing detailed user behaviour and preferences, are essential for accurately predicting energy needs, enabling DRM systems to respond more effectively. Participant B highlights the importance of customizing energy solutions to individual needs. Participant D1 notes the benefits in predicting demand patterns, while Participant D2 focuses on the value of user profiles for accurate charging schedules and energy distribution. However, this necessitates careful data management and protection, ensuring responsible use and adherence to privacy regulations. The effective use of user profiles is thus vital for enhancing DRM system efficiency and user experience in IoV, while maintaining data privacy and security.

Lesson 6 - It is important to evaluate and balance blockchain's energy consumption with its efficacy in energy trading:

- The integration of blockchain into DRM in IoV presents challenges, particularly in terms of energy efficiency, as highlighted by Participant A. Blockchain, while offering enhanced security, transparency and trust, is energy-intensive, especially in processes like PoW. This energy demand is a concern in DRM systems, where efficiency and sustainability are paramount. Blockchain's benefits in IoV and DRM include securing transactions and building trust, but these come at the cost of high energy consumption. To address this, it's crucial to evaluate and potentially adopt more energy-efficient blockchain technologies, such as those based on Proof of Stake or other less intensive consensus mechanisms. The aim is to balance the advantages of blockchain in transparency and trust with a minimal energy footprint.

Lesson 7 – Decentralization in P2P energy trading presents both efficiency opportunities and challenges related to technology, regulations and system maturity:

- Decentralization in P2P energy trading within offers potential for efficient energy distribution, as highlighted by Participants B and C, but faces technological, regulatory and developmental challenges. Participant B stresses the need for robust, secure platforms using technologies like blockchain and IoT. Regulatory challenges, as Participant C notes, require adaptable structures for fair practices and user protection. Furthermore, the maturity of these systems is crucial, with Participant B emphasizing the need for mature technologies and market structures to manage decentralized energy exchanges effectively. In summary, while promising, realizing the full benefits of decentralization in DRM requires navigating complex technological and regulatory landscapes, as well as ensuring system maturity.

Lesson 8 - Token incentives influence the model by enabling data collection, boosting user engagement and driving the evolution of DRM models:

- Tokenized incentives in play a critical role, as highlighted by Participants B, D1 and D2. Participant B notes that these incentives encourage user data sharing, enhancing the DRM system's understanding of energy usage and preferences. Participants D1 and D2 emphasize the role of tokenized incentives in boosting user engagement, motivating them to actively participate and adapt their energy behaviours, crucial for DRM effectiveness. Additionally, these incentives aid in the development and improvement of DRM models, guiding the system towards efficiency and userfriendliness. In summary, tokenized incentives are essential for data collection, user engagement and the continuous evolution of DRM strategies in the IoV context.

Lesson 9 - Sustaining the health of EV batteries is essential for DRM and long-term EV viability:

- The importance of sustainability for EVs within energy ecosystems is emphasized by Participants B, D1 and D2. They stress the need to balance DRM with preserving EV battery health. EVs are now active participants in DRM, including V2G interactions, which can strain their batteries. Participant B stresses the need to consider DRM's impact on EV batteries while acknowledging their potential in energy management. Participants D1 and D2 call for DRM strategies that optimize charging and discharging cycles and explore technologies to minimize battery degradation while maximizing energy contributions. User awareness and incentives for responsible participation are also highlighted. Thus, sustaining EVs' batteries is crucial for effective DRM.

Lesson 10 – SLAs play a crucial role by defining obligations and expectations in DRM system:

- Service Level Agreements (SLAs) are emphasized as critical tools within DRM systems. SLAs outline the responsibilities, expectations and limits for all involved parties, ensuring clarity and accountability. This lesson's insights are further enriched by the contributions and findings from participants B, D1 and D2, offering a comprehensive understanding of the complex interplay between stakeholders and the governance structures within energy management.

Lesson 11 – All model variables are interconnected. Altering one variable can trigger a chain of interconnected consequences to the model.

- This lesson emphasises the concept that modifications made to a certain variable do not occur in independent. Rather, they might trigger a chain reaction, resulting in interconnected outcomes. The findings highlight the significance of an in-depth understanding of these relationships in order to accurately forecast and efficiently handle the DRM in an IoV ecosystem.

These lessons can be used to guide the revisions and enhancements of the proposed conceptual model. The lessons listed above as well as the detailed empirical findings and hypothesis evaluation presented in Chapter 5, present the interdependency of the variables in the proposed model, illustrating that alterations in one variable can lead to a series of impacts on other variables. Thus, understanding the interconnections and relationships between them is vital for refining the model and ensuring its soundness in real-world scenarios.

6.4 Revised Blockchain-Enabled Demand Response Management Model

Building upon the empirical findings (Section 5.6.2, 5.5.2, 5.4.2 and 5.3.2) and the lessons learnt (Section 6.3) the current section revisits the proposed DRM conceptual model through an evaluation and critical analysis of the empirical case studies (Chapter 5). The empirical information gathered from these case studies supports the key components of the proposed model and suggest significant areas for improvement. For instance, the studies collectively underscore the model's efficacy in integrating blockchain technology for DRM in IoV, as indicated by the positive feedback from participants across different domains such as Hypertech, E7, SUPSI and Hive Power. The findings from these case studies bring to light key areas for enhancement, focusing on maximizing the model's effectiveness and efficiency. This includes fine-tuning the balance between data transparency and user privacy in blockchain networks and optimizing the tokenized incentive mechanisms to ensure their stability and appeal.

To that end, in the upcoming sub-sections, new variables are introduced, as well as refinement of some of the existing ones. Additionally, relationships between the model's variables are explored and presented, creating a revised and refined conceptual model. The approach described above guarantees that the model maintains its fundamental strengths while adapting to the complexities brought to light by the empirical studies presented in Chapter 5.

6.4.1 Rationale behind Model Revision

Towards the conceptual model revision, Figure 6.1 presents a visual representation of the model's evolution. This figure illustrates the initially proposed conceptual model, compared to the enhancement derived from the empirical findings. Additionally, Figure 6.1 clearly distinguishes between the hypotheses that were supported and those that were not. Sections

5.3.3, 5.4.3, 5.5.3 and 5.6.3 provide references to the empirical basis for the hypotheses evaluation.

At this point, it is helpful to revisit the variables that form the foundation of the conceptual model under consideration. In order to promote a thorough comprehension of the upcoming revisions to the model, a brief overview of these variables is provided. This overview has a dual role: to be a point of reference and to assist in placing the revisions within the proper context. A detailed presentation of these variables is presented in Section 3.4, while an overview is presented below:

- **Variable 1 - Tokenized Incentives:** The tokens provided to users for active participation in the demand response framework.
- **Variable 2 - Transparent Distribution:** The fairness and transparency of token distribution over the blockchain.
- **Variable 3 - User Profiles:** The anonymized preferences of EV users recorded on the blockchain.
- **Variable 4 - Personalized Charging Schedules:** The individual charging schedules developed for each user, based on their profile.
- **Variable 5 - Bi-directional P2P Energy Trading:** The amount of energy traded (both consumed and produced) by each user in the P2P energy market facilitated by the blockchain.
- **Variable 6 - Primary Energy Generation:** The energy generated from primary sources like photovoltaics, wind turbines, or other resources that can contribute energy to the grid.
- **Variable 7 - EV Energy Generation:** The amount of energy generated by EVs who are participating in the bi-directional energy trading, including the energy contributed back to the grid by the EVs.
- **Variable 8 - Energy Consumption:** The amount of energy used by each EV user.
- **Variable 9 - Privacy:** The extent to which the exchanged information is protected.
- **Variable 10 - Demand Response Management:** The effectiveness of the overall DRM framework.

Coming back to the rationale behind model revision, Figure 6.1 incorporates new variables (i.e., highlighted in green) that emerge as a result of the empirical findings. In Section 6.4.2 the importance and use of these new variables is presented. It is worth mentioning also, that Figure 6.1 is a crucial reference point that connects the initial hypotheses with the empirical findings and subsequent revisions to the Blockchain-Enabled Demand Response Management Model.

Towards that direction, Figure 6.1 presents a visual representation of the model's evolution. This figure illustrates the proposed conceptual model, compared to the revisions proposed by the case studies' participants. Additionally, Figure 6.1 clearly distinguishes between the hypotheses that were supported and those that were not. Furthermore, the figure incorporates new variables (i.e., highlighted in green) that emerge as a result of the empirical findings. In Section 6.4.2 the importance and use of these new variables will be presented in depth. It is worth mentioning also, that Figure 6.1 is a crucial reference point that connects the initial hypotheses with the empirical findings and subsequent revisions to the Blockchain-Enabled Demand Response Management Model.

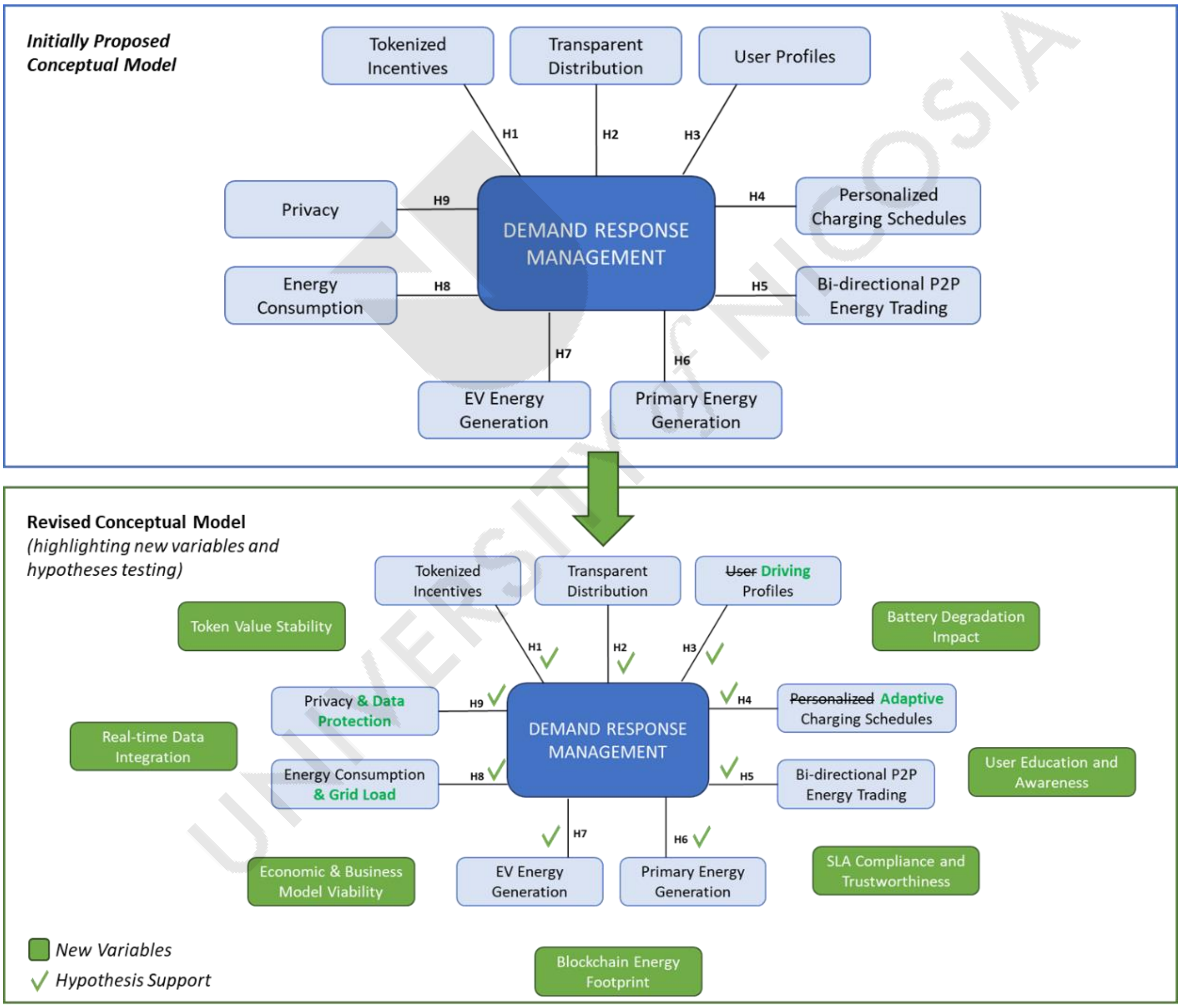


Figure 6.1: Conceptual Model Testing and Findings

The top section illustrates the initially proposed conceptual model with its core variables and hypotheses. The bottom section expands upon this, presenting the revised model, with the inclusion of new variables and hypotheses testing.

6.4.2 Introduction of New Variables

As previously mentioned, the empirical case study findings (Chapter 5) and the lessons learned have resulted in the incorporation of new variables into the conceptual model (i.e. Variable A – Variable G). The descriptions of the new variables are provided below and summarized in Table 6.1.

- **New Variable A - Blockchain Energy Footprint**: Addressing the energy demands of blockchain, highlighted by Participant A and supported by the insights of D1 and D2, this variable measures the energy required by blockchain processes in the DRM model. It aims to balance the efficiency of blockchain technology with its energy consumption, ensuring that the DRM model remains energy efficient. This aligns with Lesson 6, stressing the importance of blockchain's energy efficiency to maximize its potential in energy management.
- **New Variable B - User Education and Awareness**: The views of all participants highlight the need for adding a new variable related to User Education and Awareness. This new variable measures the degree to which users comprehend the DRM model and its related aspects (i.e., blockchain, incentivization, charging scheduling etc.), its benefits and their central role in the energy landscape. In many ways, a user's knowledge and comprehension determine the extent of their participation. In addition to the general importance of an informed user, this variable takes into consideration Lesson 1, 5 and 8. As users better understand the DRM system and their role, they are more willing to provide their energy related data, thus their profiles become more accurate, aiding in energy requirement predictions.
- **New Variable C - Real-time Data Integration**: Highlighted by Participant A and B this variable focuses on the mode's ability to seamlessly incorporate real-time data, crucial for instantaneous decision-making in DRM, particularly in P2P settings. This enhancement is in response to Lesson 2, underscoring the necessity of robust real-time data management for effective DRM in IoV.
- **New Variable D - SLA Compliance and Trustworthiness:** Building on insights from B, D1 and D2, this variable assesses the effectiveness of SLAs in DRM systems. It evaluates service providers' adherence and the confidence they inspire in users, thereby enhancing trust and clarity. The introduction of this variable, it strongly relates with Lesson 11, which emphasizes the role of such agreements in

energy management. It also aligns with Lesson 1’s focus on balancing blockchain transparency with data privacy.

- **New Variable E - Battery Degradation Impact**: Supported by B, D1 and D2, this variable evaluates the impact of DRM activities on EV battery health. It considers how participation in energy trading affects battery longevity, addressing concerns raised in Lesson 10 about the sustainability of EVs in energy ecosystems. This variable is crucial for encouraging EV owners’ participation in P2P energy trading and for tailoring individualized charging plans.
- **New Variable F - Token Value Stability**: Taking into consideration the insights of B, C, D1 and D2, this variable measures the stability and predictability of token values in the DRM model. As tokens serve as incentives, their monetary value and stability are critical in motivating user participation, aligning with Lesson 3’s emphasis on consistent token dynamics. Furthermore, as per Lesson 9, tokens facilitate data collection and user engagement, reinforcing their role beyond monetary rewards.
- **New Variable G – Economic & Business Model Viability**: This variable, highlighted by all, assesses the sustainability and scalability of the DRM model, in regard to economic and business aspects. It considers how the business model manages personalized solutions and decentralization challenges, in line with Lessons 4 and 7. The viability of the business model is central to the system’s overall success, as it dictates the value extraction mechanisms for all stakeholders and ensures the model’s alignment with the interconnected nature of DRM variables, as noted in Lesson 8. Moreover, this variable highlights the importance of an economic strategy that can respond to market dynamics, regulatory changes and technological advancements while maintaining user engagement and trust. It also considers the economic implications of decentralized models on traditional energy market structures, requiring innovative approaches that can manage fluctuating energy prices and diverse user participation levels. The economic and business model viability, therefore, serves as a foundational aspect that influences the effectiveness, efficiency and sustainability of the entire DRM system.

Table 6.1: Revised model - New variables

New Variable #	New Variable Name	New Variable Description	Supported by Participant
A	Blockchain Energy Footprint	Evaluates the energy consumed during blockchain operations, addressing concerns about the environmental sustainability of the technology.	A, D1, D2.
B	User Education and Awareness	Reflects the level of knowledge and understanding users have regarding the blockchain DRM model.	All
C	Real-time Data Integration	The system's capability to integrate real-time data from various sources to optimize demand response decisions.	A
D	SLA Compliance and Trustworthiness	Evaluates the efficacy of SLAs in terms of both provider compliance and the confidence they create in users.	B, D1, D2
E	Battery Degradation Impact	Measures the influence of battery health on EV user behaviors in terms of charging and participation in energy trading.	B, D1, D2
F	Token Value Stability	Evaluates the consistency and predictability of token value, which can impact user trust and participation.	B, C, D1, D2
G	Economic & Business Model Viability	Assesses the long-term sustainability and profitability of the blockchain DRM system from a business perspective.	All

6.4.3 Revisions in Existing Variables

In addition to the introduction of new variables as described in Section 6.4.2, the empirical data analysis revealed the necessity for improvements in five out of the nine existing variables (as those summarised in Section 6.4.1). This section will elaborate on the revisions made to enhance clarity and precision. Specifically, Variable 1 was refined to encompass a broader conceptual scope based on the empirical findings, while the Variable 3,4,8 and 9 refined primarily related to their names.

- **Revised Variable 1 - Tokenized Incentives:** This variable now includes the stability and predictability of token values, a critical aspect supported by Participant C and highlighted by Participant A's. The refinement of this variable stems from the empirical findings indicating that the stability and perceived real-world value of tokens are key determinants of user engagement and confidence in the DRM system. By enhancing the tokenized incentives to account for their economic stability and predictability, the DRM system can foster a more reliable and attractive platform for user participation. This enhancement aligns with Lesson 3 - Token Dynamics in Demand Response, ensuring that tokens serve not just as a medium of reward but also as a stable and trustworthy asset for users.
- **Revised Variable 3 - Driving Profiles** ***(previously "User Profiles"):*** The variable "Driving Profiles" replaces the previously used "User Profiles," as supported by Participant B. This revision emphasizes the necessity for detailed and comprehensive data collection, which is instrumental in personalizing and influencing user behavior within the energy trading ecosystem. This refinement aligns with the insights from Lesson 5 - Forecasting Through User Profiles, where accurate user data is needed in enhancing the predictive accuracy of energy requirements and in optimizing DRM strategies.
- **Revised Variable 4 - Adaptive Charging Schedules** ***(previously "Personalized Charging Schedules")*****:** The renaming of this variable to "Adaptive Charging Schedules," supported by Participants B, D1 and D2, reflects its dynamic and responsive nature. The variable now accounts for real-time adjustments in charging schedules, adapting to both user preferences and grid requirements. This change underscores the need for a DRM system that is responsive to fluctuating energy demands, ensuring a balance between personal user needs and broader grid stability. This revision addresses Lesson 8 - Interconnection and Impact of Model Variables, demonstrating the interconnected nature of user behavior, energy demand and grid capacity within the DRM framework.
- **Revised Variable 8 - Energy Consumption and Grid Load** ***(previously "Energy Consumption")*****:** The updated Variable 8, reflects general insights from all participants, emphasizing the relationship between energy consumption and grid load. The renaming of the variable enhances it by highlighting the challenges in maintaining a balance between energy consumption and production, especially during peak demand periods. By incorporating grid load considerations, the DRM system can more effectively manage energy resources, aligning with Lesson 5 -

Active Participation in P2P Energy Trading and ensuring a more sustainable and efficient energy ecosystem.

- **Revised Variable 9 - Privacy and Data Protection *(previously "Privacy")*:** Renamed to encompass the broader concept of data security, this variable, influenced by the general concerns of all participants, reflects the importance of achieving a balance between privacy and transparency. This refinement emphasizes the need for robust data protection mechanisms that ensures user privacy while maintaining a transparent and trustworthy DRM model. The revision aligns with Lesson 1 - Blockchain Trust and Data Privacy, highlighting the necessity of protecting user data within a blockchain-enabled DRM model, especially in GDPR-compliant contexts.

As a result, several variables have been modified to represent the complexities of this dynamic model, in an effort to improve DRM in IoV, by utilizing blockchain technology. The revised variables serve as core factors that interact, impact and form the model's outcomes. Table 6.2 provides a list of the revised conceptual model variables.

Table 6.2: Revised model - Refined variables

Refined Variable #	Refined Variable Name	Refined Variable Description	Supported by Participant
1	Tokenized Incentives	The tokens provided to users for active participation in the demand response framework.	C
3	Driving Profiles	The anonymized preferences of EV users recorded on the blockchain and the battery health data that might influence charging and energy trading behaviors.	B
4	Adaptive Charging Schedules	The dynamic charging schedules developed for each user, based on their profile and the real-time state of the grid and battery health.	B, D1, D2
8	Energy Consumption and Grid Load	The amount of energy used by each EV user and the overall load on the grid.	All
9	Privacy and Data Protection	The extent to which the exchanged information is protected, ensuring user privacy and trust.	All

6.4.4 Relationships among Refined and New Variables

The empirical findings reveal also a dynamic interplay between the variables of the proposed DRM model. The proposed model is not only defined by its explicit relationships towards the main variables (i.e., Demand Response Management), but also by its underlying ones, which form a network of interconnections, as will be analyzed in the following paragraphs.

To begin with, “Tokenized Incentives” are important to the effectiveness of the DRM. When partnered with “Transparent Distribution”, their crucial function in promoting participation is amplified.

Transparency enhances reliability, resulting in a direct relationship between increasing transparency and an increase in the perceived value of tokenized incentives.

Moving a step forward, “Token Value Stability” is crucial for raising or diminishing its perceived value. If tokens have a steady and predictable value, this encourages more users to actively participate in the DRM system. This consistency builds and maintains confidence, hence enhancing the efficacy of tokenized incentives.

Then, “Driving Profiles” emerges as a vital variable when examining user-centric approaches. These profiles, which serve as a store of user data, permit the creation of “Adaptive Charging Schedules”, thereby ensuring customized and efficient energy consumption patterns. To that end, understanding a user’s driving preferences has a huge impact on their interactions with “Bidirectional P2P Energy Trading”, ensuring that energy transactions reflect individual choices. Additionally, “Real-time Data Integration” could ensure the model’s adaptability, allowing for the implementation of dynamic “Adaptive Charging Schedules”.

However, “Battery Degradation Impact” is a significant aspect of the “Driving Profiles”. Specifically, detailed battery health data can directly influence user charging and energy trading behavior. Furthermore, concerns about battery longevity, as indicated by health data, can cause users to be more conservative or aggressive with energy transactions and charging routines. Therefore, good battery health can stimulate greater participation, but poor battery health can discourage frequent energy transactions.

On another note, as IoV transitions to energy dynamics, the importance of “EV Energy Generation” increases. As the energy contributions from EVs increase within IoV, they (i.e., the EVs) cause perceptible alterations in “Energy Consumption and Grid Load”, with each EV becoming a participant in the energy ecosystem (i.e., rising prosumer concept).

However, trust remains the backbone of this model. This is demonstrated via the intersection of “Tokenized Incentives” and “Privacy and Data Protection”, considering that users’ trust in tokenized incentives is strengthened by the assurance of data integrity. However, “Transparent Distribution” establishes a fine balance with regard to this trust, as the transparency of distribution does not put user data at risk.

Moreover, “Primary Energy Generation” emerges as a critical factor, influencing “Energy Consumption and Grid Load”, since energy from primary sources is a crucial factor in determining the equilibrium of the grid.

Nonetheless, case studies reveal also that the environmental impact becomes apparent through the “Blockchain Energy Footprint”. An increased energy footprint, although aiding DRM, can potentially compromise the “Business Model Viability”, expressing concerns about sustainability. The same occurs also for “User Education and Awareness”, since a knowledgeable user community increases the efficiency and viability of the DRM, taking into consideration also “SLA Compliance and Reliability”.

The result of all these variables is “Demand Response Management” efficiency in IoV, leveraging the blockchain capabilities.

Table 6.3 summarises the identified relationships between the conceptual model’s variables, as those interpreted from the empirical findings.

Additionally, based on the new variables, the revised ones and the relationships between them, a revised conceptual model is presented in Figure 6.2. The revised conceptual model outlines every variable, highlighting the newly introduced ones in green, the revised in blue and the unchanged ones in grey. In addition, the relationships between these variables are depicted with arrows, each of which depicts the nature and direction of the interaction between the paired variables.

Table 6.3: Relationships between revised model's variables

#	Variables		Relationship Description
1	Tokenized Incentives (V1)	Transparent Distribution (V2)	Higher transparency (V2) can enhance the perceived value and trustworthiness of tokenized incentives (V1).
2	Driving Profiles (V3)	Adaptive Charging Schedules (V4)	A robust driving profile (V3) will directly lead to more personalized and efficient adaptive charging schedules (V4).
3	Driving Profiles (V3)	Bi-directional P2P Energy Trading (V5)	Knowing a user's preferences and behaviors (V3) can influence how they participate in energy trading (V5).
4	EV Energy Generation (V7)	Energy Consumption and Grid Load (V8)	As more EVs generate and contribute energy (V7), it directly affects the overall energy consumption and grid load (V8).
5	Tokenized Incentives (V1)	Privacy and Data Protection (V9)	For users to trust tokenized incentives (V1), they need assurance regarding their data's privacy (V9).
6	Transparent Distribution (V2)	Privacy and Data Protection (V9)	Occasionally, the transparency of token distribution (V2) conflicts with privacy requirements (V9). However, a balanced strategy can provide both openness and confidentiality.
7	Primary Energy Generation (V6)	Energy Consumption and Grid Load (V8)	Energy from primary sources (V6) directly impacts the overall load and energy balance on the grid (V8).
8	Privacy and Data Protection (V9)	Demand Response Management (V10)	Users' trust, facilitated by robust privacy measures (V9), can directly impact their willingness to participate, thereby affecting the efficiency of the DRM system (V10).
9	Tokenized Incentives (V1)	Demand Response Management (V10)	The effectiveness of the tokenized incentives (V1) can either enhance or diminish the overall DRM efficiency (V10). Effective tokenized incentives directly motivate user participation, which contributes to the overall efficiency of the DRM system.
10	Adaptive Charging Schedules (V4)	Bi-directional P2P Energy Trading (V5)	As schedules adapt (V4), they can influence how users trade energy in the P2P market (V5).

11	Driving Profiles (V3)	Battery Degradation Impact (VE)	Information on battery health (VE), as part of the driving profiles (V3), can directly impact user behaviors in charging and energy trading due to concerns regarding battery longevity.
12	Tokenized Incentives (V1)	Token Value Stability (VF)	The perceived value and trust in tokenized incentives (V1) are directly influenced by the stability and predictability of the token value (VF).
13	Blockchain Energy Footprint (VA)	Economic & Business Model Viability (VG)	A high energy footprint (VA) can question the long-term sustainability and viability of the blockchain-based DRM system from a business perspective (VG).
14	User Education and Awareness (VB)	Demand Response Management (V10)	A well-informed user (VB) can actively and effectively participate in the DRM system, thereby enhancing its efficiency (V10).
15	Real-time Data Integration (VC)	Adaptive Charging Schedules (V4)	Efficient integration of real-time data (VC) is crucial for formulating accurate and dynamic charging schedules (V4).
16	SLA Compliance and Trustworthiness (VD)	User Education and Awareness (VB)	Users informed about their rights and the system’s promises (VC) will be better positioned to judge SLA compliance and its trustworthiness (VD).
17	Driving Profiles (V3)	Demand Response Management (V10)	Comprehensive and accurate driving profiles (V3) allow the DRM (V10) system to better anticipate and respond to user needs, directly enhancing the demand response’s efficiency.
18	Adaptive Charging Schedules (V4)	Demand Response Management (V10)	Adaptive charging schedules (V4) ensure users receive power when they need it and can contribute, when possible, directly streamlining DRM (V10).
19	Bi-directional P2P Energy Trading (V5)	Demand Response Management (V10)	Efficient energy trading (V5) directly stabilizes the grid, reducing drastic demand peaks and troughs, thereby facilitating better DRM (V10).
20	Primary Energy Generation (V6)	Demand Response Management (V10)	A steady supply from primary sources (V6) ensures the grid isn’t strained and can respond effectively to varying demand, directly influencing DRM’s efficiency (V10).

21	Real-time Data Integration (VC)	Demand Response Management (V10)	The timely and accurate integration of data (VC) ensures that the DRM system can make informed decisions swiftly, directly impacting its efficiency (V10).
22	Economic & Business Model Viability (VG)	Demand Response Management (V10)	A viable business model (VG) ensures sustained support, technological updates and stakeholder buy-in, which can contribute to the efficient functioning and evolution of the DRM (V10).
23	Energy Consumption and Grid Load (V8)	Demand Response Management (V10)	While a balanced energy consumption pattern (V8) facilitates easier DRM (V10), drastic peaks and troughs in grid load can strain the system, potentially affecting its efficiency.

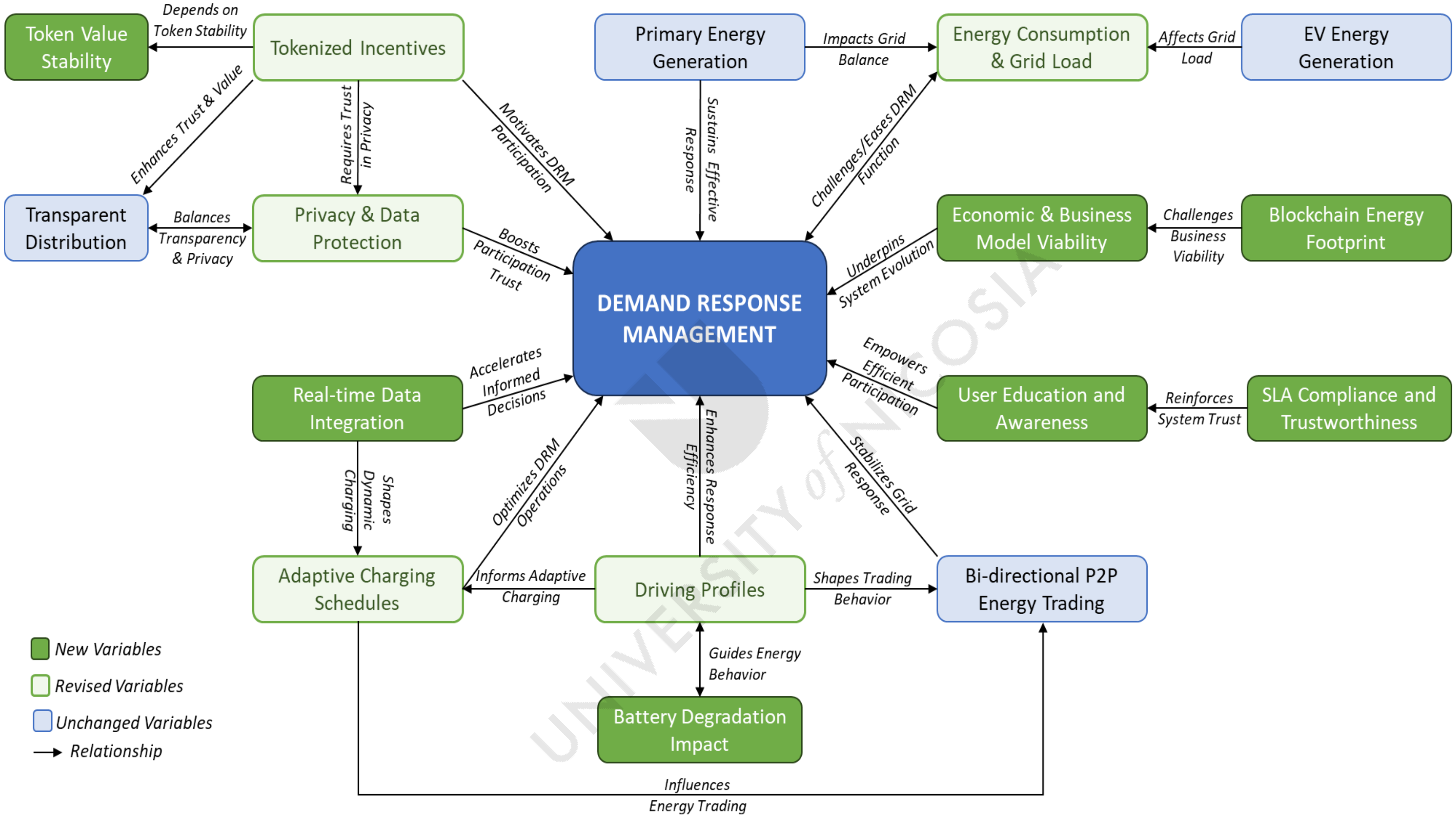


Figure 6.2: Revised Model

6.5 Conclusions

This thesis investigates the use of blockchain technology under the scope of DRM in the IoV. In doing so, the researcher proposes and revises a Blockchain Enabled Demand Response Management Model which works toward that goal. The proposed model is developed according to findings and observations derived from the literature review and it is tested and evaluated through four case studies as reported in Chapter 5. These case studies have not only validated the proposed conceptual model but also revealed areas that could benefit from refinements and additions to the model.

This chapter (Chapter 6) presents the revised version of the model, starting with the lessons learned from the empirical analysis. Figure 6.1 compares the proposed conceptual model with the revised one, highlighting new variables and hypothesis evaluations. Finally, Figure 6.2 presents the revised conceptual model, including newly introduced variables, refined variables and the relationships between them.

Compared to the proposed conceptual model the revised model includes the following new variables, as analysed in Section 6.4.2:

- New Variable A: Blockchain Energy Footprint
- New Variable B: User Education and Awareness
- New Variable C: Real-time Data Integration
- New Variable D: SLA Compliance and Trustworthiness
- New Variable E: Battery Degradation Impact
- New Variable F: Token Value Stability
- New Variable G: Business Model Viability Description

Moreover, in response to the empirical findings, some of the existing variables have been refined to better align with the findings identified in the case studies. These revisions, detailed in Section 6.4.3 are related to the following variables:

- Revised Variable 1 - Tokenized Incentives
- Revised Variable 3 - Driving Profiles (previously “User Profiles”)
- Revised Variable 4 - Adaptive Charging Schedules (previously “Personalized Charging Schedules”)
- Revised Variable 8 - Energy Consumption and Grid Load (previously “Energy Consumption”)
- Revised Variable 9 - Privacy and Data Protection (previously “Privacy”)

In Section 6.4.4, the model's usability, usefulness and accuracy are enhanced through the introduction of relationships among the variables. Specifically, the concept of "Tokenized Incentives" holds significant importance, as their value is enhanced through the implementation of "Transparent Distribution" and maintained by ensuring "Token Value Stability". Variables that prioritize user needs, such as "Driving Profiles", play a crucial role in determining "Adaptive Charging Schedules" and have a direct impact on "Bidirectional P2P Energy Trading". Additionally, the consideration of "Battery Degradation Impact" helps to guide user interactions in this context. The concept known as "EV Energy Generation" effectively modifies both energy consumption and grid load, highlighting its dynamic nature. Trust combines the concepts of "Tokenized Incentives" and "Privacy and Data Protection" within the context of transparency. In this context, it is important to acknowledge the significant influence of environmental issues, as represented by the concept of "Blockchain Energy Footprint". Additionally, user awareness and education, as summarized by the notion of "User Education and Awareness", also have a great significance. In conclusion, the DRM model reveals a complex interplay of various variables, with "Demand Response Management" serving as the endpoint.

In recognition of the need for empirical validation of the relationships identified in this revised model, the researcher acknowledges the suitability of Fuzzy Cognitive Mapping (FCM) as an innovative and effective method for future exploration. FCM, with its capacity to handle complex and dynamic systems, offers an ideal framework for testing the relationships among the various variables of the DRM model. This approach, while not implemented at this stage of the thesis, is identifies as an important next step of this research, as it will be described in Chapter 7.

In conclusion, the revised conceptual model considers empirical and research-derived findings from four case studies, combining blockchain technology, user-centric functionalities (i.e., driving profiles) and environmental factors, for efficient DRM in IoV.

7. CONCLUSIONS AND FUTURE WORK

7.1 Summary

This chapter provides a comprehensive summary of the research conducted in this thesis, emphasizing its outcomes, contributions to knowledge, and recommendations for future research. It begins by summarizing the research, followed by an analysis of conclusions drawn from both the existing literature and empirical evidence collected through case studies. Next, an overview of the research findings is presented, emphasizing the progression and empirical evidence of the blockchain-based DRM model. This is followed by an analysis, evaluating how the research successfully meets its predefined objectives. Subsequently, the chapter highlights the research contributions, demonstrating the theoretical and practical advancements it brings to the current body of knowledge. Furthermore, the research limitations inherent in this dissertation are also presented, as they serve to establish the bounds of the study. Finally, the concluding section of the chapter provides suggestions for future work in the domain of blockchain applications in the context of IoV and DRM.

7.2 Research Overview

This research investigated blockchain technology and its utilization in the context of IoV DRM. The researcher identified the important role EVs play in modern energy systems as well as the growing potential of local renewable energy sources (Chapter 1). This study was driven by the increasing integration of EVs into the energy ecosystem and a shift towards decentralization. The objective of this dissertation was not only to investigate, but also to develop and evaluate a conceptual model based on blockchain technology (Chapter 3 and Chapter 5).

As a result, with blockchain technology serving as the foundation, this research was positioned to address the dual problems of energy management and secure data management in the IoV. Thus, as stated in Section 1.3.1, the aim of this research was to *investigate the use of blockchain technology for demand response management on the IoV.*

Through a Systematic Literature Review (SLR) documented in Chapter 2, the researcher identified the following Research Challenges (RC), as those described in Section 2.4.6:

- **RC.1:** EV's privacy and security.
- **RC.2:** Impact of IoV on energy demand and response.
- **RC.3:** Lack of incentive mechanisms for EVs participation.
- **RC.4:** Unaddressed EV user charging preferences.

To that end, a research gap has been identified by critically analyzing the SLR and the research challenges: *there is a lack of empirical data and a model that integrates blockchain into DRM for IoV.* In particular, the potential of blockchain technology in DRM has not yet been completely realized in research, especially regarding participant incentives, user-centric approaches and privacy protection. Furthermore, the challenges associated with charging schemes and customized EV charging strategies were not sufficiently addressed. Consequently, the absence of empirical data regarding the efficacy of blockchain-based demand response management in IoV environments posed a research gap.

Driven by this gap, the dissertation proposed in Chapter 3 a conceptual model based on the characteristics of blockchain, including tokenization, transparency and privacy. Thus, Section 3.3 outlined the researcher's propositions to expand upon the current standards and address the challenges mentioned in Section 2.4.6.1. The researcher's propositions included tokenized incentives, user profiles, customized charging schedules, and bi-directional P2P energy trading. Additionally, ten variables were defined in the process of developing the proposed conceptual model. These variables acted as factors that influence the DRM in IoV and were presented in Section 3.4. Each variable played a unique role, affecting different aspects of the DRM process. The theoretical relationships between these variables were examined, forming nine foundational hypotheses that underpin the model. These hypotheses (H) were presented in Section 3.4.

Adopted an interpretivist stance and an abductive research approach (justified in Section), the dissertation followed a qualitative methodological approach that best aligned with the nature of this research (justified in Section 4.4.3). In Section 4.5.2, a multiple case study approach was used to dive into the complex, real-world phenomenon of blockchain technology's integration with IoV and DRM. Moreover, the empirical research methodology used in this research was graphically represented and described in Figure 4.2.

Thereafter, Chapter 6 used the empirical data derived from the case studies to: (a) provide the lessons learned from this research (Section 6.3) and (b) revise the proposed conceptual model, as presented in Figure 6.1 and analyzed in Section 6.4. Specifically, the empirical findings improved the reliability of the model, especially due to the addition of new model variables (Section 6.4.2) and the refinement of the 'old' ones (Section 6.4.3). In addition, the research investigated the relationships between these variables (Section 6.4.4), which strengthened the conceptual model and assured its application and usefulness.

The study followed a thorough approach that connected theory to empirical analysis, literature synthesis to practical application and conceptual modeling to refinement, grounded in empirical evidence.

The research overview presented in this Section summarizes the evolution of the dissertation and serves as a basis for the following sections, which describe the research contributions to the field, assess whether the research objectives were met, identify the research limitations and suggest directions for future research.

7.3 Meeting the Objectives

In order to achieve the aim of this dissertation, a number of objectives were defined in Chapter 1 and have been accomplished as discussed in the previous chapters. These objectives are summarised in Table 7.1 and analysed in the following paragraphs.

Table 7.1: Meeting the objectives of this study

Objective	Chapter
Objective 1	Chapter 2
Objective 2	Chapter 3
Objective 3	Chapter 4
Objective 4	Chapter 5
Objective 5	Chapter 6 & 7

Research Objective 1: To conduct a systematic literature review on blockchain usage in IoV and the application of it in the demand response management, investigate current challenges and identify a research gap.

- The dissertation successfully conducted a detailed SLR that shed light on the present landscape, identified a number of research challenges and a research gap to be addressed. This objective was met in Chapter 2 by critically analysing the existing literature and highlighting the areas needing further research. Furthermore, Annex E supplements Chapter 2, (i.e. which systematically reviews the literature up until 2021), by integrating and examining research contributions and empirical findings from 2022 to 2023, encapsulating recent developments.

Research Objective 2: To propose a blockchain-based conceptual model for demand response management in the IoV, to address the identified research gap.

- Grounded on the findings of the literature review, a blockchain-based DRM model was developed, through the utilization and synthesis of literature review observations. The researcher made specific propositions, addressing the identified research challenges (Section 3.3), which then were used to develop a model towards DRM (Section 3.4). The proposed conceptual model incorporated ten variables and was based on a set of hypotheses (Section 3.4.2). The model proposed solutions for key challenges such as energy trading, tokenized incentive mechanisms, energy balance in the grid, user-oriented profiling for EV charging, and trust through blockchain capabilities. This objective was met in Chapter 3.

Research Objective 3: To examine established research methodologies and select an appropriate one for this research, in order to evaluate the proposed conceptual model.

- A review was conducted in order to choose an appropriate research methodology for evaluating the conceptual model that was proposed. The procedure for selecting and justifying the research approach utilised in this study is detailed in Chapter 4. The researcher provided justifications for the philosophical stance of interpretivism (Section 4.3.3) and the qualitative research approach (Section 4.4.3), indicating why they are more suitable for the present study. Moreover, the research strategy of employing multiple case studies was justified (Section 4.5.3). This objective was met in Chapter 4.

Research Objective 4: To empirically test and evaluate the proposed conceptual model, within a case-based setting.

- The empirical data collected from the four case studies were presented and analysed in Chapter 5. During Chapter 5, the proposed model was tested. The primary focus was on evaluating the conceptual model described in Section 3.4, with particular attention paid to each research pillar, the model's variables, and the related hypotheses. Through the empirical findings, the data analysis, and a comparative analysis of the hypotheses testing, the research confirmed that the conceptual model's proposed variables have a significant impact on DRM in the IoV. It was also identified that enhancements were needed, by incorporating additional variables and highlighting the relationships between them. This objective was met in Chapter 5.

Research Objective 5: To extrapolate findings and provide contribution to knowledge around blockchain enabled DR management in IoV.

- The empirical data and research findings resulted in the revision of the conceptual model. Specific refinements were made, by incorporating additional variables and introducing relationships between them. Moreover, the last Chapter begins by summarizing the dissertation and drawing conclusions that derived from both the literature and empirical research reported in this dissertation. In addition to this, the research contributions are stated, as well as recommendations for further research. This objective was met in Chapter 6 and Chapter 7.

The research has addressed a research gap in the body of knowledge and opened the door for future investigations and practical applications by carefully pursuing each objective. The development of a blockchain-based DRM model for the IoV has enabled the achievement of the previously stated objectives. This was demonstrated by examining the challenges associated with using blockchain technology in DRM and IoV and addressing neglected issues. The various components of this dissertation, from the background information offered in Chapters 1, 2 and 3, to the research methodology described in Chapter 4, the planning and execution of the case studies reported in Chapters 4 and 5 and, lastly, the empirical analysis of the cases and the creation of the revised model presented in Chapters 5 and 6, are part of the contribution made by this work.

7.4 Main outcomes

The purpose of this study was to look into how blockchain technology might be used for IoV DRM. In doing so, it proposed a conceptual model that incorporates a set of variables, including (among others) user-centric profiles, tokenized incentives, blockchain for trust, charging schedules and bi-directional P2P energy trading. The research carried out in this dissertation leads to the following main outcomes, which are summarized below:

- **Outcome 1 - SLR Insights:** The Systematic Literature Review identifies the research gap associated with the implementation of blockchain technology in DRM by identifying the opportunities and challenges present in the IoV ecosystem, thereby establishing a strong foundation.
- **Outcome 2 - Conceptual Model Proposition:** A conceptual model for DRM in IoV is developed and proposed, integrating blockchain’s capabilities such as tokenization, transparency, and privacy, addressing the identified challenges from the SLR.
- **Outcome 3 - Empirical Validation and Model Revision:** The theoretical aspects of the model are validated by four empirical case studies, which encourage the addition and modification of variables to enhance their correspondence with real-world data. Additionally, the empirical findings reveal several relationships between the model’s variables.
- **Outcome 4 - Hypotheses Validation:** Hypothesis Validation and Theoretical Rigor: The model’s robustness and capability to handle DRM in the IoV are supported by the empirical evidence derived from the case studies, which serves to validate the model’s hypotheses.
- **Outcome 5 - Revised Conceptual Model:** The revised model with newly incorporated variables, such as the blockchain energy footprint and user education,

is empirically tested and presented. The revised model also incorporates relationships between the underlying variables towards efficient DRM.

- **Outcome 6 - Blockchain's Practicality in DRM:** The case studies shed light on practical challenges and theoretical limitations, with scalability and privacy problems emerging as critical factors to the integration of blockchain technology into DRM systems.
- **Outcome 7 - User-Centric DRM Strategies:** The significance of user profiling and adaptive charging strategies is emphasized, showcasing the need for a user-centric approach in DRM.
- **Outcome 8 - Industry Application:** The empirical findings (especially from the first case study) bring to light the conflict between the theoretical capabilities of blockchain and its practical implementation and scalability in the industry. The empirical findings highlight the importance of focused development efforts in order to address the obstacles encountered during implementation.
- **Outcome 9 - Policy Impact:** By addressing data privacy and the environmental impact of blockchain, the research impacts policy discussion and considerations for decentralized energy trading.
- **Outcome 10 - Insights for Blockchain Adoption:** Insights and suggestions are provided regarding the use of blockchain technology in DRM, outlining key criteria for its success, including the integration of real-time data analytics and the maintenance of stable token economics.

The aforementioned outcomes summarize the dissertation's key findings. They serve as a guide for future research and discussions concerning the incorporation of emerging technologies, such as blockchain, into the IoV and DRM.

7.5 Research Contributions

This section of the dissertation outlines the research contributions made through the current study in the field of blockchain technology in Demand Response Management (DRM) within the Internet of Vehicles (IoV). The section is divided in two parts: Novel Contributions and Other Contributions. The Novel Contributions part highlights the innovative aspects offered by this research, emphasizing its novelty and the advancements it achieves in tackling crucial challenges in IoV DRM. The Other Contributions part includes additional developments that, although not entirely novel, they greatly enhance knowledge and application of blockchain in DRM and IoV. Collectively, these parts showcase the broad and significant research contribution of this thesis on the field. Table 7.2 presents an overview of the research contributions.

Table 7.2: Research contributions

Novel Contributions	Other Contributions
Development of a Blockchain-Enabled DRM Model for IoV	Practical Insights into Blockchain Implementation
Introduction of User-Centric and Blockchain-Enabled DRM Strategies	Policy Impact and Market Dynamics
Incorporation of Environmental Considerations towards Sustainability	Methodological Advancements & Interdisciplinary Approach

7.5.1 Novel Contributions

This thesis presents several novel contributions to the field of blockchain technology in DRM within the IoV. These are the following:

NC.1 - Development of a Blockchain-Enabled DRM Model for IoV:

- The current study introduces an innovative conceptual model that integrates blockchain technology with DRM in IoV. This model, unique in its composition, addresses key challenges such as user privacy and security, the lack of incentive mechanisms for EV participation and the necessity for personalized EV charging strategies. The novelty of this model lies in its pioneering integration of blockchain with IoV for DRM, an area that, until now, has seen limited exploration and application. Unlike previous models that separately addressed individual aspects of DRM or blockchain applications, this study uniquely synthesizes them into a cohesive framework. Its distinctiveness lies in its holistic approach, encapsulating essential variables like tokenized incentives, bi-directional P2P energy trading and user-centric profiles. Specifically, the integration of blockchain enhances data security and transparency, critical in IoV systems where large volumes of sensitive user data are processed. The model's inclusion of tokenized incentives is a novel approach to address the often-overlooked motivational aspect of user participation in DRM systems. By using blockchain for these incentives, the model ensures transparency and fairness in reward distribution, a critical factor in user engagement and trust. Furthermore, the development of personalized charging schedules based on user profiles represents a significant advancement. It leverages blockchain's capability for secure and efficient data management, enabling dynamic and user-specific energy management strategies within the IoV ecosystem.

NC.2 - Introduction of User-Centric and Blockchain-Enabled DRM Strategies:

- This research emphasizes the importance of user-centric approaches in DRM, a relatively new area in the field. Traditionally, DRM systems have focused primarily on the technical and economic aspects, often overlooking the end-user's role and experience. This study breaks new ground by placing the user at the centre of the DRM process. This shift to a user-centric approach is a significant departure from the conventional system-centric DRM models and addresses a critical gap in existing literature. Incorporating detailed user profiles and adaptive charging schedules, the study contributes a novel perspective on tailoring DRM systems to individual user needs, thereby enhancing system efficiency and user engagement. The inclusion of user profiles, which factor in individual driving patterns, charging behaviour and energy usage, brings a level of personalization that is until now unprecedented in DRM systems. This approach not only makes the DRM more effective by aligning with users' real-world behaviours but also increases user satisfaction and engagement, as they are more likely to participate in a system that recognizes and adapts to their specific needs. Moreover, the adaptive charging schedules, informed by these detailed profiles, allow for dynamic adjustment of charging schedules. This groundbreaking approach of integrating personalized user data into the DRM process using blockchain technology through tokenised incentives represents a substantial enhancement in how DRM systems are conceptualized and implemented.

NC.3 - Incorporation of Environmental Considerations towards Sustainability:

- The model's consideration of the blockchains energy footprint and the integration of renewable energy sources represents a significant step toward aligning DRM practices with environmental sustainability goals, which is a novel aspect of this study. Traditionally, discussions around blockchain technology have often cantered on its potential for secure transactions and data integrity, with less focus on its environmental impact. This study introduces a critical and often overlooked dimension to blockchain research by addressing the energy consumption associated with blockchain technology. By evaluating the blockchain's energy footprint, the study acknowledges the environmental concerns associated with blockchain's energy use. The latter is especially relevant due to the growing global commitment to sustainability. Additionally, the integration of renewable energy sources within the DRM model is a forward-thinking strategy that enhances the model’s sustainability. This integration not only aligns the DRM practice with broader environmental goals, but also contributes to the development of more resilient and sustainable energy systems within the IoV. Additionally, the study’s approach to incorporate renewable energy sources such as solar and wind power into the DRM process, thereby reducing reliance on traditional, non-renewable energy sources, is an innovative contribution. This aspect of the model considers not only the immediate operational needs but also the long-term environmental impacts, thus contributing to the creation of a more sustainable IoV ecosystem.

7.5.2 Other Contributions

In addition to its novel contributions, the current study also makes several other important contributions to the field:

- **Practical Insights into Blockchain Implementation:** Through case studies with key industry players, the current thesis offers valuable practical insights into the challenges and limitations of implementing blockchain in DRM systems. The study’s engagement with industry leaders and practitioners brings to light the practical considerations, such as scalability, interoperability and regulatory compliance, that are essential for successful blockchain integration in DRM systems. These insights are crucial for practitioners and policymakers aiming to integrate blockchain into DRM applications. Moreover, these findings highlight the necessity for ongoing communication among developers, users and regulators in order to establish an environment that promotes innovation and practical usefulness of blockchain in DRM. This will guarantee that the technology not only meets the technical criteria but also adapts to the changing demands of society and industry.
- **Policy Impact and Market Dynamics:** The study explores the privacy, economic and business implications of blockchain technology in IoV DRM systems. It emphasizes the need for regulatory frameworks that protect user data and promote technological innovation. The research also explores the economic aspects of blockchain in DRM, laying the groundwork for future research. It highlights the need for policies that support the technological and business viability of blockchain as

well as its economic sustainability. The study serves as a guide for comprehensive policy makers that consider technological, business and economic aspects of blockchain technology.

- **Methodological Advancements & Interdisciplinary Approach:** This research uses a qualitative approach, supported by multiple case studies, to provide a comprehensive understanding of the dynamics in blockchain-enabled IoV DRM systems. This approach is rather new in this field, where quantitative approaches are commonly used. The qualitative method captures detailed insights and empirical findings that quantitative data might overlook, providing a more comprehensive understanding of the real-world implications of blockchain technology in IoV. The dissertation showcases an interdisciplinary approach, integrating concepts and practices from various fields, to address the multifaceted nature of IoV DRM challenges. The empirical validation of this model through case studies from academia, policy space, R&D and the industry reinforces the interdisciplinary nature of the research and its applicability across different sectors.

7.6 Research Limitations

This dissertation explored the utilization of blockchain technology for Demand Response Management (DRM) in the context of the Internet of Vehicles (IoV). However, it is important to note the limitations that have constrained the findings of this research. The research limitations are summarized in Table 7.3 and described in detail in this section.

The study adopted a qualitative research approach, which enabled an in-depth understanding of multidimensional phenomena under research. The justification of this selection was presented in Section 4.4.3. Nevertheless, this approach inevitably imposed restrictions on the range of application and the ability generalize conclusions from the findings. Despite this, the rich, qualitative insights offer a substantial foundational understanding for future quantitative studies that could further validate and expand upon these findings. Despite significant attempts to mitigate bias through triangulation (Section 4.6.2.3), such as the inclusion of a diverse range of case studies and the adoption of an interpretivist philosophical stance, the qualitative approach may not completely capture the spectrum of variability and broader generalization observed across a larger population. This highlights the potential benefit of incorporating a mixed-methods approach in future research to achieve a more comprehensive understanding.

Table 7.3: Research limitations

Category	Description
Qualitative Research Constraints	Limited generalizability of the research findings due to a non-quantitative approach.
Limited Case Study Range	Insights derived from the case studies are not reflecting the full spectrum of IoV applications.
Regional and Regulatory Specificity	Case studies within specific European regulatory and geographical contexts, not capturing global variances.
Rapid Technological Advancements	Findings based on the current state of blockchain and IoV technologies, which are subject to rapid changes.
Blockchain Implementation Challenges	The current study acknowledges the complexity of implementing and integrating blockchain, without delving into the technical intricacies.
Token Economics Uncertainty	Token valuation addressed, but broader market dynamics and volatility not accounted for in DRM systems.
Model Relationships	The relationships identified in Chapter 6 are not empirically tested, indicating a gap that could be bridged by employing Fuzzy Cognitive Mapping (FCM) in future research.

The dissertation draws upon the selection of four carefully selected case studies to provide empirical data. The case studies have offered valuable insights into the incorporation of blockchain technology in DRM within the IoV. However, these insights only provide a limited view of the range of potential applications in this field, as they are exclusive to specific organizations and their individual experiences. Expanding the scope of case studies to include a broader range of organizations and contexts would enhance the applicability and generalizability of the findings.

Furthermore, the study was conducted within the geographical and regulatory contexts of Europe, where specific regulatory frameworks and market dynamics are in place. Hence, it is important to note that the findings of this study may not be directly applicable to areas with different regulatory frameworks or market conditions. This geographical limitation opens avenues for future research to explore the model’s applicability in varied regulatory and cultural contexts, thereby enhancing its global relevance.

Moreover, the dissertation was formulated within the context of the current technological landscape. The domains of blockchain and IoV are seeing significant advancements, which may have the potential to influence the significance or practicality of the conclusions drawn from this research. This rapidly evolving technological landscape necessitates ongoing research to ensure that the findings remain relevant and applicable.

In the technological domain, the researcher acknowledges the complexities associated with integrating blockchain technology into existing technological frameworks, but it refrains from providing an in-depth analysis of the specific issues involved in this process. Future research could investigate the distinct technological challenges and potential advantages associated with the integration of blockchain technology.

The dissertation also explores the potential impact of tokenized incentives within DRM systems while analysing its economic aspects. However, the study does not sufficiently analyse the broader market dynamics and their underlying fluctuation, as the economic effects were deemed beyond the primary focus of this research. A more comprehensive economic analysis, perhaps through a quantitative lens, could provide greater insights into the economic viability and scalability of blockchain-based DRM systems.

Additionally, while the underlying relationships identified in Chapter 6 are crucial for understanding the model's dynamics, they have not been evaluated yet. As it will be described in the next section, future plans include employing Fuzzy Cognitive Mapping (FCM) as a method to test these relationships, offering a more robust and systematic validation of the model.

In conclusion, these limitations highlight the necessity for continuous investigation into the involvement of blockchain in DRM within the IoV.

7.7 Recommendations for Future Work

The outcomes of this study highlight the need for further research in the domain of blockchain technology in the context of Demand Response Management (DRM) and the Internet of Vehicles (IoV). The recommendations for future work, as depicted in Figure 7.3, hold the potential to not only broaden the scope of this study, but also deepen the understanding and application of blockchain technology in these rapidly evolving fields.

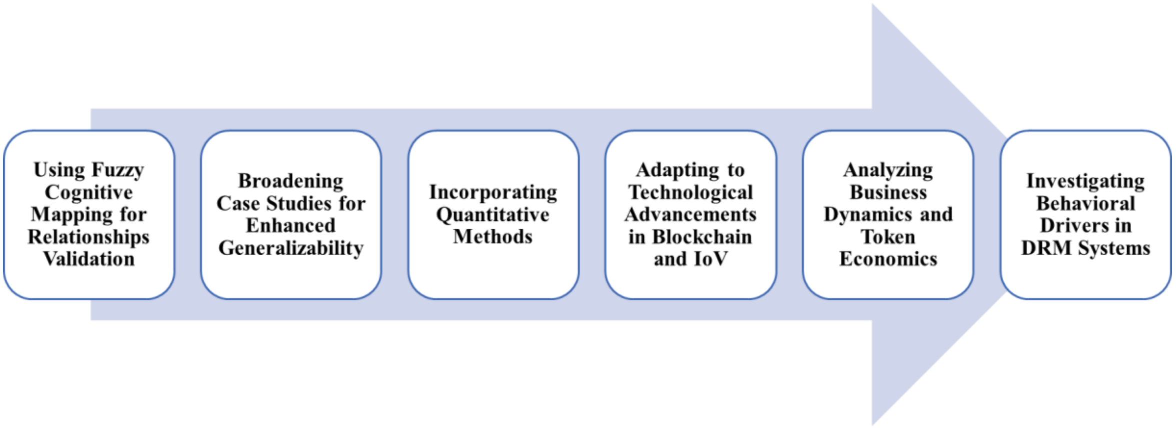


Figure 7.1: Recommendations for future work

Central to the progression of this field is the validation of the theoretical relationships presented in the revised model (Section 6.4.4). In this context, Fuzzy Cognitive Mapping (FCM) is a highly advanced technique that can effectively examine these relationships. It is especially effective at understanding the complexities observed in this field.

Additionally, an important aspect of future research will include expanding the empirical studies. The research will improve its generalizability and depth by including a broader range of case studies, notably from different regulatory and geographical contexts. This expansion is crucial because it will enable the proposed model to undergo testing and validation in a wide range of real-world scenarios, thereby verifying its suitability for various blockchain applications.

Moreover, combining qualitative insights with quantitative techniques, this study will be strengthened even further. It is recommended to adopt quantitative techniques such as surveys and statistical analysis to obtain quantifiable data, specifically addressing how users respond to tokenized incentives. Quantitative research will shed light on how incentives impact user involvement, which is crucial for improving the incentive mechanisms in the DRM system.

Ongoing study must proactively anticipate and incorporate technical improvements while examining the scalability and adaptability of blockchain models. This will guarantee the model’s continued relevance in the face of rapid advancements. Also, it is critical to do an analysis of business dynamics and token economics. The investigation should analyze the way in which market dynamics impact the perceived value and stability of tokenized incentives. This analysis should contribute to the development of business models and sustainable economic strategies.

Furthermore, it is important to research also the psychological and behavioral aspects of user interaction. It is crucial to investigate the motivating psychology that drives user involvement with DRM solutions. Gaining insight into the factors that motivate users to engage and the influence of their actions on the effectiveness of incentive schemes will guide the development of DRM systems that are both technically robust and in harmony with user motivations. To that end, behavioral analysis, together with FCM, will be an effective combination in future research. The former will analyze and examine user activities and decisions, while the latter will outline and illustrate the cognitive processes in action. Collectively, they will create intricate models that accurately depict the relationship between technology and human behavior in DRM systems.

In conclusion, the abovementioned recommendations for future work hold the potential to improve the understanding and application of blockchain in the DRM and IoV, guiding the advancement of energy management systems towards increased effectiveness, security and a user-centric design.

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APPENDICES

Appendix A: Considered Studies for the Systematic Literature Review

Systematic Literature Review – Considered Studies			
Year	Authors	Title	Full Reference
2017	Chen, S; Liu, C-C	From Demand Response to Transactive Energy: State of the Art	CHEN, S, LIU, C (2017) From demand response to transactive energy: state of the art. Journal of Modern Power Systems and Clean Energy, 5(1), 10-19
2017	Kim, Nam Ho; Kang, Sun Moo; Hong, Choong Seon	Mobile Charger Billing System Using Lightweight Blockchain	Kim, N, Kang, S, Hong, C (2017) Mobile charger billing system using lightweight Blockchain. 2017 19th Asia-Pacific Network Operations and Management Symposium (APNOMS),
2018	Danzi, Pietro; Hambridge, Sarah; Stefanovic, Cedomir; Popovski, Petar	Blockchain-Based and Multi-Layered Electricity Imbalance Settlement Architecture	Danzi, P, Hambridge, S, Stefanovic, C, Popovski, P (2018) Blockchain-Based and Multi-Layered Electricity Imbalance Settlement Architecture. 2018 IEEE International Conference on Communications, Control and Computing Technologies for Smart Grids (Smart Grid Comm),
2018	Wu, Xigao; Duan, Bin; Yan, Yinxin; Zhong, Ying	M2M Blockchain: The Case of Demand Side Management of Smart Grid	Wu, X, Duan, B, Yan, Y, Zhong, Y (2017) M2M Blockchain: The Case of Demand Side Management of Smart Grid. 2017 IEEE 23rd International Conference on Parallel and Distributed Systems (ICPADS),
2018	Liu, Chao; Chai, Kok Keong; Lau, Eng Tseng; Chen, Yue	Blockchain Based Energy Trading Model for Electric Vehicle Charging Schemes	Liu, C, Chai, K, Lau, E, Chen, Y (2018) Blockchain Based Energy Trading Model for Electric Vehicle Charging Schemes. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, 64-72
2018	Pop, Claudia; Cioara, Tudor; Antal, Marcel; Anghel, Ionut;	Blockchain Based Decentralized Management Of Demand Response Programs In Smart Energy Grids	Pop, C, Cioara, T, Antal, M, Anghel, I, Salomie, I, Bertoncini, M (2018) Blockchain Based Decentralized Management of Demand Response Programs in Smart Energy Grids. Sensors, 18(2), 162

	Salomie, Ioan; Bertoncini, Massimo		
2018	Knirsch, Fabian; Unterweger andreas; Engel, Dominik	Privacy-Preserving Blockchain-Based Electric Vehicle Charging With Dynamic Tariff Decisions	Knirsch, F, Unterweger, A, Engel, D (2018) Privacy-preserving blockchain-based electric vehicle charging with dynamic tariff decisions. Computer Science - Research and Development, 33(1-2), 71-79
2018	Tsolakis, Apostolos C.; Moschos, Ioannis; Votis, Konstantinos; Ioannidis, Dimosthenis; Dimitrios, Tzovaras; Pandey, Pankai; Katsikas, Sokratis; Kotsakis, Evangelos; Garcia-Castro, Raul	A Secured And Trusted Demand Response System Based On Blockchain Technologies	Tsolakis, A, Moschos, I, Votis, K, Ioannidis, D, Dimitrios, T, Pandey, P, Katsikas, S, Kotsakis, E, Garcia-Castro, R (2018) A Secured and Trusted Demand Response system based on Blockchain technologies. 2018 Innovations in Intelligent Systems and Applications (INISTA),
2018	Sana Noor, Wentao Yang, et al.	Energy Demand Side Management Within Micro-Grid Networks Enhanced By Blockchain	Noor, S, Yang, W, Guo, M, van Dam, K, Wang, X (2018) Energy Demand Side Management within micro-grid networks enhanced by blockchain. Applied Energy, 228, 1385-1398
2018	Tianyang Zhang, Himanshu Pota, et al.	Real-Time Renewable Energy Incentive System For Electric Vehicles Using Prioritization And Cryptocurrency	Zhang, T, Pota, H, Chu, C, Gadh, R (2018) Real-time renewable energy incentive system for electric vehicles using prioritization and cryptocurrency. Applied Energy, 226, 582-594

2018	Cioara, Tudor; Anghel, Ionut; Pop, Claudia; Bertoncini, Massimo; Croce, Vincenzo; Ioannidis, Dimosthenis; Votis, Konstantinos; Tzovaras, Dimitrios; D’Oriano, Luigi	Enabling New Technologies For Demand Response Decentralized Validation Using Blockchain	Cioara, T, Anghel, I, Pop, C, Bertoncini, M, Croce, V, Ioannidis, D, Votis, K, Tzovaras, D, D’Oriano, L (2018) Enabling New Technologies for Demand Response Decentralized Validation Using Blockchain. 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe),
2018	Liu, Chao et al.	Adaptive Blockchain-Based Electric Vehicle Participation Scheme In Smart Grid Platform	Liu, C, Chai, K, Zhang, X, Lau, E, Chen, Y (2018) Adaptive Blockchain-Based Electric Vehicle Participation Scheme in Smart Grid Platform. IEEE Access, 6, 25657-25665
2018	Juhar Abdella, Khaled Shuaib	Peer To Peer Distributed Energy Trading In Smart Grids: A Survey	Abdella, J, Shuaib, K (2018) Peer to Peer Distributed Energy Trading in Smart Grids: A Survey. Energies, 11(6), 1560
2018	Wang, Y., Su, Z., Xu, Q., & Zhang, N.	Contract Based Energy Blockchain For Secure Electric Vehicles Charging In Smart Community	Wang, Y, Su, Z, Xu, Q, Zhang, N (2018) Contract Based Energy Blockchain for Secure Electric Vehicles Charging in Smart Community. 2018 IEEE 16th Intl Conf on Dependable, Autonomic and Secure Computing, 16th Intl Conf on Pervasive Intelligence and Computing, 4th Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress(DASC/PiCom/DataCom/CyberSciTech),
2018	Thakur, Subhasis; John G. Breslin	Electric Vehicle Charging Queue Management With Blockchain	Thakur, S, Breslin, J (2018) Electric Vehicle Charging Queue Management with Blockchain. Lecture Notes in Computer Science,, 249-264
2018	Knirsch, Fabian; Andreas Unterweger; Dominik Engel	Privacy-Preserving Blockchain-Based Electric Vehicle Charging With Dynamic Tariff Decisions	Knirsch, F, Unterweger, A, Engel, D (2018) Privacy-preserving blockchain-based electric vehicle charging with dynamic tariff decisions. Computer Science - Research and Development, 33(1-2), 71-79
2019	Lazaroiu, Cristian; Roscia, Mariacristina	New Approach For Smart Community Grid Through	Lazaroiu, C, Roscia, M (2019) New approach for Smart Community Grid through Blockchain and smart charging infrastructure of EVs. 2019 8th

		Blockchain And Smart Charging Infrastructure Of Evs	International Conference on Renewable Energy Research and Applications (ICRERA),
2019	Xiaodong Yang, Guofeng Wang, Haibo He, Junjie Lu, Youbing Zhang	Automated Demand Response Framework In Elns: Decentralized Scheduling And Smart Contract	Jindal, A, Aujla, G, Kumar, N, Villari, M (2020) GUARDIAN: Blockchain-Based Secure Demand Response Management in Smart Grid System. IEEE Transactions on Services Computing, 13(4), 613-624
2019	Zhou, Zhenyu; Wang, Bingchen; Guo, Yufei; Zhang, Yan	Blockchain And Computational Intelligence Inspired Incentive-Compatible Demand Response In Internet Of Electric Vehicles	Zhou, Z, Wang, B, Guo, Y, Zhang, Y (2019) Blockchain and Computational Intelligence Inspired Incentive-Compatible Demand Response in Internet of Electric Vehicles. IEEE Transactions on Emerging Topics in Computational Intelligence, 3(3), 205-216
2019	Hu, W.; Hu, Y. W.; Yao, W. H.; Lu, W. Q.; Li, H. H.; Lv, Z. W.	A Blockchain-Based Smart Contract Trading Mechanism For Energy Power Supply And Demand Network	Hu, W, Hu, Y, Yao, W, Lu, W, Li, H, Lv, Z (2019) A blockchain-based smart contract trading mechanism for energy power supply and demand network. Advances in Production Engineering & Management, 14(3), 284-296
2019	Wang, N., Zhou, X., Lu, X., Guan, Z., Wu, L., Du, X., & Guizani, M.	When Energy Trading Meets Blockchain In Electrical Power System: The State Of The Art	Wang, N, Zhou, X, Lu, X, Guan, Z, Wu, L, Du, X, Guizani, M (2019) When Energy Trading Meets Blockchain in Electrical Power System: The State of the Art. Applied Sciences, 9(8), 1561
2019	Moradi, Jalal; Shahinzadeh, Hossein; Nafisi, Hamed; Marzband, Mousa; Gharehpetian, Gevork B.	Attributes Of Big Data Analytics For Data-Driven Decision Making In Cyber-Physical Power Systems	Moradi, J, Shahinzadeh, H, Nafisi, H, Marzband, M, Gharehpetian, G (2019) Attributes of Big Data Analytics for Data-Driven Decision Making in Cyber-Physical Power Systems. 2020 14th International Conference on Protection and Automation of Power Systems (IPAPS),
2019	Herenčić, Lin; Ilak, Perica; Rajšl, Ivan; Zmijarević, Zlatko; Cvitanović, Matej;	Overview Of The Main Challenges And Threats For Implementation Of The Advanced Concept For Decentralized Trading In Microgrids	Herencic, L, Ilak, P, Rajsl, I, Zmijarevic, Z, Cvitanovic, M, Delimar, M, Pecanac, B (2019) Overview of the main challenges and threats for implementation of the advanced concept for decentralized trading in microgrids. IEEE EUROCON 2019 -18th International Conference on Smart Technologies,

	Delimar, Marko; Pećanac, Boris		
2019	Li, Yinan; Yang, Wentao; He, Ping; Chen, Chang; Wang, Xiaonan	Design And Management Of A Distributed Hybrid Energy System Through Smart Contract And Blockchain	Li, Y, Yang, W, He, P, Chen, C, Wang, X (2019) Design and management of a distributed hybrid energy system through smart contract and blockchain. Applied Energy, 248, 390-405
2019	Jindal, Anish; Aujla, Gagangeet Singh; Kumar, Neeraj	SURVIVOR: A Blockchain Based Edge-As-A-Service Framework For Secure Energy Trading In SDN-Enabled Vehicle-To-Grid Environment	Jindal, A, Aujla, G, Kumar, N (2019) SURVIVOR: A blockchain based edge-as-a-service framework for secure energy trading in SDN-enabled vehicle-to-grid environment. Computer Networks, 153, 36-48
2019	Anish Jindal, Gagangeet Singh Aujla, Neeraj Kumar, Massimo Villari	GUARDIAN: Blockchain-Based Secure Demand Response Management In Smart Grid System	Yang, X, Wang, G, He, H, Lu, J, Zhang, Y (2020) Automated Demand Response Framework in ELNs: Decentralized Scheduling and Smart Contract. IEEE Transactions on Systems, Man and Cybernetics: Systems, 50(1), 58-72
2019	Xu, Yueqiang; Ahokangas, Petri; Yrjölä, Seppo; Koivumäki, Timo	The Fifth Archetype Of Electricity Market: The Blockchain Marketplace	Xu, Y, Ahokangas, P, Yrjölä, S, Koivumäki, T (2021) The fifth archetype of electricity market: the blockchain marketplace. Wireless Networks, 27(6), 4247-4263
2019	Baza, Mohamed; Nabil, Mahmoud; Ismail, Muhammad; Mahmoud, Mohamed; Serpedin, Erchin; Ashiqur Rahman, Mohammad	Blockchain-Based Charging Coordination Mechanism For Smart Grid Energy Storage Units	Alladi, T, Chamola, V, Rodrigues, J, Kozlov, S (2019) Blockchain in Smart Grids: A Review on Different Use Cases. Sensors, 19(22), 4862
2019	Foti, Magda; Vavalis, Manolis	Blockchain Based Uniform Price Double Auctions For Energy Markets	Foti, M, Vavalis, M (2019) Blockchain based uniform price double auctions for energy markets. Applied Energy, 254, 113604

2019	Andoni, Merlinda; Robu, Valentin; Flynn, David; Abram, Simone; Geach, Dale; Jenkins, David; McCallum, Peter; Peacock andrew	Blockchain Technology In The Energy Sector: A Systematic Review Of Challenges And Opportunities	Andoni, M, Robu, V, Flynn, D, Abram, S, Geach, D, Jenkins, D, McCallum, P, Peacock, A (2019) Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143-174
2019	Baza, M.; Nabil, M.; Ismail, M.; Mahmoud, M.; ...	Blockchain-Based Charging Coordination Mechanism For Smart Grid Energy Storage Units	Alladi, T, Chamola, V, Rodrigues, J, Kozlov, S (2019) Blockchain in Smart Grids: A Review on Different Use Cases. Sensors, 19(22), 4862
2019	Liu, C.; Chai, K. K.; Zhang, X.; Chen, Y.	Proof-Of-Benefit: A Blockchain-Enabled EV Charging Scheme	Liu, C, Chai, K, Zhang, X, Chen, Y (2019) Proof-of-Benefit: A Blockchain-Enabled EV Charging Scheme. 2019 IEEE 89th Vehicular Technology Conference (VTC2019-Spring),
2019	Gabay, D.; Akkaya, K.; Cebe, M.	A Privacy Framework For Charging Connected Electric Vehicles Using Blockchain And Zero Knowledge Proofs	Gabay, D, Akkaya, K, Cebe, M (2019) A Privacy Framework for Charging Connected Electric Vehicles Using Blockchain and Zero Knowledge Proofs. 2019 IEEE 44th LCN Symposium on Emerging Topics in Networking (LCN Symposium),
2019	Zhou, Z.; Wang, B.; Guo, Y.; Zhang, Y.	Blockchain And Computational Intelligence Inspired Incentive-Compatible Demand Response In Internet Of Electric Vehicles	Zhou, Z, Wang, B, Guo, Y, Zhang, Y (2019) Blockchain and Computational Intelligence Inspired Incentive-Compatible Demand Response in Internet of Electric Vehicles. IEEE Transactions on Emerging Topics in Computational Intelligence, 3(3), 205-216
2019	Andoni, Merlinda; Robu, Valentin; Flynn, David; Abram, Simone; Geach, Dale; Jenkins, David; McCallum, Peter; Peacock andrew	Blockchain Technology In The Energy Sector: A Systematic Review Of Challenges And Opportunities	Andoni, M, Robu, V, Flynn, D, Abram, S, Geach, D, Jenkins, D, McCallum, P, Peacock, A (2019) Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143-174

2019	Dai, H. N.; Zheng, Z.; Zhang, Y.	Blockchain For Internet Of Things: A Survey	Dai, H, Zheng, Z, Zhang, Y (2019) Blockchain for Internet of Things: A Survey. IEEE Internet of Things Journal, 6(5), 8076-8094
2019	Aggarwal, S.; Chaudhary, R.; Aujla, G. S.; Kumar, N.; ...	Blockchain For Smart Communities: Applications, Challenges And Opportunities	Aggarwal, S, Chaudhary, R, Aujla, G, Kumar, N, Choo, K, Zomaya, A (2019) Blockchain for smart communities: Applications, challenges and opportunities. Journal of Network and Computer Applications, 144, 13-48
2019	Musleh, A. S.; Yao, G.; Muyeen, S. M.	Blockchain Applications In Smart Grid–Review And Frameworks	Musleh, A, Yao, G, Muyeen, S (2019) Blockchain Applications in Smart Grid–Review and Frameworks. IEEE Access, 7, 86746-86757
2019	Alladi, T.; Chamola, V.; Rodrigues, JJPC; Kozlov, S. A.	Blockchain In Smart Grids: A Review On Different Use Cases	Alladi, T, Chamola, V, Rodrigues, J, Kozlov, S (2019) Blockchain in Smart Grids: A Review on Different Use Cases. Sensors, 19(22), 4862
2019	Tripathi, G.; Ahad, M. A.; ...	The Role Of Blockchain In Internet Of Vehicles (Iov): Issues, Challenges And Opportunities	Tripathi, G, Abdul Ahad, M, Sathiyanarayanan, M (2019) The Role of Blockchain in Internet of Vehicles (IoV): Issues, Challenges and Opportunities. 2019 International Conference on contemporary Computing and Informatics (IC3I),
2019	Kumar, I. P.; Sinha, A. K.; Singh, B. P.; ...	A Detailed Survey On Blockchain Integration For Connected Cars	Mendiboure, L, Chalouf, M, Krief, F (2020) Survey on blockchain-based applications in internet of vehicles. Computers & Electrical Engineering, 84, 106646
2020	Wang, Zhishang; Ogbodo, Mark; Huang, Huakun; Qiu, Chen; Hisada, Masayuki; Abdallah, Abderazek Ben	AEBIS: AI-Enabled Blockchain-Based Electric Vehicle Integration System For Power Management In Smart Grid Platform	Wang, Z, Ogbodo, M, Huang, H, Qiu, C, Hisada, M, Abdallah, A (2020) AEBIS: AI-Enabled Blockchain-Based Electric Vehicle Integration System for Power Management in Smart Grid Platform. IEEE Access, 8, 226409-226421
2020	Pop, Claudia Daniela; Antal, Marcel; Cioara, Tudor; Anghel, Ionut; Salomie, Ioan	Blockchain And Demand Response: Zero-Knowledge Proofs For Energy Transactions Privacy	Pop, C, Antal, M, Cioara, T, Anghel, I, Salomie, I (2020) Blockchain and Demand Response: Zero-Knowledge Proofs for Energy Transactions Privacy. Sensors, 20(19), 5678

2020	Guo, Z; Ji, Z; Wang, Q	Blockchain-Enabled Demand Response Scheme With Individualized Incentive Pricing Mode	Guo, Z, Ji, Z, Wang, Q (2020) Blockchain-Enabled Demand Response Scheme with Individualized Incentive Pricing Mode. Energies, 13(19), 5213
2020	Sciumè, G; Palacios-Garcia, E J; Gallo, P; ...	Demand Response Service Certification And Customer Baseline Evaluation Using Blockchain Technology	Sciume, G, Palacios-Garcia, E, Gallo, P, Sanseverino, E, Vasquez, J, Guerrero, J (2020) Demand Response Service Certification and Customer Baseline Evaluation Using Blockchain Technology. IEEE Access, 8, 139313-139331
2020	Bao, Jiabin; He, Debiao; Luo, Min; Choo, Kim-Kwang Raymond	A Survey Of Blockchain Applications In The Energy Sector	Bao, J, He, D, Luo, M, Choo, K (2021) A Survey of Blockchain Applications in the Energy Sector. IEEE Systems Journal, 15(3), 3370-3381
2020	Jiang, Yanni; Zhou, Kaile; Lu, Xinhui; Yang, Shanlin	Electricity Trading Pricing Among Prosumers With Game Theory-Based Model In Energy Blockchain Environment	Jiang, Y, Zhou, K, Lu, X, Yang, S (2020) Electricity trading pricing among prosumers with game theory-based model in energy blockchain environment. Applied Energy, 271, 115239
2020	Shekari, Mohammadreza; Moghaddam, Mohsen Parsa	An Introduction To Blockchain-Based Concepts For Demand Response Considering Of Electric Vehicles And Renewable Energies	Shekari, M, Moghaddam, M (2020) An Introduction to Blockchain-based Concepts for Demand Response Considering of Electric Vehicles and Renewable Energies. 2020 28th Iranian Conference on Electrical Engineering (ICEE),
2020	Aggarwal, S; Kumar, N; Gope, P	An Efficient Blockchain-Based Authentication Scheme For Energy-Trading In V2G Networks	Garg, S, Kaur, K, Kaddoum, G, Gagnon, F, Rodrigues, J (2019) An Efficient Blockchain-Based Hierarchical Authentication Mechanism for Energy Trading in V2G Environment. 2019 IEEE International Conference on Communications Workshops (ICC Workshops),
2020	Lin, Xi; Wu, Jun; Mumtaz, Shahid; Garg, Sahil; Li, Jianhua; Guizani, Mohsen	Blockchain-Based On-Demand Computing Resource Trading In Iov-Assisted Smart City	Lin, X, Wu, J, Mumtaz, S, Garg, S, Li, J, Guizani, M (2021) Blockchain-Based On-Demand Computing Resource Trading in IoV-Assisted Smart City. IEEE Transactions on Emerging Topics in Computing, 9(3), 1373-1385

2020	Kumari, Aparna; Gupta, Rajesh; Tanwar, Sudeep; Tyagi, Sudhanshu; Kumar, Neeraj	When Blockchain Meets Smart Grid: Secure Energy Trading In Demand Response Management	Kumari, A, Gupta, R, Tanwar, S, Tyagi, S, Kumar, N (2020) When Blockchain Meets Smart Grid: Secure Energy Trading in Demand Response Management. IEEE Network, 34(5), 299-305
2020	Bohloul, Seyed Mahdi	Smart Cities: A Survey On New Developments, Trends and Opportunities	Bohloul, S (2020) Smart Cities: A Survey on New Developments, Trends and Opportunities. Journal of Industrial Integration and Management, 05(03), 311-326
2020	Deshpande, Varun; George, Laurent; Badis, Hakim; Desta, Alemayehu Addisu	Blockchain Based Decentralized Framework For Energy Demand Response Marketplace	Deshpande, V, George, L, Badis, H, Desta, A (2020) Blockchain Based Decentralized Framework for Energy Demand Response Marketplace. NOMS 2020 - 2020 IEEE/IFIP Network Operations and Management Symposium,
2020	Kumari, A; Tanwar, S	A Data Analytics Scheme For Security-Aware Demand Response Management In Smart Grid System	Kumari, A, Tanwar, S (2020) A Data Analytics Scheme for Security-aware Demand Response Management in Smart Grid System. 2020 IEEE 7th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON),
2020	Zahid, Maheen; Ali, Ishtiaq; Khan, Raja Jalees Ul Hussen; Noshad, Zainib; Javaid, Atia; Javaid, Nadeem	Blockchain Based Balancing Of Electricity Demand And Supply	Zahid, M, Ali, I, Khan, R, Noshad, Z, Javaid, A, Javaid, N (2020) Blockchain Based Balancing of Electricity Demand and Supply. Lecture Notes in Networks and Systems,, 185-198
2020	Khajeh, H; Laaksonen, H; Gazafroudi, A S; Shafie-khah, M	Towards Flexibility Trading At TSO-DSO-Customer Levels: A Review	Khajeh, H, Laaksonen, H, Gazafroudi, A, Shafie-khah, M (2019) Towards Flexibility Trading at TSO-DSO-Customer Levels: A Review. Energies, 13(1), 165
2020	Torre, C Cruz De La; González, E Palomar; ...	Cooperative Demand Response Framework For A Smart Community Targeting Renewables: Testbed	Cruz, C, Palomar, E, Bravo, I, Gardel, A (2020) Cooperative Demand Response Framework for a Smart Community Targeting Renewables:

		Implementation And Performance Evaluation	Testbed Implementation and Performance Evaluation. Energies, 13(11), 2910
2020	Zabaleta, K; Casado-Mansilla, D; …	Barriers To Widespread The Adoption Of Electric Flexibility Markets: A Triangulation Approach	Zabaleta, K, Casado-Mansilla, D, Kapassa, E, Borges, C, Presmair, G, Themistocleous, M, Lopez-de-Ipina, D (2020) Barriers to Widespread the Adoption of Electric Flexibility Markets: A Triangulation Approach. 2020 5th International Conference on Smart and Sustainable Technologies (SpliTech),
2020	Duan, Qunlong; Quynh, Nguyen Vu; Abdullah, Heba M.; Almalaq, Abdulaziz; Duc Do, Ton; Abdelkader, Sobhy M.; Mohamed, Mohamed A.	Optimal Scheduling And Management Of A Smart City Within The Safe Framework	Duan, Q, Quynh, N, Abdullah, H, Almalaq, A, Duc Do, T, Abdelkader, S, Mohamed, M (2020) Optimal Scheduling and Management of a Smart City Within the Safe Framework. IEEE Access, 8, 161847-161861
2020	Tanwar, Sudeep; Kaneriya, Shriya; Kumar, Neeraj; Zeadally, Sherali	Electroblocks: A Blockchain-Based Energy Trading Scheme For Smart Grid Systems	Tanwar, S, Kaneriya, S, Kumar, N, Zeadally, S (2020) <i>ElectroBlocks</i>: A blockchain-based energy trading scheme for smart grid systems. International Journal of Communication Systems, 33(15)
2020	Cioara, T; Pop, C; Zanc, R; Anghel, I; ...	Smart Grid Management Using Blockchain: Future Scenarios And Challenges	Cioara, T, Pop, C, Zanc, R, Anghel, I, Antal, M, Salomie, I (2020) Smart Grid Management Using Blockchain: Future Scenarios and Challenges. 2020 19th RoEduNet Conference: Networking in Education and Research (RoEduNet),
2020	Khalid, Rabiya; Javaid, Nadeem; Javaid, Sakeena; Imran, Muhammad; Naseer, Nidal	A Blockchain-Based Decentralized Energy Management In A P2P Trading System	Khalid, R, Javaid, N, Javaid, S, Imran, M, Naseer, N (2020) A blockchain-based decentralized energy management in a P2P trading system. ICC 2020 - 2020 IEEE International Conference on Communications (ICC),

2020	Huang, Zhaoxiong; Chen, Dashen; Lai, Chun Sing; Zhao, Zhuoli; Lai, Loi Lei; Wang, Minghao	A Distributed Transaction Mechanism For Electricity Market With Electric Vehicles And Blockchain	Huang, Z, Chen, D, Lai, C, Zhao, Z, Lai, L, Wang, M (2020) A Distributed Transaction Mechanism for Electricity Market with Electric Vehicles and Blockchain. 2020 8th International Conference on Power Electronics Systems and Applications (PESA),
2020	Silvestre, M L Di; Gallo, P; ...	Aggregation And Remuneration In Demand Response With A Blockchain-Based Framework	Di Silvestre, M, Gallo, P, Riva Sanseverino, E, Sciume, G, ZIZZO, G (2020) Aggregation and remuneration in Demand-Response with a blockchain-based framework. IEEE Transactions on Industry Applications,, 1-1
2020	Ogawa, D; Kobayashi, K; ...	Blockchain-Based Optimization Of Energy Management Systems With Demand Response	Ogawa, D, Kobayashi, K, Yamashita, Y (2020) Blockchain-Based optimization of Energy Management Systems with Demand Response. 2020 IEEE 9th Global Conference on Consumer Electronics (GCCE),
2020	Kumari, Aparna; Gupta, Rajesh; Tanwar, Sudeep; Kumar, Neeraj	Blockchain And AI Amalgamation For Energy Cloud Management: Challenges, Solutions and Future Directions	Kumari, A, Gupta, R, Tanwar, S, Kumar, N (2020) Blockchain and AI amalgamation for energy cloud management: Challenges, solutions and future directions. Journal of Parallel and Distributed Computing, 143, 148-166
2020	Khalid, Rabiya; Javaid, Nadeem; Almogren, Ahmad; Javed, Muhammad Umar; Javaid, Sakeena; Zuair, Mansour	A Blockchain-Based Load Balancing In Decentralized Hybrid P2P Energy Trading Market In Smart Grid	Khalid, R, Javaid, N, Almogren, A, Javed, M, Javaid, S, Zuair, M (2020) A Blockchain-Based Load Balancing in Decentralized Hybrid P2P Energy Trading Market in Smart Grid. IEEE Access, 8, 47047-47062
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2020	Solanke, T. U.; Ramachandaramurthy, V. K.; Yong, J. Y.; ...	A Review Of Strategic Charging–Discharging Control Of Grid-Connected Electric Vehicles	Solanke, T, Ramachandaramurthy, V, Yong, J, Pasupuleti, J, Kasinathan, P, Rajagopalan, A (2020) A review of strategic charging–discharging control of grid-connected electric vehicles. Journal of Energy Storage, 28, 101193

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2020	Lasla, N.; Al-Ammari, M.; Abdallah, M.; ...	Blockchain Based Trading Platform For Electric Vehicle Charging In Smart Cities	Lasla, N, Al-Ammari, M, Abdallah, M, Younis, M (2020) Blockchain Based Trading Platform for Electric Vehicle Charging in Smart Cities. IEEE Open Journal of Intelligent Transportation Systems, 1, 80-92
2020	Florea, B. C.	Electric Vehicles Battery Management Network Using Blockchain Iot	Florea, B (2020) Electric Vehicles Battery Management Network Using Blockchain IoT. 2020 IEEE International Conference on Automation, Quality and Testing, Robotics (AQTR),
2020	Danish, S. M.; Zhang, K.; Jacobsen, H. A.; ...	Blockev: Efficient And Secure Charging Station Selection For Electric Vehicles	Danish, S, Zhang, K, Jacobsen, H, Ashraf, N, Qureshi, H (2021) BlockEV: Efficient and Secure Charging Station Selection for Electric Vehicles. IEEE Transactions on Intelligent Transportation Systems, 22(7), 4194-4211
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2020	Prashar, D.; Jha, N.; Jha, S.; Joshi, G. P.; Seo, C.	Integrating IOT And Blockchain For Ensuring Road Safety: An Unconventional Approach	Prashar, D, Jha, N, Jha, S, Joshi, G, Seo, C (2020) Integrating IoT and Blockchain for Ensuring Road Safety: An Unconventional Approach. Sensors, 20(11), 3296
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2020	Mollah, M. B.; Zhao, J.; Niyato, D.; Lam, K. Y.; ...	Blockchain For Future Smart Grid: A Comprehensive Survey	Mollah, M, Zhao, J, Niyato, D, Lam, K, Zhang, X, Ghias, A, Koh, L, Yang, L (2021) Blockchain for Future Smart Grid: A Comprehensive Survey. IEEE Internet of Things Journal, 8(1), 18-43
2020	Astarita, V.; Giofrè, V. P.; Mirabelli, G.; Solina, V.	A Review Of Blockchain-Based Systems In Transportation	Astarita, V, Giofrè, V, Mirabelli, G, Solina, V (2019) A Review of Blockchain-Based Systems in Transportation. Information, 11(1), 21

2020	Upadhyay, N.	Demystifying Blockchain: A Critical Analysis Of Challenges, Applications And Opportunities	Upadhyay, N (2020) Demystifying blockchain: A critical analysis of challenges, applications and opportunities. International Journal of Information Management, 54, 102120
2020	Rathore, H.; Mohamed, A.; Guizani, M.	A Survey Of Blockchain Enabled Cyber-Physical Systems	Rathore, H, Mohamed, A, Guizani, M (2020) A Survey of Blockchain Enabled Cyber-Physical Systems. Sensors, 20(1), 282
2020	Mendiboure, L.; Chalouf, M. A.; Krief, F.	Survey On Blockchain-Based Applications In Internet Of Vehicles	Mendiboure, L, Chalouf, M, Krief, F (2020) Survey on blockchain-based applications in internet of vehicles. Computers & Electrical Engineering, 84, 106646
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2021	Karandikar, N; Chakravorty, A; Rong, C	Blockchain Based Transaction System With Fungible And Non-Fungible Tokens For A Community-Based Energy Infrastructure	Karandikar, N, Chakravorty, A, Rong, C (2021) Blockchain Based Transaction System with Fungible and Non-Fungible Tokens for a Community-Based Energy Infrastructure. Sensors, 21(11), 3822
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2021	Khan, P W; Byun, Y C	Blockchain-Based Peer-To-Peer Energy Trading And Charging Payment System For Electric Vehicles	Khan, P, Byun, Y (2021) Blockchain-Based Peer-to-Peer Energy Trading and Charging Payment System for Electric Vehicles. Sustainability, 13(14), 7962

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2021	Chaurasia, Kiran; Kamath, H. Ravishankar	New Approach Using Artificial Intelligence-Machine Learning In Demand Side Management Of Renewable Energy Integrated Smart Grid For Smart City	Chaurasia, K, Kamath, H New Approach using Artificial Intelligence-Machine Learning in Demand Side Management of Renewable Energy integrated Smart Grid for Smart City. SSRN Electronic Journal,
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2021	Zhang, Xiaoshuai; Liu, Chao; Chai, Kok Keong; Poslad, Stefan	A Privacy-Preserving Consensus Mechanism For An Electric Vehicle Charging Scheme	Zhang, X, Liu, C, Chai, K, Poslad, S (2021) A privacy-preserving consensus mechanism for an electric vehicle charging scheme. Journal of Network and Computer Applications, 174, 102908
2021	Sajid, Sara; Jawad, Muhammad; Hamid, Kanza; Khan, Muhammad U.S.; Ali,	Blockchain-Based Decentralized Workload And Energy Management Of Geo-Distributed Data Centers	Sajid, S, Jawad, M, Hamid, K, Khan, M, Ali, S, Abbas, A, Khan, S (2021) Blockchain-based decentralized workload and energy management of geo-distributed data centers. Sustainable Computing: Informatics and Systems, 29, 100461

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2021	Ping, Jian; Yan, Zheng; Chen, Sijie	A Two-Stage Autonomous EV Charging Coordination Method Enabled By Blockchain	Ping, J, Yan, Z, Chen, S (2021) A Two-stage Autonomous EV Charging Coordination Method Enabled by Blockchain. Journal of Modern Power Systems and Clean Energy, 9(1), 104-113
2021	Zhang, C.; Li, W.; Luo, Y.; Hu, Y.	AIT: An AI-Enabled Trust Management System For Vehicular Networks Using Blockchain Technology	Zhang, C, Li, W, Luo, Y, Hu, Y (2021) AIT: An AI-Enabled Trust Management System for Vehicular Networks Using Blockchain Technology. IEEE Internet of Things Journal, 8(5), 3157-3169
2021	Mollah, M. B.; Zhao, J.; Niyato, D.; Guan, Y. L.; Yuen, C.; Sun, S.; Lam, K.-Y.; Koh, L. H.	Blockchain For The Internet Of Vehicles Towards Intelligent Transportation Systems: A Survey	Mollah, M, Zhao, J, Niyato, D, Guan, Y, Yuen, C, Sun, S, Lam, K, Koh, L (2021) Blockchain for the Internet of Vehicles Towards Intelligent Transportation Systems: A Survey. IEEE Internet of Things Journal, 8(6), 4157-4185

Appendix B: Interview Agenda

The interview agenda developed as part of the interview process followed during this research work consists of twelve segments.

Interview Questions Segments:

- **Segment A:** Introduction
- **Segment B:** General Organization Data
- **Segment C:** Brief Description of the Study
- **Segment D:** Background Information
- **Segment E:** Blockchain and IoV
- **Segment F:** Incentive Mechanisms and Transparent Distribution
- **Segment G:** User Profiles and Charging Scheduling
- **Segment H:** Energy Generation and Consumption
- **Segment I:** Privacy and Security
- **Segment J:** Blockchain Enabled Demand Response Management Model
- **Segment K:** Additional Comments
- **Segment L:** Participant Data

SEGMENT A: INTRODUCTION

DO YOU CONFIRM YOUR CONSENT TO PARTICIPATE IN THIS INTERVIEW AND FOR THE SUBSEQUENT USE OF THE INFORMATION THAT WE WILL GATHER, ONLY FOR ACADEMIC PURPOSES UNDER THE SCOPE OF THIS PHD STUDY?

....

....

MAY I HAVE YOUR PERMISSION TO PUBLISH DATA THAT INCLUDES NAMES AND ORGANIZATIONAL DETAILS?

....

....

IF THE CONSENT IS NOT GIVEN, WOULD ANONYMIZED REPORTING BE ACCEPTABLE?

....

....

DO I HAVE YOUR PERMISSION TO RECORD THIS INTERVIEW?

....

....

WOULD YOU AGREE IF I SENT YOU THE DATA FROM OUR CONVERSATION FOR YOU TO REVIEW AND CONFIRM ITS ACCURACY AS PART OF OUR VALIDATION PROCESS?

....

....

SEGMENT B: GENERAL ORGANIZATION DATA

ORGANIZATION NAME AND ADDRESS

Organization Name: ....

Organization Address: ....

HOW MANY EMPLOYEES WORK AT THE ORGANIZATION APPROXIMATELY?

....

....

COULD YOU BRIEFLY DESCRIBE THE NATURE OF YOUR ORGANIZATION?

....

....

WHAT ARE THE CRITICAL OBJECTIVES/TARGETS OF YOUR ORGANIZATION?

....

....

SEGMENT C: BRIEF DESCRIPTION OF THE STUDY

DESCRIPTION OF THE STUDY CONTEXT AND RESEARCH AIM

I will describe to you in detail the study context and the research aim of the current PhD study.

DESCRIPTION OF THE PROPOSED CONCEPTUAL MODEL

I will describe to you in detail the proposed conceptual model and all the involved variables (i.e., factors).

INTERVIEW AIM

I will describe to you in detail the interview aim and what is the expected outcome.

SEGMENT D: BACKGROUND INFORMATION

CAN YOU BRIEFLY DESCRIBE YOUR BACKGROUND AND EXPERIENCE IN THE FIELDS OF (ENERGY) DRM, IOV AND/OR BLOCKCHAIN TECHNOLOGY?

....

....

CAN YOU SHARE ANY SIGNIFICANT EXPERIENCES OR PROJECTS YOU'VE BEEN PART OF THAT DIRECTLY OR INDIRECTLY RELATE TO DRM IN IOV?

....

....

HAVE YOU DEVELOPED (OR BEEN A PART OF DEVELOPING) ANYTHING SIMILAR OR RELATED TO THIS CONCEPT?

....

....

SEGMENT E: BLOCKCHAIN AND IOV

HOW DO YOU PERCEIVE THE IMPACT OF BLOCKCHAIN TECHNOLOGY ON ELECTRIC VEHICLES?

....

....

CAN YOU SHARE YOUR THOUGHTS ON THE POTENTIAL BENEFITS AND CHALLENGES OF IMPLEMENTING BLOCKCHAIN TECHNOLOGY IN THE IOV?

....

....

HOW DO YOU SEE BLOCKCHAIN TECHNOLOGY ENHANCING DRM IN THE IOV?

....

....

SEGMENT F: INCENTIVE MECHANISMS & TRANSPARENT DISTRIBUTION

HAVE YOU DEVELOPED OR IMPLEMENTED ANY INCENTIVIZATION SCHEMES RELATED TO ELECTRIC VEHICLES AND/OR THE IOV? IF SO, COULD YOU PLEASE DESCRIBE THEM?

....

....

HOW DO YOU PERCEIVE THE ROLE OF TOKENIZED INCENTIVES IN INFLUENCING THE WILLINGNESS OF USERS TO PARTICIPATE IN DRM PROGRAMS AND PROVIDE THEIR INFORMATION TOWARDS THE CREATION OF CHARGING PROFILES?

....

....

CAN YOU SHARE YOUR THOUGHTS THAT SUGGEST TOKENIZED INCENTIVES COULD ENCOURAGE OR DISCOURAGE PARTICIPATION IN DRM PROGRAMS?

....

....

CAN YOU SHARE YOUR THOUGHTS ON INSTANCES WHERE AN INCREASE IN TOKENIZED INCENTIVES LED TO THE CREATION OF MORE CHARGING PROFILES?

....

....

IN YOUR OPINION, HOW DOES TRANSPARENCY IN THE PROCESS OF TOKEN DISTRIBUTION INFLUENCE TRUST IN THE DRM SYSTEM?

....

....

CAN YOU SHARE YOUR THOUGHTS ON INSTANCES WHERE HIGHER TRANSPARENCY IN TOKEN DISTRIBUTION RESULTED IN ACTIVE USER PARTICIPATION?

....

....

CAN YOU SHARE YOUR THOUGHTS ON INSTANCES WHERE ENHANCED TRANSPARENCY IN TOKEN DISTRIBUTION RESULTED IN THE CREATION OF MORE USER PROFILES?

....

....

SEGMENT G: USER PROFILES AND CHARGING SCHEDULING

HAVE YOU DEVELOPED OR IMPLEMENTED ANY MECHANISMS RELATED TO PROFILING EV USERS AND SCHEDULING PERSONALIZED CHARGING? IF SO, COULD YOU PLEASE DESCRIBE THEM?

....
....

HOW DO USER PROFILES CONTRIBUTE TO THE EFFICIENCY OF DRM, PARTICULARLY IN RELATION TO PERSONALIZED CHARGING SCHEDULES?

....
....

CAN YOU PROVIDE YOUR THOUGHTS ON INSTANCES WHERE DETAILED AND ACCURATE USER PROFILES HAVE LED TO IMPROVED DRM EFFICIENCY AND WHY?

....
....

CAN YOU DISCUSS THE IMPACT OF PERSONALIZED CHARGING SCHEDULES ON USER PARTICIPATION IN BI-DIRECTIONAL P2P ENERGY TRADING?

....
....

CAN YOU DESCRIBE HOW PERSONALIZED CHARGING SCHEDULES COULD ENHANCE DEMAND RESPONSE MANAGEMENT?

....
....

SEGMENT H: ENERGY GENERATION AND CONSUMPTION

CAN YOU EXPLAIN HOW BALANCE BETWEEN ENERGY GENERATION AND CONSUMPTION CAN BE ACHIEVED IN IOV?

....

....

IN YOUR OPINION, HOW COULD EVS ACT AS DISTRIBUTED ENERGY SOURCES CONTRIBUTING TO DEMAND RESPONSE MANAGEMENT?

....

....

CAN YOU DISCUSS HOW ENERGY GENERATION FROM EVS CONTRIBUTES TO THE BALANCE OF SUPPLY AND DEMAND?

....

....

IN YOUR EXPERIENCE, HOW DOES ENERGY GENERATION FROM PRIMARY SOURCES (E.G., PHOTOVOLTAICS, WIND TURBINES ETC) SUPPORT DRM, WHEN EVS ACT AS ENERGY PRODUCERS AS WELL?

....

....

IN YOUR OPINION, HOW DOES ACTIVE PARTICIPATION IN BI-DIRECTIONAL P2P ENERGY TRADING IMPACT THE BALANCE OF ENERGY CONSUMPTION AND GENERATION?

....

....

IN YOUR OPINION, HOW DO TOKENIZED INCENTIVES INFLUENCE ACTIVE PARTICIPATION IN P2P ENERGY TRADING?

....

....

SEGMENT I: PRIVACY AND SECURITY

HOW DO PRIVACY MEASURES INFLUENCE USER TRUST AND THEIR WILLINGNESS TO PARTICIPATE IN DRM PROGRAMS?

....

....

CAN YOU SHARE YOUR THOUGHTS REGARDING THE CORRELATION BETWEEN PRIVACY MEASURES AND PARTICIPATION LEVELS IN THE DRM PROGRAMS?

....

....

DO YOU THINK THAT BLOCKCHAIN COULD BE UTILIZED AS A TRUST LAYER IN THE IOV (E.G., SECURE ENERGY TRANSACTIONS, PROTECT PERSONAL DATA ETC.)? IF YES, HOW?

....

....

SEGMENT J: BLOCKCHAIN ENABLED DEMAND RESPONSE MANAGEMENT MODEL

HAVING GONE THROUGH THE PROPOSED BLOCKCHAIN-ENABLED DRM MODEL, WHAT ARE YOUR INITIAL THOUGHTS?

....

....

COULD YOU CREATE A DRM SCENARIO IN IOV AND IDENTIFY THE USAGE OF THE PROPOSED MODEL IN YOUR ORGANIZATION?

....

....

HOW DO YOU SEE EACH VARIABLE OF THE MODEL WORKING IN THIS SCENARIO?

....

....

ARE THERE ANY ADDITIONAL VARIABLES YOU THINK SHOULD BE INCLUDED IN THIS MODEL AND WHY?

....

....

HOW DO YOU ENVISION THE RELATIONSHIPS BETWEEN THE DIFFERENT VARIABLES AND HOW THEY AFFECT THE OVERALL IOV DRM?

....

....

CAN YOU IDENTIFY ANY GAPS OR POTENTIAL IMPROVEMENTS IN THE PROPOSED MODEL?

....

....

SEGMENT K: ADDITIONAL COMMENTS

ARE THERE ANY ADDITIONAL INSIGHTS OR THOUGHTS YOU WOULD LIKE TO SHARE THAT WERE NOT COVERED IN THE INTERVIEW?

. . . .
. . . .

WOULD YOU LIKE TO ASK ANY QUESTIONS ABOUT THE STUDY?

. . . .
. . . .

SEGMENT L: PARTICIPANT DATA

INTERVIEWEE CONTACT DETAILS

Full Name: . . . .
Telephone: . . . .
Email: . . . .

CAN YOU TELL ME ABOUT YOUR CURRENT ROLE IN THE ORGANIZATION?

. . . .
. . . .

Appendix C: Interview Participant Profiles

Participant A

Participant Details	
Name:	Davide Rivola
Email:	davide.rivola@hivepower.tech
Organization:	Hive Power
	Via Cantonale 18, 6928 Manno, Switzerland
Position/Role:	Chief Operating Officer
Background and Experience:	Davide is the COO and co-founder of Hive Power. Having obtained his master’s from the École Polytechnique Federale of Lausanne (EPFL), Davide is specialized in Industrial Automation, Embedded Computing and the Smart Grid. Before his research activities, he gained several years of industrial experience, designing industrial automation systems and developing real-time software for embedded electronics. During the last seven years, he researched, developed and trialled in pilot projects fully decentralized energy management systems for self-consumption optimization and grid instability reduction. He is personally involved in Blockchain technology since 2013, with an enthusiasm that only grew during time. As a future thinker, Davide strongly believes that renewable electricity will be the main energy vector of this century. He is committed to developing intelligent, automated management systems which make the energy transition possible.

Confidentiality	
Consent to participate in this interview and for the subsequent use of the information that will be gathered only for academic purposes under the scope of this PhD study	yes
Permission to publish data that includes names and organizational details	yes
Permission to record the interview	yes
Validation of the empirical data after the completion of the interview	yes

Participant B

Participant Details	
Name:	Davide Strepparava
Email:	davide.strepparava@supsi.ch
Organization:	University of Applied Sciences and Arts of Southern Switzerland (Italian: Scuola Universitaria Professionale della Svizzera Italiana, SUPSI) Via Pobiette 11, 6928 Manno, Switzerland
Position/Role:	Researcher and Software Engineer
Background and Experience:	Davide has a background in computer science with a master's degree from the Polytechnic of Milano. He has been working as a researcher at SUPSI since 2015 in a group that focuses on energy projects, optimized energy management on grids, using blockchain technology in the energy sector and developing algorithms based on machine learning for demand response and energy trading. He has been involved in several European projects, including PARITY.

Confidentiality	
Consent to participate in this interview and for the subsequent use of the information that will be gathered only for academic purposes under the scope of this PhD study	yes
Permission to publish data that includes names and organizational details	yes
Permission to record the interview	yes
Validation of the empirical data after the completion of the interview	yes

Participant C

Participant Details	
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Organization:	e7 energy innovation & engineering (e7)
	Walcherstraße 11, 1020 Wien, Austria
Position/Role:	Consultant
Background and Experience:	In April 2020, Guntram Pressmair finished his master’s degree in environmental and Bioresource Management at the University of Natural Resources and Applied Life Sciences, Vienna. Since 2016 he has been a member of the e7 team as project support and junior consultant, with a break for studying abroad at the Queensland University of Technology in Brisbane, Australia. Earlier, Guntram gained his first professional experience in 2015 at the Blue Minds Company in Vienna, where he got familiar with the implementation of the Austrian Energy Efficiency Act. Since January 2020, Guntram has been working as a consultant and scientific staff at e7. His main field of expertise is energy economics, mainly related to topics such as flexibility in electricity markets and the e-mobility transition. Currently, he also pursues a PhD at the University of Natural Resources and Life Sciences, Vienna. The topic of the theses is on demand response business models with a focus on local energy and flexibility markets. Guntram Pressmair has experience in demand response management, particularly from the PARITY project and a range of other projects. His main interest lies in the business model behind leveraging flexibility from electric vehicles. He has worked in projects dealing with blockchain as a priority, but he has not been deeply involved in understanding how these systems work. He is familiar with different markets where flexibility can be offered or where profits can be made from flexibility from various sources. This can be battery storage, any other demand response, or electric vehicles through smart charging or bidirectional charging.

Confidentiality	
Consent to participate in this interview and for the subsequent use of the information that will be gathered only for academic purposes under the scope of this PhD study	yes
Permission to publish data that includes names and organizational details	yes
Permission to record the interview	yes
Validation of the empirical data after the completion of the interview	yes

Participant D1

Participant Details	
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Organization:	Hypertech S.A.
	32 Perikleous street, 15232 Halandri, Athens, Greece 2 Kafkasou st. & Pontou st., 55133, Thessaloniki, Greece
Position/Role:	DSR and Flexibility Project Manager
Background and Experience:	Ismini has an MEng in Electrical and Computer Engineering and an MSc in Sustainable Energy and Environment. She has worked in the Energy industry for more than 10 years in the UK and Greece. Her expertise covers electricity networks, distributed energy resources and the energy market. Her career includes working for London's DSO UK Power Networks and the Greek Regulatory Authority for Energy. She is currently working for Hypetech SA as a Project Manager, coordinating EU-funded projects, among which are the ACCEPT and PARITY projects. In her professional journey, Ismini has accumulated approximately five years of experience at a Distribution System Operator (DSO) in London, deeply immersing herself in the network sector. During her tenure, the final two years were notably focused on the intricacies of Electric Vehicles (EVs) within the network, pinpointing potential challenges they could introduce. Notably, she was an integral part of collaborative ventures such as the project with UPS and played a pivotal role in the Optimus Prime project, overseeing the bidding process for an entire year. Her engagements extended to companies operating EV fleets and she undertook projects addressing connection challenges and the integration of residential batteries. This has given her a comprehensive understanding of battery structures, predominantly from an operator's vantage point. Transitioning to Hypertech, she has dedicated four years to projects cantered on demand response strategies and flexibility. Her contributions span a range of projects at Hypertech, including "PARITY", "ACCEPT", "iElectrics" and "FlexGrid". However, it's noteworthy that while she has encountered blockchain within her project involvements, she perceives it as an area where her expertise could be further enhanced.

Confidentiality	
Consent to participate in this interview and for the subsequent use of the information that will be gathered only for academic purposes under the scope of this PhD study	yes
Permission to publish data that includes names and organizational details	yes
Permission to record the interview	yes
Validation of the empirical data after the completion of the interview	yes

Participant D2

Participant Details	
Name:	Nikolaos Spiliopoulos
Email:	n.spiliopoulos@hypertech.gr
Organization:	Hypertech S.A.
	32 Perikleous street, 15232 Halandri, Athens, Greece 2 Kafkasou st. & Pontou st., 55133, Thessaloniki, Greece
Position/Role:	Project Manager
Background and Experience:	Nikolas Spiliopoulos collaborates with Hypertech Energy Labs and is prominently recognized for his expertise in Peer-to-Peer (P2P) exchange, a focal research area during his PhD studies. Currently, he spearheads the H2020 project titled “ACCEPT”, which integrates P2P exchange at a community level across four distinct pilot sites. His research pursuits encompass P2P exchanges in Microgrids, advanced energy management techniques, Demand Side Management (DSM) strategies and strategies for resilient network operation. With a solid engineering foundation, he holds a Doctor of Philosophy (PhD) in Electrical Engineering from Newcastle University. Additionally, Spiliopoulos possesses a robust foundation in energy demand response management (DRM), particularly emphasizing flexibility demand response. His involvement spans projects such as the Accept initiative, delving into both explicit and implicit demand response. While blockchain integration in their projects has piqued his interest, he modestly refrains from labelling himself as an expert in this domain.

Confidentiality	
Consent to participate in this interview and for the subsequent use of the information that will be gathered only for academic purposes under the scope of this PhD study	yes
Permission to publish data that includes names and organizational details	yes
Permission to record the interview	yes
Validation of the empirical data after the completion of the interview	yes

Appendix D: Understanding Aggregators in Energy Markets and Internet of Vehicles

Aggregator in the Context of Energy Markets:

In energy markets, an aggregator is a company or organization that bundles the energy consumption or production of multiple smaller consumers or producers to negotiate more favourable terms or to participate in energy markets more efficiently. Aggregators often use advanced software platforms to automatically control and optimize the energy usage or production of their aggregated portfolio in real-time.

Here are some key functions of aggregators in energy markets:

- **Demand Response**: Aggregators can bundle the energy usage of various consumers to provide demand response services to the grid, reducing or shifting consumption during peak hours.
- **Renewable Energy Integration**: Aggregators can combine the output of various small-scale renewable energy producers like wind and solar farms to sell power into the grid as a single entity.
- **Virtual Power Plants (VPPs)**: By controlling a network of decentralized energy resources such as home batteries, solar PV systems and electric vehicles, aggregators can create a “virtual power plant” that can supply power or provide grid services.
- **Market Participation**: Smaller energy producers or consumers may not have the scale to participate in energy markets directly. Aggregators can represent these smaller entities, allowing them to benefit from market rates for energy supply or demand services.
- **Grid Balancing and Ancillary Services**: Aggregators can provide services like frequency regulation, voltage support and other ancillary services to grid operators by leveraging their aggregated portfolio.

Aggregator in the Context of Internet of Vehicles (IoV):

In the context of the Internet of Vehicles (IoV), an aggregator usually refers to a system or platform that collects, analyses and manages data from multiple vehicles to provide various services. These services can range from real-time traffic updates to predictive maintenance alerts. An IoV aggregator may interact with different stakeholders, including vehicle owners, service providers and city planners.

Key functions might include:

- **Data Collection and Analysis**: Aggregators collect data from a variety of sensors and systems installed in vehicles. This data can be analysed for patterns, risks and opportunities.
- **Traffic Management**: By aggregating real-time data from multiple vehicles, aggregators can provide more accurate and timely traffic information, potentially assisting in traffic control and route optimization.
- **Fleet Management**: For commercial fleets, aggregators can offer comprehensive management solutions, including tracking, maintenance scheduling and performance analytics.
- **Service Customization**: Based on collected data, aggregators can offer customized services or promotions to drivers, such as recommending a nearby gas station or service centre.
- **Safety and Security**: Aggregators can provide real-time alerts for emergency services in case of an accident or other critical events.
- **Communication**: Aggregators may facilitate Vehicle-to-Everything (V2X) communication, including Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Grid (V2G) interactions.

Both types of aggregators serve as intermediaries that use data and network effects to provide more effective and efficient services. However, the nature of those services and the markets they operate in are quite different.

Appendix E: Terminology and Notations used in the Thesis

The terminologies and notations mentioned here are crucial for understanding the intricacies of this research topic and the methods used. The purpose of these terms is to provide consistency in comprehension and to avoid any potential confusion that may result from the varied meanings of these phrases in various settings. Each term is followed with a definition, clarifying how it’s used within the context of this research.

- **Researcher:** Refers to the author of this dissertation.
- **Author(s):** Describes other scholars or researchers whose works are referenced in the thesis.
- **Blockchain:** A digital ledger technology used for recording transactions across multiple computers in a way that ensures security, transparency and decentralization.
- **Demand Response Management (DRM):** A system for managing and adjusting the demand for energy, often in response to changes in supply or pricing.
- **Internet of Vehicles (IoV):** A networked integration of vehicles with smart technology, allowing for data exchange and intelligent control.
- **Electric Vehicle (EV):** A vehicle powered by electric motors, using energy stored in rechargeable batteries.
- **Blockchain Tokens:** Blockchain tokens are digital assets on a blockchain platform, representing various rights or assets. Types include cryptocurrencies (e.g., Bitcoin), utility tokens (granting access to services within a blockchain ecosystem), security tokens (signifying ownership in real-world assets) and non-fungible tokens (NFTs, representing unique digital items). They facilitate transactions, access services and are used in investment strategies, offering transparency and security through decentralized blockchain technology.
- **Tokenized Incentives:** Rewards or incentives in the form of digital tokens, often used within blockchain systems to encourage participation or behavior.
- **P2P (Peer-to-Peer) Energy Trading:** A decentralized model of energy exchange where individuals can buy, sell, or trade energy without central intermediaries.
- **User Profiles:** Data sets within DRM systems representing individual user behaviors, preferences and characteristics.
- **Case Study:** A research method involving an in-depth, detailed examination of a subject of study (case), as well as its related contextual conditions.

- **Systematic Literature Review (SLR):** A methodical and comprehensive literature review process aimed at identifying, evaluating and interpreting all available research relevant to a particular research question or topic.
- **Empirical Data:** Information and data derived from observation or experiment in the real world, as opposed to theory or belief.

Appendix F: Advancements in Blockchain Enabled Demand Response Management in the Internet of Vehicles (2022-2023)

This Annex supplements the core dissertation, which systematically reviews the literature up until 2021, by integrating and examining pivotal scholarly contributions and empirical findings from 2022 to 2023. This Annex aims to encapsulate recent developments, focusing on how blockchain technology is increasingly being integrated into the IoV and how it may be used in demand response management.

To achieve this, an additional search is conducted on Google Scholar using the keywords "blockchain", "demand response management" and "Internet of Vehicles", focusing on publications from 2022 to 2023. The researcher follows the same literature review process as the one presented in Chapter 2. This validation process identifies 36 relevant publications, which are currently being reviewed for their contributions to blockchain-enabled demand response management in the area of the IoV.

The main findings from the newly identified sources include:

- **Privacy and Security in Smart Grids and Electric Vehicle (EV) Systems**
    - Development of privacy-preserving schemes for smart grids to enhance anonymity and access control in electricity consumption data sharing.
    - Implementation of blockchain for secure, decentralized DRM in IoV.
    - Use of blockchain technology for secure automotive diagnostics and performance analysis in the automotive industry.
    - Introduction of a blockchain-based payment scheme for EV charging, ensuring user privacy and traceability for abnormal transactions.
- **Blockchain Applications in Smart Grid and EV Networks**
    - Exploration of blockchain-based frameworks for distributed DRM in smart grids and IoV systems.
    - Proposal of decentralized energy trading frameworks in Vehicle-to-Grid (V2G) networks using blockchain, optimizing EV charging and discharging.
    - Utilization of blockchain for energy transaction security and robustness in smart grid systems.

Literature Review on the Latest Sources:

In this section a brief overview of the findings and developments in the blockchain enabled DRM in IoV, between 2022 and 2023 is presented.

A comprehensive survey on blockchain in industrial internet of things: Motivations, research progresses and future challenges (Huo *et al.*, 2022)

In the context of the Industry 4.0 revolution, this paper presents a comprehensive survey on the integration of blockchain technology within the Industrial Internet of Things (IIoT). It highlights the potential of blockchain to enhance IIoT in manufacturing by improving resource optimization, data collection and automated control through its inherent features like decentralization and transparency. The survey reviews the literature, discusses the motivations and benefits of blockchain in IIoT and explores technical requirements for its implementation. Concluding with an overview of challenges and future research directions, this study provides valuable insights into the synergistic potential of blockchain and IIoT in transforming industrial processes.

Challenges of blockchain in new generation energy systems and future outlooks (Wang *et al.*, 2022)

This paper critically examines the application of blockchain technology in the energy sector, acknowledging its widespread adoption due to features like decentralization and transparency. It addresses the increasing awareness of blockchain’s limitations, especially in renewable energy system integration. The study reviews key application scenarios of energy blockchain, identifies generic limitations and assesses their impact on energy systems. It emphasizes that while blockchain offers significant advantages, it is not a cure-all solution, given its inherent issues. The paper advocates for tailored improvement measures that align with the practical requirements of energy systems. This work stands out for its in-depth analysis of blockchain’s shortcomings and potential remedies in the energy field, contributing a balanced perspective to the discourse on blockchain applications in energy systems.

Internet of Things and Data Mining: An Application-Oriented Survey (Sunhare, Chowdhary and Chattopadhyay, 2022)

This paper presents a systematic review of data mining techniques in large and small-scale IoT applications, emphasizing the transformation of vast data from IoT environments into valuable knowledge. It highlights the integration of IoT with cloud technologies and the role of data mining in intelligent decision-making and resource management, offering insights into the creation of intelligent environments and the importance of data mining in IoT.

A Study of Charging-Dispatch Strategies and Vehicle-to-Grid Technologies for Electric Vehicles in Distribution Networks (Mastoi *et al.*, 2023)

This article discusses electric vehicle (EV) charging and Vehicle-to-Grid (V2G) technologies, exploring their impact on energy distribution networks. It covers the benefits of V2G, such as power regulation and load balancing and addresses challenges like battery life and infrastructure changes. The study provides a comprehensive analysis of various EV charging-dispatch strategies and the implications of EV penetration on power systems, offering insights into battery degradation costs and peak capacity contributions from EVs.

BPPS: Blockchain-enabled Privacy-Preserving Scheme for Demand-Response Management in Smart Grid Environments (Park *et al.*, 2023)

Focusing on security in smart grid networks, this paper proposes a privacy-preserving authentication scheme called BPPS for demand response management. It addresses security issues in smart grids, offering a solution that achieves secure mutual authentication and integrity of data using blockchain. The paper includes both informal and formal security analyses and performance simulations, highlighting BPPS's suitability for real-world smart grid networks.

Blockchain Systems, Technologies and Applications: A Methodology Perspective (B. Cao *et al.*, 2023)

This article provides a comprehensive survey of blockchain from a methodological perspective, exploring its integration with various disciplines like mathematics and computer science. It discusses the application of methodologies like game theory and machine learning in blockchain systems and addresses technical, commercial and political challenges. This survey offers a roadmap for understanding blockchain processes and designing network services and algorithms for IoT applications.

A Survey on Vehicular Task Offloading: Classification, Issues and Challenges (Ahmed *et al.*, 2022)

This paper surveys vehicular task offloading techniques, focusing on the high computing demands of emerging vehicular applications. It classifies methods under V2V, V2I and V2X communication domains and analyses the literature from various perspectives, including approaches, objectives and performance. The paper highlights the challenges in vehicular task offloading and predicts future research trends, providing a comprehensive understanding of this evolving field.

Blockchain Technology for Distributed Generation: A Review of Current Development, Challenges and Future Prospect (Yap, Chin and Klemeš, 2023)

This comprehensive survey focuses on blockchain technology in distributed generation, addressing its applicability in vehicular task offloading. It examines methods under communication perspectives like V2V, V2I and V2X and categorizes them according to their objectives. The paper elaborates on the merits and demerits of these methods and presents open research challenges and future trends in vehicular task offloading.

State-of-the-Art Solutions of Blockchain Technology for Data Dissemination in Smart Cities: A Comprehensive Review (Mohd Shari and Malip, 2022)

Addressing the transition of smart cities to decentralized systems, this paper surveys blockchain technology's applicability in data dissemination. It focuses on smart city components like transportation and energy, analysing state-of-the-art work on blockchain integration. The paper discusses the advantages, performance efficiency, security and privacy issues and proposes a new framework for blockchain-based smart city data dissemination, highlighting open research issues and future directions.

Blockchain Technology Applied in IoV Demand Response Management: A Systematic Literature Review (Kapassa and Themistocleous, 2022)

This paper reviews blockchain applications in Internet of Vehicles (IoV) Demand Response Management (DRM), highlighting the role of blockchain in addressing challenges like incentivization and privacy. It emphasizes blockchain's potential in decentralized P2P energy trading within IoV, noting the early stage of research in this area and identifying future challenges and research directions.

Blockchain-Envisioned Access Control for Internet of Things Applications: A Comprehensive Survey (Bagga *et al.*, 2022)

This survey focuses on blockchain in IoT access control, detailing IoT architecture, security challenges and countermeasures. It categorizes access control mechanisms, analysing their implementation in various IoT applications like smart homes and healthcare. The paper also compares these mechanisms in terms of efficiency, highlighting open research issues in blockchain-based IoT networks.

Energy Trading Scheme Based on Consortium Blockchain and Game Theory (Chen *et al.*, 2023)

Addressing distributed energy trading, this paper proposes a scheme combining consortium blockchain and game theory. It focuses on P2P trading and security of transaction data, using game theory for transaction matching and benefit maximization. The scheme's security and effectiveness are validated, showing potential in distributed energy transaction scenarios.

A Blockchain-Based Authentication Scheme and Secure Architecture for IoT-Enabled Maritime Transportation Systems (Zhang *et al.*, 2023)

This study proposes a blockchain-based system for maritime transportation, addressing safety and reliability challenges in IoT-enabled Maritime Transportation Systems (MTS). It introduces a novel consensus mechanism for secure and efficient management, demonstrating its effectiveness in simulated environments and its potential to enhance security and transaction processing in MTS.

Blockchain Applications in Sustainable Smart Cities (Ullah *et al.*, 2023)

Investigating blockchain's role in sustainable smart cities, this paper reviews its applications in areas like food supply, healthcare and intelligent transportation. It provides a statistical study of selected articles, summarizing recent trends and challenges and discussing future research directions for blockchain in sustainable urban development.

Barriers to Blockchain-Based Decentralised Energy Trading: A Systematic Review (Karumba *et al.*, 2023)

This paper conducts a systematic review of challenges in integrating blockchain into Distributed Energy Trading (DET) systems. It proposes a conceptual framework for evaluating these challenges, focusing on technical, administrative and economic barriers and offering insights into potential solutions for advancing blockchain in DET markets.

Derived Blockchain Architecture for Security-Conscious Data Dissemination in Edge-Envisioned Internet of Drones Ecosystem (Singh, Aujla and Bali, 2022)

Addressing security in the Internet of Drones (IoD), this study proposes a derived blockchain architecture for secure data dissemination. It introduces a lightweight consensus mechanism and a branching concept to manage data storage and security challenges. The work is validated in a simulated environment, offering promising results in terms of security and efficiency.

A Survey of Cyber-Physical Systems from a Game-Theoretic Perspective (Tushar *et al.*, 2023)

This paper surveys cyber-physical systems (CPS) using a game-theoretic approach. It discusses different types of CPS and their characteristics, the relevance of game theory in modelling CPS and reviews the literature on this topic. The study identifies key research challenges and potential game theory applications in CPS.

An Efficient and Secure Energy Trading Approach with Machine Learning Technique and Consortium Blockchain (Ashfaq *et al.*, 2022)

Proposing a blockchain-based energy trading mechanism, this paper addresses challenges in vehicular energy networks (VEN). It introduces a demand-response pricing strategy and a branching concept for efficient communication and security in VENs. The paper validates the approach's effectiveness in reducing charging costs and time and enhancing security against attacks.

A Survey of Applications of Artificial Intelligence and Machine Learning in Future Mobile Networks-Enabled Systems (Yazici, Shayea and Din, 2023)

This survey explores AI and machine learning applications in systems enabled by future mobile networks. It provides an overview of use cases like intelligent transportation and smart energy, summarizing available studies and discussing challenges and future research directions in AI and machine learning applications in these areas.

Digital Twin-driven SDN for Smart Grid: A Deep Learning Integrated Blockchain for Cybersecurity (Kumar *et al.*, 2023)

This paper introduces a novel smart grid network design incorporating Digital Twin (DT) technology, Software-Defined Networking (SDN), Deep Learning (DL) and blockchain for enhanced cybersecurity. It focuses on creating secure communication channels and employing a DL architecture for improved attack detection, leveraging SDN for real-time services and DT for monitoring and communication with smart meters. The effectiveness is demonstrated through blockchain implementation and intrusion detection performance.

Vehicle to Everything in the Power Grid (V2eG): A Review on the Participation of Electric Vehicles in Power Grid Economic Dispatch (Ke *et al.*, 2022)

This review discusses the role of electric vehicles (EVs) in power grid economic dispatch through Vehicle to Everything in the Power Grid (V2eG) technology. It covers the application process, current research, modelling techniques and applications of V2eG in economic dispatch, including communication technologies, policies and electricity market access criteria. The paper also prospects future development directions of V2eG.

Blockchain-Enabled Internet of Vehicles Applications (Gao *et al.*, 2023)

This paper explores the application of blockchain in the Internet of Vehicles (IoV), focusing on creating a safe and reliable vehicle network. It reviews recent studies, summarizing and comparing them according to their purposes and discusses future trends and opportunities in blockchain applications within IoV.

IoT-Based Decentralized Energy Systems (Biegańska, 2022)

Focusing on the transition from traditional centralized to decentralized energy systems, this paper reviews the integration of renewable energy sources into the energy system, facilitated by advancements in digitalization, Industry 4.0 and IoT. It provides a bibliometric analysis-based review of current international research in this area.

Model-free Dynamic Management Strategy for Low-carbon Home Energy Based on Deep Reinforcement Learning Accommodating Stochastic Environments (Hou *et al.*, 2023)

This study presents a model-free dynamic management strategy for low-carbon home energy systems using deep reinforcement learning. It introduces a deep Q network algorithm for load modelling and multi-agent dynamic management, focusing on real-time energy management in stochastic environments. The strategy is verified to significantly reduce overall costs and user satisfaction penalties.

Blockchain-based Internet of Vehicles (BIoV): A Systematic Review of Surveys and Reviews (Hemmati, Zarei and Souri, 2023)

This article systematically reviews 28 survey articles from 2018 to 2022 on blockchain-based Internet of Vehicles (BIoV), investigating their aspects, contributions, findings and limitations. It offers a new taxonomy for BIoV, discusses security concerns and suggests open issues and future research directions.

Certifying Battery Usage for V2G and Second Life with a Blockchain-Based Framework (Augello *et al.*, 2023)

The paper describes a blockchain-based framework for data sharing in Vehicle-to-Grid programs, focusing on monitoring vehicle battery health and remuneration. It develops a platform and smart contracts for interaction among actors and battery usage profiling, enhancing the management of electric vehicles in grid services.

Towards Cyber Security for Low-Carbon Transportation: Overview, Challenges and Future Directions (Y. Cao *et al.*, 2023)

This review addresses the cybersecurity aspects of low-carbon transportation, categorizing typical attack risks and reviewing defence technologies from data, network management and application security perspectives. It outlines future research directions and concerns for the long-term development of low-carbon transportation security.

Blockchain-Based Co-Operative Caching for Secure Content Delivery in CCN-Enabled V2G Networks (Miglani and Kumar, 2023)

Proposing a CCN-based content delivery scheme for Vehicle-to-Grid networks, this paper introduces in-network caching, a contract theory-based incentive scheme and a proof of authority consensus algorithm for secure content delivery. It demonstrates the scheme’s superiority in reducing delay, increasing social welfare and enhancing throughput and latency compared to existing solutions.

2D2PS: A Demand-Driven Privacy-Preserving Scheme for Anonymous Data Sharing in Smart Grids (Chang, Li and Li, 2023)

This paper proposes 2D2PS, a privacy-preserving scheme for smart grids, enhancing anonymity and fine-grained access control in electricity consumption data sharing. It introduces an authenticable pseudonym method and a proxy re-encryption technique, along with a data separation algorithm. The scheme’s effectiveness in ensuring privacy and authentication is demonstrated through simulations.

A Blockchain-Based Approach for Demand Response Management in Internet of Vehicles (Kapassa, Touloupou and Christodoulou, 2022)

The paper explores a blockchain-based framework for Demand Response (DR) management on the Internet of Vehicles (IoV). It addresses decentralized energy trading, charging scheduling and incentives for driver participation in IoV-assisted smart cities, proposing a system for optimal energy trading and vehicle-to-vehicle/grid interactions.

Smart Automotive Diagnostic and Performance Analysis Using Blockchain Technology (Yassin, Aslan and Abdel Halim, 2023)

This study introduces a blockchain-based system for remote vehicle diagnostics, providing a secure way to store and verify vehicle data. It evaluates the system's performance using MATLAB Simulink and OMNET++, focusing on throughput, end-to-end delay and power consumption and offering a scalable and adjustable solution for vehicle manufacturers.

Smart and Sustainable Cities in Collaboration with IoT: The Singapore Success Case (Ferro-Escobar, Vacca-González and Gómez-Castillo, 2022)

This chapter discusses the role of IoT in smart and sustainable cities (SSC), examining Singapore's approach to integrating smart mobility, energy efficiency and health using IoT and other technologies. It provides a comparative analysis of SSC concepts, highlighting advantages, challenges and adaptability in the context of urban resilience.

Privacy-Preserving and Traceable Blockchain-Based Charging Payment Scheme for Electric Vehicles (Wu, Zhang and Zhu, 2023)

Focusing on EV charging payment scenarios, this article proposes a blockchain-based scheme that ensures user privacy and transaction unlikability, while allowing traceability in abnormal situations. Theoretical and experimental analyses confirm the scheme's effectiveness in protecting privacy, reliability, authentication and efficiency.

Secure and Robust Demand Response Using Stackelberg Game Model and Energy Blockchain (Samadi *et al.*, 2023)

This paper uses energy blockchain and a mixed-strategy stochastic game model for secure and robust demand response in smart grids. It incorporates IoT devices, validates performance using real datasets and shows the impact of EV discharging and customer demand reduction on successful block mining and customer profits.

Systematic Analysis of the Blockchain in the Energy Sector: Trends, Issues and Future Directions (Ma *et al.*, 2023)

Conducting a qualitative and quantitative analysis of 622 articles, this study explores blockchain's integration in the energy sector. It identifies technical paths, thematic trends and highlights the need for addressing technology's negative impacts, such as regulatory lag and high energy consumption.

Electric Vehicle Energy Trading Framework in V2G Network Based on Blockchain (Fang *et al.*, 2022)

This paper proposes a blockchain-based framework for decentralized energy trading in V2G networks, utilizing a reverse auction mechanism for dynamic pricing. It aims to maximize the income of charging and discharging vehicles and the feasibility and performance of the model are validated through simulations on the Ethereum platform.

Implications of Recent Findings on the Current Study:

The recent advancements in blockchain technology, as highlighted in the newly identified papers, resonate significantly with the objectives and challenges identified in the current research. The growing incorporation of decentralized energy resources, particularly EVs, into the smart grid, as described in the newly introduced studies, underlines the need for robust DRM systems, a core focus of this thesis. Additionally, the surveyed papers collectively underscore the potential of blockchain technology in enhancing the security, privacy and efficiency of DRM systems, aligning with the challenges this research currently identifies.

Specifically, the new findings have the following implications for the research presented in this thesis:

- The new findings in blockchain applications for enhanced privacy and security in IoV align with the privacy and security challenges identified in this thesis. The new findings offer potential solutions and support that there is still a significant need for practical ways that address these challenges.
- Recent papers provide insights into efficient energy management and balancing using blockchain. However, the dynamic and highly decentralized nature of IoV energy systems means that this remains an evolving field requiring continuous exploration, especially in real-world settings.
- The new literature provides examples of possible blockchain-based incentive models. These models serve as practical examples that may validate the proposed conceptual model of this study. However, the practical implementation and

effectiveness of these incentive mechanisms in large-scale, real-world IoV ecosystems remain areas for further empirical research.

- Recent studies do not highlight user-centric approaches and the importance of personalized charging schedules. Therefore, the comprehensive development and integration of personalized strategies within the broader IoV ecosystem still require empirical validation.
- The integration of blockchain in smart city initiatives, as explored in the new literature, aligns with the broader implications of the current research. These findings expand the potential application of this study, demonstrating its relevance in a wider context.

Justification of Ongoing Relevance and Validity of the Current Study:

The recent scholarly developments in blockchain technology, specifically in the IoV and DRM, underscore the ongoing relevance and necessity of the current study. The issues and research gap noted in this thesis have not been addressed by the recent studies (i.e., between 2022 and 2023) despite their undeniably contributions and innovative approaches.

Firstly, the concerns regarding privacy and security in IoV ecosystems (Research Challenge 1), while investigated through enhanced privacy-preserving schemes and secure blockchain-based systems, continue to pose significant challenges. The complexity of ensuring complete data protection in decentralized environments like IoV is far from resolved, highlighting the need for continued exploration and refinement of privacy solutions.

Secondly, the intricacies of energy generation and consumption within IoV (Research Challenge 2) have been further illuminated by recent studies. However, the dynamic nature of decentralized energy systems in IoV means that this remains an evolving and critical area of research. New insights into efficient energy management and balancing, while valuable, underscore the necessity for ongoing empirical research to adapt these findings to real-world, scalable IoV ecosystems.

Regarding the lack of adequate incentive mechanisms for EVs with surplus energy (Research Challenge 3), the introduction of tokenized incentive models in recent literature presents promising directions. Yet, the practicality, effectiveness and broader implications of these incentives within large-scale IoV networks are still under-explored.

Furthermore, the most recent studies confirm the necessity of personalized EV charging strategies (Research Challenge 4). While these studies support the importance of user-centric approaches, comprehensive development and integration of these strategies within IoV systems are not yet realized in practice. This gap in practical application and empirical validation directly aligns with the thesis’s focus.

Thus, the research gap — *the full exploitation of IoV’s potential in facilitating efficient and sustainable energy management via blockchain technology* — remains relevant. The recent literature contributes to this field but is limited at offering comprehensive empirical evidence on the real-world effectiveness of blockchain-based DRM in IoV. This gap underscores the need for the current study, which aims to close this gap by offering empirical perspectives on the usefulness and practical application of blockchain enabled DRM in IoV.