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METHODOLOGY

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Ecosystem-driven business opportunity identification method and web-based tool with a case study of the electric vehicle home charging energy ecosystem in Denmark

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Abstract

Understanding the local needs and challenges is critical for technology adoption in the energy sector. However, it is still a big challenge for most ecosystem stakeholders. Furthermore, technology adoption theories have mainly focused on the technology itself, and the business ecosystem perspective has been neglected. Therefore, this paper proposes an ecosystem-driven business opportunity identification method, a systematic approach for ecosystem stakeholders to conduct business opportunity analysis and evaluation based on the CSTEP ecosystem analysis and evaluation method. This method includes four correlated steps: Step 1: Identify the five CSTEP dimensions of the business ecosystem; Step 2: Identify potential changes in the business ecosystem; Step 3: Identify future ecosystem trends and timeline; Step 4: Select business opportunities; and Step 5: Potential solution identification. A web-based tool called opportunity identifier is developed for implementing the proposed method. A case study of the electric vehicle (EV) home charging energy ecosystem in Denmark is applied and demonstrates the application of the proposed method and the implementation of the developed web-based tool. Three value propositions are identified in the case study: (1) EV users can have optimal EV charging cost and optimal CO2 emission consumption with the intelligent EV charging algorithms that consider electricity prices, tariffs, and CO2 emission; (2) DSOs can avoid grid overloads and postpone the grid upgrade by applying intelligent EV charging algorithms; (3) Independent aggregators can aggregate EVs and participate in the ancillary service market or provide Vehicle-to-Grid services by using intelligent EV charging algorithms. Moreover, three feasible decentralized EV charging strategies (Real Time Pricing, Time-of-Use Pricing, and Timed charging) are identified as the potential solutions targeting the first value proposition.

Keywords: Energy ecosystem, CSTEP ecosystem impact factors, Business opportunity, Electric vehicle, Future trend, Ecosystem stakeholder

Introduction

Undoubtedly, understanding the local needs and challenges is the first and most crucial stage for the success of any implementation, especially in the energy sector. Business opportunities come from needs and challenges in the existing markets and trends towards the transition to future markets. Companies need to capture opportunities and predict when the market will have the needs. However, although companies realize the importance of the above matters and try to improve the situation, it is still a big challenge for most companies.

In recent years, ecosystem thinking has been popularly used for investigating complex systems from a business perspective. The use of 'ecosystem' in business has started since the term 'business ecosystem' was introduced in 1993 (Moore 1993) to describe how the economic community works. Without ecosystem thinking, companies mainly focus on developing customer insight, building core competencies, and beating the competition. In the business ecosystem domain, the evolution/co-evolution perspective is rarely discussed, although there are discussions in, e.g., system thinking (Rubenstein-Montano et al. 2001); furthermore, there is no systematic approach for investigating unmet needs and megatrends in a given business ecosystem.

Technology and innovation adoption has been well discussed in the literature, and several popular technology adoption models are proposed, e.g., Rogers' adoption curve (Rogers 2003). The technology adoption theories try to understand the adoption behaviors toward new technologies, especially behaviors and constructs during the decision process. However, technology adoption theories have mainly focused on the technology itself, the adoption process and influential factors for decision making, and the business ecosystem perspective has been neglected.

Some theories in strategy management, such as ETPS (Economic, technical, political, and social; Aguilar 1967), STEP (Social, technical, economic, political; Brown and Weiner 1984), and STEPE (Social, technical, economic, political, and ecological; Davenport and Prusak 1997), intend to investigate the impact factors in business and strategies. However, the main focus is personal or organizational.

Therefore, this paper proposes a method for identifying business opportunities based on the theories of business ecosystem modelling (Ma 2019), ecosystem architecture design (Ma et al. 2021), and CSTEP-the five business ecosystems dimensions (Ma 2022). Furthermore, the proposed method is implemented as a web-based tool (called 'business opportunity identifier') to be applied in research and teaching.

A case study of the electric vehicle (EV) home charging energy ecosystem in Denmark is chosen to demonstrate the application of the method with a complex ecosystem impacted by all the five CSTEP business ecosystem dimensions. The electric vehicle home charging energy ecosystem is chosen because there potentials for EVs to provide energy flexibility due to their larger energy consumption compared to other home appliances (Ma et al. 2018a; Howard et al. 2020) and the potential flexibility due to intelligent EV charging algorithms (Billanes et al. 2017, 2018). However, EV home charging usually involve multiple stakeholders from both energy and EV ecosystems which potentially causes high uncertainty (Ma et al. 2015, 2017a).

Table 1 Business ecosystem life cycle by Moore (1996)

Stage	Definition
Pioneering (Vision)	When the basic paradigm of the ecosystem is being worked out
Expansion (with the goal of market domination)	When the community broadens its scope and consumes resources of all types
Authority (and the inevitable challenges to authority	When the community architecture becomes stable and competition for leadership and profits within the ecosystem gets brutal
Renewal (or death)	When continuing innovation must take place for the community to survive or die

Table 2 Three types of roles in business ecosystems

Ecosystem role	Definition	Refs.
Keystone specie	Is simply a species that governs the most important ecosystem health through specific behaviours or features that have effects that propagate through the entire system, often without being a significant portion of the ecosystem itself. Removal of biological keystones can have dramatic cascading effects through the entire ecosystem	Levien (2004)
Dominator	Integrates vertically or horizontally to own and manage a large part of its network directly and seizes a greater part of the value	Iansiti and Levien (2004)
Niche players	Develop specialized capabilities to add value to a business ecosystem. Niche species individually do not have broad-reaching impacts on other species in the ecosystem, but collectively they constitute the bulk of the ecosystem both in terms of total mass as well as a variety	Levien (2004)

Background

Business ecosystem theory

The term of ecology was introduced by Haeckel in 1866 as the science of relations between organisms and the surrounding outer world (Haeckel 1866). Accordingly, based on ecology and observations of how biological organisms function, the ecosystem considers nature, society and business as integrated from a system's perspective (Capra and Luisi 2014). In general, an ecosystem is a system with thousands of organisms that live in a constant relationship with their environment, the members benefit from each other's participation through symbiotic relationships, and relationships also develop among them (Maracine and Scarlat 2008).

Business ecosystems are analogous to biological ecosystems. In 1993, Moore (1993) uses biological metaphors and introduces the business ecosystem concept. Moore describes how the economic community works and highlights the interaction between companies and their business environment. Moore (1996) divides the business ecosystem into four stages for analysis and management (the definition is shown in Table 1). These four stages represent the business ecosystem life cycle.

Following Moore's definition, (Iansiti and Levien 2002) describes the business ecosystem as a large number of loosely interconnected participants who depend on each other for mutual effectiveness and survival. Iansiti and Levien (2004) introduces a framework for studying and understanding innovation and operations management in business ecosystems. They define specific indicators of ecosystem structure and develop specific operational implications for different types of ecosystem roles and corresponding strategies as dominator, keystone, and niche firms (the definitions are shown in Table 2; Levien 2004).

Among many definitions in the literature, there are three key phases in the business ecosystem defined as the community of interdependent organizations, business environment (opportunity space), platform and co-evolution (the definitions are shown in Table 3; Rong and Shi 2015).

Besides the discussion of the business ecosystem by Moore (1993, 1996); Iansiti and Levien 2002, 2004) and (Power and Jerjian 2001), there are other ecosystem analogies discussed in the literature, e.g., service ecosystem, digital business ecosystem (Peltoniemi and Vuori 2004), IT/Technology ecosystem (Iansiti and Richards 2006; Adomavicius et al. 2006), platform ecosystem (Ceccagnoli et al. 2012; Parker et al. 2016; Gawer and Cusumano 2014), digital ecosystem (Cliff and Grand 1999; Iyawa et al. 2016), innovation ecosystem (Adner 2006; Oh et al. 2016). Some popular definitions are listed in Table 4.

Other ecosystem analogies used regularly in academic research and business practice have been discussed as the customer ecosystem that focuses on the customer views of the business ecosystem, e.g., (Ma et al. 2017b;; Manning et al. 2002), the organizational ecosystem that emphasizes the aspect of human organizational structures (Mars et al. 2012), and product ecosystem that denotes "the consideration of multiple related products in a coherent process, compared with the conventional viewpoint of static, isolated products" (Zhou et al. 2011).

Although a large amount of literature has discussed and analyzed the business ecosystem structure, no systematic approach has been proposed. Therefore, (Ma 2019) proposes a framework for business ecosystem modeling based on the combined theories from system engineering, ecology, and business ecosystem. This framework includes three parts of business ecosystem architecture development: factor analysis, ecosystem simulation, and reconfiguration. Based on the work by Ma (2019), a methodology for business ecosystem architecture design with the business ecosystem ontology is introduced by Ma et al. (2021). Several business ecosystem architecture terms are defined in Ma et al. (2021). This methodology has been popularly applied in the energy field. For instance, (Ma et al. 2019a) applies the method to investigate microgrid solutions for reliable power supply in India's power system, and (Hack et al. 2021) investigate the digitalization potentials in the electricity ecosystem in Germany and Denmark.

Table 3 Three key phases in the business ecosystem (Rong and Shi 2015)

Phase	Definition
Community of interdependent organization	It means the relationship among network partners is dependent on one another and share in a common fate
Business environment	It can be treated as an opportunity space where interdependent organizations share their ideas and visions for future development. It means that organizations in a business ecosystem should expand their views beyond the supply-chain partners of their core business. The business environment includes other non-direct business partners who shape the industry greatly and the business environment
Co-evolution	It means that interdependent organizations will co-evolve with one another in the dynamic business environment. Co-evolution highlights the importance of key firms' interactions with their business environment as well as with core business partners

Table 4 Definitions of various ecosystem analogies

Term	Definition	Refs.
Digital business ecosystem	'Constructed when the adoption of internet-based technologies for business is on such a level that business services and the software components are supported by a pervasive software environment, which shows an evolutionary and self-organizing behaviour'	Peltoniemi and Vuori (2004)
IT/ Technology ecosystem	The network of organizations that drives the delivery of information technology products and services	Iansiti and Richards (2006), Adomavicius et al. (2006)
Platform ecosystem	The network of innovation to produce complements that consummate matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants Four types: technological platforms within firms, platforms across supply chains, multi-sided markets and industry-wide platforms	Ceccagnoli et al. (2012), Parker et al. (2016), Gawer and Cusumano (2014), Tanev et al. (2010)
Digital ecosystem	A network of digital communities consisting of interconnected, interrelated and interdependent digital species, including stakeholders, institutions and digital devices situated in a digital environment, that interact as a functional unit and are linked together through actions, information and transaction flows	Iyawa et al. (2016)
Innovation ecosystem	The complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation	Oh et al. (2016)

Business ecosystem dimensions

In the framework for studying and understanding the management of innovation and operations in business ecosystems proposed by Iansiti and Levien (2004), the indicators of the ecosystem structure 'health' is defined with three dimensions:

- Robustness: a business ecosystem's capability of facing and surviving perturbations and disruptions.
- Productivity: how effectively does the ecosystem convert raw materials into living organisms.
- Niche creation: the ecosystem's capacity to create new valuable niches. It refers to the capacity to increase meaningful diversity over time by creating new valuable functions.

The measures for the three dimensions are also proposed by Iansiti and Levien (2002) as shown in Table 5.

However, the three dimensions proposed by Iansiti and Levien (2002) only focus on the business aspect of a business ecosystem and do not cover all aspects. For instance, in an energy business ecosystem, the climate is an important dimension that impacts the energy production (e.g., wind energy or solar power), and all

Table 5 The measures of robustness, productivity, and niche creation proposed by Iansiti and Levien (2002)

Dimension	Measure	Description
Robustness	Survival rates	Ecosystem participants enjoy high survival rates, either over time, or relative to other, comparable ecosystems
	Persistence of ecosystem structure	Changes in the relationships among ecosystem members are contained; overall the structure of the ecosystem is unaffected by external shocks. Most connections between firms or between technologies remain
	Predictability	Change in ecosystem structure is not only contained, it is predictably localized. The locus of change to ecosystem structure will differ for different shocks, but a predictable "core" will generally remain unaffected
	Limited obsolescence	There is no dramatic abandonment of "obsolete" capacity in response to a perturbation. Most of the installed base or investment in technology or components finds continued use after dramatic changes in the ecosystems environment
	Continuity of use experience and use cases	The experience of consumers of an ecosystem's products will gradually evolve in response to the introduction of new technologies rather than being radically transformed. Existing capabilities and tools will be leveraged to perform new operations enabled by new technologies
Productivity	Total factor productivity	Leveraging techniques used in traditional economic productivity analysis, ecosystems may be compared by the productivity of their participants in converting factors of production into useful work
	Productivity improvement over time	Do the members of the ecosystem and those who use its products show increases in productivity measures over time? Are they able to produce the same products or complete the same tasks at progressively lower cost?
	Delivery of innovations	Does the ecosystem effectively deliver new technologies, processes, or ideas to its members? Does it lower the costs of employing these novelties, as compared with adopting them directly, and propagate access to them widely throughout the ecosystem in ways that improve the classical productivity of ecosystem members?
Niche creation	Variety	The number of new options, technological building blocks, categories, products, and/ or businesses being created within the ecosystem in a given period of time
	Value creation	The overall value of new options created

segments in the energy supply chain, e.g., the lighting, heating, or cooling at the consumption side. Therefore, (Ma 2022) proposes five critical business ecosystem dimensions called CSTEP for systematically understanding a targeted business ecosystem (as shown in Table 6). Furthermore, each dimension consists of several sub-dimension and macro and micro levels (as shown in Table 7). Various energy ecosystem cases have applied the CSTEP, e.g., microgrids (Ma et al. 2018b) and distribution tariffs (Christensen et al. 2021).

Table 6 Definitions of CSTEP five dimensions (Ma 2022)

Dimension	Sub-dimension	Explanation
Climate, environmental and geographic situation	Climate	The general weather (including seasons) conditions that are usually found in a particular place;
	Environment	The conditions that people live, work or spend time in and the way that they influence how they feel, behave or work;
	Geographic situation	The natural features of a place, such as mountains and rivers
Societal culture, demographic environment	Societal culture	The way of life or work, especially the general customs and beliefs, of a society or an organization;
	Demographic environment	The demography of an area is the number and characteristics of the people who live in an area, in relation to their age, sex, if they are married or not, etc.
Technology readiness	Infrastructure	The basic systems and services, such as transport and power supplies, that a place uses in order to work effectively
	Technology development capacity	The set of capacities to plan for technology transfer and development to achieve regional and national goals
	Technology maturity	Refer to the Technology Readiness Levels (TRL) for assessing the maturity level of a particular technology
	Technological skills	The knowledge and expertise needed to accomplish complex actions, tasks and processes relating to computational and physical technology
Economy and Finance	Economy	Economy relating to market trade, industry
	Finance	Cost of labour, material, maintenance, and service Revenue from sales, income, compensation, Return-on-Investment
Policies and regulation	Policies	the activities of the government, members of law-making organizations, or people who try to influence the way a country is governed;
	Regulation	An official rule or the act of controlling something

Technology adoption theories and models

The innovation adoption theory is firstly introduced by Rogers in 1960, in his publication called "Diffusion of Innovation Theory" (Rogers 1962). This theory's essential elements are the S-shaped (logistic function) shown in Fig. 1 and the adoption rate curve shown in Fig. 2.

Additional technology adoption theories and models have been addressed for many years. The theory tries to describe the adoption behavior toward new technology. Understanding and knowing such behavior can help develop business models aiming to achieve a fast and/or high adoption. In total, 30 technology adoption theories are identified from the literature (Gangwar et al. 2014; Taherdoost 2018; Sharma and Mishra 2014; Lai 2017; Oliveira and Martins 2011; Maryam Salahshour et al. 2018; Molinillo and Japutra 2017; Qayyum and Ali 2012) and shown in Table 8. Among the 30 theories, the main focuses of the most popular discussed technology adoption theories are summarized as shown in Table 9 based on the discussion in Taherdoost (2018) (Sharma and Mishra 2014; Lai 2017).

Furthermore, many constructs in the technology adoption theories have been identified and discussed in the literature, as shown in Table 10. The application of these

Table 7 Macro and micro levels of the five CSTEP dimensions

Dimension	Macro-level	Micro-level
Climate, environmental and geographic situation	Climate and geographic situation: the general weather conditions and the natural features of a place, e.g • Nature resources (e.g., wind, solar, natural gas) • Natural disasters (e.g., earthquakes, tsunamis) • Climate zone	Environment: the living, working or production environment or conditions e.g., • Temperature • Humidity • Lighting • CO_2, • Noise, TVOC, PM2.5, etc • Pollution
Societal culture, demographic environment	Demographic environment: the demography of an area is the number and characteristics of the people who live in an area, in relation to their age, sex, if they are married or not, etc. E.g., • Population • Gender equality • Public safety • Societal stability • Corruption • Cultural dimension • Social relations • Education	Societal culture: organizational/ market/ sectorial interests, concerns, beliefs, e.g., • Convenience • Uncertain avoidance • Cost–benefit acceptance • Social/ environmental welfare, security (e.g., environmental concern)
Technology (Infrastructure, facilities, technological skills, technology readiness)	Infrastructure: the basic systems and services, such as transport and power supplies, that a place uses to work effectively; Technology development capacity: The set of capacities to plan for technology transfer and development to achieve regional and national goals	Technology Readiness Levels (TRL) for assessing the maturity level of a particular technology (NASA 2021) Technological skills: the knowledge and expertise needed to accomplish complex actions, tasks and processes relating to computational and physical technology
Economy and Finance	Economy relating to market, trade, and industry, e.g. • Employment rate • Living costs • Investments • Growth rate • Financial stability • Inflation rate	• Cost, e.g., energy bill, labour, material (e.g., resources, raw material), maintenance (e.g., facilities), and service fees • Revenue, e.g., sales, income, compensation, Return-on-Investment
Policies and regulation	Polices: the activities of the government, members of law-making organizations, or people who try to influence the way a country is governed, e.g., • Climate agenda/ goals • Political focus areas	Regulation: an official rule or the act of controlling something, e.g. • Laws • Regulations • Incentive/compensation scheme

constructs in the technology adoption decision processes can be divided into "before adoption," "adoption decision," and "after the decision," as shown in Table 11.

Technology adoption has been applied in the energy domain with several focuses. For instance, Ma et al. (2018c) identifies influential factors for Industrial consumers to adopt smart grid concept. Ma et al. (2019b) conducts a survey to investigate demand response control preferences, stakeholder engagement, and cross-national differences for retail stores' demand response adoption. Furthermore, technology evaluation and adoption of energy related solutions has been conducted with modeling and simulations, and applied for both energy efficiency (Christensen et al. 2020a, 2019) energy flexibility (Værbak et al. 2019; Christensen et al. 2020b), and CO2 emission reduction (Christensen et al. 2020c).

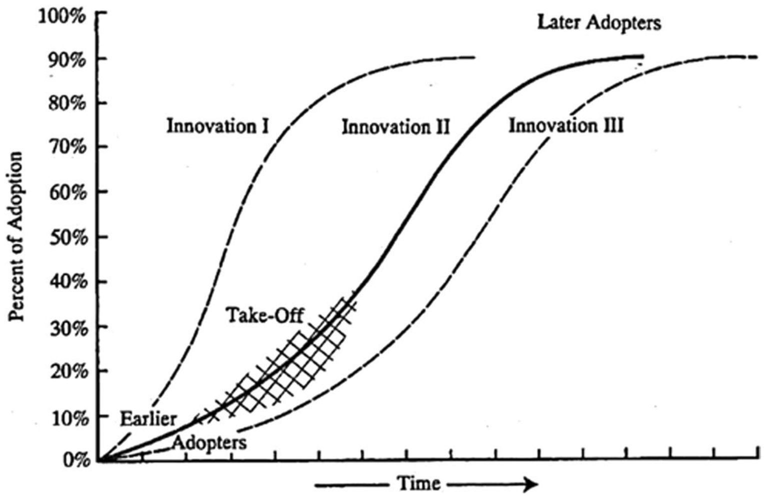


Fig. 1 Rogers' S-shaped adoption curve (Rogers 2003)

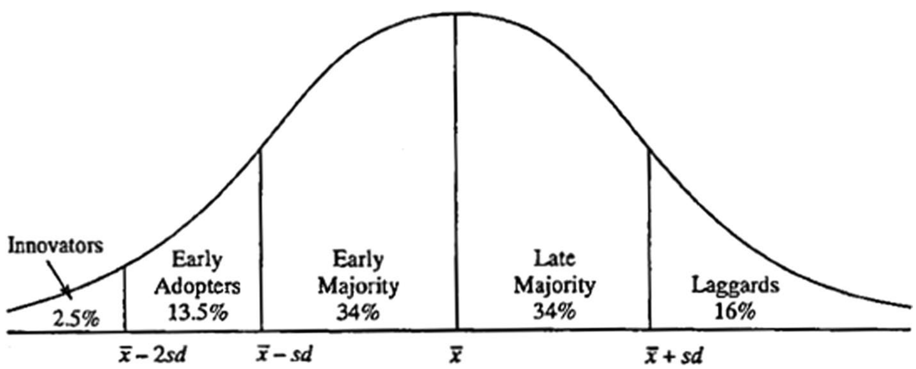


Fig. 2 Rogers' adoption rate curve with adopter categorization (Rogers 2003)

Methodology

To identify business opportunities in a business ecosystem, it is essential to clarify two terms unmet needs and megatrends that trigger the potential changes in a business ecosystem:

- *Unmet needs* usually indicate needs, demands, or challenges that have not yet been met or solved in the current business ecosystem. The unmet needs are usually related to climate (climate changes) or economic challenges in the energy ecosystems, e.g., electricity supply for the inhabited islands in Indonesia.
- *Megatrends* usually indicate how a business ecosystem evolves and how the future of the targeted business ecosystem will look. Megatrends are usually due to political goals (e.g., climate neutrality in 2050 in Denmark), advanced technologies (e.g., digitalization), or society's willingness in industrial ecosystems. Megatrends can help to understand what future ecosystems look like. There might be several or many megatrends in an ecosystem. The application of CSTEP can facilitate the evaluation of these future trends and the selection of the most potential ones for development.

Table 8 Technology adoption theories in the literature

Model/theory	Author and year	Refs.
Diffusion of Innovation Theory	Rogers (1960)	Rogers (1962)
Inter-organizational relationship theory	Clark (1965)	Clark (1965)
Flow theory	Csikszentmihalyi (1975)	Play and Rewards (1975)
Theory of Reasoned Action	Fishbein and Ajzen (1975)	Ajzen and Fishbein (1975)
Expectation confirmation theory	Oliver (1977)	Oliver (1977)
Theory of Interpersonal Behavior	Triandis (1977)	Triandis (1977)
Social identity theory	Tajfel (1978)	Tajfel (1978)
Institutional theory	DiMaggio and Powell (1983)	DiMaggio and Powell (1983)
Theory of Planned Behaviour	Ajzen (1985, 1991)	Ajzen (1985, 1991)
The Social Cognitive Theory	Bandura (1986)	Bandura 1986)
Perceived value model	Zeithaml (1988; 1988)	Zeithaml (1988, 1988)
Social capital theory	Coleman (1988)	Coleman 1988)
Technical/Technology Adoption/acceptance Model	Fred D Davis et. al. (1986, 1989, 1996)	Davis (1989; Davis and Venkatesh 1996; , 1986)
Technology–organization–environment framework	Tornatzky and Fleischer (1990)	Tornatzky et al. 1990)
Perceived Characteristics of Innovating Theory	Moore and Benbasat (1991)	Moore and Benbasat 1991)
The Model of PC Utilization	Thompson et. al. (1991)	Thompson et al. 1991)
The Motivation Model	Davis et al. (1992)	Davis et al. 1992)
Big Five theory	Tupes and Christal (1992)	Tupes and Christal (1992)
Delone and McLean IS success model	DeLone and McLean (1992)	DeLone and McLean (1992)
Igbaria's Model	Igbaria et Al. (1994)	Igbaria et al. (1994)
Task technology fit model	Goodhue and Thompson (1995)	Goodhue and Thompson (1995)
Decomposed Theory of Planned Behaviour	Taylor and Todd (1995)	Taylor and Todd (1995)
Trust model	Kipnis (1996)	Kipnis (1996)
Extended Technology Adoption Model 2	Venkatesh and Davis (2000)	Venkatesh and Davis (2000)
Uses and Gratification Theory	Ruggiero (2000)	Ruggiero (2000)
Unified Theory of Acceptance and Use of Technology	Venkatesh (2003)	Venkatesh et al. (2003)
Compatible UTAUT	Bouten (2008)	Bouten 2008)
Extended technology acceptance model	Venkatesh and Bala (2008)	Venkatesh and Bala (2007)
Model of Acceptance with Peer Support (MAPS)	Sykes et al. (2009)	Sykes et al. (2009)
Unified theory of acceptance and use of technology	Venkatesh et al. (2012)	Venkatesh et al. (2012)

Four steps in the ecosystem-driven business opportunity identification method are designed for the investigation of business opportunities in the targeted business ecosystem, and each step includes several sub-steps (as shown in Fig. 3):

Step 1: Identify the CSTEP dimensions of the current business ecosystem.

Step 2: Identify potential changes in the business ecosystem.

Step 3: Identify future ecosystem trends and timeline.

Step 4: Select business opportunities.

Step 5: Potential solution identification.

Table 9 The main focuses of the most popular technology adoption theories

Model/theory	Main focus	Author and year	Refs.
Diffusion of Innovation Theory	• Four elements that influence the spread of a new idea • The diffusion process • Six categories of users	Rogers (1960)	Rogers (1962)
Theory of Reasoned Action	• Three general constructs • Behaviour explained from figure and table	Fishbein and Ajzen (1975)	Ajzen and Fishbein (1975)
Theory of Planned Behaviour	• Adds a construct to the TRA • The new construct is explained in table	Ajzen (1985, 1991)	Ajzen 1985; Ajzen 1991)
The Social Cognitive Theory	• Focus on self-efficacy • Behaviour of the user is influenced by expectations of outcome related to personal as well as performance-related gains	Bandura (1986)	Bandura 1986)
Technical/Technology Adoption/acceptance Model	Two constructs to predict technologies adoption	Fred D Davis et. al. (1989)	Davis (1989)
The Model of PC Utilization	• Primarily deals with extend of utilization of a PC by a worker • Behaviour affecting by several factors (see figure)	Thompson et. al. (1991)	Thompson et al. (1991)
The Motivation Model	• Study for IT adoption and use • Extrinsic and intrinsic motivation for shaping the behavior	Davis et al. (1992)	Davis et al. (1992)
Extended Technology Adoption Model 2	TAM with additional constructs	Venkatesh and Davis (2000)	Venkatesh and Davis (2000)
Unified Theory of Acceptance and Use of Technology	Four key constructs affecting the acceptance and use of technology	Venkatesh (2003)	Venkatesh et al. (2003)

Step one: Identify CSTEP dimensions for the current business ecosystem

To identify related CSTEP dimensions in a business ecosystem, firstly, it is necessary to investigate CSTEP dimensions to the related actors and objects in the defined business ecosystem, as shown in Table 12. The relevant value chain segments, actors and objects can be identified and listed during the business ecosystem architecture development introduced by Rogers (2003). However, not all actors and objects are relevant to the evolution of the ecosystem.

For instance, in the EV home charging energy ecosystem (presented in the case study section), there is an actor called electricity supplier. The electricity supplier buys electricity from the electricity markets and is obliged to supply all household customers with electricity with a payment. However, this is not relevant to the evolution of the EV home charging energy ecosystem. Therefore, to reduce the analysis workload, this step should focus on the critical actors and objects relevant to the ecosystem's evolution.

Based on the result of Table 12, the current business ecosystem condition can be further described in detail (as shown in Table 13). Meanwhile, it is important to analyze the ecosystem conditions with references. The investigation of the regulations at the

Table 10 Definition of the identified constructs in the technology adoption theories

Construct	Definition	Author and year
Affect Towards Use	"Feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act."	(Thompson, 1991)
Intrinsic motivation	"if performing an activity leads to a feeling of pleasure and results in satisfaction for the individual, such behaviour can be classified as intrinsic motivation."	(Davis, 1992)
Affect	"Positive contribution is made by the factor "affect" which is the extent to which an individual likes his job."	(Bandura, 1986)
Anxiety	"Negative contribution to desired behaviour is made by the factor "anxiety" which is the anxious reaction of the person while performing a job such as trying to use a computer with which the person is not very familiar."	(Bandura, 1986)
Facilitating conditions	"Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system."	(Venkatesh 2003)
Result demonstrability	"tangibility of the results of using the innovation."	(Venkatesh and Davis, 2000)
Long-term consequences	"Outcomes that have a pay-off in the future."	Thompson, (1991)
Subjective norm	Person's perception that most people who are important to him think he should or should not perform the behaviour in question	Venkatesh and Davis (2000)
Image	"the degree to which use of an innovation is perceived to enhance one's... status in one's social system"	Moore and Benbasat (1991)
Social influence	Social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system	Venkatesh and Davis (2000)
Social factors	"Individual's internalization of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations."	Thompson et. al. (1991)
Perceived usefulness	The degree to which a person believes that using a particular system would enhance his or her job performance	Fred D Davis et. al. (1989)
Perceived ease of use	The degree to which a person believes that using a particular system would be free of effort	Fred D Davis et. al. (1989)
Job relevance	Defined as an individual's perception regarding the degree to which the target system is applicable to his or her job. Regarded as cognitive judgment that exerts a direct effect on perceived usefulness, distinct from social influence processes	Venkatesh and Davis (2000)
Output quality	Output quality measures perception of how well the system performs the job related tasks	Davis et al. (1992)
Performance expectancy	Performance expectancy is defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance	Venkatesh (2003)
Effort expectancy	Effort expectancy is defined as the degree of ease associated with the use of the system	Venkatesh (2003)
Attitudes	"Sum of beliefs about a particular behaviour weighted by evaluations of these beliefs"	Ajzen (1991)
Perceived behavioural control	"people's perception of the ease or difficulty of performing the behaviour of interest"	Ajzen (1991)
Job-fit	"The extent to which an individual believes that using a technology can enhance the performance of his or her job."	Thompson et. al. (1991)

Table 10 (continued)

Construct	Definition	Author and year
Complexity	"The degree to which an innovation is perceived as relatively difficult to understand and use."	Thompson et. al. (1991)
Extrinsic motivation	the perception that users want to perform an activity "because it is perceived to be instrumental in achieving valued outcomes that are distinct from the activity itself, such as improved job performance, pay, or promotions". Examples of extrinsic motivation are perceived usefulness, perceived ease of use, and subjective norm	Davis et al. (1992)
Self-efficacy	"the judgments of how well one can execute courses of action required to deal with prospective situations."	Venkatesh (2003)

P-dimension can help to understand the current ecosystem condition, and the policies will later be used for understanding the future business ecosystem. The main difference between Tables 12 and 13 is: Table 12 is from the individual ecosystem elements' perspective, and Table 13 is from the relevance of the ecosystem perspective.

Step two: Identify potential changes in the business ecosystem

To identify potential changes in the business ecosystem, step two is divided into two sub-steps:

1. Identify political or business statements critical to the business ecosystem
2. Portray future ecosystem condition

- Sub-step 1: Identity political or business statements critical to the business ecosystem

  Although some policies related to the identified actors and objects are investigated in Step one, the policies related to the future ecosystem conditions are not completed. Therefore, it is necessary to investigate and identify political or business statements critical to the business ecosystem.

  The transformation of a business ecosystem is usually strongly influenced by the ecosystem dominators, e.g., governmental authorities or leading companies. For instance, energy-related business ecosystems are driven by political agendas, such as 70% CO_2 reduction in 2030 and climate neutrality in 2050 in Denmark; High-tech related business ecosystems, are usually driven by leading giant companies. For instance, in the social media business ecosystem, the announcement of Facebook to be in the metaverse business indicates a social media ecosystem trend.

  Although the initiatives created by leading giant companies, such as Google glasses, can provide inspiration or highly possibly become megatrends in the related business ecosystems, the future (e.g., when and in what way) is unclear because megatrends are usually formed with strong collective effort. Therefore, investigating unmet needs or megatrends in a given business ecosystem is rec-

Table 11 Constructs applied in the technology adoption theories and technology adoption decision process

Theories	Before adoption	Adoption decision	After decision
Diffusion of Innovation Theory	• Knowledge • Persuasion • Characteristics of the decision-making unit • Perceived characteristics of the innovation • Communication channels	• Decision • Adoption • Rejection • Communication channels	• Implementation • Confirmation • Continued adoption • Later adoption • Discontinuance • Continued rejection
Technical/Technology Adoption/acceptance Model (final version 1996)	• External variable • Perceived usefulness • Perceived ease of use	• Behavioral intention	• Usage behavior
Extended Technology Adoption Model 2	Subjective Norm • Image • Job relevance • Output quality • Result demonstrability • Perceived usefulness • Perceived ease of use	• Intention to use	• Usage behavior
Unified Theory of Acceptance and Use of Technology	• Performance expectancy • Effort expectancy • Social influence • Facilitating condition • Gender • Age • Experience • Voluntariness of use	• Behavioral intention	• Actual system use
Theory of Reasoned Action	• Attitude towards act or behavior • Subjective norm	• Behavioral intention	• Behavior
Theory of Planned Behaviour	• Attitude towards act or behavior subjective norm perceived behavior control	• Behavioral intention	• Behavior
The Model of PC Utilization	• Long-term consequences • Affect towards use • Social factors • Facilitating conditions • Complexity • Job-fit	• PC utilization	
The Motivation Model	• Extrinsic motivation (perceived usefulness, perceived ease of use, and subjective norm) • Intrinsic motivation (if performing an activity leads to a feeling of pleasure and results in satisfaction for the individual)		• Behavior
The Social Cognitive Theory	• Self-efficacy (the judgments of how well one can execute courses of action required to deal with prospective situations) • Affect (positive contribution) • Anxiety (negative contribution)	• Expectations of outcome (personal as well as performance-related gains)	• Behavior

ommended to focus on the political goals. The ecosystem boundary can indicate related political or business statements, since the boundary is defined by the supply chains, market or systems in a certain geographical/cultural boundary.

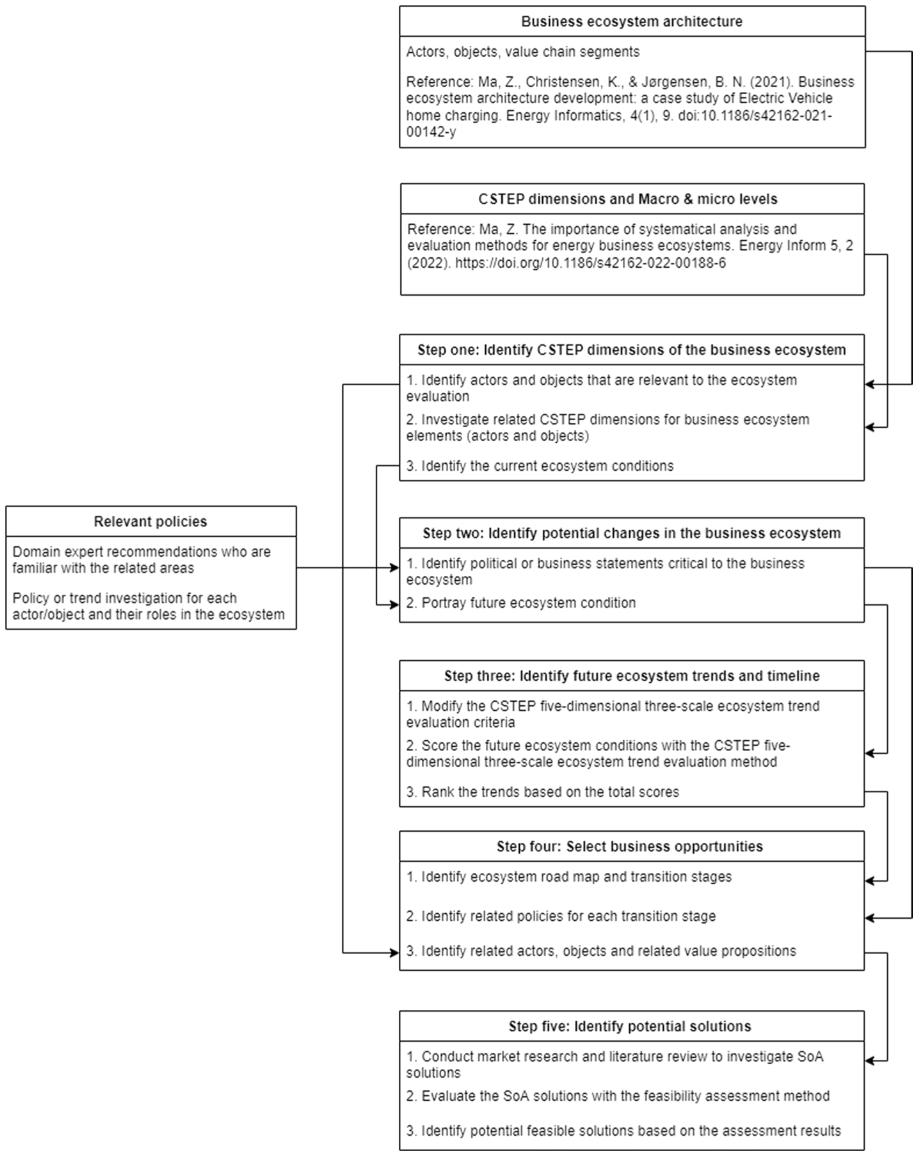


Fig. 3 CSTEP-driven business opportunity identification method process

There are two approaches to identifying relevant policies: domain expert recommendations for those familiar with the related areas; Policy or trend investigation for each actor/object and their roles in the ecosystem. Especially, the information in governmental white papers and reports provides a detailed description of the focus areas, and is often supported by numbers and data.

- Substep 2: Portray future ecosystem conditions
  The critical political or business statements usually provide a direction where the current business ecosystem might evolve (the future business ecosystem). Therefore, the potential changes can be identified by the gap analysis. To do so, it is necessary to ask the following questions about each current ecosystem condition with each identified critical political or business statements:

Table 12 Investigation of related CSTEP dimensions for business ecosystem elements

Value chain segment	Relevant business ecosystem elements	C S T E P
List the related value chain segment in the ecosystem	• Evaluate all the actors and objects in the ecosystem • List actors and objects that are relevant to the evaluation of the ecosystem	Based on Table 7 (Macro and micro levels of the five CSTEP dimensions), for each relevant actor and object, ask the following question with each CSTEP dimension: 1. If yes, how is it related to this actor/object? 2. Write down the relation

Regarding the business ecosystem architecture development, please see (Ma et al. 2021) for details

Table 13 Identification of the current ecosystem conditions

	C	S	T	E	P
Current ecosystem condition	Based on the right column in Table 8 (Investigation of related CSTEP dimensions for business ecosystem elements), summarize and describe the current ecosystem condition at this dimension				

- Whether the current ecosystem condition can fulfil this identified policy or trend?
- If not, what future ecosystem conditions should look like to fulfil the identified policy or trend?

Sub-step 2 strongly requires expert input, and at some dimensions, there might not be any significant difference between current and future ecosystems. Therefore, it doesn't need to be included. The summarized guideline and result of Step two: Identify potential changes in the business ecosystem is shown in Table 14.

Based on Table 14, the future ecosystem conditions can be identified at each CSTEP dimension. In most cases, the policy and regulation dimension will be blank, since governmental authorities make decisions. Meanwhile, there might be overlaps among the identified future ecosystem conditions across the CSTEP dimensions. Therefore, it is necessary to conduct merging and reorganizing, and present the future ecosystem conditions precisely and comprehensively.

Table 14 Identification of future ecosystem conditions

Current ecosystem condition	Analysis	Future ecosystem condition
It is from the current ecosystem conditions in Table 13 (Identification of the current ecosystem conditions)	1. Ask the following questions to each current ecosystem condition with each identified critical political or business statements: a. Whether the current ecosystem condition can fulfil this identified policy or trend? b. If not, what future ecosystem condition should look like to fulfil the identified policy or trend? 2 Evaluate the overlaps among the identified future ecosystem conditions across the CSTEP dimensions, merge and reorganize the future ecosystem conditions	Present each future condition with related political or business statements

Step three: Identify future business ecosystem trends and timeline

Although the future ecosystem conditions are identified at Step two. The realization timeline is not clear. The realization timeline relates to when (in short-, medium-, or long terms) and what (which part of the ecosystem) will change. A CSTEP five-dimensional three-scale evaluation method for ecosystem trends (shown in Table 15) is introduced to answer this question.

This evaluation method might have different weights among the five CSTEP dimensions. The presentation of the weight differences can be qualitative (indirect and descriptive) or quantitative (direct and quantified). In different cases, it might apply different prioritization based on the purpose of the evaluation, e.g., research gap identification.

Table 15 CSTEP five-dimensional three-scale evaluation

CSTEP dimension		Criteria	Evaluation question
C	Climate and environmental benefit	1: No significant climate or environmental benefit 2: There is climate or environmental benefit, but remain unclear 3: There are significant and clear climate or environmental benefit	At which scale of climate and environmental benefits that this trend will provide to the ecosystem?
S	Social awareness and feasibility	Social awareness and feasibility mainly refer to the increasing awareness of certain social norms and convenience (from full/semi-manual labour involvement to fully automatic): 1: No significant increasing awareness or convenience 2: Might have increasing awareness or convenience, but remain unclear 3: There is significant and clear increasing awareness or convenience	At which scale of this stakeholders' awareness or convenience requirement that trend matches?
T	Technology readiness level	The evaluation also corresponds to the Technology Readiness level 1: May be reached within a long-term period (TRL 1–2) 2: May be reached within a medium period (TRL 3–6 3: Can be realized within a short-term period. (TRL 7–9)	At which scale of the required technology is ready to realize this trend?
E	Economic feasibility	1: Long-term return-on-investment, or no financial significant benefit but large investment/cost 2: Medium-term return-on-investment 3: Short-term return-on-investment, or significant financial benefit and low investment	At which scale of financial benefits that this trend will provide to the core stakeholders?
P	Political and regulatory feasibility	1: Policy agenda is under discussion, and the related regulations remain unclear 2: Political agenda is there, and the regulation will be ready after a certain period 3: The regulations are ready or will be ready in a short-term period	At which scale of regulations and policy agendas are ready to support the realization of the trend?

As Table 15 shows, the higher score at a dimension, the higher likelihood that a trend would happen. It is based on the principle that the evolution of a business ecosystem is always towards the direction that can benefit the ecosystem the most.

To identify future ecosystem trends and timeline, this step is divided into 3 substeps:

1. Modify the evaluation criteria from the CSTEP five-dimensional three-scale evaluation (shown in Table 12) if necessary.
2. Evaluate the future ecosystem conditions, and score how likely the future ecosystem conditions will happen in the near future based on the CSTEP three-scale ecosystem trend evaluation method with scores (shown in Table 16).
3. Rank the future ecosystem conditions based on the total scores

Step four: Select business opportunities

The ranking of the total scores from Step three represents the realization timeline of the identified trends. The ecosystem roadmap and the transition stages can be identified based on this ranking. According to Ma et al. (2021):

- Ecosystem roadmap: is a critical path with sequenced ecosystem transition stages for achieving the planned/future ecosystem.
- Transition stage: One Minimum Variable Ecosystem (MVE) or expanded/shifted ecosystem is designed at one transition stage. The sequence of the transition stages can be either horizontal (boundary scale) dependent on the boundary coverage or vertical (time scale) dependent on the realization terms (short, medium, and long terms).

Therefore, each of the top-ranked ecosystem trends will be at one transition stage. Based on the ranking, the sequence of the transition stages can be identified. Sometimes, there are sub-transition stages at one transition stage because the ecosystem trends can happen simultaneously or the ecosystem trend happens with certain conditions. Therefore, it is important to ensure the sequence of the (sub)transition stages

Table 16 Evaluation of ecosystem potential change

Future ecosystem condition	C S T E P	The total score	Explanation
From Table 10 Identification of future ecosystem conditions	Scoring each future ecosystem condition by asking the question at each dimension in the right column from Table 11 (CSTEP five-dimensional three-scale evaluation)	Sum up the total scores from the left five columns	Explain reasons to give the score for each dimension. It usually needs references. The reasons are usually the related political or business statements identified in Table 14 (Identification of future ecosystem conditions)

according to the realization conditions. However, there might be different results due to different stakeholders' focuses.

It is necessary to match identified policies with the identified trends. It not only can clarify the goals of the identified trends, but also can confirm whether the identified trends are the megatrends or unmet needs in the targeted ecosystem. The related policies can be stated as shown in Table 17.

To portray the future ecosystem, it is necessary to map the transition stages to the identified relevant actors and objects with value chain segments of the ecosystem (at Step one) as shown in Table 18. Therefore, the future ecosystem can be described according to the summary in Table 18. Furthermore, the value proposition for each actor can be proposed as shown in Table 19.

Step five: Potential solution identification

With the identified value propositions, potential solutions can be investigated, evaluated and identified. To do so, two sub-steps should be conducted:

- State-of-the-art (SoA) solution investigation
- SoA solution evaluation
- State-of-the-art (SoA) solution investigation

The SoA investigation includes market research and literature (sometimes, patent search is also conducted to avoid any infringement issue). The purpose of the market research is to investigate whether there are any existing products in the targeted ecosystem that provide similar value. If yes, this value proposition is not considered for further because there is no opportunity for the ecosystem stakeholders unless the existing product can not fully fulfil the value proposition.

The literature research aims to investigate whether there is any solution that (1) can provide the identified value; (2) has not been implemented in the current ecosystem, and (3) uses the most modern or advanced techniques or methods.

- SoA solution evaluation

Table 17 Identified transition stages and related policies

Ecosystem roadmap	Details	Related policies
Transition stage number	• The sequence of the transition stage is based on total scores of ecosystem trends identified from Table 3.6 (Evaluation of ecosystem potential change). The higher the total score is, the earlier the transition stage is • The ecosystem trends that have the same total score are allocated at the same transition stage • The sequence of the sub-transition stages is based on the individual CSTEP score. The result might be different due to different stakeholders' focuses. However, recommended priority among the CSTEP dimension is: T, E, S, P, C	Allocate the relevant policies identified at Step 2 for each (sub)transition stage

Table 18 The future ecosystem description

Value chain segment	Relevant business ecosystem elements	Future ecosystem
From column- Value chain segment in Table 8 Investigation of related CSTEP dimensions for business ecosystem elements	From column- Relevant business ecosystem elements in Table 8 Investigation of related CSTEP dimensions for business ecosystem elements	For each transition stage* and actor/object**, ask the following question: • Whether this transition stage make anything change to this actor or object? •How this actor/object will be changed due to this transition stage? Describe the change result of the actor/object

*Transition stages are from Table 17 Identified transition stages and related policies

** Actor/object is from the column of Relevant business ecosystem elements

Table 19 The proposed value propositions

Market segment	Related technology	Identified value proposition
List each actor* in the relevant business ecosystem elements	List object* in the same value chain segment and the same transition stage as the listed actor	The value proposition formula is: The identified object will have the ability of (the object's future ecosystem condition) for (the actor) to have (the actor's future ecosystem condition)
		Note: If an object is at a transition stage with no actor in the same value chain segment, it should consider actors in other value chain segments at the same transition stage

Actor/object is from the column of Relevant business ecosystem elements in Table 14 The future ecosystem description

Not all the investigated SoA solutions are feasible to be applied in the targeted ecosystem. Therefore, a feasibility assessment needs to be conducted and identify the most feasible solutions that potentially can be applied in the targeted ecosystem. One method can be applied with modification is the feasibility assessment method applied (Christensen et al. 2021).

Software architecture

The software architecture of the CSTEP tool aims to capture and describe the fundamental building blocks and what they consist of. The tool is built on a classic client/server approach, which relies on considering the separation of concern on the client-side and server-side. The architecture consists of the three following tiers:

- Frontend
- Backend
- Database

On the client-side, the frontend, acting as a presentation tier, provides the user interface and allows for sending requests to the server side. The communication for these requests are established through the API (Application Programming Interface) exposed by the server-side, consisting of the backend and the database. The backend act as a business tier, responsible for handling the incoming requests from the user and replying with a response. All data required for the functionality to function is stored in the database, acting as a data tier. Together, these components constitute the foundation for a web application offering the functionality required by the proposed method.

With the basics in place, a more detailed description of the architecture, what components the tiers hold and how they associate is now introduced. Figure 4 depicts the three tiers, including their respective components. The structure and content of each tier are highly affected by the different technologies applied in the project. The goal is to include technologies that help ensure the ability to provide the required functionalities in terms of following the procedure of the proposed method and promote core software qualities appropriate for the application supporting these functionalities. The focus was to create a lightweight, easily maintainable and flexible application for the users.

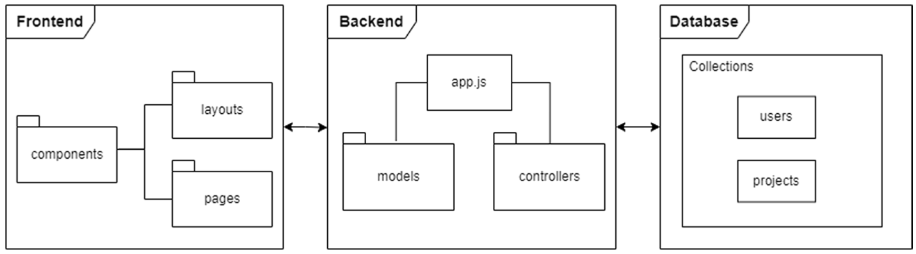


Fig. 4 System Architecture

Frontend

The nature of Vue.js and Nuxt.js highly impacts the architecture of the frontend. These frameworks allow developers to build user interfaces on a component-based programming model that allow for easy structuring and encourages flexibility. Together, these frameworks offer features that ease and improve the development experience through easy routing, modularity and reusability, virtual DOM rendering, reactive data binding and more. Communication from the frontend to the backend is established through a tool called Axios, which is an HTTP client for JavaScript, providing the ability to make HTTP requests from the application running in the user's browser.

Backend

The backend and API are built using Node.js as it provides a great runtime environment for backend services, where fast and easy development in JavaScript, simple file structure, support for many open-source libraries and performance are in focus. The architecture of Node.js ensures asynchronous handling of requests from the user, allowing more efficient processing and the ability to serve multiple clients on one thread without having to create a thread for every request. This makes Node.js suitable for this project as the potentially many concurrent users and the nature of the features in the application result in I/O-intensive activity.

Regarding the API, the backend uses a tool called Express to expose the endpoints accessible from the frontend. Each endpoint calls a method from a controller related to the object related to the requested functionality. These methods that set the boundary and actions of an event are defined in the controllers' folder. The exposed endpoints are specified in the app.js file, which also holds information on how the connection to the database is established. This connection is made possible through the Mongoose library. This library is applied in the backend and not only allows the backend to manipulate data in the database but also to help define data models or schemes for the documents stored in the database.

Database

For storing data about the users and the projects they create in the application, MongoDB is used. MongoDB is a document-based NoSQL database offering flexibility and scalability. Data on users and projects are stored in separate collections, analogous to tables in relational databases, that each holds a set of individual documents, one for each user or project. These documents are similar to rows in a relational database and are structured as specified by the backend model, which looks similar to a JSON object when stored.

Case study

An example of the EV home charging energy ecosystem is used to explain the implementation of the proposed method. The ecosystem map generator investigates the business ecosystem architecture of the case (ecosystemmapgenerator.sdu.dk). Meanwhile, the critical actors and objects relevant to this case study are exported to the tool-CSTEP business opportunity identifier, as shown in Table 20.

CSTEP dimension identification for the targeted business ecosystem

According to Table 12 (Investigation of related CSTEP dimensions for business ecosystem elements) in the methodology section, the CSTEP dimensions related to each actor and object can be added as shown in Table 21. Furthermore, the current ecosystem conditions can be summarized and presented based on CSTEP.

Potential change identification in the business ecosystem

Related political or business statements can be defined based on the boundary of the EV home charging energy ecosystem:

1. Danish climate goals (Energy and Agency 2022)

    - 70% CO2 reduction by 2030
    - Climate-neutral by 2050

2. Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030 (The Danish Ministry of Taxation 2020)

    - Reliefs on electricity used for charging and registration tax
    - An expected reduction of greenhouse gasses of 2 million tons
    - Ambitions of 1 million EVs in 2030 – consideration of further initiatives in 2025 to reach the ambition

Table 20 The critical actors and objects related to the EV home charging energy ecosystem

Supply chain segment	Name	Type	Description	Roles
Consumption	Charging-box supplier	Actor	Supply charging-box and charging services	Service provider
Distribution	DSO (Distribution System Operator)	Actor	Operate distribution networks and meter points responsible	Distribution system operator Meter operator
Consumption	EV users	Actor	Consume electricity for household and EV charging	Electric vehicle user Electricity consumer

Table 21 Investigation result of related CSTEP dimensions for business ecosystem elements

CSTEP dimension	Agent name	Current ecosystem condition
Climate, environmental and geographic situation	EV users	• The Danish weather (not too hot in the summer and not too cold in the winter) is suitable for EVs
Societal culture, demographic environment	EV users	• Currently, EVs represent 2.4% of the Danish car population (Statistics Denmark: Bestanden af elbiler og plugin hybrider fordoblet 2021) • People may believe in EVs as a good investment or a green solution. And EVs may, in many circumstances, be a good investment (compared to conventional) due to the current and future regulations
Technology (Infrastructure, facilities, technological skills, technology readiness)	Charging box supplier DSO	• Use Advanced Metering Infrastructure in EV charging boxes to collect consumer data (such as charging rate and battery capacity) • A limited number of implemented EV charging algorithms • EV users manually decide the time for charging • Distribution grids are not dimensioned to the increasing electrification that introduces new Distributed Energy Resources (DERs), such as EVs
Economy and finance	EV users DSO	• Distribution tariffs are close to being simple flat rate (one peak period price change during winter)
Policies and regulation	EV users DSO	• Today all Danish electricity consumers should, by law, be able to pay by hourly electricity prices (Agency 2019)

3. Sector roadmap for the energy- and supply sector's contribution to the 70% goal (Regeringens klimapartnerskaber - Energi- og forsyningssektoren. I mål med den grønne omstilling 2030)

   - Modernized pricing
   - Flexibility in households
   - Freeing supply data
   - Local flexibility markets
   - Innovation

4. The Sustainable and Smart Mobility Strategy (European Comission: Mobility Strategy 2020)

   - Reduce transport-related greenhouse gas emissions by 90% by 2050
   - Increasing the uptake of zero-emission vehicles
   - Supporting digitalization and automation

5. European Green Digital Coalition (European Comission 2022)

   - Investing in the development and deployment of green digital solutions with significant energy and material efficiency that achieve a net positive impact in a wide range of sectors

- Developing methods and tools to measure the net impact of green digital technologies on the environment and climate by joining forces with NGOs and relevant expert organizations
- Co-creating, with representatives of other sectors, recommendations and guidelines for the green digital transformation of these sectors that benefits the environment, society, and economy

Future ecosystem conditions

Based on Step 2 and Table 14 Identification of future ecosystem conditions, the potential future ecosystem conditions can be identified as shown in Table 22.

Future business ecosystem trend identification

Based on Step three: Identify future business ecosystem trends in the methodology section, the results of ecosystem potential change evaluation for this case study can be shown in Table 23.

Business opportunity selection

Based on Table 23 (Results of ecosystem potential change evaluation), four transition stages are defined as shown in Table 24:

The transition stages represent the realization potentials. The future ecosystem description and the proposed value propositions for each transition stage can be described as shown in Table 25.

Potential solution identification

The value proposition related to the Transition stage 1 (1.1 and 1.2) and 2 (2.1 and 2.2) is considered for the investigation of the potential solutions. Based on the market research, the EV charging algorithms in the Danish market are either the traditional charging that EV users charge EVs immediately when they arrive home or electricity price signal based charging. However, none of these two consider the dynamic distribution tariffs or CO2 emission, and the second charging strategy needs to be manually configured.

Therefore, a literature review is conducted to investigate State-of-the-art (SoA) EV charging strategies. According to Christensen et al. 2020d, the EV charging strategies can be categorized as centralized and decentralized, and the decentralized charging strategies are usually used by the EV users. Furthermore, based on evaluation with the modified feasibility assessment method (Christensen et al. 2021), Real Time Pricing (Nimalsiri et al. 2019), Time-of-Use Pricing (Chunlin et al. 2017), and Timed charging (Huachun et al. 2012) are the most feasible decentralized EV charging strategies in Demark.

Discussion

The case study of the EV home charging energy ecosystem shows that the proposed methodology can facilitate the business opportunity identification process. However, although there are only four steps in the method, it is difficult to follow the steps in practice due to the complex logic behind each step and across steps. Therefore, the

Table 22 Investigation results of the potential future ecosystem conditions

CSTEP	Current ecosystem condition	Related policies and targeted trends	Future ecosystem condition
C	The Danish weather (not too hot in the summer and not too cold in the winter) is suitable for EVs	Danish climate goals; Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; The Sustainable and Smart Mobility Strategy	Increase in the number of EVs
S	Currently, EVs represent 2.4% of the Danish car population	Danish climate goals; Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; The Sustainable and Smart Mobility Strategy	Increase in the number of EVs
	People may believe in EVs as a good investment or a green solution. EVs may, in many circumstances, be a good investment (compared to conventional) due to the current and future regulations	Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; 3. Sector roadmap for the energy- and supply sector's contribution to the 70% goal	Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction
T	Use Advanced Metering Infrastructure in EV charging boxes to collect consumer data (such as charging rate and battery capacity)	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services
	A limited number of implemented EV charging algorithms	The Sustainable and Smart Mobility Strategy and European Green Digital Coalition	More EV charging algorithms and strategies will be allowed with high intelligence and automation level
	EV users manually decide the time for charging	The Sustainable and Smart Mobility Strategy and European Green Digital Coalition	The automation and intelligent levels of EV charging algorithms will be increased
	Distribution grids are not dimensioned to the increasing electrification that introduces new Distributed Energy Resources, such as EVs	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid
E	Distribution tariffs are close to being simple flat rate (one peak period price change during winter)	Regulations for the design of distribution tariffs, such as no price discrimination	Dynamic distribution tariffs that comply with regulations will be designed and implemented
P	Today all Danish electricity consumers should, by law, be able to pay by hourly electricity prices	From 2020, all small electricity consumers are eligible to have hourly electricity prices	All EV users will adopt an hourly electricity price scheme

Table 23 Results of ecosystem potential change evaluation

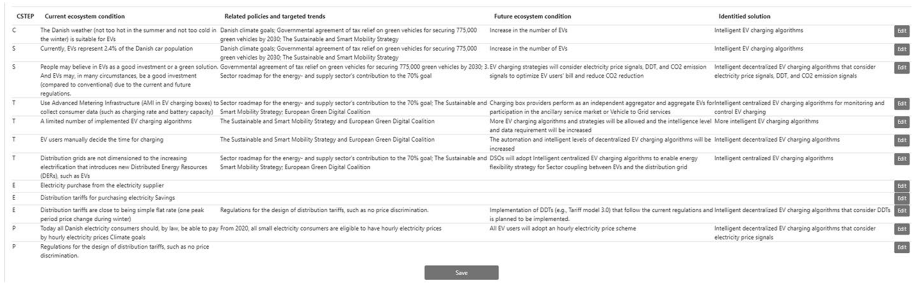
Future ecosystem condition	C	S	T	E	P	Total
Increase in the number of EVs	3	3	3	3	3	15
All EV users will adopt an hourly electricity price scheme	3	3	3	3	3	15
Dynamic distribution tariffs that comply with regulations will be designed and implemented	2	3	3	3	3	14
Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction	3	2	3	3	3	14
DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid	2	2	3	3	1	11
Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services	2	1	3	2	2	10

Table 24 The identified transition stages of the EV home charging energy ecosystem with future ecosystem conditions

Future ecosystem condition	Transition stage
Increase in the number of EVs	1.1
All EV users will adopt an hourly electricity price scheme	1.2
Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction	2.1
Dynamic distribution tariffs that comply with regulations will be designed and implemented	2.2
DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid	3
Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services	4

Table 25 The future ecosystem description and the proposed value propositions for each transition stage

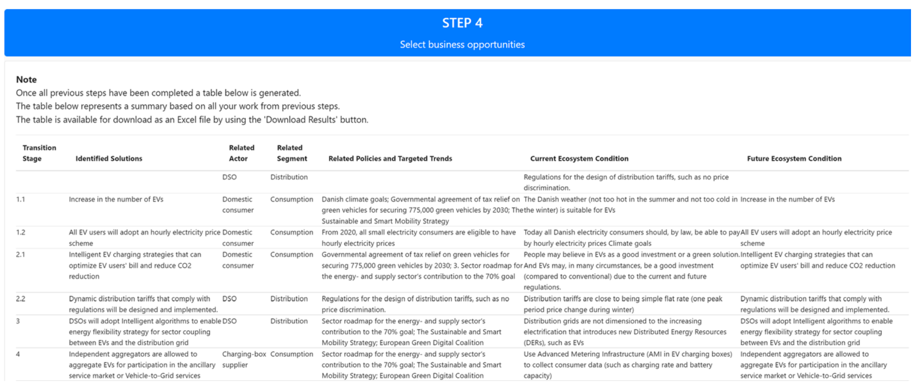
Transition stage	Future ecosystem condition	Related actors	Value proposition
1.1	Increase in the number of EVs	EV users	EV users can have optimal EV charging cost and optimal CO2 emission consumption with the intelligent EV charging algorithms that consider electricity prices, tariffs, and CO2 emission
1.2	All EV users will adopt an hourly electricity price scheme		
2.1	Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction	EV users	
2.2	Dynamic distribution tariffs that comply with regulations will be designed and implemented	DSOs	
3	DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid	DSOs EV users	DSOs can avoid grid overloads and postpone the grid upgrade by applying intelligent EV charging algorithms
4	Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services	Charging box providers EV users	Independent aggregators (e.g., EV charging box providers) can aggregate EVs and participate in the ancillary service market or provide Vehicle-to-Grid services by using intelligent EV charging algorithms



CSTEP	Current ecosystem condition	Related policies and targeted trends	Future ecosystem condition	Identitied solution	
C	The Danish weather (not too hot in the summer and not too cold in the winter) is suitable for EVs	Danish climate goals; Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; The Sustainable and Smart Mobility Strategy	Increase in the number of EVs	Intelligent EV charging algorithms	Edit
S	Currently, EVs represent 2.4% of the Danish car population	Danish climate goals; Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; The Sustainable and Smart Mobility Strategy	Increase in the number of EVs	Intelligent EV charging algorithms	Edit
S	People may believe in EVs as a good investment or a green solution. And EVs may, in many circumstances, be a good investment (compared to conventional) due to the current and future regulations.	Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; 3. Sector roadmap for the energy- and supply sector's contribution to the 70% goal	EV charging strategies will consider electricity price signals, DDT, and CO2 emission signals to optimize EV users' bill and reduce CO2 reduction	Intelligent decentralized EV charging algorithms that consider electricity price signals, DDT, and CO2 emission signals	Edit
T	Use Advanced Metering Infrastructure (AMI in EV charging boxes) to collect consumer data (such as charging rate and battery capacity)	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	Charging box providers perform as an independent aggregator and aggregate EVs for participation in the ancillary service market or Vehicle to Grid services	Intelligent centralized EV charging algorithms for monitoring and control EV charging	Edit
T	A limited number of implemented EV charging algorithms	The Sustainable and Smart Mobility Strategy and European Green Digital Coalition	More EV charging algorithms and strategies will be allowed and the intelligence level and data requirement will be increased	More intelligent EV charging algorithms	Edit
T	EV users manually decide the time for charging	The Sustainable and Smart Mobility Strategy and European Green Digital Coalition	The automation and intelligent levels of decentralized EV charging algorithms will be increased	Intelligent decentralized EV charging algorithms	Edit
T	Distribution grids are not dimensioned to the increasing electrification that introduces new Distributed Energy Resources (DERs), such as EVs	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	DSOs will adopt Intelligent centralized EV charging algorithms to enable energy flexibility strategy for Sector coupling between EVs and the distribution grid	Intelligent centralized EV charging algorithms	Edit
E	Electricity purchase from the electricity supplier				Edit
E	Distribution tariffs for purchasing electricity Savings				Edit
E	Distribution tariffs are close to being simple flat rate (one peak period price change during winter)	Regulations for the design of distribution tariffs, such as no price discrimination.	Implementation of DDTs (e.g., Tariff model 3.0) that follow the current regulations and is planned to be implemented.	Intelligent decentralized EV charging algorithms that consider DDTs	Edit
P	Today all Danish electricity consumers should, by law, be able to pay by hourly electricity prices Climate goals	From 2020, all small electricity consumers are eligible to have hourly electricity prices	All EV users will adopt an hourly electricity price scheme	Intelligent decentralized EV charging algorithms that consider electricity price signals	Edit
P	Regulations for the design of distribution tariffs, such as no price discrimination.				Edit

Save

Fig. 5 Screenshot for the first two steps' partly results in the web-based tool- CSTEP business opportunity identifier



STEP 4

Select business opportunities

Note

Once all previous steps have been completed a table below is generated.

The table below represents a summary based on all your work from previous steps.

The table is available for download as an Excel file by using the 'Download Results' button.

Transition Stage	Identified Solutions	Related Actor	Related Segment	Related Policies and Targeted Trends	Current Ecosystem Condition	Future Ecosystem Condition
		DSO	Distribution		Regulations for the design of distribution tariffs, such as no price discrimination.	
1.1	Increase in the number of EVs	Domestic consumer	Consumption	Danish climate goals; Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; The Sustainable and Smart Mobility Strategy	The Danish weather (not too hot in the summer and not too cold in the winter) is suitable for EVs	Increase in the number of EVs
1.2	All EV users will adopt an hourly electricity price scheme	Domestic consumer	Consumption	From 2020, all small electricity consumers are eligible to have hourly electricity prices	Today all Danish electricity consumers should, by law, be able to pay by hourly electricity prices Climate goals	All EV users will adopt an hourly electricity price scheme
2.1	Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction	Domestic consumer	Consumption	Governmental agreement of tax relief on green vehicles for securing 775,000 green vehicles by 2030; 3. Sector roadmap for the energy- and supply sector's contribution to the 70% goal	People may believe in EVs as a good investment or a green solution. And EVs may, in many circumstances, be a good investment (compared to conventional) due to the current and future regulations.	Intelligent EV charging strategies that can optimize EV users' bill and reduce CO2 reduction
2.2	Dynamic distribution tariffs that comply with regulations will be designed and implemented.	DSO	Distribution	Regulations for the design of distribution tariffs, such as no price discrimination.	Distribution tariffs are close to being simple flat rate (one peak period price change during winter)	Dynamic distribution tariffs that comply with regulations will be designed and implemented.
3	DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid	DSO	Distribution	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	Distribution grids are not dimensioned to the increasing electrification that introduces new Distributed Energy Resources (DERs), such as EVs	DSOs will adopt Intelligent algorithms to enable energy flexibility strategy for sector coupling between EVs and the distribution grid
4	Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services	Charging-box supplier	Consumption	Sector roadmap for the energy- and supply sector's contribution to the 70% goal; The Sustainable and Smart Mobility Strategy; European Green Digital Coalition	Use Advanced Metering Infrastructure (AMI in EV charging boxes) to collect consumer data (such as charging rate and battery capacity)	Independent aggregators are allowed to aggregate EVs for participation in the ancillary service market or Vehicle-to-Grid services

Fig. 6 Screenshot for the final evaluation result

web-based tool- CSTEP business opportunity identifier (https://opportunityidentifier.sdu.dk/) solves this challenge.

For instance, the first two steps (CSTEP dimension identification for the targeted business ecosystem and potential change identification in the business ecosystem) can be presented on one webpage (a screenshot is shown in Fig. 5). Furthermore, the calculation error increases when evaluating the ecosystem's potential changes including many evaluation subjects. The tool can automatically calculate and rank the total score, making the process much easier (as shown in Fig. 6). Moreover, the analysis result can be downloaded as an Excel file for further work.

Furthermore, the tool allows a collaborative environment that multiple users can share and edit the same project. In this way, relevant stakeholders can be involved to ensure a clear interpretation shared among the stakeholders, and stakeholders' opinions/feedback, e.g., on the derived value propositions, can be captured during the whole process.

Conclusion

This paper proposes an ecosystem-driven business opportunity identification method. This method includes four correlated steps, and the proposed method is implemented as a web-based tool. A case study of the EV home charging energy ecosystem is applied and demonstrates the application of the proposed method and the implementation of the developed web-based tool.

The results show that the potential changes can be identified, and the future business ecosystem conditions can be portrayed. Furthermore, the business opportunities can be selected, and correlated value chain segments can be placed at the actor and object level. For instance, three value propositions are identified in the case study: (1) EV users can have optimal EV charging cost and optimal CO2 emission consumption with the intelligent EV charging algorithms that consider electricity prices, tariffs, and CO2 emission; (2) DSOs can avoid grid overloads and postpone the grid upgrade by applying intelligent EV charging algorithms; (3) Independent aggregators can aggregate EVs and participate in the ancillary service market or provide Vehicle-to-Grid services by using intelligent EV charging algorithms. Moreover, three feasible decentralized EV charging strategies (Real Time Pricing, Time-of-Use Pricing, and Timed charging) are identified as the potential solutions targeting the first value proposition. This result also illustrates the importance of digitalization in the energy transition, especially for energy efficiency, energy flexibility, and CO2 emission reduction. Moreover, the web-based tool- CSTEP business opportunity identifier proves the ability to facilitate and ease the whole analysis process.

The proposed ecosystem-driven business opportunity identification method addresses gaps and contributes to three research domains: business ecosystem, technology adoption, and strategy management. The proposed method is a systematic approach that allows ecosystem stakeholders to conduct collaborative business opportunity analysis and evaluation. Furthermore, the application of the CSTEP dimensions and ecosystem architecture design ensures all aspects and elements related to the targeted ecosystem can be covered and investigated. Meanwhile, the user-friendly web-based tool, business opportunity identifier, can facilitate teaching in class for students to quickly understand the needs and value of the technical solutions in the energy sector.

The web-based tool, business opportunity identifier, will be available via opportunityidentifier.sdu.dk. The tool is developed and passed the initial verification and validation testing. Later this year, the tool will be further tested in the course of "Ecosystem driven technology development and adoption" for the Master programs of energy system and technology and welfare technology.

Abbreviations

CSTEP	Climate, environmental and geographic situation; Societal culture, demographic environment; Technology readiness; Economy and finance; Policies and regulation
TRL	Technology Readiness Levels
MVE	Minimum Variable Ecosystem
EV	Electric Vehicle
DSO	Distribution System Operator
DDT	Dynamic Distribution Tariff
ETPS	Economic, technical, political, and social
SoA	State-of-the-art
STEP	Social, technical, economic, political
STEPE	Social, technical, economic, political, and ecological

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Author contributions

ZM developed the methodology, and designed the software specification, and the main contributor to the manuscript writing. KC contributed to the literature analysis of technology adoption theories and models and case study analysis, and is the main contributor to the sections of technology adoption theories and models, and case study. TFR realized the software development and the main contributor to the software architecture section writing. BNJ contributed to the discussion of the methodology, the software specification and software development. All authors read and approved the final manuscript.

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References

Adner R (2006) Match your innovation strategy to your innovation ecosystem. Harv Bus Rev 84(4):98

Adomavicius G, Bockstedt J, Gupta A, Kauffman RJ (2006) Understanding Patterns of Technology Evolution: An Ecosystem Perspective. In: Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06). p. 189.

Aguilar FJ (1967) Scanning the Business Environment. Macmillan

Ajzen I (1985) From Intentions to Actions: A Theory of Planned Behavior. In: Kuhl J, Beckmann J (eds) Action Control: From Cognition to Behavior. Springer, Berlin, pp 11–39

Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen I, Fishbein M (1975) A Bayesian analysis of attribution processes. Psychol Bull 82(2):261–277. https://doi.org/10.1037/h0076477

Bandura A (1986) Social foundations of thought and action: A social cognitive theory. Prentice-Hall, Englewood Cliffs

Billanes JD, Ma Z, Jørgensen BN (2017) Consumer Central Energy Flexibility in Office Buildings. J Energy Power Eng 2017(11):621–630. https://doi.org/10.17265/1934-8975/2017.10.001

Billanes JD, Ma Z, Jørgensen BN (2018) The Bright Green Hospitals Case Studies of Hospitals' Energy Efficiency And Flexibility in Philippines. In: 2018 8th International Conference on Power and Energy Systems (ICPES). p. 190–5.

Bouten M (2008) Compatibility and technology acceptance : consolidating, validating and extending concepts. Maastricht University, Faculty of Economics and Business Administration. Maastricht

Brown A, Weiner E (1984) Supermanaging: How to Harness Change for Personal and Organizational Success. McGraw-Hill, New York

Capra F, Luisi PL (2014) The Systems View of Life: A Unifying Vision. Cambridge University Press, Cambridge

Ceccagnoli M, Forman C, Huang P, Wu DJ (2012) Cocreation of value in a platform ecosystem! the case of enterprise software. MIS Q 36(1):263–290. https://doi.org/10.2307/41410417

Christensen K, Ma Z, Jørgensen BN (2021) Technical, economic, social and regulatory feasibility evaluation of dynamic distribution tariff designs. Energies 14(10):2860

Christensen K, Ma Z, Varbak M, Demazeau Y, Jorgensen BN (2020a) Agent-based Simulation Design for Technology Adoption. SII 2020a - International Symposium on System Integration: IEEE; 2020a. p. 873–8

Christensen K, Ma Z, Demazeau Y, Jorgensen BN (2020b) Agent-based Modeling of Climate and Electricity Market Impact on Commercial Greenhouse Growers' Demand Response Adoption. RIVF International Conference on Computing and Communication Technologies (RIVF). Ho Chi Minh City, Vietnam: IEEE; 2020b. p. 1–7

Christensen K, Ma Z, Demazeau Y, Jørgensen BN (2020c) Agent-based Modeling for Optimizing CO2 Reduction in Commercial Greenhouse Production with the Implicit Demand Response. 6th IEEJ international workshop on Sensing, Actuation, Motion Control, and Optimization (SAMCON2020c). Tokyo, Japan: IEEJ Digital Library. p. 6

Christensen K, Ma Z, Jørgensen BN (2020d) (Submitted to Journal) Technical, Social and Regulatory Feasibility Evaluation of Electric Vehicle Charging Strategies Renewable & Sustainable Energy Reviews

Christensen K, Ma Z, Værbak M, Demazeau Y, Jørgensen BN (2019) Agent-based Decision Making for Adoption of Smart Energy Solutions. IV International Congress of Research in Sciences and Humanities Science and Humanities International Research Conference (SHIRCON 2019). Lima, Peru: IEEE

Chunlin G, Dequan H, Qinbo Y, Zhou M (2017) Dynamic sorting intelligent charging control strategy of electric vehicles based on time-of-use price. In: 2017 China International Electrical and Energy Conference (CIEEC) 2017. p. 199–204
Clark BR (1965) Interorganizational Patterns in Education. Adm Sci Q 10(2):224–237. https://doi.org/10.2307/2391414
Cliff D, Grand S (1999) The Creatures Global Digital Ecosystem. Artif Life 5(1):77–93. https://doi.org/10.1162/106454699568683
Coleman JS (1988) Social capital in the creation of human capital. Am J Sociol 94:S95–S120
Davenport TH, Prusak L (1997) Information Ecology: Mastering the Information and Knowledge Environment. Oxford University Press, Inc.
Davis FD (1986) A technology acceptance model for empirically testing new end-user information systems: theory and results. Sloan School of Management. Massachusetts Institute of Technology, Sloan School of Management.
Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 13(3):319–340. https://doi.org/10.2307/249008
Davis FD, Venkatesh V (1996) A critical assessment of potential measurement biases in the technology acceptance model: three experiments. Int J Hum Comput Stud 45(1):19–45. https://doi.org/10.1006/ijhc.1996.0040
Davis FD, Bagozzi RP, Warshaw PR (1992) Extrinsic and intrinsic motivation to use computers in the workplace1. J Appl Soc Psychol 22(14):1111–1132. https://doi.org/10.1111/j.1559-1816.1992.tb00945.x
DeLone WH, McLean ER (1992) Information systems success: the quest for the dependent variable. Inf Syst Res 3(1):60–95
DiMaggio PJ, Powell WW (1983) The Iron cage revisited: institutional isomorphism and collective rationality in organizational fields. Am Sociol Rev 48(2):147–160. https://doi.org/10.2307/2095101
European Comission: European Green Digital Coalition (2022) https://digital-strategy.ec.europa.eu/en/policies/european-green-digital-coalition. Accessed 24 Feb 2022
European Comission: Mobility Strategy (2020) https://transport.ec.europa.eu/transport-themes/mobility-strategy_en. Accessed 24 Feb 2022
Gangwar H, Date H, Raoot AD (2014) Review on IT adoption: insights from recent technologies. J Enterp Inf Manag 27(4):488–502
Gawer A, Cusumano MA (2014) Industry platforms and ecosystem innovation. J Prod Innov Manag 31(3):417–433. https://doi.org/10.1111/jpim.12105
Goodhue DL, Thompson RL (1995) Task-technology fit and individual performance. MIS Q 19(2):213
Hack T, Ma Z, Jørgensen BN (2021) Digitalisation potentials in the electricity ecosystem: lesson learnt from the comparison between Germany and Denmark. Energy Informatics 4(2):27. https://doi.org/10.1186/s42162-021-00168-2
Haeckel E (1866) Generelle Morphologie der Organismen. Reimer, Berlin
Howard D, Ma Z, Engvang J, Hagenau M, Jørgensen K, Olesen J, et al (2020) Optimization of Energy Flexibility in Cooling Process for Brewery Fermentation with Multi-Agent Simulation. In: 6th IEEJ International Workshop on Sensing, Actuation, Motion Control, and Optimization. Shibaura Institute of Technology, Tokyo, Japan
Huachun H, Haiping X, Zengquan Y, Yingjie Z (2012) Interactive charging strategy of electric vehicles connected in Smart Grids. In: Proceedings of The 7th International Power Electronics and Motion Control Conference 2012. p. 2099–103
Iansiti M, Levien R (2002) The New Operational Dynamics of Business Ecosystems: Implications for Policy, Operations and Technology Strategy. Harvard Business School Working Paper. No. 03–030
Iansiti M, Levien R (2004) Strategy as Ecology. Harv Bus Rev 82(3):68–78
Iansiti M, Richards GL (2006) The Information Technology Ecosystem: Structure, Health, and Performance. The Antitrust Bulletin 51(1):77–110. https://doi.org/10.1177/0003603x0605100104
Igbaria M, Schiffman SJ, Wieckowski TJ (1994) The respective roles of perceived usefulness and perceived fun in the acceptance of microcomputer technology. Behav Inform Technol 13(6):349–361. https://doi.org/10.1080/01449299408914616
Iyawa GE, Herselman M, Botha A (2016) Digital health innovation ecosystems: from systematic literature review to conceptual framework. Procedia Computer Science 100:244–252. https://doi.org/10.1016/j.procs.2016.09.149
Kipnis D (1996) Trust and Technology. Trust in organizations. p. 39–50
Lai PC (2017) the literature review of technology adoption models and theories for the novelty technology. Journal of Information Systems and Technology Management : JISTEM 14(1):21–38. https://doi.org/10.4301/S1807-17752017000100002
Levien R (2004) The keystone advantage: what the new dynamics of business ecosystems mean for strategy, innovation, and sustainability. Harvard business school press, Cambridge, MA
Ma Z (2022) The importance of systematical analysis and evaluation methods for energy business ecosystems. Energy Informatics 5(1):2. https://doi.org/10.1186/s42162-022-00188-6
Ma Z, Energy JBN, Flexibility of The Commercial Greenhouse Growers, The Potential and Benefits of Participating in The Electricity Market. IEEE PES Innovative Smart Grid Technologies North America (ISGT North America, (2018a) Washington, DC. IEEE, USA, p 2018
Ma Z, Asmussen A, Jørgensen BN (2018c) Industrial Consumers' Smart Grid Adoption: Influential Factors and Participation Phases. Energies 11(1):182
Ma Z, Kuusinen K, Kjærgaard MB (2019b) A survey of demand response adoption in retail stores DR control preferences, stakeholder engagement, and cross-national differences. Energy Informatics 2(1):8. https://doi.org/10.1186/s42162-019-0073-3
Ma Z, Christensen K, Jorgensen BN (2021) Business Ecosystem Architecture Development: a Case Study of Electric Vehicle Home Charging Energy Informatics 4:37. https://doi.org/10.1186/s42162-021-00142-y
Ma Z (2019) Business Ecosystem modeling - The Hybrid of System Modeling and Ecological Modeling: An application of the smart grid. Energy Informatics
Ma Z, Jørgensen BN, Asmussen A (2015) Industrial consumers' acceptance to the smart grid solutions: Case studies from Denmark. In: 2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA). p. 1–6

Ma Z, Friis HTA, Mostrup CG, Jørgensen BN (2017a) Energy Flexibility Potential of Industrial Processes in the Regulating Power Market. In: Proceedings of the 6th International Conference on Smart Cities and Green ICT Systems. Porto, Portugal: SCITEPRESS - Science and Technology Publications, Lda. p. 109–15
Ma Z, Billanes JD, Jørgensen BN (2017b) A Business Ecosystem Driven Market Analysis: The Bright Green Building Market Potential. In: The 1st Annual International Conference of the IEEE Technology and Engineering Management Society. Santa Clara, California USA: IEEE
Ma Z, Santos AQ, Gamborg F, Nielsen JF, Johannesen JM, Jensen MDH, et al (2018b) Solutions for Remote Island Microgrids: Discussion and analysis of Indonesia's remote island energy system. The International Conference on Innovative Smart Grid Technologies (IEEE PES ISGT Asia 2018b). Singapore: IEEE
Ma Z, Broe M, Fischer A, Sørensen TB, Frederiksen MV, Jørgensen BN (2019a) Ecosystem Thinking: Creating Microgrid Solutions for Reliable Power Supply in India's Power System. 2019a 1st Global Power, Energy and Communication Conference (GPECOM). p. 392–7
Manning B, Runge B, Thorne C, Moore G (2002) Demand driven: 6 steps to building an ecosystem of demand for your business. McGraw-Hill Companies, New York
Maracine V, Scarlat E (2008) Dynamic knowledge and healthcare knowledge ecosystems. In: Proceedings of the 9th European Conference on Knowledge Management
Mars MM, Bronstein JL, Lusch RF (2012) The value of a metaphor: Organizations and ecosystems. Organ Dyn 41(4):271–280. https://doi.org/10.1016/j.orgdyn.2012.08.002
Maryam Salahshour R, Nilashi M, Halina MD (2018) Information technology adoption: a review of the literature and classification. Univ Access Inf Soc 17(2):361–390. https://doi.org/10.1007/s10209-017-0534-z
Molinillo S, Japutra A (2017) Organizational adoption of digital information and technology: a theoretical review. Bottom Line 30(1):33–46. https://doi.org/10.1108/BL-01-2017-0002
Moore JF (1993) The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems. Harper Paperbacks
Moore MJ (1996) Book Reviews. Proceedings of the Institution of Mechanical Engineers, Part A. J Power Energy 210(6):482. https://doi.org/10.1243/pime_proc_1996_210_076_02.
Moore GC, Benbasat I (1991) Development of an instrument to measure the perceptions of adopting an information technology innovation. Inf Syst Res 2(3):192–222
NASA: Technology Readiness Level (2021) https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level. Accessed 18 Jan 2022.
Nimalsiri NI, Mediwaththe CP, Ratnam EL, Shaw M, Smith DB, Halgamuge SK (2019) A Survey of Algorithms for Distributed Charging Control of Electric Vehicles in Smart Grid. IEEE Trans Intell Transport Syst. https://doi.org/10.1109/TITS.2019.2943620
Oh D-S, Phillips F, Park S, Lee E (2016) Innovation ecosystems: A critical examination. Technovation 54:1–6. https://doi.org/10.1016/j.technovation.2016.02.004
Oliveira T, Martins MF (2011) Literature review of information technology adoption models at firm level. Electronic Journal of Information Systems Evaluation 14(1):110–121
Oliver RL (1977) Effect of expectation and disconfirmation on postexposure product evaluations: An alternative interpretation. J Appl Psychol 62(4):480–486. https://doi.org/10.1037/0021-9010.62.4.480
Parker GG, Alstyne MWV, Choudary SP (2016) Platform Revolution: How Networked Markets Are Transforming the Economy and How to Make Them Work for You, 1st edn. W. W. Norton & Company, London
Peltoniemi M, Vuori E. Business ecosystem as the new approach to complex adaptive business environments. Tampere, Finland: Frontiers of E-business research; 2004. p. 267–81.
Play CM, Rewards I (1975) J Humanist Psychol 15(3):41–63. https://doi.org/10.1177/002216787501500306
Power T, Jerjian G (2001) Ecosystem: Living the 12 Principles of Networked Business. FT.com
Qayyum F, Ali H (2012) Factors determining customers' adoption of internet bankingResearch. Malardalen University Eskilstuna, School of Sustainable Development of Society and Technology. Västerås
Regeringens klimapartnerskaber - Energi- og forsyningssektoren (2020) I mål med den grønne omstilling 2030
Rogers EM (1962) Diffusion Of Innovations. The Free Press of Glencoe.
Rogers EM (2003) Diffusion of Innovations. Fifth ed. Free Press
Rong K, Shi Y (2015) Business Ecosystems: Constructs, Configurations, and the Nurturing Process. 1 ed. Palgrave Macmillan
Rubenstein-Montano B, Liebowitz J, Buchwalter J, McCaw D, Newman B, Rebeck K (2001) A systems thinking framework for knowledge management. Decis Support Syst 31(1):5–16. https://doi.org/10.1016/S0167-9236(00)00116-0
Ruggiero TE (2000) Uses and Gratifications Theory in the 21st Century. Mass Commun Soc 3(1):3–37. https://doi.org/10.1207/S15327825MCS0301_02
Sharma R, Mishra R. A Review of Evolution of Theories and Models of Technology Adoption. 2014.
Statistics Denmark: Bestanden af elbiler og plugin hybrider fordoblet (2021) https://www.dst.dk/da/Statistik/nyheder-analyser-publ/nyt/NytHtml?cid=33098. Accessed March 3 2022
Sykes TA, Venkatesh V, Gosain S (2009) Model of acceptance with peer support: a social network perspective to understand employees' system use. MIS Q 33(2):371–393. https://doi.org/10.2307/20650296
Taherdoost H (2018) A review of technology acceptance and adoption models and theories. Procedia Manufacturing 22:960–967. https://doi.org/10.1016/j.promfg.2018.03.137
Tajfel H (1978) Differentiation between social groups: Studies in the social psychology of intergroup relations, vol Book. Academic Press, Whole. London
Tanev S, Thomsen MS, Ma Z (2010) Value co-creation: from an emerging paradigm to the next practices of innovation
Taylor S, Todd PA (1995) Understanding information technology usage: a test of competing models. Inf Syst Res 6(2):144–176
The Danish Energy Agency (2019) Fakta om flexafregning
The Danish Ministry of Taxation: Markant afgiftslettelse sikrer 775.000 grønne biler (2020) https://www.skm.dk/aktuelt/presse-nyheder/pressemeddelelser/markant-afgiftslettelse-sikrer-775000-groenne-biler/. Accessed 3 Mar 2022

The Danish Energy Agency (2022) Danish climate policies. https://ens.dk/en/our-responsibilities/energy-climate-politics/danish-climate-policies. Accessed 24 Feb 2022
Thompson RL, Higgins CA, Howell JM (1991) Personal computing: toward a conceptual model of utilization. MIS Q 15(1):125
Tornatzky LG, Fleischer M, Chakrabarti AK (1990) The processes of technological innovation. Lexington Books, Lexington
Triandis HC (1977) Subjective culture and interpersonal relations across cultures. Ann N Y Acad Sci 285(1):418–434. https://doi.org/10.1111/j.1749-6632.1977.tb29370.x
Tupes EC, Christal RE (1992) Recurrent personality factors based on trait ratings. J Pers 60(2):225–251. https://doi.org/10.1111/j.1467-6494.1992.tb00973.x
Værbak M, Ma Z, Christensen K, Demazeau Y, Jørgensen BN (2019) Agent-Based Modelling of Demand-Side Flexibility Adoption in Reservoir Pumping. 2019 IEEE Sciences and Humanities International Research Conference (SHIRCON) 2019. p. 1–4.
Venkatesh V, Davis FD (2000) A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Manage Sci 46(2):186–204
Venkatesh V, Morris MG, Davis GB, Davis FD (2003) User acceptance of information technology: toward a unified view. MIS Q 27(3):425–478. https://doi.org/10.2307/30036540
Venkatesh V, Thong JYL, Xu X (2012) Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. MIS Q 36(1):157–178. https://doi.org/10.2307/41410412
Venkatesh V, Bala H (2008) Technology acceptance model 3 and a research agenda on interventions. Receiv: May 2007. Malden, USA: Zentralbibliothek der Wirtschaftswissenschaften in der Bundesrepublik Deutschland. p. 273–315
Zeithaml VA (1988) Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. J Mark 52(3):2. https://doi.org/10.2307/1251446
Zhou F, Xu Q, Jiao RJ (2011) Fundamentals of product ecosystem design for user experience. Res Eng Design 22(1):43–61. https://doi.org/10.1007/s00163-010-0096-z

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