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Building decarbonized society: an XaaS roadmapping approach

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Abstract

Purpose – The main goal of this study is to introduce an XaaS roadmapping framework integrating Futures Literacy (FL) with service-oriented strategies to accelerate decarbonization and promote consumer well-being.
Design/methodology/approach – This study presents XaaS (Everything-as-a-Service) roadmapping framework that integrates FL to create service-oriented businesses aligned with carbon reduction and consumer well-being. The framework uses historical data and a forward-looking perspective to help businesses anticipate future trends and challenges. Collaborative workshops with representatives from various sectors generate a macro-level XaaS roadmap, outlining potential scenarios for transforming service businesses.
Findings – This approach fosters the co-creation of innovative service value chains with industry associations, unlocking sustainable growth opportunities. This partnership leverages expertise to address sector-specific challenges and opportunities, ensuring the development of realistic and impactful roadmaps while driving collective action for accelerated implementation.
Research limitations/implications – Although the XaaS roadmapping framework shows strong potential, further research is required to validate its scalability across various industries and geographic contexts.
Practical implications – The framework is demonstrated through a case study of "Carbon Credit Trading-as-a-Service," illustrating its practical application. Businesses and organizations can adopt this approach to develop sustainable, service-oriented business models. Industry associations are crucial in fostering collaboration and co-creating innovative service value chains.
Originality/value – This framework integrates Technology Roadmapping with XaaS and FL, emphasizing cross-sector collaboration in developing service-oriented business models. By shifting the focus from traditional product-based to XaaS, it fosters service innovation, adaptability and sustainable transformation within a low-carbon economy.

Keywords XaaS roadmapping, Decarbonization, Service roadmap, Knowledge co-creation workshop, Futures literacy

Paper type Research paper

1. Introduction

Global warming significant threatens the climate, water scarcity and sea levels (Gandhok and Manthri, 2023). The recent COP29 summit in Baku revealed challenges such as insufficient fossil fuel phase-out and financial gaps (UNFCCC, 2024). Achieving carbon neutrality by 2050, as agreed in the Paris Agreement, requires innovative business models that promote

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public engagement, behavioral change and technological advancement (Das *et al.*, 2023; Labanca *et al.*, 2020; Rüdele *et al.*, 2024; Trapp *et al.*, 2022; Wüstenhagen *et al.*, 2007). A societal transition toward widespread clean energy adoption and sustainable consumption is necessary (Boisseau *et al.*, 2018; Cobo-Gómez, 2024; Groves *et al.*, 2023; Lipschutz, 2012). Policy frameworks, such as carbon pricing and international agreements, are also critical, along with the socioeconomic effects of decarbonization (International Labour Organization (ILO), 2018; Stern *et al.*, 1999; Weerasinghe *et al.*, 2024; World Bank, 2023).

Most research has focused on technological advancements in renewable energy and carbon capture to reduce reliance on fossil fuels (IRENA, 2021, Chapter 2, pp. 49–52; Wesseling *et al.*, 2017; Zaghdoud, 2025). While technological advancements are crucial, achieving a rapid and equitable transition to a decarbonized society requires a multifaceted approach that fosters innovation, collaboration, future-oriented thinking, and behavior change (Terashima, 2024). This requires a fundamental change in business operations and consumer engagement with products and services.

Everything-as-a-Service (XaaS) supports this transformation by replacing ownership with access, fostering resource efficiency, and enabling scalable and flexible solutions (Bhattacharya and Bhattacharya, 2021; Singh *et al.*, 2022). Futures literacy can enhance this model by equipping stakeholders to anticipate disruptions and strategize for sustainable futures; consequently, a futures-oriented perspective informs strategies to address XaaS adoption challenges. These challenges include technological readiness, organizational resistance and policy inadequacies. Therefore, this study explores how XaaS roadmapping provides a framework for service innovation and enables a futuristic perspective to guide sustainable transformation.

This paper is structured as follows: Section 2 presents the theoretical background, exploring: (1) Roadmapping, (2) Futures Literacy (FL), (3) Scenario planning and (4) Research gaps and a position of this research. Section 3 describes the XaaS roadmapping framework. Section 4 covers the implementation of the framework, focusing on a case study of "Carbon Credit Trading-as-a-Service," demonstrating its effectiveness and contribution to existing knowledge. Section 5 provides an evaluation. Sections 6 and 7 conclude the paper.

2. Literature review

2.1 Roadmapping

Roadmapping is an industry-specific approach to visualize future goals, strategic plans and communication (Kerr and Phaal, 2022; Phaal, 2004). Technology and service roadmapping guide the development of technology and services (Cho and Lee, 2014; Kindström and Kowalkowski, 2014; Suh and Park, 2009), while integrated framework include product-service and service-device-technology roadmaps (An *et al.*, 2008; Geum *et al.*, 2011; Kim *et al.*, 2022). Most roadmapping literature emphasizes technology roadmapping (TRM) across various industries such as SMEs, the retail industry, renewable energy, telecommunications and smart infrastructure (Cho and Lee, 2014; Kerr and Phaal, 2022; Murata *et al.*, 2021; Nonaka and Lewin, 1994; Phaal, 2004; Suh and Park, 2009). Agile roadmapping supports dynamic adaptation (De Souza *et al.*, 2022). Researchers have also been conducted on large-scale projects within the electrical and electronics industries, as well as coastal ecosystems (Letaba and Pretorius, 2022; Manuel *et al.*, 2023). Noh *et al.* (2020) have proposed an opportunity-driven roadmapping method. Foresight and future thinking enhance roadmapping decisions by fostering an understanding of challenging situations and providing strategies for addressing risks and opportunities (Hussain *et al.*, 2017; Reilly-King *et al.*, 2024). Nonetheless, the literature review reveals a limitation in the study addressing incorporating macro-level service ecosystem and future thinking.

2.2 Futures literacy (FL)

Futures Literacy (FL), advocated by UNESCO, as a critical tool for businesses to navigate uncertainty and enhance resilience (Karjalainen *et al.*, 2022; Miller, 2018). This cognitive

ability allows individuals and organization to consider the future in their actions and explore possible future scenarios (Miller, 2007). While early studies focused on education and teenagers (Kononiuk *et al.*, 2021; Toivonen *et al.*, 2021), FL supported revolutionary business strategies, particularly through the integration of crisis learning (Cagnin, 2018; Karjalainen *et al.*, 2022). However, FL faces organizational barriers and lack integration with roadmapping for foresight (Mortensen *et al.*, 2021).

FL enables organizations to navigate uncertainty through three levels: Awareness (recognizing change), Discovery (imagining alternatives) and Choice (strategic action).While FL enhances foresight and innovation, challenges include organizational culture and measurability (Bradfield *et al.*, 2005; Gáspár, 2023; Karlsen, 2021; Rhisiart *et al.*, 2015). Despite its potential, FL remains underutilized in strategic roadmaps, particularly within XaaS model. Organizations still struggle to translate foresight insights into structured, multi-stage processes that integrate technology trends, market evolution and policy landscapes. This gap highlights the need for a structured workshop-based approach to FL (Mortensen *et al.*, 2021).

Furthermore, future-oriented technology analysis (FTA) can be enhanced by FL to better address disruptive transformations (Cagnin *et al.*, 2013). By embedding FL within multi-stage strategic foresight frameworks, organizations can move beyond passive adaptation and toward actively co-creating desirable futures that align with long-term sustainability and innovation goals (Weber and Rohracher, 2012).

FL empowers individuals and organizations to develop future-oriented XaaS business models that satisfy current demands and anticipate future carbon neutrality challenges and opportunities (Toivonen *et al.*, 2021). This framework allows stakeholders to proactively identify and develop XaaS solutions for the evolving needs of a decarbonized society.

2.3 Scenario planning

Scenario planning is a strategic approach used by businesses to explore possible future scenarios and their consequences (Postma and Liebl, 2005). It involves a systematic process like the Six Thinking Hats method, Kipling Method (Cheng *et al.*, 2016) and Fuzzy Cognitive Maps (FCMs) provides structured foresight by simulating potential outcomes and supporting decision-making (Son *et al.*, 2020). In considering XaaS, it is essential to consider the rapid technological change and shifting customer expectations. Incorporating scenario development into XaaS roadmapping enables firms to recognize emerging opportunities and challenges, develop adaptable strategies and enhance value for users and stakeholders.

2.4 Research gaps and a position of this research

This research focuses on futures literacy and roadmapping into XaaS business strategy and its ecosystem. While existing research has examined their individual advantages, it does not explore their synergistic application. The majority of roadmapping literature focuses on technology and service strategy, but there is an opportunity for more exploration of the business ecosystem.

Recent empirical studies strengthen the article by demonstrating real-world applications and barriers to XaaS and FL adoption across sectors. For example, Mortensen *et al.* (2021) discussed corporate resistance to FL, emphasizing the difficulty of integrating future-oriented strategic thinking into XaaS innovation. Wang *et al.* (2024) found that Farming-as-a-Service (FaaS) in Agriculture 4.0 is driven by personalization, financial benefits and network effects, whereas perceived risk and regulatory inconsistencies hinder it. Yadav *et al.* (2020) identified trust issues and technological barriers as key challenges in blockchain-enabled models, which align with broader adoption concerns in service-oriented sustainability frameworks. Fernando *et al.* (2023) discovered that blockchain technology adoption for carbon trading in manufacturing is impeded by firm size and compatibility issues.

These findings underscore the necessity for roadmapping strategies that integrate FL methodologies to anticipate challenges, align multi-stakeholder interests and facilitate XaaS-driven transformations to improve XaaS models scalability and efficacy in service-oriented and sustainability-centric sectors.

Recent research explores the role of digital and green servitization in technological innovation and cleaner production, respectively (Rabetino *et al.*, 2024; Upadhayay *et al.*, 2024). These studies highlight the increasing importance of service-oriented models in achieving decarbonization goals. Alternative paradigms like product-service systems based on life cycle assessment results and rental clothing schemes also offer sustainable alternatives (Herold and Prokop, 2023; Neramballi *et al.*, 2020), providing insights into how different service-oriented approaches can contribute to decarbonization.

Furthermore, Johl *et al.* (2024) examine the interplay between green servitization, the circular economy and sustainability in achieving sustainable performance. This research emphasizes the importance of integrating green initiatives and circular economy principles to enhance operational performance and sustainability.

Recognizing this gap, this article introduces a new XaaS roadmap that conceptualizes all offerings as services, aligning with the XaaS paradigm. This roadmap aims to help organizations identify emerging service opportunities and design an innovative XaaS ecosystem. Grounded in customer needs, market trends, technological advancements and tailored to XaaS attributes, this roadmap contributes to service innovation for carbon neutrality. It uses electronic tools for real-time communication, version control and integration with project management systems, and visual tools enhance communication and stakeholder engagement (Miro, 2023; Oliveira *et al.*, 2021).

By incorporating the three levels of FL, knowledge co-creation workshops can effectively harness participant expertise and foresight. This enables the development of strategic roadmaps that respond to evolving market trends and technological advancements, shaping the future of XaaS in alignment with the desired outcomes.

3. XaaS roadmapping framework

We developed a comprehensive XaaS roadmap using a rigorous multi-stage process that integrating future trends, current need and historical context through collaborative workshops (Boonswasd and Shirahada, 2022) to systematically identify and validate potential business opportunities in the evolving XaaS landscape (Inayatullah, 2008).

To navigate business landscape complexities and anticipate future opportunities and challenges, organizations need futures literacy, which involves equipping individuals to think critically and creatively using tools like trend and scenario analysis (Murata *et al.*, 2021). Honing future-oriented capabilities, such as synthesizing external data with imaginative insights, enables businesses to proactively recognize emerging trends, anticipate potential disruptions and make informed decisions aligned with long-term goals (Rohrbeck, 2011). Organizations can better anticipate and adapt to change by integrating future thinking and business scanning approaches, such as analyzing megatrends, technological advancements and intellectual property landscapes (Miller, 2018; Murata *et al.*, 2021).

Based on XaaS and futures literacy literature, the knowledge co-creation workshops provide a collaborative environment for participants to share ideas and develop strategy roadmaps by combining future imagination with a review of megatrends, technological advancements and intellectual property landscapes (Boonswasd *et al.*, 2023; Boonswasd and Shirahada, 2022).

Compared to Delphi studies, which use surveys for consensus (Linstone and Turoff, 2011), this approach fosters dynamic, real-time interaction for service innovation (Geum *et al.*, 2014), through Delphi lack the participatory depth of workshops.

System dynamics modeling (Sterman, 2000) simulates complex systems but does not capture the qualitative insights and industry expertise of knowledge co-creation workshops

(Hussain *et al.*, 2017). Traditional focus groups are often used to gather stakeholder opinions but lack the structured foresight planning inherent in Futures Literacy and roadmapping (Benson *et al.*, 2021; Konrad *et al.*, 2019). Integrating these methodologies ensures stakeholders participation in shaping the roadmap while leveraging data-driven insights from topic modeling and historical analysis.

The roadmapping framework comprised four stages, as depicted in Figure 1. The XaaS roadmap innovates by integrating futures literacy into the roadmapping process, enabling innovative service ideas for a future society (Lee *et al.*, 2013; Martin and Daim, 2012; Phaal *et al.*, 2024) and employs the XaaS concept to broaden the service innovation within the ecosystem, representing a macro perspective for societal change.

Compared to existing models, the proposed framework focuses on the XaaS paradigm and its role in achieving a low-carbon economy. It incorporates FL and emphasizes cross-sector collaboration, enabling stakeholders to anticipate disruptions, assess sustainable technologies and make informed decisions aligned with long-term climate goals. The framework also provides a structured approach for scenario planning, allowing stakeholders to explore alternative futures and develop adaptable strategies.

3.1 Stage I: XaaS ideation workshop

Stage I begins with Level 1 of FL (awareness) to raise awareness of global warming through the bilingual video (JP/EN). Participants then imagine their ideal future world (Miller, 2007, 2018). The initial stage of level 2 of FL, referred to as discovery, involves engaging in guided activities such as imagining the future and brainstorming. The approaches utilized in this build upon service innovation tools for idea generation, including thinking aloud, speed thinking and idea discussion (Hidalgo, 2020). During these activities, participants collaborate to generate a wide range of prospective XaaS business ideas. This stage also serves as an integral component of the socialization process, involving the sharing of thoughts and the exchange of ideas. The selection of ideas employs four criteria, which encompass (1) Strategic aspects that align with decarbonization, consumer well-being and business strategy. (2) Desirability that meets customer needs is unique or is better than existing services. (3) Viability based on market size prospects and future market growth potential. (4) Feasibility determined by the confidence that

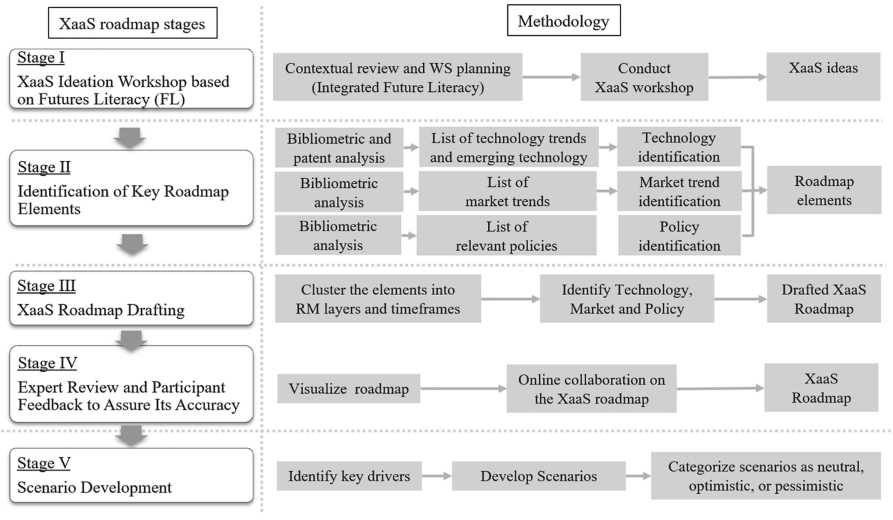

Figure 1. Knowledge co-creation workshop approach for XaaS Roadmapping. Source: Authors' own work

ideas can be implemented through technological/scientific development and can revolutionize existing services (Baldassarre *et al.*, 2020; Ssegawa and Muzinda, 2021). The selected ideas will establish value propositions, and experts will collaborate to identify potential XaaS offerings within the ecosystem that align with the value constellations (Chen, 2020; Norman and Ramirez, 1993).

3.2 Stage II: identification of key roadmap elements by intelligence activities

Stage II analyzes external factors influencing XaaS development. The workshop employs topic modeling to analyze patents and Scopus journal articles to address knowledge space limitations. This analysis involves identifying specific domains within the XaaS roadmap layer related to technical, policy and market aspects. Participants actively verify these elements for inclusion in the XaaS roadmap and explicitly share knowledge through online surveys using Google Forms. This stage remains at level 2 of FL (discovery) and involves the externalization of acquired knowledge and shared experiences.

3.3 Stage III: XaaS roadmap drafting

Stage III organizes verified elements from Stage II into a drafted XaaS roadmap, categorizing elements (XaaS, technology, market trends and policies) into layers. This stage continues at FL level 2 (discovery) and employs the combination process to map elements in its layer of roadmap utilizing available data.

3.4 Stage IV: expert review and participant feedback to assure its accuracy

Stage IV converts the drafted roadmap into a digital format. The Miro platform facilitates real-time collaboration for participants to edit and visualize and refine the roadmap. The validation of the XaaS roadmap occurs through expert review and participant feedback to ensure its accuracy, relevance and feasibility. This stage, encompassing level 3 of FL (choice), provides new insights into the potential of the current world. Participants can also retrieve the final XaaS roadmap to gain further understanding and develop their own new business or enhance existing strategies through the process of internalization (Murata *et al.*, 2021).

3.5 Stage V: scenario development

At this stage, the primary objective of scenario development is to comprehensively explore the potential opportunities and challenges associated with the XaaS roadmap, leveraging futures literacy principles to assess the likelihood of uncertainty for guiding strategic decision-making (Hussain *et al.*, 2017; Miller, 2018) This study employs a scenario-based approach to illustrate the future of XaaS, considering market trends, technological advancements and regulatory changes. The industry experts conduct a thorough assessment of potential outcomes, classifying scenarios as neutral, optimistic and pessimistic (Geum *et al.*, 2014).

This approach specifically encourages participants to actively embrace the uncertainties and possibilities that are inherent in the future. It enables organizations to make initiative-taking decisions in shaping the XaaS roadmap. FL is a capability that exists at this stage. FL Levels II (discovery) and III (choice) are utilized to explore alternative futures to provide valuable insights for making strategic decisions.

4. Implementation of XaaS roadmapping framework

4.1 Participants

A knowledge co-creation workshop involved a Japanese non-profit organization, including members from engineering and social infrastructure industries. The organization's priority is the reduction of carbon emissions and the implementation of a circular economy. These efforts aim to fulfill the common goal of environmental protection and the establishment of a

prosperous society without competing mindsets. The seven participants are experts in their respective industries and have prior experience developing a smart infrastructure construction roadmap. This ensures that collaboratively formed plans are grounded in practical realities.

4.2 Implementation

4.2.1 Stage I: XaaS ideation workshop. The ideation workshop introduced participants to FL and the XaaS concept via bilingual videos and a pilot session. On the day, an icebreaker and scenario envisioning activities guided participants to imagine their ideal 2040 world, generating 14 service ideas focused on decarbonization and well-being as shown in Figure 2. Table 1 presents fourteen service concepts, with defined value proposition. We selected service ideas from the concepts to prototype roadmap. The chosen ideas were developed further by establishing value propositions and identifying XaaS service value chains. based on a multi-faceted evaluation.

4.3 Service ecosystem and value constellation development

Among the 14 generated service concepts, the most promising, 'Carbon Credit Trading-as-a-Service (CTaaS)," was selected. It became the core of an extended XaaS ecosystem roadmap, connecting ten service chains aimed at enabling carbon-neutral lifestyles.

4.3.1 Stage II: identification of key roadmap elements by intelligence activities. The chosen XaaS ideas will be considered for 2022–2050 implementation, based on market, technology and policy factors. Data from patents and research publications were analyzed using topic modeling and bibliometric analysis to identify trends and elements for the XaaS roadmap (Aria and Cuccurullo, 2017; Baldassarre *et al.*, 2020), resulting in 25 roadmap elements.

Technology Opportunity Discovery (TOD) using keyword-based patent analysis is a valuable method for leveraging patent information (Feng *et al.*, 2020). Examining keywords frequency, co-occurrence, and interconnections in patent texts helps researchers identify emerging technological trends, white spaces and potential areas for innovation. Strategies to enhance keyword-based TOD include text mining (Lee *et al.*, 2009), semantic analysis (Seo, 2022; Wang *et al.*, 2022) and machine learning algorithms (Lee *et al.*, 2021), to address keyword ambiguity, synonyms and complex technological relationships (Boonswasd *et al.*, 2021; Boonswasd and Shirahada, 2023; Boonswasd and Vatananan-Thesenvitz, 2019).

This paper utilized Derwent innovation in patent analysis to extract the keywords for technology layer elements. Top technology trends from a 2012–2022 keyword search of carbon credit trading and its relevance to the XaaS business value chain include blockchain, transaction, payment, inventory, asset, cloud and computing. We consolidated keywords and assessments, then use a Google form survey to validate elements and determine the period

Figure 2. XaaS Ideation Workshop. Source: Authors' own work

Table 1. Potential service ideas from brainstorming session

Future service ideas			Value proposition
Environmental and energy	E−1	Natural resource visualization and optimization service	The natural environment will be virtually created for relaxation and to meet the expected needs
	E−2	Point service for shifting ecological behavior	The necessary advice for shifting behavior in accordance with ecological considerations will be delivered
	E−3	Corporate carbon credit exchange service	Corporate carbon credits are tradable
	E−4	Consumer carbon credit exchange service	Household carbon credits are tradable
Mobility security	M-1	Advanced luggage delivery service	Intelligent automated luggage delivery without required process
	M-2	Advanced On-demand mobility service	Intelligent and pollution-free transportation on demand
Wellness	W-1	Personal mental health service	Mental health issues will be alleviated personally and comfortably with expertise
	W-2	Physical health assistance service (Human body)	A smart assistant monitors and advises on physical health maintenance
	W-3	Health maintenance service	Physical health issues will be treated with expertise and ease of access to services
Daily living	L-1	Daily life information service	The required information is delivered in a timely and full manner through synthesis of only the desired content and predictability of the necessary data
	L-2	Expected-value anticipation service	The desired value can be anticipated and delivered beyond expectation
	L-3	Housework robot service	Housework can be made easier with robot services. (For the elderly or when there is a shortage of labor.)
Virtual environment services	V-1	Metaverse in “second life”	A second real-life experience is created and securely interacts with the virtual environment
	V-2	Virtual emotional well-being creation service (e.g. virtual onsen)	Desired vacation destinations are presented in a virtual form to create emotional well-being whenever and wherever it is preferred

Source(s): Authors’ own work

between 2023 and 2050, based on participants experiences. Throughout these stages, participants can examine supplementary information and provide relevant details.

4.3.2 Stage III: XaaS roadmap drafting. After gathering responds to the surveys, which examined each element and included additional comments, certain elements were found to be less significant while additional issues were introduced, each with their respective time frames. Given that this is an individual point of view, opinions may vary for each individual element. The XaaS roadmap is reformed into a digital format to facilitate collaboration throughout Stage IV: Expert review and participant feedback to assure its accuracy.

4.3.3 Stage IV: expert review and participant feedback to assure its accuracy. A digital roadmap was created and refined through expert reviews and participant feedback using collaborative tools like Google Forms and Miro, ensuring clarity, accuracy and feasibility. Figure 3 illustrates the carbon credit trading-as-a-service roadmap, which can be briefly stated as Table 2 for strategic target.

In addition to assessing the possible development timeframe for each XaaS business based on its ecosystem, participants also considered each step to determine a timeline for business

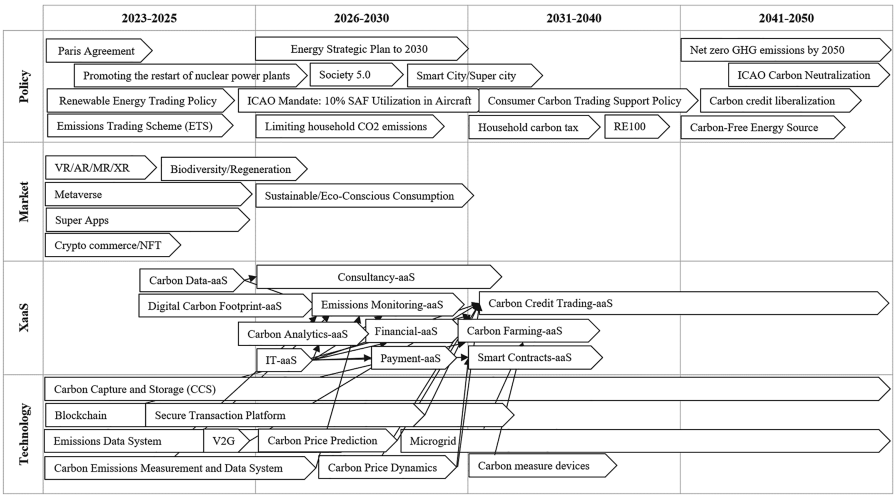

Figure 3. Stage IV carbon credit trading-as-a-service roadmap. Source: Authors' own work

Table 2. Strategic target of XaaS roadmap

Phase	I	II	III	IV
Time frame	2023–2025	2026–2030	2031–2040	2041–2050
Target	Promote renewable energy	Enhance energy efficiency	Develop carbon capture and storage technologies	Achieve net-zero carbon emissions
XaaS launching	Carbon Data-as-a-Service, Digital Carbon Footprint-as-a-Service	Consultancy-, Emissions Monitoring-, Carbon Analytics-, IT-, Financial-, and Payment-as-a-Service	Carbon Credit Trading-, Carbon Farming-, and Smart Contracts-as-a-Service	Enhance the service system
Area for technology development	Develop blockchain technology, a secure trading platform and a carbon emissions data system	Further develop emissions data systems and explore the integration of microgrids	Further leverage blockchain technology and develop advanced models for carbon price forecasting	Continue developing carbon capture and storage technology and carbon measuring devices

Source(s): Authors' own work

development. Participants can obtain a complete XaaS roadmap to deepen their comprehension and create their own new business or enhance the existing strategy.

The XaaS layer in the roadmap outlines the evolution of specific service offerings within the Carbon Credit Trading-as-a-Service (CTaaS) ecosystem across different time frames. The details for each phase, with a focus on the XaaS layer, are outlined as follows:

Phase I (2023–2025) The Foundation Phase: The initial phase focuses on establishing fundamental XaaS offerings, including Digital Carbon Footprint-as-a-Service, which involves calculating and monitoring the carbon footprint of digital activities, and Carbon Data-as-a-Service, which involves the collection, processing and analysis of carbon data. This data is essential for effectively monitoring and managing carbon emissions.

Phase II (2026–2030) The Expansion Phase: This phase aims at expanding the range of XaaS offerings on Consultancy, Emissions monitoring, Carbon Analytics, IT, Finance and Payment-as-a-Service.

Phase III (2031–2040) The Integration and Optimization Phase: This phase integrates and optimizes the various XaaS offerings, introducing Carbon Credit Trading-as-a-Service, which is a digital platform or solution that facilitates the buying and selling of carbon credits. These credits represent decreasing or eliminating of greenhouse gas emissions, usually measured in metric tons of carbon dioxide equivalent (CO_{2e}). Furthermore, it includes Carbon Farming-as-a-Service, a service model that aids farmers in adopting carbon farming practices on their land. It also offers Smart Contract-as-a-Service, which provides smart contract solutions to automate and streamline various aspects of carbon credit trading, such as agreement execution, compliance monitoring and payment processing.

Phase IV (2041–2050) The Maturity and Sustainability Phase: The final phase aims to establish a fully developed and sustainable CTaaS ecosystem that supports the transition to a decarbonized society. Continuous improvement, innovation and adaptation to new challenges and opportunities are the primary emphasis. The XaaS roadmap demonstrates a strategic and phased approach to developing a comprehensive CTaaS ecosystem. Through the leveraging of futures literacy and knowledge co-creation, the roadmap anticipates future trends and challenges, ensuring that the XaaS offerings remain relevant and effective in supporting the transition toward a decarbonized society.

4.3.4 Stage V: scenario development. The CTaaS roadmap was developed considering neutral, optimistic and pessimistic scenarios, based on varying policy, technology and market conditions, offering strategic insights for future planning.

The neutral scenario projects moderate technological advancement due to absent policy support and limited social pressure for decarbonized consumption, with typical adoption rates and stable funding for essential technologies aligning with steady market growth.

The optimistic scenario envisions rapid growth and technological advancements in the XaaS industry driven by a supportive policy environment and strong public advocacy. Increased sustainability focus accelerates XaaS adoption, and strategic investments in key technologies create synergistic value and promote collaboration.

Conversely, the pessimistic scenario depicts a challenging landscape for XaaS businesses due to insufficient government backing and limited public awareness of sustainability, resulting in low adoption, slow technological advancement and high upfront costs to establish a foundational XaaS ecosystem. Table 3 details each scenario's assumptions. Integrating scenario development into XaaS roadmapping leverages the strengths of technology and service roadmaps. Considering potential future scenarios helps organizations proactively identify opportunities and challenges, develop adaptable strategies and create greater user and stakeholder value. This is crucial XaaS, where rapid technological change and evolving customer expectations necessitates a forward-looking and responsive approach to service innovation. The XaaS roadmap's influence from these scenarios highlights that robust policy support and public demand for sustainability in an optimistic scenario could accelerate XaaS adoption beyond projections, while policy inadequacies, limited public awareness, and high investment needs in a pessimistic scenario could hinder progress, with the neutral scenario assuming moderate progress.

4.4 Scalability of the XaaS framework

The XaaS framework is adaptable across industries and geographies due to its collaborative and futures-oriented design. For instance, in agriculture, the XaaS framework could create a "Farming as a Service" (FaaS) strategy, outlining the transition from traditional farming to a service-oriented approach and considering technological readiness.

The XaaS model can also formulate strategies for services across various sectors including natural resource visualization and optimization, point services aimed at altering ecological

Table 3. Scenario of XaaS roadmap

	Scenario	Policy layer	Market layer	XaaS layer	Technology layer
2026–2030	Optimistic	Ambitious renewable energy targets and carbon pricing, widespread adoption of Society 5.0 principles	Increasing consumer demand for sustainable products and services, growing interest in biodiversity and regeneration	Widespread adoption of Emission Monitoring-as-a-Service, Financial-as-a-Service, etc., lead to efficient and transparent carbon credit trading	Mature and integrated emissions data systems, microgrids, and blockchain technology
	Neutral	Moderate progress on renewable energy targets and carbon pricing, Society 5.0 faces implementation challenges	XaaS market growth is steady, but growth is limited by price sensitivity and uncertainties	XaaS use rising, but complexity and cost concerns remain	Advancements in emissions data systems, microgrids and blockchain continue, but integration and scalability remain issues
	Pessimistic	Policy implementation stalls, limited progress on renewable energy and carbon pricing, resistance to Society 5.0	A decline XaaS market, limited consumer interest and lack of financial incentives for businesses	XaaS adoption is slow, organizations and individuals prefer traditional methods	Slow technological advancements and integration challenges hinder the development of CTaaS ecosystem
2031–2040	Optimistic	Stricter regulations and incentives for carbon reduction, flourishing smart city initiatives	Exponential growth in XaaS market.	Mature and optimized CTaaS ecosystem, seamless integration of services, significant investments in carbon neutrality initiatives	Blockchain becomes ubiquitous, advanced models for carbon price forecasting and dynamics enable proactive risk management
	Neutral	Gradual increase in regulations and incentives for carbon reduction, steady progress in smart city initiatives	Moderate growth in XaaS market.	CTaaS ecosystem expands, but integration and optimization face hurdles, increased adoption, but some remain cautious	Advances in technology but does not reach its full potential
	Pessimistic	Policy progress stagnates, limited enforcement and lack of new incentives, setbacks in smart city initiatives	Slower adoption in XaaS market, limited consumer interest and unclear policy	CTaaS ecosystem struggles, limited adoption of new offerings, challenges in maintaining existing services	Slow technological advancements and integration challenges hinder development

Source(s): Authors' own work

behavior, and corporate and consumer carbon credit exchanges, advanced luggage delivery, on-demand mobility, personal mental health, health maintenance, daily life information, expected-value anticipation, and housework robot, metaverse and virtual emotional well-being creation services. This study demonstrates the XaaS framework's scalability and potential to drive cross-sector service innovation and carbon-neutral initiatives.

5. Evaluation

Workshop evaluation applied the Participant Satisfaction Questionnaire (PSQ) (Lewis and Lewis, 2006) to assess design, process and outcomes. Open-ended questions allowed deeper insights into participant experiences, supported by thematic analysis (Braun and Clarke, 2008; Thomas, 2006). The survey, completed by seven subcommittee experts, included Likert-scale and qualitative items. Statistical analysis revealed high satisfaction across areas, informing improvements for future workshops.

The questions were derived from three perspectives: (1) the process, (2) the activities conducted during the workshop and (3) the result. The questions were pre-coded and open-ended, utilizing a five-point Likert scale. Throughout the analysis of the responses, we conducted statistical processing to examine satisfaction, detailed in Table 4.

The findings reveal a positive response to the XaaS roadmap process, with most factors exceeding four on a 5-point scale. Futures literacy integration (1–1) had the highest mean (4.714) and lowest standard deviation (0.488), indicating strong recognized in the roadmap process and aligning with the study's emphasis on its integral. The result received the lowest average rating (3.857) and highest standard deviation (0.690), showing broader participant opinions range and lower overall satisfaction.

Qualitative feedback emphasized the benefits of diverse perspectives and scenario planning in developing actionable strategies. The XaaS roadmapping workshop effectively facilitated strategic planning and collaboration among industry experts. Recommendations to enhance XaaS Roadmapping workshops include an introductory process overview, secure online collaboration platforms, roadmaps tailored to city size and scenario-based activities. Online collaboration tools security concerns, such as Miro's compatibility with enterprise security regulations, require careful organizational evaluation before incorporating them into workshops. Participants also suggested tailoring roadmaps based on city size and balancing

Table 4. Descriptive statistics of questionnaire responses

No	Variable	Mean	SD	95% CI Lower limit	Upper limit	Minimum value	Maximum value
1	(1–1) Process Futures literacy integration	4.714	0.488	4.474	4.954	4	5
2	(1–2) Process: XaaS ideation	4.286	0.488	4.046	4.526	4	5
3	(1–3) Process Roadmap elements identification	4.429	0.535	3.512	4.488	4	5
4	(1–4) Process: e-Roadmap collaboration	4.286	0.488	4.165	4.693	4	5
5	(2–1) Workshop activities: Overall	4.000	0.577	4.046	4.526	3	5
6	(2–2) Workshop activities Validating RM element using Google Forms	4.000	0.816	3.718	4.282	3	5
7	(2–3) Workshop activities: Miro-based electronic XaaS roadmap	4.286	0.488	3.602	4.398	4	5
8	(3) Result	3.857	0.690	4.046	4.526	3	5

Source(s): Authors' own work

industrial development with environmental concerns. This feedback emphasizes the importance of considering the city characteristics in XaaS roadmap implementation. Future research could compare cities of varying sizes, considering population density, economic structure and environmental regulations.

The study concludes that integrating FL into the XaaS roadmapping framework enhances businesses' strategic vision for sustainable service models. Results support the hypothesis that FL fosters innovative value chains, especially in carbon credit trading. Although its effectiveness depends on regulatory frameworks and market readiness.

6. Discussion

6.1 Implications for theory

The XaaS roadmapping framework offers a structured approach for businesses to transition to a decarbonized society. Technology and service roadmapping focus on planning technology or service evolution within specific industries, often using foresight techniques and market analysis (Kerr and Phaal, 2022). In contrast, XaaS roadmapping integrates FL and scenario analysis, emphasizing service-oriented business transformation and decarbonization goals.

Traditional roadmapping (RM) has limitations that make it less adaptable to dynamic and evolving business landscapes. It tends to have a narrow focus, primarily emphasizing technology or service development while overlooking the broader ecosystem interactions essential for sustainable and scalable business models (Kishita *et al.*, 2024; Phaal *et al.*, 2024) Additionally, online collaboration, textual big data analysis and scenario-based strategies are not integrated within a unified framework (Nishinaka *et al.*, 2023). Unlike linear, this framework employs a multi-stage, collaborative framework, leveraging knowledge co-creation and extensive textual data, including patents and academic papers, for ecosystem-wide innovation (Boonswasd *et al.*, 2023). It also incorporates scenario-based strategies (optimistic, neutral, pessimistic) to ensure adaptability in an evolving business landscape (Hussain *et al.*, 2017). While traditional roadmapping is widely applied in technology-driven sectors such as telecommunications and renewable energy, XaaS roadmapping fosters cross-industry collaboration, enabling new service-based business models like CTaaS. Ultimately, XaaS roadmapping provides a future-oriented, sustainable framework for businesses seeking to innovate beyond product ownership and drive societal transformation.

This study examines a knowledge co-creation workshop that enhances participants' futures literacy and expands service innovation within the ecosystem, reflecting a macro perspective intended to promote societal change. The XaaS roadmap adapts a roadmapping method to leverage XaaS models within innovative ecosystems that drive decarbonization and enhance consumer well-being. In addition, the XaaS framework can be applied to education by developing future thinking and sustainability-focused curricula and training.

Integrating FL into the XaaS roadmapping framework enhances businesses' strategic vision toward sustainable service models. The study's results support the hypothesis that FL fosters innovative value chains, especially in carbon credit trading. Although, its effectiveness depends on regulatory frameworks and market readiness. Aligning with prior research (Rohrbeck and Schwarz, 2013), the results support FL's potential to transform business models, contingent on regulatory incentives and technological readiness. Further empirical validation across industries is needed to establish this framework's broader applicability.

6.2 Implications for managers

The XaaS roadmapping provides managers with tools to adopt innovative and sustainable business models, as illustrated by CTaaS enable households carbon credit exchange and promotes carbon neutrality (Huang *et al.*, 2024). This model also supports smart city creation for carbon reduction (Di Vaio *et al.*, 2024). The roadmap's collaborative approach engages industry experts, without a competitive mindset, to co-create solutions and social

infrastructure, allowing managers to anticipate risks and opportunities, ensuring firms' adaptability and alignment with sustainability.

Specifically, in the optimistic scenario, managers can proactively invest in R&D to accelerate XaaS adoption and capitalize on market opportunities; in the pessimistic scenario, they can focus on risk mitigation and develop contingency plans for challenges like policy inadequacies or public disengagement; and in the neutral scenario, they can adapt to environmental changes.

This paper also explores the XaaS framework's economic benefits, including household expense savings and new market opportunities. The scenario development process aids managers by providing optimistic and pessimistic outlooks that emphasize strong policy support and public demand for sustainability.

6.3 Implications for policymakers

Policymakers are essential to effectively execute the XaaS strategy, scenario development highlights the importance of robust policy frameworks for sustainable practices and public engagement, with optimistic scenario emphasizes proactive policy interventions to drive sustainability demand and decarbonization investment, while the pessimistic scenario warning of consequences from underinvestment, inadequate policymaking and public disengagement. Policymakers can use these insights to design regulatory measures, incentivize sustainable business models like CTaaS, and facilitate smart cities development. Furthermore, the collaborative approach demonstrated by the XaaS framework offers a model for cross-sector partnerships to enhance policy initiatives for carbon neutrality. For example, in the optimistic scenario, managers can proactively invest in research and development to accelerate XaaS adoption and capitalize on market opportunities. In the pessimistic scenario, they can focus on risk mitigation and contingency plans for policy inadequacies or public disengagement. In the neutral scenario, they can adopt a balanced approach, adapting to environmental changes. The XaaS framework can also scale across regions and industries, considering technological readiness, regulation and cultural differences.

To enhance FL in business strategy, policymakers ought to establish regulatory frameworks that promote foresight-oriented decision-making. Cross-sector foresight committees can also improve collaboration among enterprises, government agencies and research institutions, promoting a more proactive strategy for sustainable economic development.

6.4 Limitations of the study and future research directions

This study's focus on Japanese industry stakeholders may limit the generalizability. The number of participants and the iterative process may affect validity and reliability. Although data-driven methodologies are utilized in the roadmap approach, the development of future business innovations necessitates greater imagination and expertise from participants, which is beyond mere to examination of prior data.

These findings illustrate FL's tangible benefits in fostering innovative service ecosystems. Companies adopting FL-based frameworks may gain a competitive advantage by proactively addressing sustainability challenges. However, successful implementation requires organizational commitment and policy support, reinforcing the need for a multi-stakeholder approach.

Future research should focus on refining the methodology to enhance anticipation accuracy and exploring the scalability of the XaaS framework across diverse industries and geographic contexts. This could involve conducting simulations to test the robustness of the framework under different conditions (Pora *et al.*, 2022). Additionally, future research could explore the use of different data sources and analytical techniques to improve the accuracy of future predictions. These efforts will ensure the continued development of effective tools for both theoretical advancement and practical application in decarbonization initiatives.

7. Conclusion

This study demonstrates how XaaS roadmapping, enhanced by FL, can drive sustainable service innovation. The CTaaS case illustrates the framework's potential for cross-sector collaboration and strategic foresight.

The XaaS roadmap establishes a large-scale new business model that encourages collaborative development of essential infrastructure for carbon neutrality. This roadmap is applicable for micro and macro levels communication in business and policy. It also allows ecosystem organizations to actively contribute XaaS sector growth, through the roadmap for business transformation necessitates further refinement for the sub-XaaS businesses.

The findings have practical implications for businesses and policymakers seeking to leverage XaaS for decarbonization and a sustainable future. However, sustainable digital transformation is complex, requiring significant investment and ongoing evaluation (Nyagadza, 2022).

While previous roadmapping studies primarily focus on technology and service strategy (Kerr and Phaal, 2022; Suh and Park, 2009), this study applies an anticipatory framework enabling businesses to co-create service value chains aligned with sustainability goals. This positions our research within the broader discussion on foresight-oriented business transformation.

A limitation of this study is the relatively small sample size, which may impact generalizability. Subsequent research should explore larger-scale implementations across industries to validate this framework's scalability and further refine standardized metrics for measuring FL's impact.

Further research could investigate the long-term impacts of XaaS models on carbon emissions reduction and consumer well-being, and the deployment of XaaS roadmap plans across industries.

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