

論文 / 著書情報
Article / Book Information

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Title(English)	Digital innovation in the energy value chain: An analysis of prospects for distributed, renewable energy in Japan
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Type(English)	Summary

(博士課程)
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論文要旨

THESIS SUMMARY

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

What is the next phase in the sustainable energy transition? The integration of renewable and distributed energy resources is essential, but also presents several complexities that call for resource control and coordination. This can be supported by digital technologies, such as blockchain and artificial intelligence, which will likely be a key competitive differentiator in the energy sector. Indeed, energy is undergoing digitalization in addition to decarbonization and decentralization. However, the implementation of digital energy solutions remains complex in practice. **Energy systems involve social, economic, and institutional processes in addition to technology.** Despite the multidimensional nature of energy innovation, energy-related research has often focused on individual technologies and technical issues. There are several grey areas in the strategic landscape of digital innovation in the energy transition, and a need for further research and practical insights integrating economic, social, environmental, and institutional dimensions.

Based on a multi-dimensional approach, this thesis explores how digitalization in the energy value chain can facilitate renewable, distributed energy in Japan. **The focus is on 1) renewable energy exemplified by woody biomass, and 2) distribution networks exemplified by blockchain.** The overall goal is to develop a holistic framework for the assessment of digital strategies in the renewable energy value chain, which may be further built upon in academia as well as industry and government. **An exploratory, qualitative approach was adopted, leveraging semi-structured interviews with experts and case studies.** Case studies and expert interviews can be valuable for data collecting, mapping, and theory induction in new academic areas, as these methods can support insight creation and manifold perspectives. Based on these insights and discussion with a strong foundation in recent literature, implications for digital strategies in the energy value chain are identified.

From the perspective of 1) **renewable energy**, key challenges across the **woody biomass supply chain** as well as potential for digital technologies to contribute to overcoming them are identified. The challenges include transportation infrastructure; biomass quality monitoring and control; stakeholder respect, relationships and trust; local community

revitalization and socioeconomic development. It is found that digital technologies can contribute to solving the challenges via various mechanisms such as improved transparency, information-sharing, accountability, automation, and value maximization. However, digitalization would also call for new approaches in management and policy, such as education and community outreach programs. From the perspective of 2) **distribution networks**, an analytical framework for **blockchain-based peer-to-peer (P2P) microgrids** is developed. The framework is titled TESEI, and incorporates 1) Technological, 2) Economic, 3) Social, 4) Environmental and 5) Institutional dimensions. Based on this framework, a blockchain-based P2P microgrid case in Urawa Misono, Japan, was analyzed. Concrete challenges of scaling this case and opportunities to overcome them are identified and discussed. Examples of key challenges include blockchain throughput, subsidy-dependence, behavioral change among consumers/prosumers, emissions reduction scheme uncertainty, and grid interconnection regulations. Opportunities include blockchain consensus mechanisms development, platform markets, business model innovation, user-friendliness, enhanced user choice, renewable energy-trading transparency, emissions-tracking, and regulatory sandboxes.

Findings indicate that digital innovation in the renewable energy value chain faces multi-dimensional and inter-related challenges and opportunities. The incorporation of this multi-dimensionality and interoperability between current and future systems can be important in supporting innovation. A framework of pathways for digital innovation, or a digital toolbox, based on challenges and opportunities identified across the renewable energy value chain is created. In addition, a digital innovation process is suggested, based on 1) concept creation rooted in this digital toolbox and challenges in the energy value chain, 2) multi-dimensional experimentation, and 3) scaling. Living Labs and regulatory sandboxes can support this experimentation, multi-stakeholder innovation ecosystems, and decision-making in both the private and public sectors. **This thesis offers holistic conceptualization, contributing with research to support more substantiated strategies for digital innovation in the renewable energy value chain in Japan.** These implications would be of interest in academia, business, and among policy-makers that are working to support the energy transition.

While exploratory findings and an initial assembly of aspects are shared, further research would be needed on the nexus of renewable energy and digital technologies. This may include how digital technologies can contribute to social, economic, and environmental sustainability in regional woody biomass supply chains. An important question is also what regulatory and policy support would be needed to facilitate the nexus of digital innovation and woody biomass. An additional suggestion for further research is the development of the TESEI framework as well as its application to different cases, such as off-grid microgrids. Finally, further research is also needed in terms of governance to support digital innovation

in the energy transition. Such research may delineate a future development route that assimilates digital technologies, the renewable energy value chain, and impactful, sustainable development.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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