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CHAPTER 13

Social and economic analysis of integrated building transportation energy system

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13.1 Introduction

Numerous studies have demonstrated that global temperatures have climbed by 0.5°C−1°C over the past 100 years due to greenhouse gas emissions. The rise in global temperature has caused a series of environmental and ecological problems, including a dramatic increase in extreme weather [1−5]. Carbon emissions from the building and transportation sector account for a large proportion of total global carbon emissions. With rapid urbanization, energy consumption and carbon emissions from the building sector will also become more prominent [4,6−8]. Many countries have made significant efforts to tackle the increase in greenhouse gas emissions [9−11,12]. For instance, the Paris Agreement, an international treaty signed in 2016 under the United Nations Framework Convention on Climate Change, targets limiting global warming to well below preindustrial levels of 2°C and strives to limit temperature increases to 1.5°C. By 2021, 197 parties had ratified the Paris Agreement, which is regarded as a milestone achievement for global efforts to combat climate change. The Paris Agreement is widely recognized as the most ambitious and comprehensive international agreement on climate change to date [13−15]. To achieve this international agreement, one essential measure is to design buildings that consume less energy by adopting more renewable energy sources and using electric vehicles (EVs) on a large scale [16,17]. As representatives of decarbonization technologies, common renewable energy technologies include solar energy (photovoltaic and solar thermal) [18,19], geothermal energy (shallow geothermal [20−24], medium, and

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deep geothermal), wind energy (wind power) [25,26], and also the applications of some advanced energy storage technologies (e.g., electrochemical and chemical energy storage [27–29], phase change energy storage [30–33]). Numerous studies have shown that CO_2 emissions from building and transportation sectors account for approximately 75% of total global carbon emissions [16,34]. Using cleaner electricity production, smart and flexible integration, and advanced energy management are necessary pathways and effective solutions to achieve carbon neutrality in buildings and transportation [35,36]. Therefore a mitigation strategy that combines the adoption of renewable energy for buildings with the use of fully EVs rather than traditional gasoline-powered vehicles appears to be most promising for achieving this target [37,38].

With the accelerated development of EV technology, the energy integration and synergy of the integrated building transportation energy system (IBTES) have attracted widespread attention from researchers, engineers, and manufacturers [39,40]. The synergistic function between buildings and EVs provides a favorable solution to increase the resilience and flexibility of the electric grid in the case of fluctuating energy supply from multiple energy systems. EVs can be used to support building energy demand through on-site charging and smart discharging of renewable energy systems, such as photovoltaics, thereby achieving energy sharing between EVs and buildings [41,42]. With the widespread deployment of EVs, the use of redundant storage capacity in EVs has been widely adopted to increase renewable energy penetration, mitigate renewable energy intermittency, and stabilize the grid [43,44]. In addition, the integration of EVs with buildings can improve the self-sufficiency of buildings' energy requirements and decrease their dependence on the power grid [45,46]. Multilateral synergistic functional benefits can be realized between buildings and transportation through their integrated applications.

In terms of technoeconomic aspects, it is currently important to consider the system performance matching and decarbonization capabilities of IBTES in different application scenarios. With the application of smart technologies, the monitoring and regulation capabilities are improved to make the management of IBTES more intelligent, thereby further increasing the application potential of this system [47–49]. For instance, Karan et al. [34] comparatively analyzed energy usage in buildings and transportation to provide an appropriate approach to assess the effectiveness of CO_2 mitigation strategies and the potential of CO_2 emission reductions. Studies showed that mitigation strategies, including EVs powered by conventional electricity, resulted in an average reduction of 3.7% in CO_2 emissions. The mitigation strategy using EVs obtained from grid-connected solar panels resulted in a 12.2% reduction in daily CO_2 emissions. Karan et al. [34] developed an appropriate approach to evaluate the potential CO_2 emission reductions and the effectiveness of greenhouse gas mitigation strategies in the building and transportation sector. Research showed that the average person produces about 20 lb of carbon dioxide per day, with 62% of that coming from transportation. EVs powered by electricity generated from coal-fired power plants can reduce CO_2 emissions by an average of 3.7%. EVs powered by solar energy obtained from grid-connected solar panels reduce CO_2 emissions by 12.2% per day (from 12.38 lb/day to 10.87 lb/day). This study also further demonstrated that combining EVs with off-grid power sources was the most successful strategy. It also estimated the initial cost per pound of CO_2 reduction per day for each mitigation strategy. Zhou et al. [50] systematically analyzed an application framework for energy integration and interaction between buildings and EVs containing different energy forms, advanced energy conversion, diverse energy storage systems, and hybrid grids. The buildings involved in this study include residential, public, and transportation buildings, and the involved EVs include conventional gasoline, biofuel, battery, and fuel cell EVs. Perspectives from the systematic review include different vehicle models, battery sizes, hydrogen tank capacities, and home charge and discharge rates. This study also systematically presented and discussed technical solutions for enhanced energy interactions from the perspective of buildings, such as on-site photovoltaics, on-site wind turbines, biofuels, and geothermal energy, and EVs, such as mobile storage and mobile renewable systems.

The integration of building energy systems with EVs has been seen as one of the main potential solutions of addressing greenhouse gas emissions in the building and transportation sectors [51–53]. As the social sciences are receiving increasing attention in energy studies, it has become more significant to explore IBTES from a social perspective. Therefore it is necessary to further study the social aspects to increase consumer awareness and acceptance of IBTES. This study provides an overview and analysis of recent research and application advancements in buildings, interactive EVs, and their interactions in facilitating IBTES to achieve energy flexibility and carbon footprint reduction from a social and economic perspective.

13.2 Social impacts and contributions of integrated building transportation energy system

After two decades of development, the innovation capacity of the socio-technical system of EVs has continuously increased, but it is still at a preliminary stage, which makes it difficult to meet users' requirements. Compared with the EV industry, IBTES is a more complex system, containing various interrelated elements that interact with each other. The advancement and implementation of IBTES in practice not only require technological developments but also the coordinated development of specific social factors. Therefore the analysis and summary of social aspects are particularly salient for the application and development of IBTES.

Kachirayil et al. [54] systematically reviewed 116 case studies of locally integrated energy system models to determine best practice approaches for model flexibility and addressing nontechnical constraints. There was rarely consideration of coupling with the transportation sector in the examples, especially EVs, although they could be used for smart charging or vehicle-to-grid (V2G) operations. And the societal aspects are often completely ignored. However, Rith et al. [55] demonstrated that improving community access to key services and facilities can promote equitable social development. Wu et al. [56] systematically summarized the positive contributions of the interactive trading behavior of buildings and EVs in establishing sustainable trading energy communities. An exploration of the physical space of energy, the cyberspace of data, and the social space of humans was presented. Low-carbon interactive energy solutions with key technologies and recent advances for net-zero energy buildings with high EV densities are discussed in a hierarchical manner.

In practice, many benefits of IBTES are inadequately understood, and social impacts are often overlooked in cost-benefit analyses. However, these benefits are closely related to social content and economic growth. Omahne et al. [57] systematically reviewed the research on the social impact of EVs. This study assesses the social impact of EVs by identifying the main current research priorities related to the perception of EVs. This study systematically divided the literature into the following social factors: acceptance, perception, impact, cost, welfare, and user experience. The findings indicated that existing studies are still lacking to assess the impacts of EVs on social well-being and user experience, but acceptance and user perceptions are frequently studied. In terms of potential user perceptions, the extended area of social perspectives of EVs is the research focus and trend. In addition, publications on the assessment of social impacts frequently study economic and environmental aspects in addition to social aspects. The results also indicated that 87.5% of the publications also integrated economic and environmental aspects when assessing the social impact of EVs. This is due to the fact that all aspects of sustainability are interconnected.

Wu et al. [58] adopted the socio-technical transition theory and multilevel perspective (MLP) approach in forecasting the transition route from conventional vehicles to new energy vehicles in the future. The study showed that the socio-technical system for new energy vehicles is still in its infancy and that many specific consumer requirements are difficult to satisfy. Fig. 13.1 illustrates the three MLP layers: ecological niche, regime, and landscape, for a four-stage transition. Both the supporting environment and the groundbreaking innovation of new energy vehicles have put pressure on the current sociotechnical system of the traditional vehicle industry. Meanwhile, the traditional vehicle system puts much pressure on the development of new energy vehicles, but the development of new energy vehicles is also supported by the exogenous environment. This study contributes to the formation of a sustainable low-carbon transformation route for the Chinese vehicle industry.

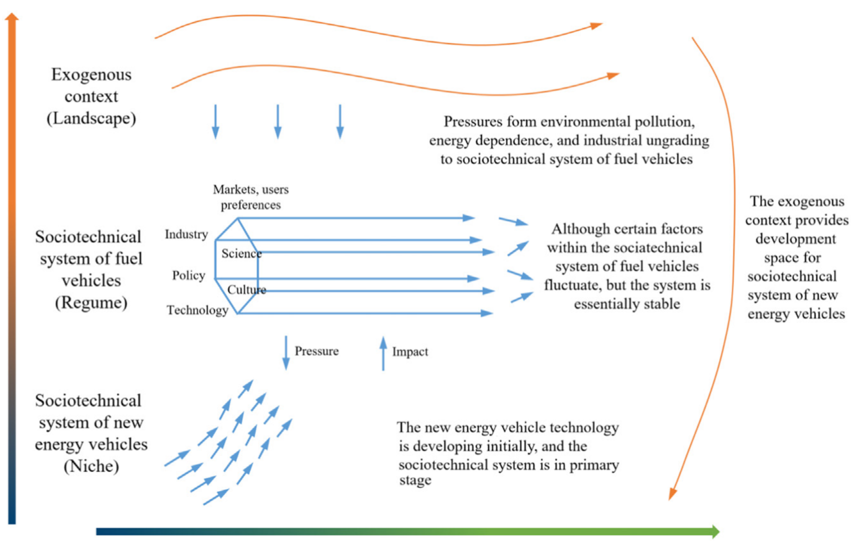

Figure 13.1 Interaction of the three MLP dimensions: landscape, system, and niche, in the sociotechnical system of the Chinese vehicle industry in four stages [58]. *MLP*, Multilevel perspective.

Dall-Orsoletta et al. [59] investigated possible related injustices in the life cycle of EVs. The findings clarified how EVs can contribute to flexibility justice through smart grid and V2G development. Fig. 13.2 represents the main aspects regarding distributive justice and flexibility justice based on life cycle stages being considered, along with positive (+), negative (−), or a combination of symbols (− +) indicating the potential impacts of EVs. As can be seen in Fig. 13.3, the distributive injustice is evenly distributed throughout the life cycle stages, which indicates the existence of potential negative impacts of EVs and is against the just energy transition. EVs seem to have the potential to positively impact flexibility justice, mainly in the distribution and operation stages. In addition, this study provides some suggestions for the development of the social aspects of EV technology to promote its inclusive social innovation.

V2G is an approach that improves the sustainability and reliability of the electric and transportation systems by enabling a two-way connection between them. The transition from conventional vehicles to V2G allows vehicles to simultaneously increase the efficiency (and profitability) of the grid, decrease greenhouse gas emissions from transportation, and save operational costs for vehicle owners and other users. To understand the state-of-the-art in this research area, Sovacool et al. [60] conducted a systematic review of 197 peer-reviewed articles that addressed V2G-related studies. The study revealed that there are still many social barriers to V2G

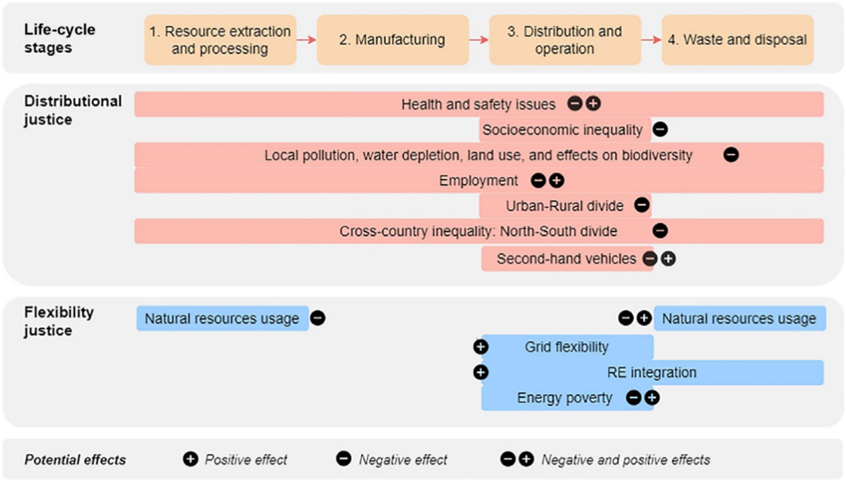

Figure 13.2 Distributive and flexible justice: the potential impacts of EVs [59].

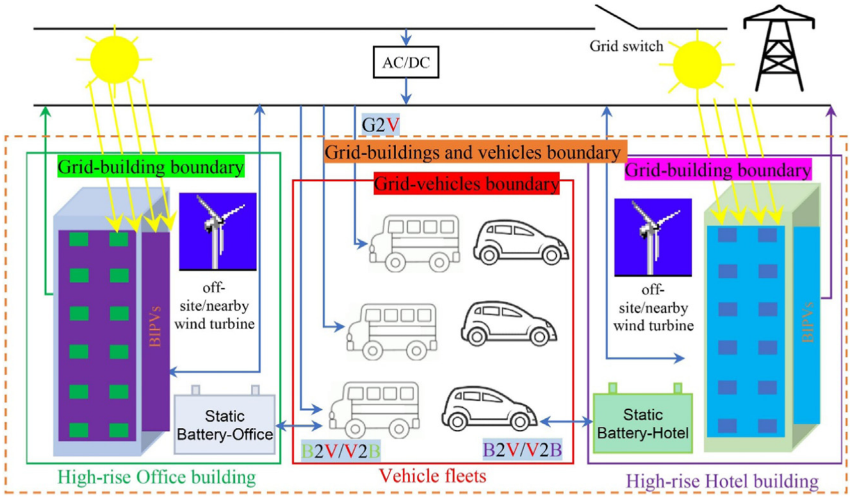

Figure 13.3 Schematic diagram of the renewable energy-buildings-vehicles energy-sharing network [42].

research, and many unexplored socially relevant questions remain for research. The complexities of business models, market segmentation, and the motivations of users have been virtually ignored in recent V2G studies. In addition, the study also clarified that the integrated energy communities need to consider a combination of human and social factors in their future studies.

The decentralized peer-to-peer energy-sharing technology is remarkably promising as the next-generation mechanism for smart building energy management that can facilitate the realization of near-net-zero energy buildings. In this background, Lyu et al. [61] proposed an integrated smart building energy-sharing framework that considers multiple dynamic components, including the heating, ventilation, and air conditioning system, the battery storage system, and EVs, aiming to maximize social benefits through peer-to-peer energy cooperation. An extensive case study based on a smart building community shows that the proposed peer-to-peer interaction framework can significantly improve the overall social welfare of the smart buildings involved.

In summary, with regard to government decision-making, the ministries and statistical agencies responsible for buildings and energy should collect data on sociocultural trends and more active community participation should be mandated to minimize communication and collaboration barriers [62–64]. The government could also recommend that socioculturalism be considered a core competency required by practices responsible for planning and implementing low-carbon transitions [65,66]. Policymakers should also pay more attention to the aspirations and capacities of groups and collective phenomena to shape and influence low-carbon transitions. Moreover, such socioculturally aware measures, as well as any resulting policies, will also need to be inclusive [67].

13.3 Technoeconomic analysis of integrated building transportation energy system

The techno-economic analysis of IBTES is an essential step to successfully implementing the application in practice, which contributes to optimizing energy utilization, informing decisions, reducing costs, improving energy security, decreasing carbon emissions, and achieving economic benefits [68–71]. A summary analysis of this integrated system from different perspectives can provide some valuable recommendations to decision-makers so that they can make informed decisions about IBTES implementation and ensure that the systems are implemented in a cost-effective and sustainable manner.

Plenty of studies have shown that by integrating EVs into building energy systems, the degradation cost of batteries will increase due to the increased charge/discharge cycles [72–74]. The IBTES is economically feasible only if the operational cost savings of the integrated system exceed the battery degradation cost. Therefore considering the battery depreciation cost, some researchers have developed a dynamic battery degradation model [42] and a fuel cell degradation model [16] that are applicable for IBTES. Based on the life-cycle economic performance analysis of this system, the battery performance was overestimated by 20% (from 2.404×10^8 to 3.005×10^8 HK$) if the battery cycle degradation was not taken into account [40].

Zhou et al. [42] proposed a resilient energy network with interactive renewable energy-buildings-vehicles energy sharing, as shown in Fig. 13.3. In this study, energy management is performed through a centralized collaborative controller of renewable energy and grid power to be responsive to the mobile consumption and energy demand of the buildings. The study also developed an advanced battery conservation energy control strategy for EVs to investigate equivalent CO_2 emissions, import costs, energy flexibility, and the equivalent relative capacity of battery storage. It also proposed a robust solution for relative capacity improvement by limiting the lower limit of the fractional state to 0.7. In addition, in another study by Zhou et al. [75], a transition framework from negative to positive regional energy-sharing networks, considering battery cycle degradation, advanced battery management strategies, and flexible building-vehicle interaction, was proposed, as shown in Fig. 13.4. The study also investigated the techno-economic performance, including net present value, discounted rate payback period, and net direct energy consumption. The results indicated that as the energy paradigm shifted from a negative to a positive system, the

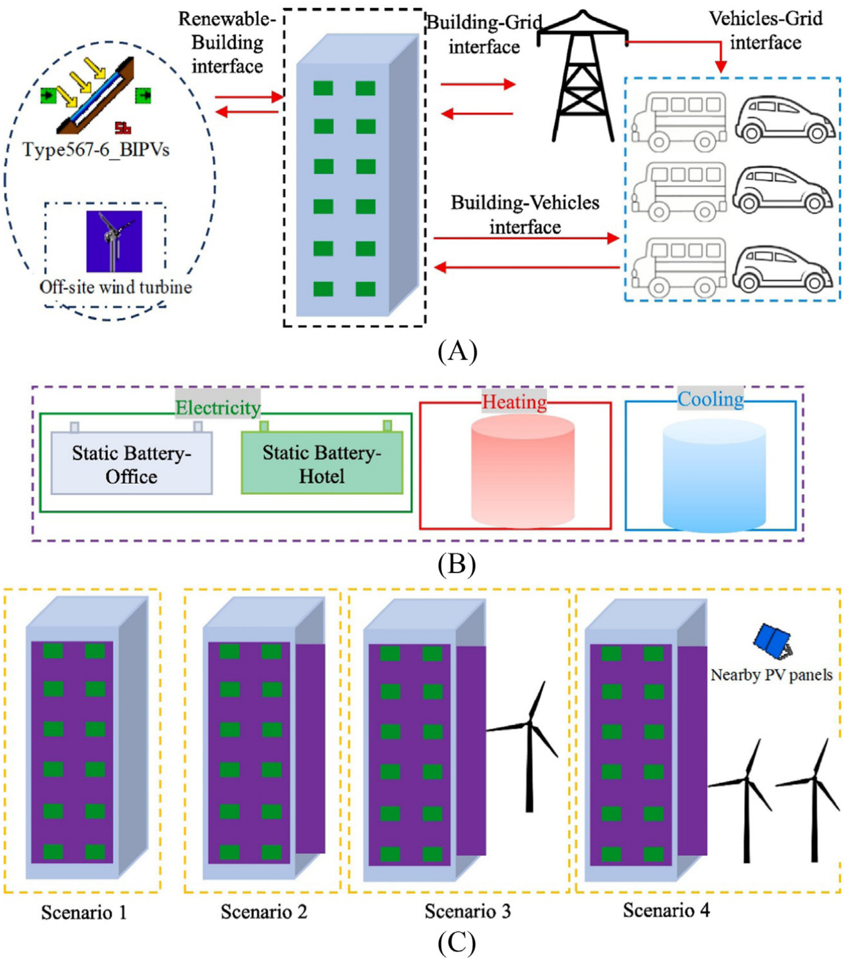

Figure 13.4 Schematic diagram of the proposed system: (A) system interface; (B) hybrid power and thermal energy storage; (C) energy paradigm transition from negative to positive system [75].

net present value increased from -7.182×10^7 to 5.164×10^8 HK$ and the average annual net direct energy consumption decreased from 249.1 to -343.3 kWh/m^2. The study also demonstrated the techno-economic performance of the district building-vehicle system and the shifting of the energy paradigm from negative to positive and proposed a series of promising solutions.

With the advancement of smart homes and smart electric grids, buildings as the largest consumers of electricity can participate in this smart operation to realize the integrated application of building and EV interactive grid system. Mirakhorli et al. [76] presented a building energy management system that takes into account electricity prices and occupant behavior, as shown in Fig. 13.5. In this coupled management system, air conditioners, water heaters, EVs, and battery storage are controlled in a building equipped with photovoltaics. The results indicated that these methods of real-time five-minute pricing can achieve cost savings of 20%–30% on these devices compared with traditional control systems. When the added battery-optimized control is considered in the control strategy, the total electricity cost savings for these appliances is 42%.

Zhou et al. [77] developed an interactive building-vehicle energy-sharing network with multidirectional energy interactions as well as a grid response strategy for managing nonpeak renewables and grid power, as shown in Fig. 13.6. The study addressed energy congestion conflicts and energy-related economic and environmental conflicts using an advanced multiobjective optimization algorithm (i.e., the Pareto-archived NSGA-II algorithm) to achieve optimal design and reliable operations. Results showed that the formulated interactive building-vehicle energy-sharing

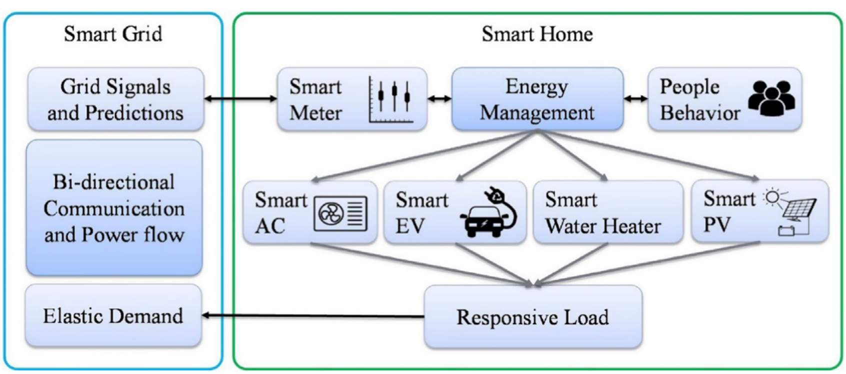

Figure 13.5 Overview of smart building and smart grid integration [76].

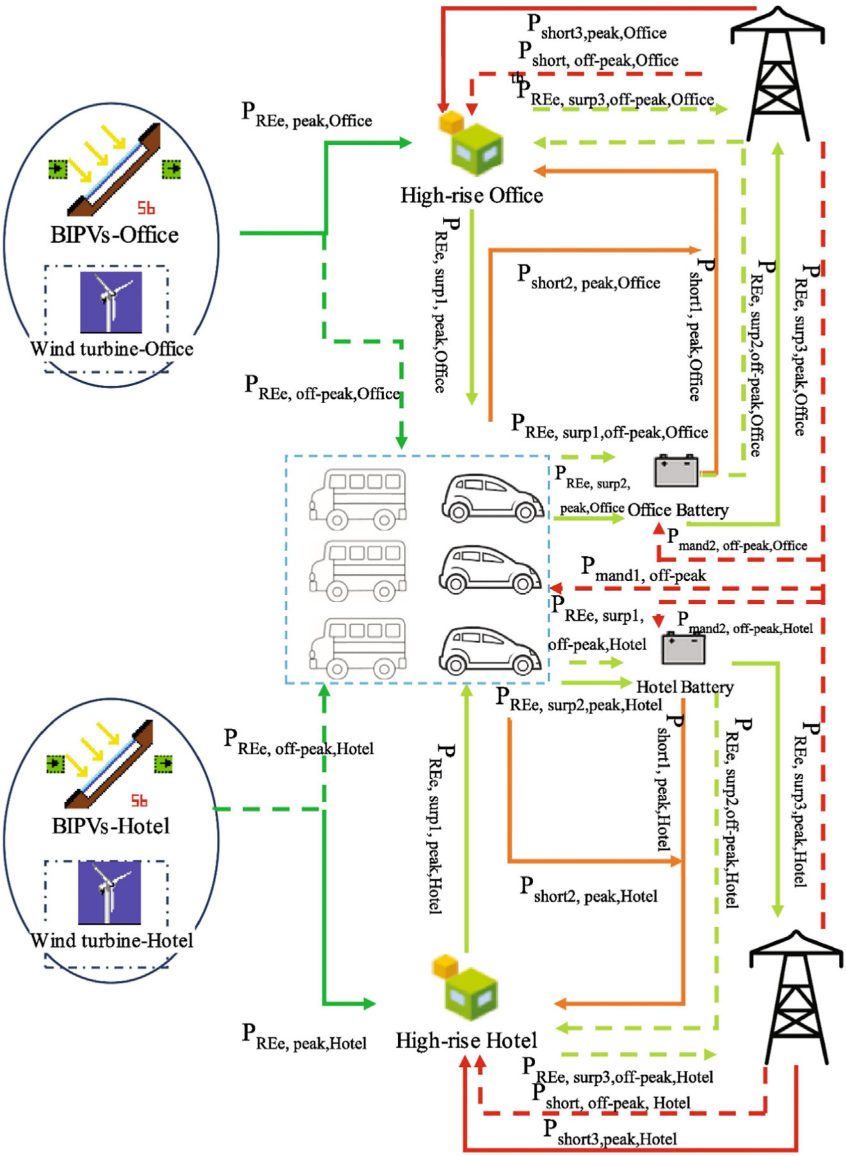

Figure 13.6 Schematic diagram of the interactive building-vehicle energy-sharing network [77].

network exhibits greater advantages over traditional isolated systems in terms of cost, emissions, and energy flexibility. Specifically, the optimized integrated system was able to decrease CO_2 emissions by 7.5%, from

147.4 to 136.4 $kg/m^2 \cdot a$, and import costs from the grid by 8.5%, from 212.7 to 194.6 HK$/$m^2 \cdot a$, compared with the pre-optimized system. This study is critical for an interactive building-vehicle energy-sharing network with high-level energy flexibility for smart cities and can provide effective solutions and implementation recommendations for decision-makers.

13.4 Implementation challenges and recommendations of integrated building transportation energy system in social and economic aspects

Achieving ambitious greenhouse gas emissions targets will require multi-sectoral, participatory programs that address direct emissions as well as supply chain and end-user emissions [38,78]. In addition to the technical challenges, there will be dual challenges in the social and economic aspects. This section will discuss and analyze the implementation barriers to IBTES and the effective targeted solutions of these two aspects.

13.4.1 Social perspectives

Technological developments can effectively address some issues during the implementation of IBTES. However, technological developments alone are not sufficient to effectively promote the development of IBTES applications. It is equally important to focus on the social aspects, such as public awareness and acceptance, the participation of different stakeholders, public policies, and regulations.

13.4.1.1 Public perception and acceptance

Challenges: Public perception and understanding of the IBTES is critical to its successful implementation. Perceptions, for example, its benefits, costs, and impact on the environment, regarding the system need to be positive to gain public support and acceptance [79,80]. In practice, the general public may not have sufficient awareness of the concept and benefits of IBTES, resulting in a lack of acceptance and support. Implementation of this IBTES may require some major modifications to building and transportation infrastructure, including retrofitting buildings, upgrading transportation systems, and changing energy usage patterns [45,81]. As a new technology, the public may question its effectiveness and reliability, and users are concerned about the series of problems that will arise during its usage. The public may resist these changes, preferring to stick to familiar systems, even though the IBTES system may be more effective and sustainable.

Recommendations: To increase the acceptance of IBTES, the benefits and reliability of the system can be illustrated through demonstration projects, case studies, and actual monitored data. It is necessary to share the monitored data and results of these projects with the public, including performance metrics and realized savings. Public awareness and understanding of this integrated system and its benefits can also be improved through the development and implementation of educational campaigns, workshops, and other outreach activities. In addition, regular monitoring and evaluation of the impacts of this integrated system on the public and the environment are necessary to make adjustments and improve the system over time. These measures include establishing feedback mechanisms, such as surveys and focus groups, as well as performance metrics and data analysis. Based on this, addressing concerns and fears about the applications of these new technologies through open and transparent communication will also help build public support for their usage.

13.4.1.2 Cooperation and participation of stakeholders

Challenges: The collaboration and engagement of stakeholders are critical aspects of the successful implementation of some advanced energy systems [82–84]. Therefore when promoting the implementation of IBTES in practice, different stakeholders may have different priorities and conflicting interests among them, which can hinder cooperation and engagement due to a lack of trust. On the other hand, different stakeholders may have various levels of expertise and experience, and they may have different viewpoints on promoting the implementation of IBTES, which may lead to misunderstandings and communication barriers to some extent. Stakeholders may also oppose the changes due to a lack of understanding of the advantages and benefits of IBTES. In addition, it is difficult for many stakeholders to participate in decision-making about the implementation of IBTES, which can affect trust and prevent collaboration among different stakeholders.

Recommendations: Creating trust among stakeholders is essential in ensuring their effective collaboration and participation, which can be achieved through open and transparent communication, as well as creating opportunities for feedback and input from stakeholders [85,86]. Effective communication and knowledge sharing are essential in ensuring that all stakeholders have a mutual understanding of the integrated system and its benefits. This is accomplished through regular training and education programs and opportunities for knowledge sharing and collaboration. Encouraging the participation of stakeholders in the decision-making process contributes to building trust and fostering collaboration, which can be achieved through regular meetings and joint decision-making processes between different stakeholders.

13.4.1.3 Incentive measures for participants

Challenges: Numerous studies have shown that the process of the practical application of new energy systems usually lacks effective incentives, which decreases the usage rate of the technologies [87,88]. Conventional energy plants and energy efficiency service companies do not prefer to adopt a decentralized model to replace their already well-established revenue streams. Therefore targeted incentives are necessary to promote the participation of all energy stakeholders in the implementation of IBTES, such as price incentives that allow consumers to choose a nearby distributed energy retailer, and policy incentives that allow utilities to coordinate and distribute peer-to-peer energy transactions in the district community.

Recommendations: For this integrated energy system incentives must be developed to satisfy the diverse requirements of users with different roles and functions in the decentralized environment. Through decentralized identity management, the integration and extension of various roles, responsibilities, and interactions of decentralized market actors at different levels can be supported. The customized incentives must be deployed in different organizations and individuals, which will encourage an increasing number of participants and facilitate a more interoperable, consistent, transparent, and trustworthy energy society.

13.4.1.4 Regulatory policies and government support

Challenges: Regulatory policies and restrictions can pose significant barriers to IBTES implementation [89]. The inconsistency of regulations and related policies in different jurisdictions can cause many problems in the implementation of IBTES. In practice, there is still a lack of standard procedures for implementing IBTES, making its implementation less efficient and the whole process more time-consuming and complex. In addition, national and local government support is critical to the successful implementation of IBTES, as regulatory policies and restrictions are typically driven by government decision-making [89,90].

Recommendations: To overcome the barriers of inconsistent regulations, it may be necessary to develop consistent common standards and regulations for the system across regions and to harmonize policies to minimize confusion and improve predictability. To mitigate the barriers of standardized procedures, it may be necessary to develop common protocols and procedures for different regions, and simplify and streamline the permitting process, and make the application process more straightforward and user-friendly to ensure the smooth implementation and effective operation of the integrated system. In addition, it is beneficial to build political support for the implementation and advancement of this system by engaging different stakeholders and achieving consensus on their interests and potential impacts.

Overall, to overcome these societal barriers, a comprehensive and coordinated approach that involves all relevant stakeholders, including government agencies, building owners and suppliers, and the public, will be required in future studies. This can ensure that regulations and policies are introduced that effectively support the implementation of the system and avoid creating unintended barriers to its implementation. Effective stakeholder engagement and collaboration can contribute to building an understanding of this system and identifying and addressing some issues that arise during the advancement process.

13.4.2 Economic perspectives

The implementation challenges and recommendations of IBTES from the economic perspective include the initial build cost of the system and the maintenance costs, uncertain return-on-investment cycle, financial incentive measures, and market demand and competition of the system.

13.4.2.1 System initial build and maintenance costs

Challenges: The implementation of IBTES requires a significant initial investment, which may include the cost of design and construction, as well as retrofitting existing buildings and transportation systems. The high up-front costs can make it difficult for building owners, energy providers, and transportation operators to adopt the system, especially in areas with limited financial resources or incentives. The major factors hindering the development of the IBTES market also include high equipment purchase prices, and high vehicle depreciation costs [91]. Many users are unsure about the cost of charging their cars or exactly how much power is required. This lack of knowledge hinders the calculation of possible costs and savings and therefore leads to inaccurate cost comparisons [92]. The battery lifetime of EVs is generally limited, and it may be a concern for many users that the costs of battery replacement will outweigh the lower operating costs, resulting in no significant economic benefit from EVs [93]. In addition, upgrading existing buildings and transportation infrastructure to support an IBTES may be expensive. These costs include the costs of equipment and technologies, such as smart energy management systems, EV charging stations, and building automation systems.

Recommendations: Faced with the high initial build and maintenance cost of IBTES, a number of scientifically reasonable measures need to be taken to overcome them. For example, obtaining funding and grants from government agencies, private sector organizations, and other sources can contribute to offsetting the high costs of technology and infrastructure upgrades. Leveraging existing building and transportation infrastructure, such as existing electrical and communications systems, can help reduce the costs of renovation and upgrading. The implementation of cost-effective technologies, such as low-cost building automation systems and EV charging stations, is available to assist in reducing costs and making integrated systems more affordable.

13.4.2.2 Uncertain return-on-investment cycle

Challenge: Users may be hesitant to invest in IBTES due to concerns about return on investment (ROI). This uncertainty stems from multiple factors, including the lack of standard metrics to assess ROI, the complexity of technologies, and limited case studies. The lack of standard metrics to assess the ROI of IBTES hinders the process of quantifying the benefits and accurately calculating the ROI [94,95]. Lack of standardization can cause confusion and mistrust among stakeholders and complicate the procedure of securing funding and support for IBTES implementation. In addition, technical complexity makes it challenging to quantify energy savings and benefits and increases uncertainty about the ROI.

Recommendations: The uncertainty of the ROI cycle can make it difficult to obtain funding and support for IBTES, especially when there is limited data and experience with these systems. The development of standard metrics to assess the ROI for IBTES can help quantify the benefits, accurately calculate the ROI, reduce uncertainty, and make it easier to obtain funding and system support. Encouraging collaboration among stakeholders, including building and transportation providers and technology providers, can help address the technical complexities of IBTES and increase the availability of data and case studies on the ROI of the integrated systems.

13.4.2.3 Financial incentive measures

Challenges: One of the main barriers to implementing financial incentives is the lack of awareness among users about the existence of these incentives and the potential benefits they can bring [96–98]. Many users may not be sufficiently aware of the policies and opportunities that exist for financial support. In addition, many users may perceive the application process for financial incentives as potentially complex and time-consuming because the process can involve extensive documentation and verification of information. This can be a challenge for users who are unfamiliar with the process, discouraging them from pursuing these financial incentives. The availability of financial incentives may be limited, which creates some uncertainty for users who are considering investing in the integrated system. The restrictions on the availability of financial resources can make it challenging for some users to obtain effective incentives [89,99].

Recommendations: To overcome these barriers, a number of measures can be adopted for the promotion of financial incentives for IBTES. These measures include awareness campaigns, seminars, and training sessions to increase users' understanding of the system's benefits and the incentives that support them [100,101]. To minimize the burden of applying for incentives, it is possible to simplify the application process. This can be achieved by streamlining the documentation and verification processes and providing clear and comprehensive guidance on the application process.

13.4.2.4 Market demand and competition

Challenges: The success of IBTES is dependent on the level of market demand, which can be influenced by several factors, including energy costs, public awareness, and availability. The demand level for IBTES can also be influenced by the level of competition from other energy systems. This is because users may not be aware of the benefits of these systems, or may not understand their potential benefits. The market demand for IBTES remains low at this stage, especially in areas where people are not yet aware of the benefits of such systems. For these systems to be successful, there needs to be a significant level of interest and demand from users. In addition, the lack of public awareness and understanding of these systems may limit their ability to compete with more mature energy sources, such as geothermal energy, which may also make it difficult for these new energy systems to establish a firm foothold in the marketplace [102,103].

Recommendations: To overcome these barriers, it is necessary to emphasize the building of awareness among users. It is critical to provide education about the potential benefits of these systems so that users can realize the potential savings on their energy bills and the positive impact of these systems on the environment. It is important to search for solutions to reduce component costs, optimize energy production, and improve energy efficiency. In addition, partnerships with other organizations and businesses can help increase market demands and contribute to decreasing competition by sharing resources and knowledge. Government incentives can play a key role in increasing market demands for new energy systems, including tax credits, subsidies, and grants, which can be used to make these systems more affordable and accessible, thereby increasing market demands and diminishing competition from conventional energy sources [104–106].

13.5 Conclusions and future studies

This chapter summarizes the current application and development status of IBTES from two different perspectives, social and economic. The results illustrated that IBTES has a large decarbonization potential and can effectively mitigate carbon emissions in the building and transportation sector. The system also has promising social and economic benefits as well as good potential for applications. In addition, this chapter also discusses the main issues and challenges in the practical application of IBTES from social and economic perspectives, including low social acceptance; unfamiliarity with the technology; poor stakeholder cooperation, participation, and motivation; high initial build and maintenance costs of the system; and inadequate incentives. Based on these existing challenges, this chapter proposes recommendations to effectively promote the implementation of IBTES in practice. This study can provide theoretical guidance and suggestions in IBETS-related industrial developments for policymakers.

As the role of IBTES becomes increasingly important in achieving global carbon neutrality, future studies will be conducted in the following areas to improve their practical applications:

1. An analysis of current and future market trends around IBTES can be conducted in the future. This includes consumer demand, adoption rates, and market growth, as well as the key driving factors for market demand and competition, which will provide valuable insights into the most effective strategies for increasing market demand and reducing competition, as well as opportunities for growth and improvement.
2. Future studies are expected to integrate the user experience of IBTES with the evaluation of social welfare. In addition, the evaluation of the social aspects of IBTES should incorporate the assessment of perception or acceptance to facilitate the commercialization of the system.
3. Comparative studies of IBTES in different regions and countries can be conducted in the future, including its implementation, adoption rates, and market demands. This will help identify best practices and lessons learned from other regions, as well as opportunities for their improvement.
4. A life-cycle analysis of IBTES should be considered, including the environmental and social impacts, as well as their economic costs and benefits. This will help identify the most sustainable and cost-effective strategies for implementing these systems, as well as the overall environmental and social impacts.

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