Future social acceptance of the sustainable heating solution assessment: a participatory modelling approach

Abstract

The long time horizon of sustainable energy developments is often associated with all sorts of issues that are caused by changes in values. The public attitude can be affected by these changes and potential risks in the lack of social acceptance could occur, which always lead to public oppositions to the implementation of the sustainable energy system in a city district. Integrating social acceptance into the long-term planning of energy projects is necessary to lower the risks. However, it is hard to assess the future acceptance of energy consumers in different sustainable energy options. Also, different stakeholders always have different opinions and concerns on the public accepted solutions, which causes conflicts in negotiation in the planning and decision-making phases. This research employed a participatory modelling approach to forecast the possible future developments in the district heating network in Amsterdam Southeast concerning the value changes. This method also helps stakeholders to understand the design requirements of the more public accepted sustainable energy system in the future.

Keywords: Sustainable energy development; Regional long-term planning; Participatory modelling; Scenario analysis; Cross-impact balance

1. Introduction

Reducing carbon emissions has become an increasingly significant part of the efforts that most countries put in fighting climate change and promoting sustainable development. The national climate agreement of the Netherlands (2019) asks for a 49% reduction by 2030, and a 95% reduction by 2050, compared with 1990 levels. To achieve this goal, the city of Amsterdam is pursuing sustainability in its district heating and cooling system development. One of the pilot projects is the low-temperature (LT) heating grids expansion in Amstel III, which utilizes the waste energy from data centres to supply heat to different energy consumers in this area. This energy solution can benefit both sides of the network. For local inhabitants, the new energy source can supply the space and hot water heat in a more environmental-friendly and efficient way. The overall energy costs will also be reduced in the long term. For data centres, they will exchange their residual heat with additional cooling capacities in the summer, which can lower their operation cost in heat dissipation as well. Since the data centre is one of the largest electricity consumers in Amsterdam Southeast, increasing energy use efficiency has become its KPI for future development.

In this LT district heating network, the aquifer thermal energy storage (ATES) system will be employed to store and extract heat or cold in the groundwater in different seasons. The central heat pump will be used to produce heat to provide sufficient space heating energy to the houses, and the smaller booster heat pumps that are installed in individual dwellings can be used for the domestic hot water. This type of heat network is suitable for houses that have limited space for a complete heat pump. Moreover, the houses that join this LT system must meet the preconditions, for instance, the adequate insulation of buildings. Therefore, this network is particularly suited for the new-built or recently renovated house with at least an energy label C (Duurzaam Verwarmen, 2019).

However, there are still many challenges in implementing this more sustainable system in Amstel III. The potential issue that is caused by the lack of social acceptance is one of the risks that should be considered in the planning phase of this project. The long duration and the long-term investment in the energy infrastructure deployment and operation require an assessment of the futures social acceptance, in order to design the network to avoid possible disruptions (e.g., the resistance of local inhabitants).

The previous literature either does not consider the possible future changes in the social acceptance investigations, or does not integrate public attitude factors into the long-term planning of renewable energy projects. This research is intended to investigate' *How can the social acceptance of sustainable heating systems be assessed and improved for a city district's future development plan?'*. Appropriate approaches and indicators shall be selected for this assessment. In this project, values, which are relatively stable over time, are chosen as the social acceptance criteria to examine the sustainable district heating system designs in Amstel III. The changes in public perception and preferences for values can reveal the issues that could occur in future decades.

2. Social acceptance and values in the sustainable heating solution

Social acceptance can be defined as '*positive attitude towards technology or measure*' (Batel et al. 2013). The lack of social acceptance will reduce the readiness of energy transition to meet a city district's needs for sustainable heating and cooling (Neofytou et al., 2020), and may lead to much public opposition.

There are various research approaches to investigate the social acceptance of specific activities that are intended to implement. For instance, the work of Lidynia et al. (2016) employed the Knowledge, Attitude and Practices (KAP) survey model to look into the public acceptance and perceived barriers to civil drones in different usage scenarios. In this project, the future public attitude is evaluated by the possible value changes for the local energy consumers. It is because this study is oriented to the long-term planning of sustainable heating development in the case of Amstel III, while the future public attitude of renewable heating solutions is hard to be assessed in the long time horizon with appropriate criteria. To identify the potential issues concerning the lack of social acceptance, the perception and preference of local energy consumers to social and moral values, which are more durable factors, are used to be the criteria to foresee different types of sustainable energy behaviours (e.g., the adoption of sustainable energy sources) in the future.

Hofman (2015) suggests that energy consumers' acceptance of sustainable energy options (e.g., the wind farm) could be affected by the fulfilment of values to which they attach great importance. Four values are selected in this project (Table 1) based on the sustainability index for energy grids from the city of Amsterdam. Additionally, the value 'Fairness' that represents one of the biggest concerns of local inhabitants is added to the list based on the literature review, which is also validated by experts through interviews and workshop.

The relationships among different values can be either conflicting or promoting. Those interdependencies of values can be used to forecast future scenario concerning the possible changes, since the scenario with many conflicts among its internal elements should be considered as unrealistic.

Besides the public attitude that is reflected by values, other assessment factors in KAP model, i.e., knowledge and practice, are not involved in this research directly. It is because the criteria selection of this project is mainly based on expert elicitation in the semi-structured interviews, and they are not identified as major driving forces for social acceptance in the case of Amstel III. However, they still have impacts on other personal and contextual factors in the assessment framework of social acceptance in this research, and are considered indirectly.

Table 1 Identified values in assessment criteria

Values	Definition
Environmental sustainability	The system meets its carbon obligation. (55% reduction by 2030 and 95% reduction by 2050)
Affordability	Energy consumers pay costs for the system with a reasonable amount of their budget.
Openness	The system has no lock-in in technology or market for energy suppliers and end-users.
Fairness	The system provides equitable access to energy for local inhabitants and keeps distributive justice and procedural justice in energy transition processes.

3. Research methods

This project employed a research approach that combines both qualitative and quantitative techniques to identify the potential mismatches between the possible futures concerning value changes and the sustainable heating network designs in Amstel III (Figure 1). This approach contains two parts:

Figure 1 Research approaches

First, by conducting in-depth interviews with experts in energy-related sectors from governments, NGOs, commercial organizations, and local communities in Amsterdam Southeast (Table 2), the insights on regional sustainable energy development were gathered to understand the future trends in sustainable district heating and cooling system, as well as the conflicts and correlations between different values that are of great importance for local inhabitants in energy solutions assessment.

Table 2 Participants of interviews

Interviewee	Organization	Times
Policymaker 1	The city of Amsterdam	1
Policymaker 2	The city of Amsterdam	2
System operator 1	Equinix	1
System operator 2	Waternet	1
System operator 3	Vattenfall	1
System operator 4	Firan	1
Project initiator 1	AMS Institute	1
Project initiator 2	IF Technology	1
Citizen 1	ZO!City	2
Citizen 2	CoForce	1

Second, through a systematic scenario analysis by using CIB matrix, which is a participatory modelling approach, the most likely value changes for the energy consumers in the district heating system in this area can be forecasted by computing the internal consistencies of future scenarios based on the interdependencies of scenario elements, including the importance of critical values and other exogenous factors that can affect the fulfilments of values.

CIB matrix

The model in this research is the Cross-Impact Balances (CIB) matrix, which is developed by Weimer-Jehle (2006) and used for the construction and internal consistency evaluation of scenarios. The CIB approach can be separated into five stages (Kunz and Vogele, 2017):

- Delimitation of the field of research
- Identification of system elements (Descriptor)
- Defining the possibility-room and shaping of CIB elements (Descriptor state)
- Expert judgments
- Interpretation and scenario-output

The scope of this research mainly concentrates on the potential issues in future sustainable heating development in Amstel III, resulted from the lack of social acceptance, which is assessed by the possible value changes for local energy consumers. The defined variables in CIB, which are called descriptors, and their corresponding states (Table 2) were collected through expert elicitation during the interviews. Besides values, other determinant social factors that have impacts on the fulfilments of the

Table 3 Scenario descriptor and descriptor states

Descriptors:	variant [1]	variant [2]	variant [3]
A. Importance of 'Environmental sustainability'	A1. High	A2. Medium	A3. Low
B. Importance of 'Affordability'	B1. High	B2. Medium	B3. Low
C. Importance of 'Openness'	C1. High	C2. Medium	C3. Low
D. Importance of 'Fairness'	D1. High	D2. Medium	D3. Low
E. CO2 Emissions	E1. 0 reduction	E2. 55% reduction	E3. 95% reduction
F. Household income	F1. Top 20%	F2. Medium	F3. Bottom 40%
G. Technical lock-in	G1. Strong	G2. Weak	
H. Public participation	H1. High	H2. Medium	H3. Low

selected values are also included in the CIB matrix.

The combinations of those descriptor variants form different scenarios. In this research, 8 selected descriptors with 23 variants in the CIB matrix generate 4374 (=3*3*3*3*3*3*2*3) scenarios in total. In those scenarios, the internally consistent ones are considered as the most possible futures in the case of Amstel III. This internal consistency is computed with an algorithmic method based on the interdependencies among different descriptor variants, which are collected through the interpretation of experts' statements from a workshop.

Workshop designs

The workshop was held during the weekly online meeting of the city of Amsterdam, with around 20 experts and employees in the energy field. The participants were invited to provide judgements on the relationships between scenarios descriptor variants. Based on their verbatim statements, the interdependencies of scenarios elements were transformed into semi-quantitative (ordinal) data in the cross-impact matrix for the computation of Inconsistency Score. The most frequently used way of coding (CIB-Lab, n.d.) is presented below:

Table 4 Scales of interdependency

Relationships	**Code**
Strongly restricting influence	-3
Moderately restricting influence	-2
Weakly restricting influence	-1
No influence	0
Weakly promoting influence	+1
Moderately promoting influence	+2
Strongly promoting influence	+3

It should be noted that only direct influence is taken into account to avoid double-counting. Also, standardization of CIB is performed to enhance the comprehensibility of the data. An example of the cross-impact matrix, which indicates a weakly restricting impact of high 'Importance of 'Environmental sustainability' on high or medium-level' Importance of Affordability'.

Table 5 A section of CIB matrix

		Importance of 'Affordability'		
		High	Medium	Low
Importance of 'Environmental sustainability'	High	-1	-1	2
	Medium	-1	0	1
	Low	0	0	0

The CIB matrix in this research consists of 56 (=8*8-8) such sections in total. By collecting and interpreting experts' judgements to fill these sections, the full matrix is built to reflect the complex interdependencies among scenario elements (Figure 2).

	A			B			C			D			E			F			G		H		
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3	F1	F2	F3	G1	G2	H1	H2	H3
A. Importance of 'Environmental sustainability'																							
A1. High				-1	-1	2	0	0	0	0	0	0	-2	-1	3	0	0	0	0	0	1	1	-2
A2. Medium				-1	0	1	0	0	0	0	0	0	-1	1	0	0	0	0	0	0	1	0	-1
A3. Low				0	0	0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0	-1	0	1
B. Importance of 'Affordability'																							
B1. High	0	0	0				-1	-1	2	1	1	-2	0	0	0	0	0	0	0	0	1	1	-2
B2. Medium	0	0	0				-1	0	1	1	0	-1	0	0	0	0	0	0	0	0	1	0	1
B3. Low	0	0	0				1	0	-1	0	0	0	0	0	0	0	0	0	0	0	-1	0	1
C. Importance of 'Openness'																							
C1. High	0	0	0	-1	-1	2				1	1	-2	0	0	0	0	0	0	-3	3	1	0	-1
C2. Medium	0	0	0	-1	0	1				1	0	-1	0	0	0	0	0	0	-1	1	0	0	0
C3. Low	0	0	0	1	0	-1				-1	0	1	0	0	0	0	0	0	1	-1	-1	0	1
D. Importance of 'Fairness'																							
D1. High	0	0	0	-1	-1	2	1	1	-2				0	0	0	0	0	0	0	0	2	1	-2
D2. Medium	0	0	0	-1	0	1	1	0	-1				0	0	0	0	0	0	0	0	1	0	-1
D3. Low	0	0	0	1	0	-1	0	0	0				0	0	0	0	0	0	0	0	-2	-1	3
E. CO2 Emissions																							
E1. 0 reduction	2	1	-3	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0
E2. 55% reduction	1	0	-1	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0
E3. 95% reduction	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0
F. Household income																							
F1. Top 20%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0
F2. Medium	0	0	0	1	0	-1	0	0	0	1	0	-1	0	0	0				0	0	0	0	0
F3. Bottom 40%	0	0	0	2	1	-3	1	0	-1	1	1	-2	0	0	0				0	0	0	0	0
G. Technical lock-in																							
G1. Strong	0	0	0	0	0	0	2	1	-3	1	0	-1	0	0	0	0	0	0			0	0	0
G2. Weak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0
H. Public participation																							
H1. High	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1			
H2. Medium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
H3. Low	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			

Figure 2 Full matrix for the case of LT network in Amstel III

4. Scenario modelling results

The internally consistent scenarios from the CIB matrix are considered as the most possible future developments in the sustainable heating system in Amstel III. Due to the enormous workloads, the internal consistency of each scenario is computed by using the software 'ScenarioWizard'. The outcome of consistency evaluation of CIB matrix indicates that the consistent scenarios all show the characteristics as presented in Table 6.

A sensitivity analysis is also conducted to validate the model through the robustness assessment. By introducing new cross-impact relationships and adjusting the impact values in non-zero sections based on new assumptions (Schweizer et al., 2012), the sensitivity of the baseline matrix to the fluctuations (e.g., the relationship that is missed by the workshop participants) is evaluated. Five sensitivities are investigated for this research. The results show that, in most cases, the characteristics of consistent scenarios deviate little from the baseline model, while the consistency of some scenarios can be strongly affected by adding a new restricting influence of 'importance of fairness' on 'CO2 emission'.

Table 6 Variants in consistent scenarios

Descriptors	Descriptor states
Importance of 'Environmental sustainability'	High
Importance of 'Affordability'	Low
Importance of 'Openness'	High
Importance of 'Fairness'	High or Medium
Carbon reduction	95% reduction
Household income	All groups
Technical lock-in	Weak
Public participation	High

The outcome of the baseline CIB matrix suggests that the local energy consumers in Amstel III will be more willing to pay for more 'environmental-friendly', 'open' and 'fair' district heating networks in the future, no matter how their income levels are. Besides, they will be more active in participating in the planning and decision-making of sustainable energy projects, and they also expect the technical lock-ins in the heating system can be reduced significantly.

The current designs of LT network in this area could probably satisfy the environmental-friendly goals, while there are still many potential risks that challenge the social acceptance of this solution:

First, the district heating network cannot be as flexible as the electricity grid that allows more suppliers to join, since the system is not mature enough. The technical lock-ins will still exist in the following years, while future public expectations that are forecasted in the scenario analysis of this project indicate that choosing energy supplier freely every year is desired for local inhabitants.

In addition, Vattenfall, which is the energy monopolist in Amstel III, will continue to be responsible for the whole chain of heating supply. This monopoly will not comply with the increasing public concerns for the 'Fairness' in the future heating system. Also, there is a lack of institutional design to involve local energy consumers in the planning and decision-making processes of the project, despite the efforts that the city of Amsterdam put in sustainable energy promotion in local communities.

Furthermore, it is suggested by the interviewees that the feasibility of the LT solution from a technological perspective still needs further research to investigate in the future. For instance, the potential failure of the insulation system could lead to additional costs in electricity consumption for local energy consumers. However, it is observed during the interviews that the issue concerning engineering designs is a major point of contention among different stakeholders, for instance, the reliability of the infrastructure.

In sum, the LT system is likely to be accepted by the public due to its sustainability, while further improvements are still essential to meet the future public expectations in some specific values, for example, the openness of the network.

5. Participatory modelling

In the case of Amstel III, the negotiation among stakeholders is often difficult, since each party has its own interests, concerns, and studies in sustainable energy development. To enable the collaboration among different stakeholders to realize a more accepted district heating system for the public in Amstel III, it is essential to mitigate their potential conflict of opinions and identify the most suitable network designs to reach consensus.

The CIB matrix in this project is mostly contributed by the participants of interviews and workshop. They are the representatives of different key actors in the district heating system of Amstel III. Their participation in the modelling is critical for the stakeholder involvement in planning processes (Basco-Carrera et al., 2017), which improves the credibility of the outcomes of CIB matrix, and helps to have a better understanding of the complexities in sustainable energy network development.

As a participatory modelling approach, CIB matrix is used to clarify the potential lack of social acceptance in future sustainable heating grids designs (e.g., regulation formulation) for different stakeholders in this project. Also, by inviting stakeholders to collaborate on the matrix building, their knowledge and understanding of the interests, conflicts, and dynamics in the system can be enhanced (Voinov & Bousquet, 2010). Although the stakeholders' participation in planning can lead to the confrontational situation (Soriani et al., 2015), the traceability and transparency of CIB matrix can help stakeholders to figure out the causes of specific modelling outcomes, and help them to come to an agreement., Even though they may not be satisfied with the outcomes, they can understand the necessity of some tradeoffs, since they have participated in the whole processes of model building

For instance, in the baseline matrix in this project, most consistent scenarios show a low level 'importance of affordability'. By using the impact diagram in CIB matrix (Figure 3), it can be shown distinctly the influences that contributed to this result.

In addition, compared with other modelling approaches that are integrated with quantitative techniques (e.g., agent-based modelling), CIB matrix, which combines qualitative and semi-quantitative scenario analysis in this project are more suitable for long-term planning (Thomas, 2012). This advantage can satisfy the requirements of the energy development project that generally have a long time horizon and many uncertainties.

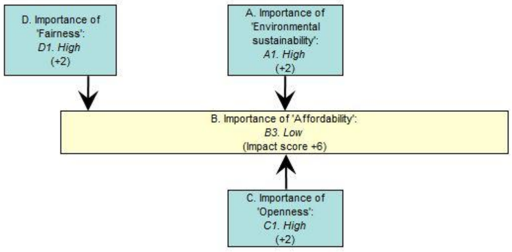

Figure 3 Impact diagram of 'Low importance of affordability'

However, the time and effort that the participants can provide could be a limitation for the CIB matrix (Broll et al., 2020). Therefore, adequate preparation (e.g., necessary training) and effective leadership (e.g., time control) could be critical for accomplishing this task. The organization like the joint venture (Diffen & Rocha, 2019) that gathers the people from different parties to work together and utilize their expertise in planning and decision-making processes, could better exploit the full potential of this model.

6. Conclusion

This project used a participatory modelling approach to involve stakeholders in scenario analysis model building, in order to identify the potential risks in the lack of social acceptance in the sustainable district heating network designs in Amstel III.

The outcome reveals that the LT heating system, which is in the future sustainable energy developemt planning of this area, can be a more accepted solution for the public as a result of its advantages in increasing the energy use efficiency and reducing the carbon emission, since the local community is estimated to attach more importance to environmental sustainability in the future. However, there are still some drawbacks in current LT network designs that could cause a lack of social acceptance, such as the lock-ins of the network and the public demand for procedural justice. Further improvements are required to design the network to meet the public expectations that are assessed by the value changes in this research.

In addition, this research indicates that the participatory modeling, especially a CIB matrix approach, is particularly suitable in dealing with the negotiations among stakeholders that have conflicting interests and opinions for more public accepted energy system designs. Future research could be further implemented by increasing the time and effort of participants in the modelling processes (e.g., training for the tasks beforehand) to improve the quality of models.

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