Enabling Citizen Participation in Sustainable Collective Action In Smart Cities: The Case Of Buiksloterham

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Abstract

Cities are responsible for 70 percent of greenhouse gas emissions worldwide, so they can significantly contribute to emission mitigation. Since cities are socio-technical systems, reducing emissions requires a combination of technological innovations, social engagement and institutional arrangements. In this study, we take a common pool resource (CPR) perspective to analyse cities as socio-technical systems that can reduce emissions. As a case study, we take Buiksloterham (BSH), a neighbourhood in Amsterdam, which is known as an experimental lab to test future plans towards being a smart, sustainable and circular neighbourhood.

Electricity and water are two major interconnected CPRs in BSH that play an important role in the liveability and sustainability of the neighbourhood. Managing these resources can be treated as a collective action problem that is highly dependent on the level of citizen participation. BSH has a well-specified action plan and future vision, which mainly focuses on the technological developments of the neighbourhood, but lacks plans regarding social engagement and institutional arrangements. We used Ostrom's Social Ecological System framework to analyse the two CPRs in BSH in order to study social engagement scenarios and to propose new institutional arrangements. We designed and formalized the institutions in the system using ADICO grammar of institutions [Crawford and Ostrom, 1995].

Widespread institutions like monitoring and sanctioning are costly mechanisms for avoiding free-rider behavior in collective action situations like BSH. They are also morally contested; we therefore do not consider them to be a preferred strategy for BSH. We propose to use a "grouping system" instead. Grouping is an institutional arrangement that gives households an opportunity to choose a colour-label based on their level of contribution to the system. Our grouping system is based on 1) the mechanism of assortative matching [Gunnthorsdottir et al., 2010] in voluntary contribution game and 2) motivation factor of "glory" in collective action [Malone et al., 2009]. We suggest grouping as a potential strategy that can tackle free-riding while also promoting citizen participation.

Keywords: commons, collective action, community, citizen participation, institution design, assortative matching

1 Introduction

Cities carry responsibility for the future sustainability of the world. They are consuming 75 percent of natural resources and producing 70 percent of green house gas emission worldwide. This situation will deteriorate as big cities will host 70 percent of the world population by 2030 [TNO, 2015]. Cities can take a significant role in facing the problems through the collective action of citizens. Citizen participation can collectively move the current state of cities into a more sustainable one [Forrest and Wiek, 2014].

Cities are composed of neighborhoods, from which sustainable transition is expected to take off [Mesch and Schwirian, 1996]. Neighborhoods of future cities will require great assistance from modern technology in order to facilitate sustainable collective actions. The realization of such projects seek the participation and engagement of inhabitants living in neighborhoods.

Researchers have done research on collective action in cities, suggesting that some institutional arrangements can promote and sustain such activities in cities [Forrest and Wiek, 2015]. Foster and Iaione [2015] study collective action around urban space / open space in general, and collective action around urban garden has been studied by Barthel et al. [2010], Scheromm [2015], and Petrescu et al. [2016]. Chatterton [2016] studies urban housing with a collective action perspective. The above-mentioned scientists have analyzed collective action around urban shared resources that are called ”urban commons” [Foster and Iaione, 2015].

The focus of studies on urban commons has mainly been on urban space (such as parks and gardens). None of the studies of urban commons to-date relate to technology-driven resources such as energy and water. Given the importance of technology-driven commons in cities, there is still limited research on studying technology-driven urban commons and collective action around them. Therefore, the goal of this research is to explore appropriate institutions for social engagement that enable citizen participation in collective action around technology-driven urban commons. The focus of this research is on collective action in a neighborhood located in the northern part of Amsterdam called Buiksloterham (BSH).

2 Methodology

We theoretically and empirically analyze the case of BSH. The theoretical analysis employs theories and frameworks. We used the SES framework to identify the technical and institutional components of the collective action happening around the urban commons in BSH.

We used the IAD framework, the Adaptive Institution framework, and other

institutional theories in order to design the institutions. ADICO Grammar of institutions is used to formalize the institutions.

3 Buiksloterham: an emerging neighborhood for sustainable collective action

The focus of this research is on collective action in a neighborhood located in the northern part of Amsterdam called Buiksloterham (BSH): a living lab for sustainable community-based development which is based on collective actions approach. Future plans of BSH are mostly about the technical interventions in this region. The technological future approaches of BSH focuses on the implementation of new technologies and infrastructures in the neighborhood. Such technical interventions will help to make the neighborhood of BSH smart and circular through local energy production and water and waste recycling.

However, there is not enough consideration on the systematic approach in BSH. This requires insight into the management of these technical interventions. BSH has a future vision on implementation of community-based governance, yet the possible methods to involve citizens in collective actions and arrange institutions still need to be investigated.

There are many short and long term future development plans in BSH. The future ambitions for BSH have a broad scope, ranging from targets in energy and material to mobility and wellbeing with a broad, systematic, integrated approach of long-term vision up to 2035. There have been several goals and future ambitions set in each domain, yet the main domains of interest in BSH are: Energy, Material, and Water (EMW). As shown in figure 1, BSH aims at local renewable energy production, a zero waste neighbourhood, and water recycling.

After recognizing the three main domains of interest in BSH and the prospect of a local Bio-refinery in BSH, we propose a framework of interconnected energy, material and water: the EMW framework in figure 2.

The EMW framework shows that material, in forms of food waste and urine, are recovered into energy and low-grade water.

First, in case of Energy, except from the demand reduction, BSH desires to: produce local renewable energy into a local smart grid with a smart energy management system. Therefore, there is a need for a local production of renewable energy by means of solar panels, for instance.

Second, in case of Material, and except from the demand reduction, BSH wants to: reuse and recycle material waste and wastewater such as organic waste in the kitchens. In this case, BSH needs to have a bio-refinery, organic waste collection in the kitchens via so called kitchen macerators, and a collection system

Figure 1: Three main future ambitions of BSH in three main domains of Energy, Material and Water (EMW)

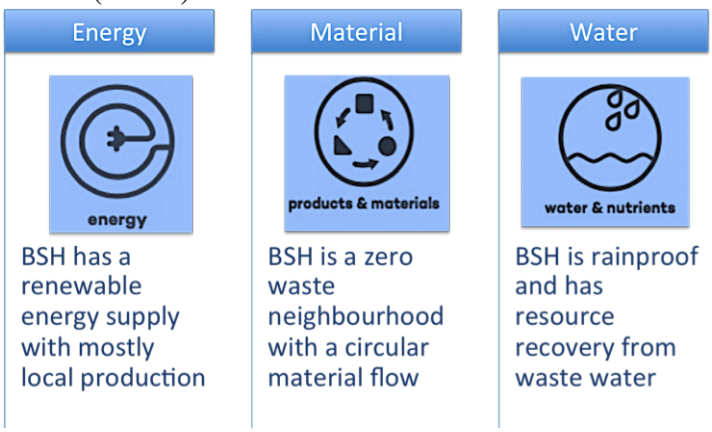
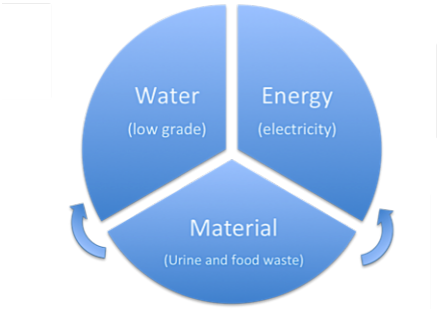


Figure 2: Proposed framework of EMW which shows interconnectivity in EMW through the local bio-refinery in BSH



of organic wastes.

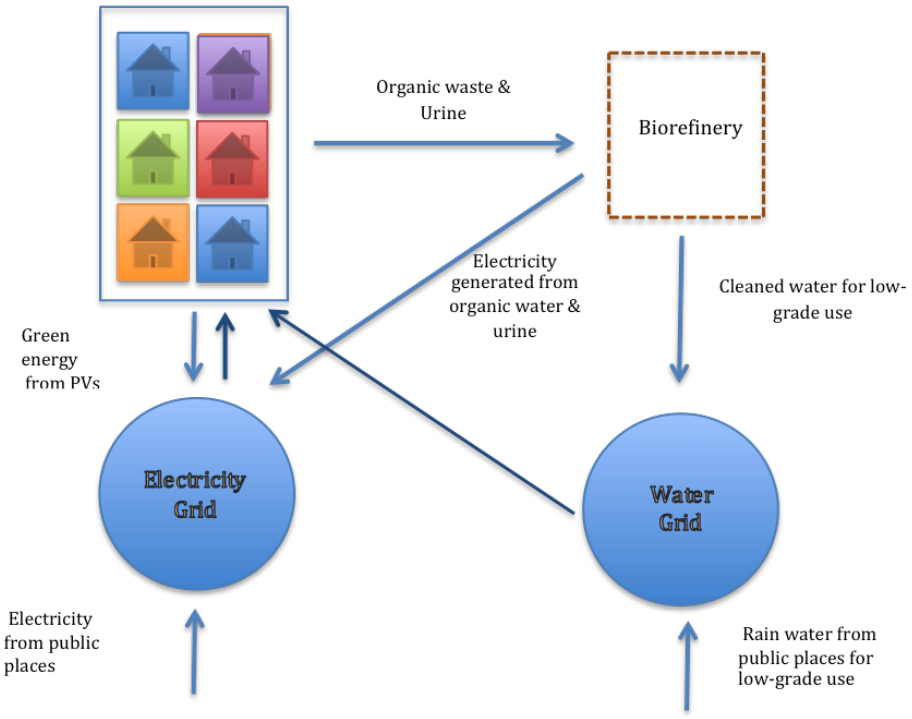
Third, in case of Water, BSH aims at collecting rainwater with a rainwater harvesting system. Besides, there are plans to separate highly polluted water from the lightly polluted water, and to recycle the water (remove micro-pollutants from waste water) for low-grade use. The mentioned ambitions call for a urine separation, rainwater collection, and the bio-refinery. In fact, the bio-refinery recovers the wastewater (collected from the kitchen and through urine separation in the toilets) into energy and low-grade water (for irrigation use).

After developing the EMW framework and its technical infrastructures, we propose a technical system that shows the components of the system.

As shown in figure 3, the EMW system (inter-connected Energy, Material, and Water) is technically realized through the bio- refinery in BSH, where recovery of waste and water is taking place. The outputs of the bio-refinery are resources of Water and Energy, which are locally shared with the inhabitants of BSH. These

two resources are the technology-driven urban commons in BSH. The two urban commons in BSH are in form of electricity produced by solar panels and through the bio-refinery, and water that is collected from rainwater and recycled through the bio-refinery. There are also some inputs into the urban commons of electricity and water from public places that produce electricity and collect rainwater. A theoretical analysis of the EMW system is presented in the following section.

Figure 3: The technical system of EMW with the technology-driven urban commons of Electricity and Water

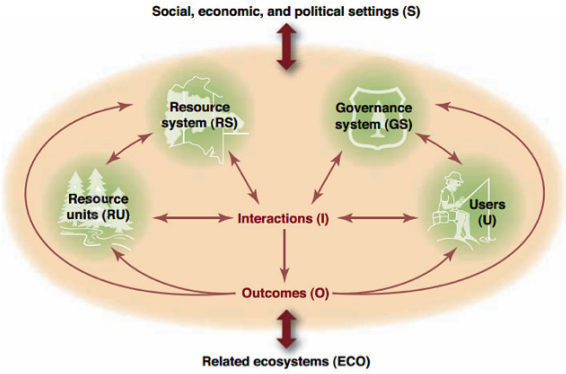


4 Theoretical Analysis of BSH Using the SES Framework

All humanly used resources are a component of social-ecological system (SES) [Ostrom, 2009]. The SES framework shown in figure 4 is basically used to an-

alyze the system with natural resources. As a case in point, imagine a social-ecological system with interactive subsystems of: a coastal fishery (resource system), shrimps (resource units), fishers (users), and rules that govern fishing on that coastal fishery (governance systems). However, in our research we use it for a system with technology driven urban commons, and we will have some contributions into the traditional use of SES. In fact, we employ the SES framework to theoretically analyze the EMW system and identify the main components of the system. The main reasons behind the choice of SES is that all humanly used resources are embedded in complex, social-ecological systems (SESs), and this framework is a common base for researchers working in the related field.

Figure 4: Social Ecological System (SES) framework. *Source* [Ostrom, 2009]

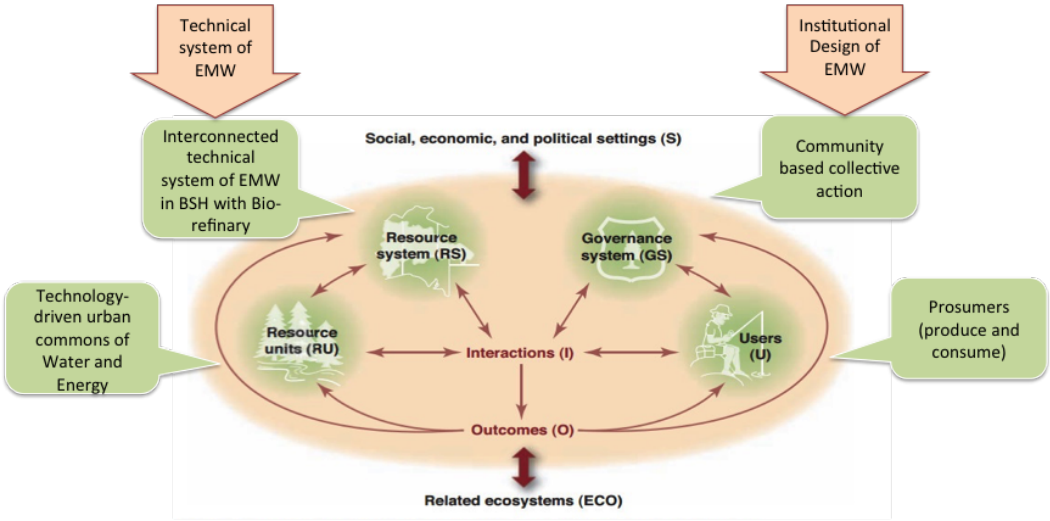


SES has four subsystems that are classified into two main categories of technical (resource system and resource unit, located on the right part of the framework) and institutional (governance system and users, located on the left part of the frame- work) (see figure 4). As figure 5 shows, each four sub-systems of resource system, resource units, governance system, and users in BSH are:

- Resource system: interconnected technical system of EMW in BSH,
- Resource units: locally shared technology-driven resources of water and electricity that are connected through the bio refinery,
- Governance system: community based collective action for which we design an institutional system of EMW (see the following section),
- Users: prosumers (inhabitants who produce and consume the resources of water and electricity)

The information gathered through the main report of BSH and interviewing the experts in BSH shows that, apart from the well defined technical developments, there is a need to investigate and study the possible social engagement

Figure 5: The SES (Ostrom, 2007) analysis of the EMW system in BSH and identification its four sub-systems of: resource unit, resource system, governance system, and users.



and institutional arrangement in the community-based governance system in BSH. Therefore, as it is shown in figure 5 the governance system to be developed for the EMW in BSH needs an institutional design approach, which will be addressed in the next section.

5 Institutional Design for the Socio-technical System of EMW in BSH

To design institutions that govern and promote collective action around the technology-driven urban commons of electricity and water in BSH, we adopted theoretical frameworks for institutional design: IAD [Ostrom, 2011] and adaptive institution frameworks [Koontz et al., 2015] (see the appendix). We also considered the success factors in sustainable transitions [Forrest and Wiek, 2015] as guidelines in designing institutional arrangements in BSH. Two theories of the Assortative matching [Gunnthorsdottir et al., 2010] and the Glory factor of motivation [Malone et al., 2009] are also the sources of inspiration to design the institutions.

In order to formalize institutions, we use ADICO (Attribute, Deontic, aIm, Condition, Or else) as a tool. It is a syntactical tool to help in explaining the institutions of a socio-technical system like our socio-technical system of EMW. We use Institutional Analysis and Development (IAD) framework to benefit from

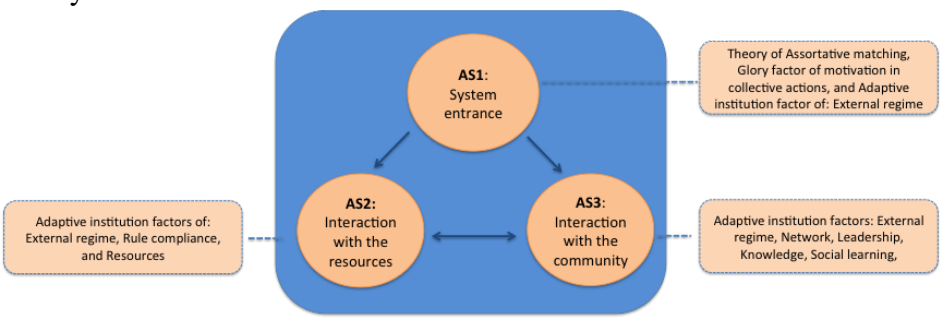
the concept of ”action arena”, in which the participant interact while they are affected by the attributes of the physical world, community, and rules (see IAD framework in the appendix). Interaction of the participants in the action arena may happen in different ”action situations”. In our case, we propose three action situations in the action arena. By having three different action situations, we add new structures that help analyzing institutions in more details.

There are three action situations (ASs) of:

- AS1: System entrance, in which inhabitants enter the system,
- AS2: Interaction with the resources, in which inhabitants prosume (produce and consume) the urban commons of electricity and water,
- AS3: Interaction with the community (social interaction), which includes the social interaction of the inhabitants.

As figure 6 shows, the first action situation is followed by the second and third action situation; inhabitants enter the system and start interacting with the resource and with each other. The one-directed arrows from AS1 to AS2 and AS3 show the sequence in the system from the first AS to the second and third. The two-directed arrow between AS2 and AS3 indicates that there are inter-connections between them (for instance, the social interaction of the inhabitants in AS3 can lead to learning, which can change their interaction with the resources). Furthermore, the figure shows the theories and frameworks that are used in each action situation. They will be explained more in details with their connection and relevance to our institutional system in the following sections.

Figure 6: The SES/IAD driven institutional system for governing the EMW resource system in BSH: one action arena and the three action situations (ASs) with the theory and framework used in each action situation



5.1 Designing Institutions Using: Adaptive Institution Framework and Contextual Success Factors

In order to identify and design appropriate institutions for social engagement in the EMW system, we also use (1) the framework of adaptive institution [Koontz et al., 2015] and (2) success factors in sustainable transitions in small scale communities[Forrest and Wiek, 2015].

There is a difference between institutional change and adaptive institution, since the former is not necessarily in the direction of maintenance or improvement of a desirable state. In adaptive institutions actors are able to act in a way that improve or sustain a desirable state. Considering the case in this study (BSH) and existence of a desirable state in the main future ambitions of the system (EMW) such as *renewable energy supply with mostly local production*, the concept of adaptive institution was included in the institutional design of the EMW system. In addition, adaptive institutions have been highlighted by scholars studying the "tragedy of commons" in social ecological systems [Cannibal and Winnard, 2001, Cook et al., 2010, Huntjens et al., 2012, Méndez et al., 2012, Moench, 2010].

Furthermore, adaptive institutions promote institutional dynamic and avoid *institutional fragility and failure* with both leading to more interactions of the citizens and management of the commons in the community [Koontz et al., 2015]. Adaptive institutions give room for creating, changing, adjusting and expanding rules, norms, and shared strategies that can avoid institutional failure. Therefore, in our institutional system design we used the concept of adaptive institutions that can adjust rules based on changes in the system.

The success factors [Forrest and Wiek, 2015] that are used in designing EMW institutions are selected among the contextual factors that are important for successful transition processes i.e. that produce sustainable outcomes. The list of contextual success factors are presented in the appendix. We use the success factors in our case as BSH is facing a big sustainable redevelopment including transitions in energy production and material and water recycling.

The theoretical analysis in the next section provides our institutional design with more theoretical background. We will indicate that the theory of Assortative Matching in game theory can offer solution in collective action problems by enabling more citizen contribution.

5.2 Assorative Matching (Group-based Matching) and Factor of Glory in the Institutional System of the EMW

Our institutional design in action situation 1 (system entrance) is inspired by the theories of Assortative Matching and the glory factor of motivation in collective action. These two theories offer an approach to facilitate citizen participation in

collective actions, so they are aligned with the goal of our institutional design: (1) The Assortative Matching in voluntary contribution game theory claims that the game, in which the players are matched based on their level of contribution, can lead to increased contributions of by players. This theory is explained more in details in this section, (2) the other theory claims the importance of the glory as a motivational factor in collective actions, meaning that the actors in a collective action show a higher level of participation when they are recognized for their contributions in the collective action arena. More explanation of this theory is also presented later in this section.

Based on this, we formulated that the citizens entering the system in action situation 1 have to choose smart-labels. This is formalized as *Labeling Institution* in the ADICO table of action situation 1 (see appendix). It means that each inhabitant chooses a smart- label that shows the level of his contribution to the EMW system. The main points of the labeling institution are:

1. It gives a sign of recognition to the inhabitants based on their level of contribution (inspired from the theory of motivation factor of Glory);

2. The smart-labels also open the opportunity for the further interaction of the inhabitants in different groups;

In general, the recognition of the citizen contribution through their smart-labels and their interactions in different groups are inspired from the theories of: (1) "Assortative matching" [Gunnthorsdottir et al., 2010] in voluntary contribution game [Isaac et al., 1985] and (2) the motivation factor of "glory" in collective actions [Malone et al., 2009]. These two theories are elaborated in the following paragraphs.

5.2.1 Theory of Assortative Matching (Meritocratic Group-based Matching) in Voluntary Contribution Game

Collective action can be seen as a game. For public goods, the game is called "public good game" or "voluntary contribution game" [Isaac et al., 1985] in which the players have the dominant strategy of "free-riding". It means that in such game, players who are practicing a collective action would benefit from high contributions, yet each inhabitants has "strategic incentive" [Nash et al., 1950] to contribute less. The game has an equilibrium with the dominant strategy of free-riding, which leads to a "social dilemma" for public goods and "tragedy of the commons" for common pool resources [Hardin, 1968].

Ostrom proposes some mechanisms to relax this problem such as monitoring and sanctioning, which are costly and morally contested. Application of such institutions means investigating and enforcing the people to participate on a specific

level. Investigating and enforcing people in the context of a neighborhood is not morally acceptable, because this mechanism threatens their privacy. People do not like to be investigated for their participation and they need to have freedom in deciding about their level of participation. Some people are more motivated to participate and some have less motivation in participating in collective action.

In case of sanctioning, people are forced to follow some specific rules, or they will receive a fine. Sanctioning people to follow rules in a context of collective action in a neighborhood could enforce citizens to participate into collective actions, yet it is fundamentally in contradiction with the concept of sustainable collective action. Sustainable collective action is a form of governance structure in which the individuals collectively make some changes having a sustainability goal in common. In our research we were interested to enable citizen participation and not to enforce it. Enabling the citizen participation in sustainable collective actions can happen through motivating the citizens and allowing more cooperative forms of governance [Euchner and Preidel, 2014].

Yet, there is another mechanism that is categorized in moral suasion (to borrow a term from [Ledyard, 1995]). Meritocratic Group Based Matching [Gunnthorsdottir et al., 2010] or Assortative Matching is a theory that takes a positive approach toward solving the problem of free-riding. With Assortative Matching the players are matched in groups based on their level of contribution and play the same game. In the game with groups of players *new equilibria* can emerge that has a better payoff for all players (the community) and also increased contribution of the players. In fact, in group-based merit or assortative matching (as relaxing mechanisms) game players can show a higher level of contribution [Nax et al., 2014].

BSH, like any other collective action situation, has the problem of "free riding" regarding the management of its resources. This problem is the problem of voluntary contribution game in public goods which lead to the social dilemma and in CPRs lead to tragedy of the commons. EMW system has two shared resources of electricity and water as the common pool resources. Such situation is equivalent to the voluntary contribution game [Isaac et al., 1985] when the players (inhabitants of BSH in our case) can take strategies of "contributor", "non-contributor", or "free-riders" benefiting from the resources. In such game, players as a community practicing a collective action would benefit from high contributions, but individuals (each inhabitants) have strategic incentive [Nash et al., 1950] to contribute less, with the dominant strategy of free-riding. It means that they have "strategic incentive" [Nash et al., 1950] to contribute less.

However, scholars show that in case of some mechanisms like "meritocratic group based matching" [Gunnthorsdottir et al., 2010] new equilibria can emerge that has a better payoff for players (community) and also increase the contribution of the players. In fact, in group-based merit or assortative matching (as relaxing

mechanisms) game players can show higher level of contribution.

In the game with Assortative matching mechanism, the players are matched in groups based on their level of contribution and play the same game. Similarly, our labeling institution identify the citizens based on their level of contribution to the system of EMW (with their smart-labels in action situation 1). The labeling institution also influences the following interactions of the citizens with the resources (in action situation 2), and with the other inhabitants in the form of group interactions in action situation 3 (see the ADICO tables in AS3). Therefore, our proposed institutional design could work as a group-base matching mechanism paving the way for more contribution of individuals in the community.

5.2.2 Motivation Factor of "Glory" in Collective Actions

Besides, the second source of our inspiration in designing the institutions for the EMW system is: the importance of the so-called "glory" factor, which recognized as a motivation factor in collective intelligence system. In fact, glory or recognition is recognized as an important motivator factor in people participation in collective actions [Malone et al., 2009]. This theory is also aligned with our labeling institution in EMW when citizens are recognized for their contribution. The implementation of the above mentioned frameworks and theories in designing our institutions are presented in our proposed institutional system of EMW and in the ADICO tables of institutions for the three action situations (see appendix).

5.3 Formalizing Institutional Arrangements with ADICO

Formalizing institutions in the three action situations (ASs) were illustrated in ADICO tables (see the appendix). In the first action situation, inhabitants have to choose smart-labels (Labeling ADICO). In the second action situation, resource institution ensures that the benefiting from the resources is based on the smart-labels (Resource ADICO), and inhabitants can receive funds for improving the technical support to the system that can limit the overuse (Rule compliance and External regime ADICO). In the third action situation, inhabitants form groups (energy, water and material associations) of interaction in which they can meet regularly to negotiate new or existing rules (Leadership and Network ADICOs), for instance, they can also exchange knowledge, get inspired and be recognized within their groups (Learning ADICOs).

6 Discussion and Conclusions

6.1 Overview

Cities can take a role in their future sustainability through the collective action of citizens. Collective action in cities requires citizen participation, which collectively leads to achieve sustainable goals. Collective action activities have mainly carried out around shared urban spaces like gardens and parks, which are considered as the urban commons. However, through observing the future of cities embedded in modern technology, we shifted our focus into collective action around technology-driven urban commons. We studied such collective action in a neighborhood of Buiksloterham (BSH) as a case study in this research. Therefore we aimed at proposing a method that can enable citizen participation in collective action around technology-driven urban commons in BSH.

The proposed institutional design presented (see figure 6 for an overview to the institutional system composed of three action situations, and see the institutional arrangements in ADICO tables) can promote citizen contribution into the technological urban commons through the group-based citizens' interaction in the community of BSH. The proposed institutional system design is adaptive as it has room for involving the citizens in group-based interactions for incorporating new information to avoid institutional fragility and support institutional change. It is also able to foster social learning through the knowledge and experience exchange in the group-based interactions. The color-labels in the system bring transparency; every citizen can be recognized for the level of his contribution into the technical shared resources. It also provides the community with trust and legitimacy with the existence of a core group that promotes the collective action.

6.2 EMW system with technology-driven urban commons

After gathering case related information through the main report of BSH and interviewing the people in charge in BSH, we drew an overview of the three main future ambitions in BSH. They are renewable energy production (Energy), material recovering (Material), and water recycling (Water) in the neighborhood. These three main domains of interest in BSH can be connected through a local bio-refinery in the region, in which the green waste collected in the kitchens and the urine separated in the toilets are recovered into electricity and low-grade water grids, respectively.

Therefore, we proposed a technical system of EMW (Energy, Material, Water) as the resource system (see figure 3) with its two shared resources of Electricity and Water. The Material is not considered as an individual resource in this resource system, as it is recovered into the electricity and low-grade water in the

system. Electricity and water are the shared technical resources with the two characteristics of CPR: non-excludable and sub-tractable. The shared resources of electricity and water are the technology-driven urban commons in BSH. Based on the vision in BSH and our theoretical argumentation (e.g. CPR perspective), they are expected to be governed through community-based collective action.

6.3 SES analysis of BSH and EMW institutional system

By using the SES framework, we analyzed and identified the components of our socio-technical system of EMW. The technical components are the technical resource system of EMW and the technology-driven urban commons of electricity and water (see figure 5).

The main components of the system that require in depth analysis is the community-based collective action shown in figure 5. In order to enable collective action we proposed an institutional design for the EMW system which is embedded in the resource system of EMW. We also considered the success factors in sustainable transitions as guidelines in designing institutional arrangements in BSH. Two theories of the Assortative matching and the Glory factor of motivation are also the sources of inspiration to design institutions. Institutions are designed in three main action situations (ASs) of: (1) AS1; inhabitants entering the EMW system, (2) AS2; interactions of the inhabitants with the grids of water and electricity, and (3) AS3; social interactions of the inhabitants (see figure 6). Formalizing institutions in the three action situations (ASs) were illustrated in ADICO tables (see appendix).

Therefore, our designed institutional system (shown in figure 6) includes the institutions presented in the ADICO tables, which can enable the citizens to interact based on their level of contribution. This institutional system can govern the collective action and enable citizen participation in the resource system of EMW.

The Assortative Matching theory inspired us to design our institutional system in AS1, which entails a Labeling institution. This theory can solve the social dilemma in a voluntary contribution game through increasing the actors' contribution when they are grouped based on their level of contribution. Since the Labeling institution is a big assumption in our institutional design, we decided to further explore the functionality of this theory using an abstract agent-based model.

We propose the design of an institutional arrangement for collective action in the context of urban commons that entails:

- Creating transparency in the system by Labeling institution which shows the level of contribution of every house in the system;
- Establishing legitimacy in the system by Leadership institution which requires the existence of a core group in the system;

- Making groups (networks) of social interaction by Network institution which ensure an arena for communication of the citizens and knowledge production;
- Social learning as the result of knowledge production in the community;
- Strengthening collective action through External regime institution that ensures the existence of enough support (from municipality for instance) in forms of funding (or subsidy), training, capacity building, etc;

6.4 Lesson Learned for BSH

Sustainable transition in BSH is based on community governance, which seeks citizen participation. Besides, realization of BSH future ambitions depends on citizen contribution to the projects such as local renewable energy production. BSH needs a systematic structure that can govern its future projects. This systematic structure is a community-based governance that involves the citizens and other stakeholders (e.g. municipality), having the objective in increasing citizen participation. Our institutional system design of the EMW system in BSH is a prototype of such a systematic structure. It is adaptive, and it is built based on the designed institutions of labeling and group-based interaction, which confirm increasing contribution. Besides, it gave us some insights of:

- Capacity building in the community:
  - Creating transparency in BSH through labeling the houses based on their level of contributions to the sustainable practices of renewable Energy production, Material recovery, and Water recycling (represented in our EMW system). The transparency in the community leads to a better management of the shared resources because it eliminates overuse (label-based consumption and production);
- Social learning in social groups:
  - Creating an arena for social interactions in the community through some associations, social networks, or groups of citizens with similar interests and sustainable practices. Energy association in the community can include the citizens who are contributing in energy production (they are recognized by their labels). So, labeling institution helps in recognition of the citizens with same interests and similar sustainable practices. Such community can produce knowledge in social groups through knowledge exchange and experience sharing;

– Knowledge production in groups of inhabitants leads to learning, which changes the behavior of the citizens. It means that the citizens, who learned, care more about the sustainability in the community and increase their participation;

6.5 Future Work

This research can be further developed in three areas of future work.

Further Research on the Feasibility of the Resource System of EMW

The realization of future ambitions in BSH (e.g. local renewable energy production and water recycling) depends on implementation of the technical development and infrastructures. The technical system of EMW will be composed by several technical interventions such as urine separation, kitchen macerator, and existence of a bio-refinery in BSH which are expected by 2035. Therefore, study on the feasibility of the technical interventions used in EMW technical resource system in BSH is one of the fields of further research. The technical system of EMW composed of several technical interventions such as urine separation, kitchen macerator, and existence of a bio-refinery in BSH.

Technology-driven urban commons in other fields of interest in BSH

The domain of future ambitions in BSH is very broad from energy and water to mobility and health. We have considered the three main domains of energy, material, and water in our technical system of EMW, yet more research can be done on the collective action around different technology-driven urban commons in other fields of transportation and health and wellbeing, for instance.

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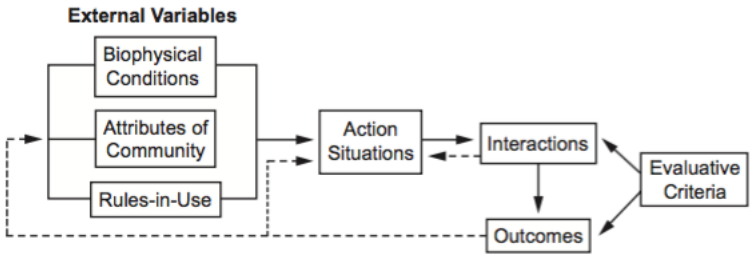
7 Appendix

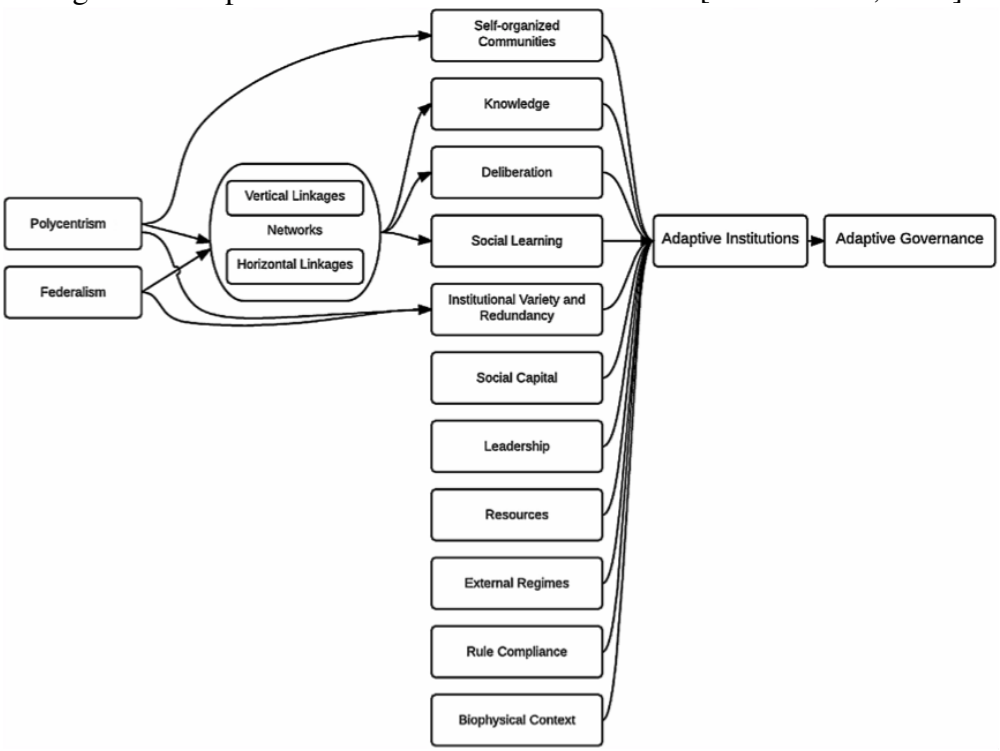
7.1 Institutional Analysis and Development (IAD) Framework

Figure 7: Institutional Analysis and Development (IAD) framework. *Source* [Ostrom, 2011]



7.2 Adaptive Institutions Framework

Figure 8: Adaptive Institutions framework. *Source* [Koontz et al., 2015]



7.3 Success Factors in Sustainable Transitions

The list of contextual success factors:

- Socio-demographics: population size was recognized as a main factor affecting engagement and mobilization of the community.
- Community governance: this factor plays a direct part in the transitions by providing legitimacy and administrative support for instance.
- Skills and experience: in all the three cases, the transition depends on the extent of skills and experience of volunteers.
- Funding opportunities: Public funding was important in the three cases of sustainable transition.
- Community: social cohesion is identified as a possible factor leading to greater participation in the three cases.
- Core group and Leadership: a core group of volunteers is important in driving transitions.

7.4 ADICO Tables of the Three Action Situations

7.4.1 ADICO table of Action Situation 1 (system entrance)

Name	Attributes	Deontic	aIm	Condition	Or else	Type
Labeling: selection	Inhabitants	Obligation	Select a smart-label	Signing a contract	No contract	Rule
External regime: Green-label Subsidy	Inhabitants	Permission	Obtain a green-package subsidy	If they have green label	-	Rule
External regime: Blue-label Subsidy	Inhabitants	Permission	Obtain a blue-package subsidy	If they have blue label	-	Rule
External regime: Violet-label Subsidy	Inhabitants	Permission	Obtain a violet-package subsidy	If they have violet label	-	Rule
External regime: Yellow-label Subsidy	Inhabitants	Permission	Obtain a yellow-package subsidy	If they have yellow label	-	Rule

Table 1: ADICOs of Action situation 1

7.4.2 ADICO table of Action Situation 2 (interaction with the urban commons)

Name	Attributes	Deontic	aIm	Condition	Or else	Type
Resource-1	Inhabitants	Obligation	Use shared resources based on their level of contribution (smart-labels)	Joining EMW system	Receive fine	Rule
Rule compliance	Inhabitants	Prohibition	Cheat on using the shared resources	Joining EMW system	Receive sanction	Rule
External regimes	Inhabitants	Permission	Receive funds to improve the technical support of the system (EMW)	If the EMWers reach a specified size of population	-	Rule

Table 2: ADICOs of action situation 2

7.4.3 ADICO table of Action Situation 3 (interactions with the community)

Name	Attributes	Deontic	aIm	Condition	Or else	Type	Best practices
Leadership-1	Inhabitants	Obligation	Form association of EMWA	-	-	Rule	Building legitimacy and trust within community that help to promote adaptation in the system [Forrest and Wiek, 2015, Koontz et al., 2015]; 1) Leaders help to build "trust, make sense, manage conflicts, compile and generate knowledge, communicate information, and mobilize broad support for change" [Koontz et al., 2015] (p. 146). 2) leaders can help to promote innovative approaches that makes the institutional system more adaptive to changes [Cook et al., 2010]
Leadership-2	Inhabitants	Obligation	Negotiate new or existing rules	Joining EMWA	-	Rule	Leadership providing innovative approaches and adaptive institutional system (Cook et al, 2011; Koontz, 2015); in India, in an irrigation society, the lack of adequate leadership was perceived to be affecting the distribution of water for two-thirds of the households [Saravanan, 2015].

Table 3: ADICOs of action situation 3, first part

Name	Attributes	Deontic	aIm	Condition	Or else	Type	Best practices
Network-1: establishing arena	EMWA members (inhabitants)	Obligation	Meet regularly (once a month)	-	-	Norm	Establishing new arena for incorporating new information to inform institutional change [Koontz et al., 2015]
Network-2: fitting population	EMWA members (inhabitants)	Obligation	Meet more regularly (twice a month)	If the population of EA, MA, WA is reached a population threshold	-	Norm	Avoiding institutional fragility and failure by reflecting new information [Ostrom, 1990]
External regimes: providing resources in form of providing information and training	EMW Association and its sub-associations	Permission	Gain fund for arranging workshops (foster learning) and building informative and real time data platforms (improve the acceptability to information; building reliability and trust of the system)	if they reach and specific number of population	-	Norm	Strengthening long lasting collective actions by training and awareness building similar to the case of NGOs in India [Barnes and van Laerhoven, 2015]

Table 4: ADICOs of action situation 3, second part

Name	Attributes	Deontic	aIm	Condition	Or else	Type	Best practices
Learning-1:institutional linkage	EMWA members	Obligation	Select the best performed member (best practicer) of the EMWA in the every gathering	If the members of each association has reached to a population threshold (or it can be without condition	-	Rule	The importance of institutional linkage for learning. Institution that avoid institutional gap and supports the availability of the critical knowledge in one level of institution and to make required changes in the other level of institutions [Olsson et al., 2006] (creating institutional linkage between learning-1 and learning-2)
Learning-2: knowledge acquisition and accumulation	EMWA members	Permission	Inspired by or imitate the actions of the best practicer through information exchange and creation of knowledge (including modifying their smart-label)	-	-	Shared strategy	Institution of fostering accumulation of knowledge through local experience [Koontz et al., 2015]; social learning happens through producing knowledge within the community that is relational and collectively oriented [Muro and Jeffrey, 2008, Schusler et al., 2003]
Learning-3: recognition or glory	EMWA members	permission	Gain glory points	If they are selected as best practicer in the association	-	Shared strategy	Increasing the motivation among the EMWers by the desire to be recognized by peers for their contribution similar to ”top contributor” lists such as ”top reviewers” in Amazon [Malone et al., 2009]

Table 5: ADICOs of action situation 3, third part