# Facilitating Citizen Participation In Sustainable Collective Action In Smart Cities: The Case Of Buiksloterham

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”Do not go where the path may lead, go instead where there is no path and leave a trail.”
Ralph Waldo Emerson

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*Mahtab Aghamiri, April 17, 2017*

**Executive Summary**

This thesis is about community-based collective action in smart cities. Cities are responsible for future sustainability of the world. Cities are composed of neighborhoods, from which sustainable transition is expected to take off. Since cities are socio-technical systems, sustainable transitions requires a combination of technological innovations, social engagement and institutional arrangements. In this study, we take a common pool resource (CPR) perspective to analyze the collective action around technology-driven urban commons in cities. The goal of this research is to propose a systematic institutional structure to enable citizen participation in collective action around technology-driven urban commons. As a case study, we take Buiksloterham (BSH), a neighborhood in Amsterdam, which is known as an experimental lab to test future plans towards being a smart, sustainable and circular neighborhood.

Electricity and water are two major interconnected CPRs (technology-driven urban commons) in BSH that play an important role in the liveability and sustainability of the neighborhood. 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 neighborhood, but lacks plans regarding social engagement and institutional arrangements. We used Ostrom's Social Ecological System framework to analyze the two CPRs in BSH in order to study social engagement scenarios and to propose new institutional arrangements. These arrangements benefited from the framework of Adaptive Institution [Koontz et al., 2015]. 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 behaviour 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 *color-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 an institutional system embedded in the technical resource system in BSH, which is composed of the grouping mechanism as a potential strategy that can tackle free-riding while also promoting citizen participation.

In order to test the effectiveness of our grouping mechanism, we built an agent-based simulation model in an abstract resource system. The model is based on the theory of Assortative matching and the SES analysis, that captures the behaviour

of agents and the state of the commons in a comparative analysis between a system with and without grouping. The simulation results show that the grouping mechanism would increase citizen contribution to the resource system. Using MAIA framework [Ghorbani et al., 2013], we also developed a comprehensive conceptual agent-based model that used our technical and institutional system in BSH. This model helped to refine our proposed institutional system design through more practical and detailed thinking in the system, and it can be used as a product for future research in building an agent-based model in BSH.

In conclusion, this research proposes an institutional system for promoting collective action around the technology-driven urban commons of electricity and water in BSH. In fact, this institutional system can promote citizen contribution into the technological urban commons through the group-based citizens' interaction in the community and neighborhood in BSH. The color-labels in the system bring transparency; every citizen can be recognized for the level of his/her contribution into the shared technical resources. The proposed institutional system 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.

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# 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.

## 1.1 Problem Definition

Researchers have done research on collective action in cities, suggesting that some institutional arrangements can promote and sustain such activities in cities [Foster and Iaione, 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].

## 1.2 Scientific Gap and Research Objective

The focus of studies on urban commons has mainly been on urban space (such as parks and gardens). None of the studied urban commons to-date relate to technology-driven resources such as energy and water. Given the important 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 propose a method to 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).

It is an interesting case as it is a living lab for sustainable community-based development. Besides, there are many short and long term future ”technical” and ”systematic” development plans. The technical development plans are accomplished through the implementation of new technology and infrastructures, while the systematic development plans will happen by establishing governance structures aimed at helping the future management of developments[Gladek, van Odijk, Theuws, Herder, 2014]. Realization of the future management of such developments in BSH need citizen participation. As a case in point, the implementation of new technology can happen through modern infrastructures for local renewable energy production, the realization of which requires citizen participation.

## 1.3 Technological and Systematic Approaches in BSH

Future plans of BSH are mostly about the technical interventions in this region. The technological future approaches of BSH are mainly about 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. In fact, the question arises on how these technical interventions are going to be managed? BSH has a future vision on implementation of community-based governance, yet there is requirement for investigating the possible methods to involve citizens and arrange institutions among them.

## 1.4 Research Question

**research question**

The main research question to be answered in this research is:

*"What form of institutional arrangement can facilitate citizen participation in collective action around technology-driven urban commons in the neighborhood of Buiksloterham?"*

In order to answer the main research question, the following sub-questions will be explored:

1. What are the technology-driven urban commons in the sustainable neighborhood of BSH?
2. How can a technology-driven resource be systematically and institutionally analyzed with a commons perspective?
3. What institutional arrangement can be designed to govern collective action around technology-driven urban commons in BSH?
4. How can citizen participation in a collective action be increased?
5. How can the dynamics of collective action in the context of BSH be studied?

## 1.5 Approach

This research will take different approaches to answer each sub-question. Table 1 shows that "Desk research" is the approach chosen to deal with the first sub-question which is done by identifying the technological urban commons in BSH. Desk research is done through reading (1) reports of the companies involved in the project, (2) the master thesis reports of TU Delft and AMS (Amsterdam Institute of Advanced Metropolitan Solutions) students, (3) and the main report of "Circular Buiksloterham" [Gladek, van Odijk, Theuws, Herder, 2014]. "Interview" is the other tool used to know more about the case from the standpoint of the experts and the project leaders: (1) Circular Buiksloterham project (e.g., Frank Alsema, Peter Dortwegt, Saskia Muller), and (2) Adaptive Circular Cities project (Wim de Haas, leading the research project) .

To answer the second and third sub-questions we will theoretically analyze the case of BSH. This theoretical analysis employs some theories and frameworks. When analyzing the BSH case in order to answer the second sub-question, we will use the SES framework (introduced in section 3 of Theoretical Background ). This framework helps us to identify the technical and institutional components of the collective action happening around the urban commons in BSH.

The third sub-question investigates the institutional arrangements in the collective action in BSH. Here, we will use the IAD framework, the Adaptive institution framework, and other institutional theories in order to design the institutions. ADICO will be used to formalize the institutions. The mentioned frameworks and ADICO are explained in the section of Theoretical Background in 3.

To explore the fourth research sub-question, we will build a computer simulation. Agent-based modelling (ABM) is the taken tool in order to build a theoretical model of the Assortative matching theory (introduced in section 3 of Theoretical Background ). The reasons behind the choice of ABM instead of other simulation methods such as system dynamics, are: (1) it can give insight on the collective effects of individual (agent) behaviors and interactions [Macal and North, 2010], (2) it captures emergent patterns and structures from bottom-up individual interactions [Macy and Willer, 2002]. The model will be developed using Netlogo, a multi-agent programmable modeling environment, which is used by many researchers worldwide. Data analytical tool 'R' is also used to analyze the outcome of the model.

Finally, conceptual modeling will help us understanding the dynamic of the collective action in BSH. Modeling Agent systems based on Institutional Analysis (MAIA) [Ghorbani et al., 2013] is the tool that will be used. The reasons behind this choice are: (1) MAIA helps in structuring all our findings about the socio-technical system in BSH with a comprehensive institutional analysis, and (2) it helps to capture the complexity and interactions of the components, and the

| Sub RQ | Approach | Theory / tool |
|---|---|---|
| 1 | Desk research | Interview, BSH report |
| 2 | Theoretical analysis | SES framework |
| 3 | Theoretical analysis | ADICO, IAD, adaptive institution framework, success factors in sustainable transitions |
| 4 | Theoretical analysis and modeling | Theory of Assortative matching and motivation factors in collective actions, and ABM |
| 5 | Conceptual modeling | MAIA, ABM (conceptual) |

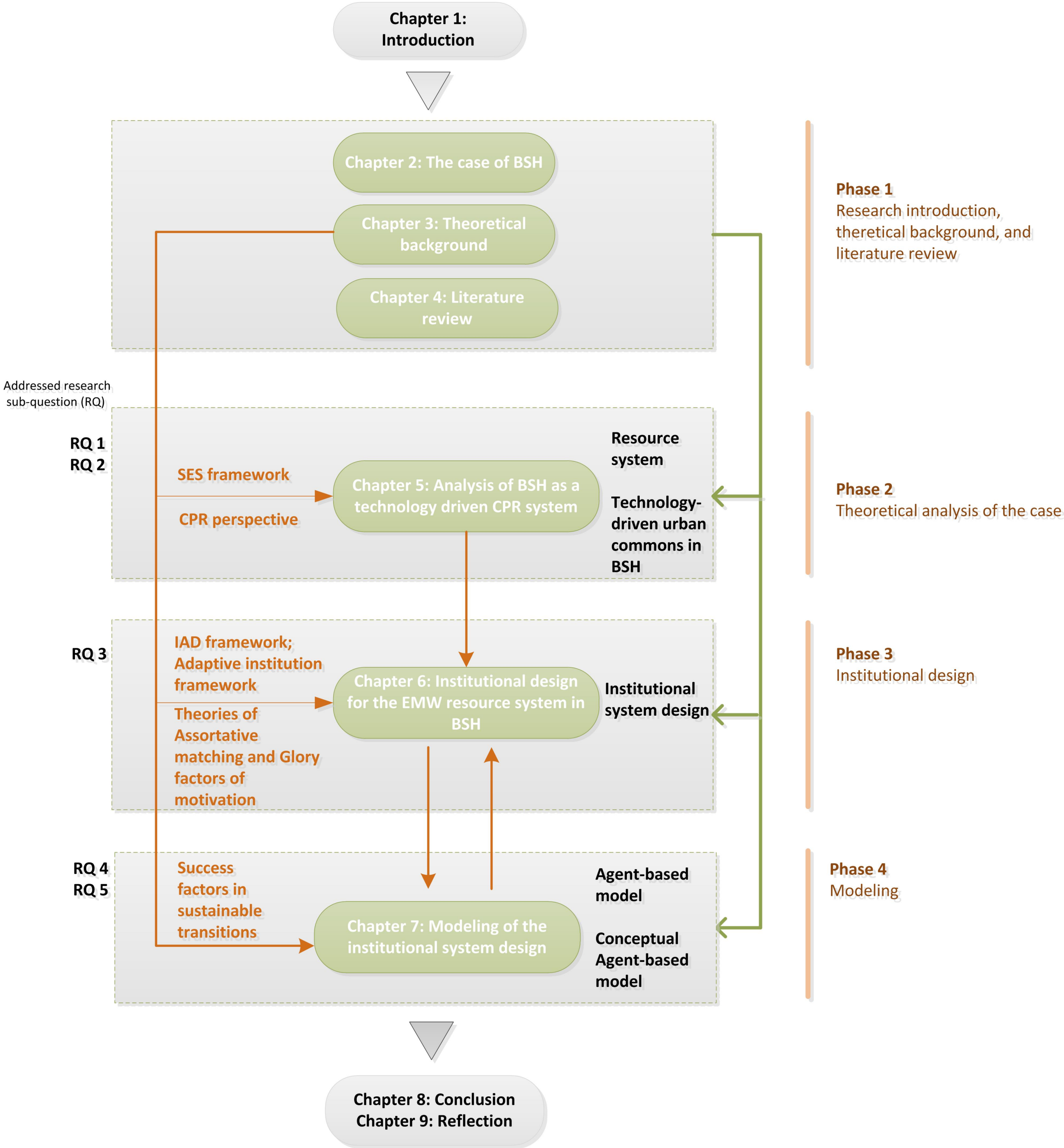
Table 1: The research approach for each research sub-questions

dynamic of the system. Making a simulation of our conceptual model is out of the scope of this research because of insufficient data to draw valid conclusions.

An overall view of the research process is illustrated in figure 1. It includes four phases represented in four grey-color rectangles with the addressing research sub-question (RQ) in the left and the expected research outcome in the right of the rectangles. After the research introduction, the case description and the theoretical background of the research in phase 1, the identification of the urban commons along with the theoretical analysis of the case will lead to an adaptive SES in BSH (phase 2) and to designing the institutional system in BSH (phase 3). Then, we will evaluate the institutional system designed in chapter 6 through an agent-based model. Beside a conceptual agent-based model will be developed based on our institutional design. The insights of the two models developed in chapter 7 (phase 4 of the research) will be used to improve our institutional design in an iterative process between the chapter 6 and 7.

The arrows from the "chapter 3: theoretical background" in phase 1 to the chapter 5 in phase 2 and to the chapter 6 in phase 3 in the research flowchart show the use of the theoretical frameworks and the theories to answer the research sub-questions in each chapter. The introduction to the theoretical background used in this research and their relevance and usage in the research are presented later in chapter 3 of Theoretical background.

Figure 1: The research process



## 1.6 Outline

The structure of this thesis is as follows. In chapter 2, a short overview of the case of BSH and its main future plans will be elaborated. The theoretical background of this research will be presented in chapter 3. We introduce and justify the used theories and frameworks in this research. In chapter 4, the literature review on governing the commons and community energy will be elaborated, which gives a history and overview of similar research and practices worldwide. In chapter 5, we will analyze the case of BSH and identify its components as a socio-technical system using the SES framework. The analysis of this chapter gives will be used in chapter 6, where we will design institutions for BSH through proposing institutional arrangement and social engagement that enable citizen participation in BSH. In chapter 7, we will explore the functionality of theory of Assortative matching in a collective action by using AMB. Then, the development of a conceptual model of BSH using MAIA will be presented in the same chapter. Chapters 8 represents our conclusion to this research, and we will show the limitations and future works of this research. In final chapter of 9, we will make our reflection.

# 2 The Case of Buiksloterham (BSH)

In this chapter we introduce the case of BSH with its main future visions and ambitions. We also focus on three main domains of interest in BSH: Energy, Materia, and Water. Furthermore, the interconnectivity of the three main domains is investigated in forms of a framework.

## 2.1 Main Redevelopment Future Plans in Buiksloterham

Buiksloterham as it is shown in figure 2 is a neighborhood in north of Amsterdam. It is known as a living lab/experimental zone with ambitious future plans to make the neighborhood sustainable, circular and smart.

Figure 2: Buiksloterham in Noorth of Amsterdam


### Buiksloterham Manifesto

On March 2015, a manifesto was signed among 24 people and 22 parties (local parties: several companies such as Metabolic, Waternet, de Alliantie, etc. and Alderman of municipality of Amsterdam) about the development plans, goals, ambitions, and actions in BSH. Future vision and ambitions of BSH based on the manifesto is documented in an extensive report of Circular Buiksloterham [Gladek, van Odijk, Theuws, Herder, 2014]. This manifesto and the report are the result of two main key stakeholders gathering in September and October 2014 about co-creating shared visions and action plans respectively.

The conclusion on the mentioned process is ambitious vision of BSH for a big transaction toward being a “sustainable, circular, biobased, and smart” neighborhood [Gladek, van Odijk, Theuws, Herder, 2014]. 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.

The broad scope defines in eight main domains of interest. These main domains are:

1. Energy
2. Materials and Products
3. Water
4. Ecosystem and Biodiversity
5. Infrastructure and Mobility
6. Socio-cultural
7. Economy
8. Health and Wellbeing

There have been several goals and future ambitions set in each domain resulting the main future ambitions of BSH, that will be briefly elaborated in the next section.

## 2.2 Main Future Visions of BSH

Each of these eight domains has its defined long and short term future goals. An overview of full future ambitions of BSH is presented in figure 3. As figure 3 shows, in the field of Energy, BSH wants to be self sufficient with a fully renewable energy supply; in case of water and material, BSH objects at 100 percent resource recovery of wastewater and zero waste neighborhood respectively.

The red rectangle in figure 3 separates the first three domains of Energy, Material, and Water from the rest. These three domain have the highest priority in BSH, and they are also the focused areas in this research. the reasons behind this choice is presented below:

1. Generally, energy, material and water have their own importance in sustainable urban development [Lehmann, 2011]
2. These three have also the highest priority among all the eight domains of interest in BSH (see figure 3)
3. These three domain are highly interconnected through a local bio-refinery in BSH, see figure 6 (waste water and organic waste are recovered in forms of energy and low-grade water) [Gladek, van Odijk, Theuws, Herder, 2014]

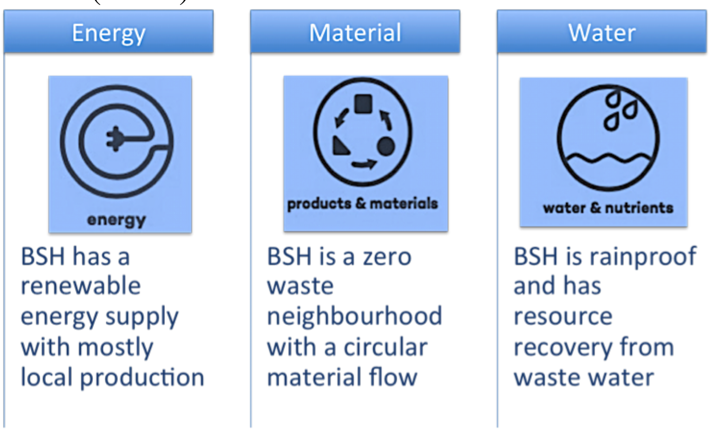
Figure 3: Key Ambitions for Circular Buiksloterham in 2035; eight comprehensive goals for BSH development (retrieved from Circular Buiksloterham, full report[Gladek, van Odijk, Theuws, Herder, 2014])

- Energy: Buiksloterham is energy self-sufficient with a fully renewable energy supply
- Materials & products: Buiksloterham is a zero waste neighbourhood that with a near 100% circular material flow
- Water: Buiksloterham is rainproof and has near 100% resource recovery from waste water
- Ecosystems and biodiversity: Buiksloterham's ecosystems are regenerated and its base of natural capital is self-renewing
- Infrastructure & mobility: infrastructure is maximally-used and local mobility has zero emissions
- Socio-cultural: Buiksloterham has a diverse and inclusive culture, and a high quality, livable environment
- Economy: Buiksloterham has a strong local economy that stimulates entrepreneurship and encourages the creation and exchange of multiple kinds of value (social, environmental, cultural)
- Health & wellbeing: Buiksloterham is a healthy, safe and attractive environment with recreational activity space for all residents

Therefore, we propose an interconnected Energy, Material, and Water (EMW) systematic framework in BSH assuming the existence of a local bio-refinery which gives an interesting interconnectivity to EMW. In fact, as it is mentioned in the report of BSH, a local bio-refinery will ensure circularity of BSH by waste recovery into some useful outflows such as energy and low-grade water.

Three main domains of future ambitions are around Energy, Material, and Water. Figure 4 shows future goals of the three main domains of in BSH. They are also very interconnected through a local bio-refinery in BSH.

Figure 4: Three main future ambitions of BSH in three main domains of Energy, Material and Water (EMW)




After the identification of the three main domains in BSH, it is time to have a closer look and make a list of main ambitions of each domain of Energy, Material, and Water. Figure 5 lists all them.

## 2.3 Energy, Material, and Water (EMW) in BSH

After recognizing the main three important domains in BSH and existence of a local Bio-refinery in BSH, we propose a framework of interconnected energy, material and water: EMW framework in figure 6.

Figure 5: List of all the ambitions of EMW (the texts inside the blocks are from the Circular BSH, full report [Gladek, van Odijk, Theuws, Herder, 2014])

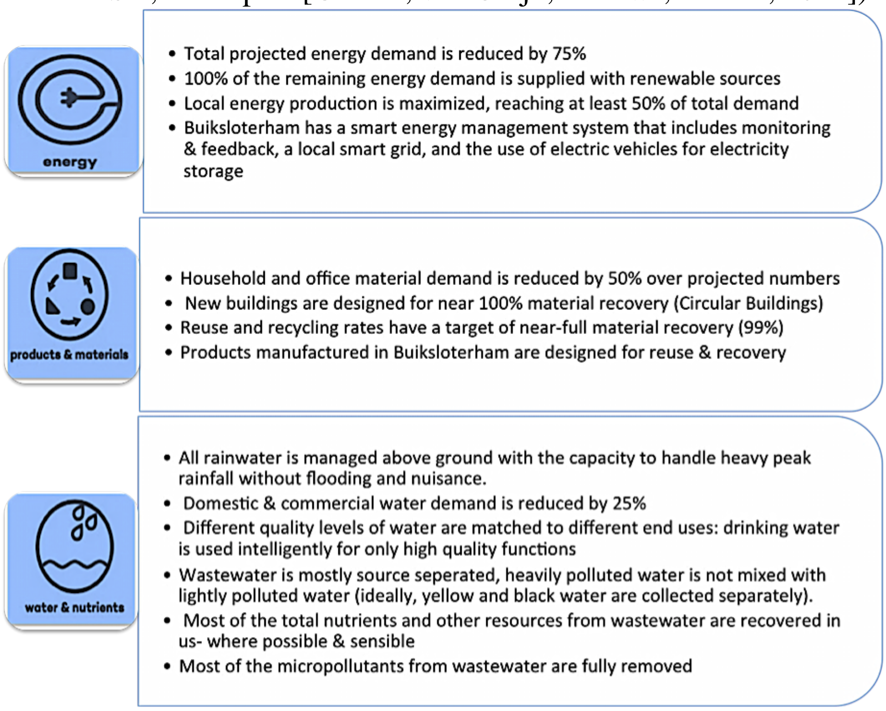
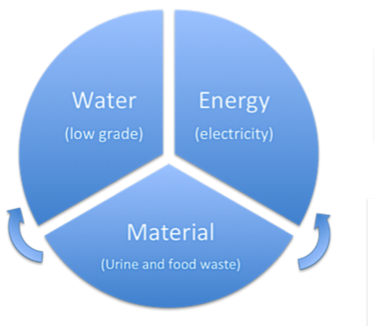


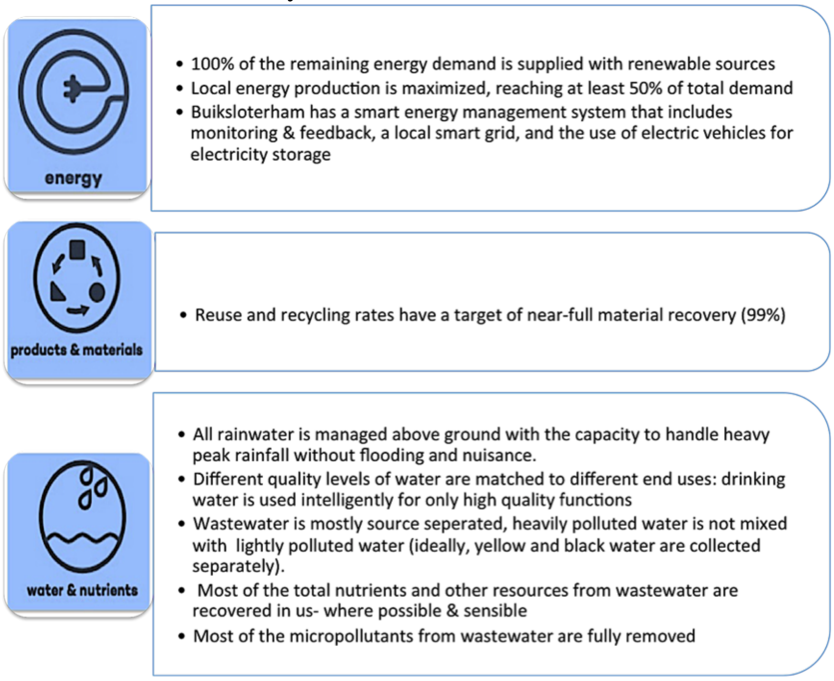

Figure 6: Proposed framework of EMW which shows interconnectivity in EMW through the local bio-refinery in BSH




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

Apart from the demand reduction in energy, material, and water, there are short and long term ambitions ranging from source separation and recovery of waste-water to near-full recovery of organic waste and a smart energy management system [1] see figure 5. In this research for the sake of simplicity and keeping the interconnected system of EMW with a bio-refinery, we delineate a list of future ambitions of EMW in figure 7. This list is the base of the further technical interventions that technically ensure the realization of EMW system.

Figure 7: Proposed list of ambitions compatible with interconnected EMW technical system with a bio refinery in BSH




Implementation of these ambitions in the system of EMW needs some technical interventions. Technical interventions include ”specific initiatives, infrastructure, programs, and policies that are a means of achieving the higher level goals set for the project” [Gladek, van Odijk, Theuws, Herder, 2014]. Therefore, in chapter 5, we propose a list of essential technical interventions in forms of new private (located in houses) and public (located in the neighborhood) infrastructures in order to ensure the realization of EMW system.

To conclude, in this chapter, three main aspects in BSH are elaborated: (1) the introduction to the case of BSH, (2) its main future ambitions in the three fields

[1] Includes monitoring and feedback, a local smart grid, and use of electric vehicle for electricity storage

of Energy, Material, and Water (EMW), and (3) the interconnectivity in the EMW system through the bio-refinery in BSH. After recognition of the theoretical background in this research (presented in the next chapter), we will use a framework (SES framework) to theoretically analyze the EMW system and identify the main components of the system (see chapter 5).

# 3 Theoretical Background

Urban sustainability goals are aimed at collective action seeking citizen participation. BSH, similar to any other city or neighborhoods with community based sustainable transitions is looking for collective citizen efforts in diverse approaches such as promoting household energy efficiency or establishing community gardens. They all are sharing the general description of *collective action*, aimed at bringing sustainable changes [Forrest and Wiek, 2014]. BSH is also taking a lead in a bigger transition of the whole Amsterdam into a smart city. The importance of citizen participation is also very critical in smart cities. Smart cities are those that maximize social and environmental capital through three factors: (1) Use of modern infrastructure, (2) Highly efficient resource management, and (3) Active citizen participation [Gladek, van Odijk, Theuws, Herder, 2014].

Therefore, the role of citizen participation is clearly shown in stepping toward making smarter cities. City population needs to make a bigger *contribution* apart from only being a consumer. New forms of urban development are seeking citizen participation, in which the cities themselves take an important role. Hollands [2008] also indicates that cities become smarter when they utilize digital technologies or ICT in order to reach higher quality and performance of urban services, less cost and resource consumption, and more *effective participation* of citizens. As a case in point, a simple application can encourage citizens in a community like BSH to fix small public space problems Gladek, van Odijk, Theuws, Herder [2014]. The idea is that the small problems such as broken lamp can be fixed by the community members, in case they do not have time, they can upload a picture and location of the problem to the app. Others can find the solution, report it, and solve it (one who solves the problem will gain service points). BSH has already made clarification about its future ambitions and the technical interventions, yet the systematic interventions that can manage them is very unclear [Gladek, van Odijk, Theuws, Herder, 2014]. It is very dependent to the citizens who are going to live in BSH and the level of their contribution to the sustainability of the neighborhood.

As it is already mentioned in the introduction, the role of cities in urban sustainability is gaining more attention. Therefore, studying the *contribution of the city population* to make the cities smarter has been gaining attention from scholars. Ostrom's approach of self-organized/user driven institutions in sustainability of commons guarantees the role of citizens in making the cities smarter [WorldBank, 2012]. Ostrom states in her last article that our movement toward sustainability needs every single individual effort [Ostrom, 2012]. Egyedi et al. [2007] and Ubacht (2008) also state that local inputs by end users' activities will *accumulatively* optimize the system in order to reach *a bigger common goal* (like sustainability). In this regard, Buiksloterham as a living lab for smart city has held several citizen-driven projects with sustainability goals that are moving the neighborhood toward being smarter (the case of BSH will be introduced in chapter 5.

The concepts of collective action, common pool resource management, and institutions are very complex and difficult to understand. There is not only one framework and theory that can give a comprehensive and sufficient details and structure in order to understand, analyze, and propose institutional system in collective action around the common pool resource system. Therefore, to address this issue, *a set of theories and frameworks* are selected that in combination will lead us in detailed and comprehensive understanding, analyzing, and finally proposing institutional system embedded in technical resource system.

Before introducing the theories and frameworks in this chapter, we find it necessary to give a short explanation about the concept of theory and framework and the difference between them based on Ostrom's definition[Ostrom, 2011]

- Framework: framework is the *most general* forms of theoretical analysis. Elements and general relationship among them are identified by frameworks Ostrom [2011].

- Theory: theories "enable the analyst to specify which elements of a framework are relevant to particular questions, and to make *general assumptions* about the shape and strength of these elements." Clark and Wallace [2015] (p. 235)

  In this research we also use modeling (agent-based model), so it is useful to add the definition of models and its difference with theory.

- Models: models help to study a very specific problem by making "*precise assumptions* about a limited number of variables" in order to explore the case and possible outcomes Ostrom [2010] (p. 6)).

Models make precise assumptions about limited number of variables while in theory only general assumptions are made about shape and strength of the elements in the framework. So, models are the most specific form of analysis among the two other forms of theoretical analysis (framework and theory), and the frameworks are the most general form compared to theory and model.

The goal of this chapter is to introduce and explain the theoretical backbone of this research more in detail. We adopt theories and frameworks in answering each of the sub-questions. Except from the second section that listed all the frameworks for institutional studies, the order of the rest of the sections is aligned with the order of their relevant sub-question.

CPR perspective in the first section and SES framework in the second section are used to analyze the case of BSH and identify the resource system and the technology-driven resource units (urban commons), which answer the first and second sub-questions. Then, we use two theories of Group-based matching or Assortative matching, and the theory of motivated factors in collective actions, presented in section three and four respectively, and the framework of Adaptive institution along with the success factors in sustainable transition (presented in section five) to help us proposing our institutional design (the issue of the third sub-question). Finally in answering the third sub question, we take the success factors in sustainable transition from a cross case study, presented in section five, plus the frameworks of IAD and adaptive institution, resented in section two.

## 3.1 The Common Pool Resource Perspective

In order to deal with the complexity of collective action and its governance, we take a CPR perspective. This helps us in identification and analysis of the technical CPR system and its components. CPRs are similar to public goods as they are non-excludable. It means that it is difficult to exclude people from them. And, they are similar to private goods as they have high subtractability. It means that one user extraction of the resource negatively lead to another user extraction. Although, Hardin [1968] indicates the danger of resource destruction as ”tragedy of the commons”, the Nobel Prize laureate, Elinor Ostrom, proves that the tragedy of commons can be avoided by carefully designed *endogenous institutions*. The well-established theories and frameworks in the area of CPR management by Ostrom and her colleagues provide the opportunity in this research to analyze and propose institutions manifesting CPR management in Buiksloterham.

As it also mentioned in the introduction, in her 1990 book, *Governing the commons*, Elinor Ostrom, the Nobel Prize winner, demonstrates through theoretical and empirical work on the *management of CPRs* that the “tragedy of commons” [Hardin, 1968] can be avoidable *without* state intervention or privatization. Ostrom’s work through a detailed comparative analysis of several case studies, show that the tragedy can be avoided through decentralized/bottom-up governance in the community of the resource users by carefully *designed institutions*. The CPR perspective in cities has in fact gained so much momentum that it is referred to as Urban Commons [Foster and Iaione, 2015]. Simply, urban commons are the CPRs in the city. Variety of urban goods can be seen as commons such as public space, air, city land, environmental resources, etc., but with view of technology, we are focused on technology-driven urban commons such as electricity grid.

Therefore, in this research we use the CPR perspective, or more specifically, *urban common perspective* in BSH. This perspective helps us to identify and analyze urban commons in the resource system. This resource system requires an institutional system. In fact, the institutional system will be embedded in the resource system in BSH. In doing so, we first need to analyze the resource system using SES framework, that is elaborated in the next section. Then, we also introduce the frameworks which are used to develop the institutional system embedded in the resource system.

## 3.2 Frameworks for Institutional Studies

There are many well-established theories and frameworks by Ostrom and her colleagues around the governance of CPRs. Among the theories and frameworks, the frameworks of Social Ecological System (SES) [Ostrom, 2007b] and Institutional Analysis and Development (IAD) [Ostrom, 2011] is used and applied by a great number of scholars, researchers and students working in this field of science. Similarly, in our study about the collective action around the urban commons (CPRs in cities), we will use the SES in order to analyze the structure of the collective action and the technical and social components of the system. And, we use IAD in developing our institutional design. In addition, the framework of Adaptive Institution [Koontz et al., 2015] is used in designing adaptive institutions that promotes *institutional dynamic* leading to self-organization and collective action within a community.

### 3.2.1 Institutions

A leading definition of institutions is "enduring regularities of human action in situations structured by rules, norms, and shared strategies" [Crawford and Ostrom, 1995] (p. 582). People create institutions, and , in turn, institutions organize their behavior towards collective ends [Ostrom, 2005].

Sustainable transitions need both technical and systematic (social) interventions. For instance, technical renewable electricity resource system needs social engagements and institutional arrangements such as rules in production and consumption of electricity. These rules include laws, regulations, social norms, and strategies among the individuals in the system. The creating of rules is either through an evolutionary process or deign [Ghorbani, 2013]. Important to notice that these rules can be called institutions only if they are, with a certain degree of durability, accepted and practiced by the involved actors [Koppenjan and Groenewegen, 2005]. In cities, citizens consume (and sometimes produce) resources such as electricity and water, so the functionality of resource systems is highly depending on the behavior of citizens in consuming (or producing) the resources. Institutional interventions give structure to the behavior of citizen in interacting to the resource system that can highly influence the sustainability and management of the resource. More explanation about the frameworks and the reason behind the choice of them are presented in the following sections.

Institutions also help us in understanding and explaining complexity in individual behaviors [Ghorbani, 2013]. In order formalize institutions ADICO (Attribute, Deontic, aIm, Condition, Or else) is a tool. It is a syntactical tool to help in explaining the institutions of a socio-technical system like our technical (resource system) and social (institutional system) as a whole. More specifically, ADICO assists in clarifying the institutional statements of such system [Crawford and Ostrom, 1995] (see figure 8 for examples and more explanation).

Figure 8: The components of the ADICO syntax and how they define rules, norms, and strategies in form of a institutional statement [Watkins and Westphal, 2015]

| Component | Definition |
|---|---|
| *A* | Attribute (the "who"—who does this statement refer to?) |
| *D* | Deontic (may, must, must not, should, should not) |
| *I* | aIm (the "what"—what is the statement about?) |
| *C* | Condition (under what conditions must the aIm occur?)<br>*Default can be "in all times and in all places" (Ostrom, 1995, p. 149) |
| *O* | Or Else (sanction for not following a rule, norm, or strategy)<br>*The term "Or Else" is only used for rules<br>*Can be gradual-initial or accidental violations may not incur tangible sanctions, but repeated violations lead to them (Ostrom, 1995, p. 152; 2012) |

*ADICO* = Rule, *ADIC* = Norm, and *AIC* = Strategy

**RULE**[a]: All villagers [**A**ttribute] must not [**D**eontic] let their animals trample [a**I**m] the irrigation channels [**C**ondition, note that the animals *may* trample elsewhere and not trigger this rule] or else the villager who owns the livestock will have to pay a fine [**O**r Else].

**NORM**: If you [**A**ttribute] use the microwave [**C**ondition], you must [**D**eontic] clean up your own mess [a**I**m]!

**STRATEGY**: The person who places a phone call [**A**ttribute] calls back [a**I**m] when the call gets disconnected [**C**ondition].

[a]Rule, norm, and strategy examples are from Ostrom (1995, p. 139).

### 3.2.2 Social Ecological System Framework (SES)

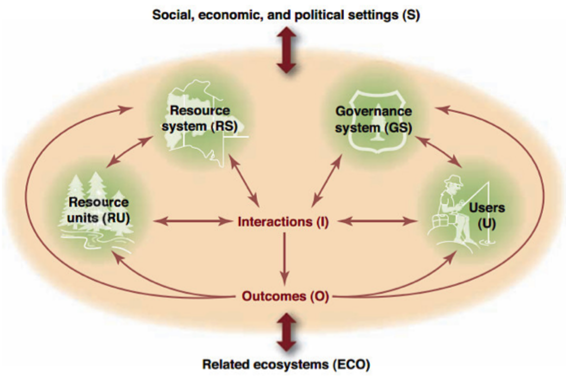
SES framework shown in figure 9, is the more recent outgrowth of IAD (see figure 10), will be used in this research to theoretically analyze and understand our resource system and its components. Ecological system is a system with a natural resource like forest and fisheries, and when humans are involved, using the natural resource, then we have a Social Ecological System (SES). In fact, all humanly used resources are a component of social-ecological system (SES) [Ostrom, 2009]. As it is shown in figure 9 the framework consists of four subsystems of: resource system, resource unit, users, and governance system. SES is basically used to analyze 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 (see chapter 6: Theoretical analysis of BSH).

The main reasons behind the choice of SES are listed below:

1. all humanly used resources are embedded in complex, social-ecological systems (SESs) Ostrom [2009], and this framework is a common base for researchers working in the related field.

2. it facilitates a multidisciplinary effort toward a better understanding of complex SESs.

Figure 9: Social Ecological System (SES) framework. *Source* [Ostrom, 2009]




### 3.2.3 Institutional Analysis and Development Framework (IAD)

The Institutional Analysis and Development (IAD) framework has been gradually developed as a more general institutional framework since it was originally designed to address the problem of commons [Oakerson, 1992]. The concepts of ”action arena” and ”action situation” are borrowed from the IAD framework in analyzing the interactions of the actors in our institutional system in this research. Action arena, the central concept in IAD, contains one or more action situation and involved actors, so as shown in figure 10, the IAD is simply focused on the action situation leading to interactions and outcomes [Ostrom, 2011].

Figure 10 shows that action situation is affected by ”rule-in-use”, ”attribute of community”, and ”biophysical conditions”. It means that the interactions of the actors is influenced by (1) what are ”required, prohibited, or permitted” as rules, (2) the structure of the community within which the situation occurs, and (3) the ecological system.

In fact, the term of ”biophysical world” contains all relevant concepts for analyzing ecological system. In SES framework Ostrom focused on how the subsystems in SES: ”Resource System”, ”Resource Units”, ”Governance System”, and ”Users” embedded in ”Social, Economic, and Political Settings and Related

Figure 10: Institutional Analysis and Development (IAD) framework. *Source* [Ostrom, 2011]

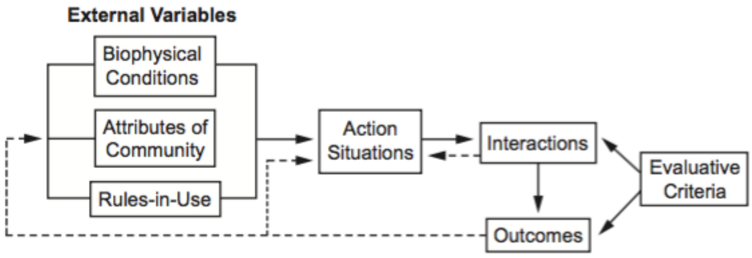
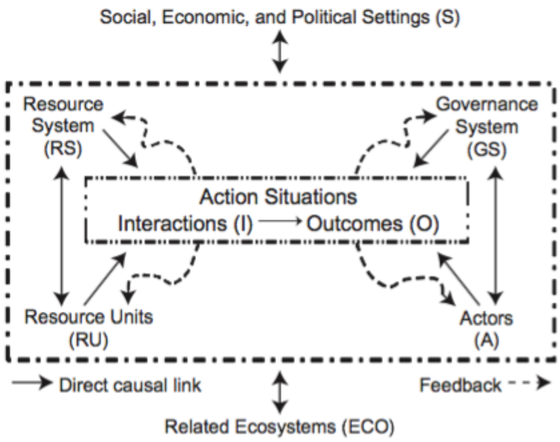



Figure 11: Action Situations Embedded in Broader Social-Ecological Systems. *Source* [Ostrom, 2007a]




Ecosystems" might influence interactions and outcomes [Ostrom, 2007a]. As figure 11 shows the interaction of actors in action situation lead to interactions and outcomes that are affected by and affect the subsystems in SES, which then affect and are affected by "Social, Economic, and Political Settings and Related Ecosystems". [Ostrom, 2011].

### 3.2.4 Adaptive Institution Framework

Institutions that are designed in this research are based on factors from the Adaptive Institutions framework [Koontz et al., 2015] shown in figure 12. In their paper in 2015, Koontz et al. have found *key factors* related to adaptive institutions from collecting 40 manuscripts included SES across a variety of locations, types and scales. Such factors are shown in a synthesis framework of Adaptive institutions framework. This framework shows the base factors that lead to having adaptive institutions. Adaptive institutions promote *institutional dynamic* leading to bottom-up governance and self- organization within a community. This happens by *creating, changing, adjusting and expanding* rules, norms, and shared strategies.

In contrast, non-adaptive institutions are difficult to change and they show *stable* characteristics. This can be as result of lacking factors such as "*regular collective choice discussions, inadequate means to incorporate new information to inform institutional change, and collective choice discussion rules that prevent changes without high level of agreement (such as consensus)*"[Koontz et al., 2015] (p.142).

A good example in lacking of adaptive institutions is a case introduced by Ostrom (1990) of *"institutional fragility and failure"*: a Turkish in-shore fisheries. In this case institutions were well suited to the context of limited number of fishers in which increased number of fishers and demand for fishing did not incorporate in collective choice discussions. Such discussions could happen by establishing new arena for incorporating new information among the user to inform institutional change. This case shows non-adaptive institutions that could lead to loss for the users and/or resource depletion (tragedy of the commons).

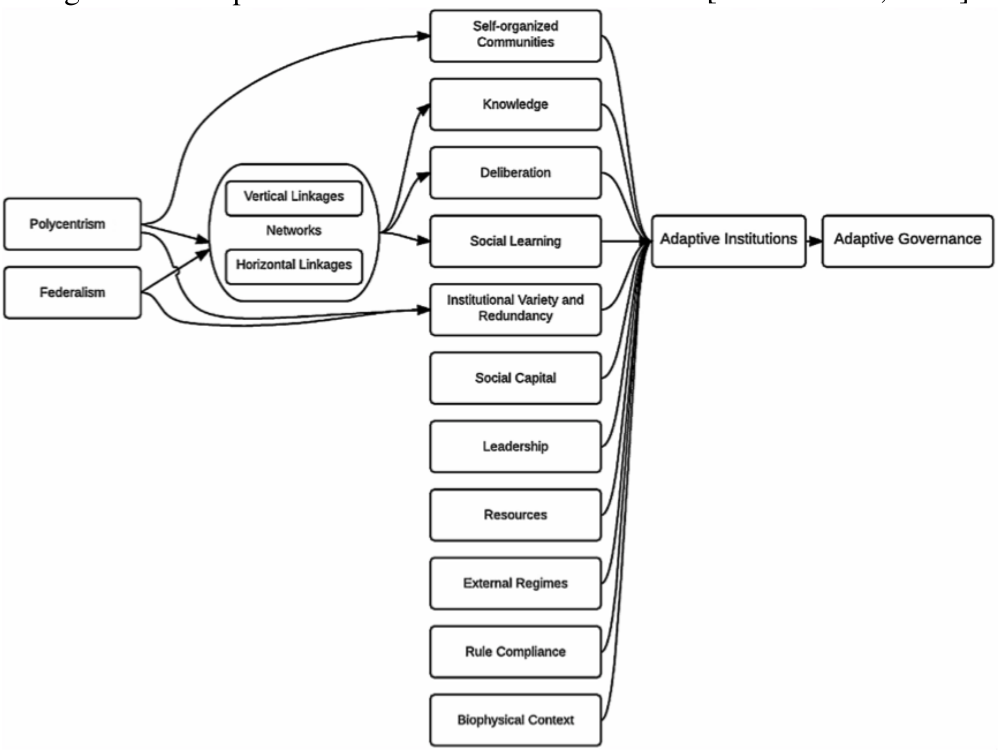
Therefore, in this research, and more specifically in proposing our institutional system design, we use six factors of the adaptive institutions framework. As figure 12 shows, the factors of: external regime, rule compliance, resources, network, social learning, and leadership are adopted this framework in designing institutions in our research.

The institutions that are designed in this research are presented in ADICO tables, which help to formalize the institutions. Our designed institutions organize and structure citizens behavior of BSH in three main action situations borrowed from the IAD framework. The action situations are affected by four sub systems in the SES framework (resource system, resource unit, users, and governance system), which will be identified and analyzed for the case of BSH. The six mentioned factors of the Adaptive framework are used in designing adaptive institutions in the three action situations. We also use theories of: Assortative matching in voluntary contribution game and motivation factors in collective actions, in designing our institutions that are explained in the following sections.

## 3.3 Theory of Assortative Matching (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

Figure 12: Adaptive Institutions framework. *Source* [Koontz et al., 2015]



game, players who are practicing a collective action would benefit from high contributions, *yet* each inhabitants have "*strategic incentive*" [Nash et al., 1950] to contribute less. The game has an equilibrium with the dominant strategy of free-riding, which lead to "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. Investigating and enforcing people in the context of neighborhood is not moral. Monitoring people living in a neighborhoods threatens their privacy. People do not like to be investigated for their participation and they need to have freedom on 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, unless 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 this thesis we are 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].

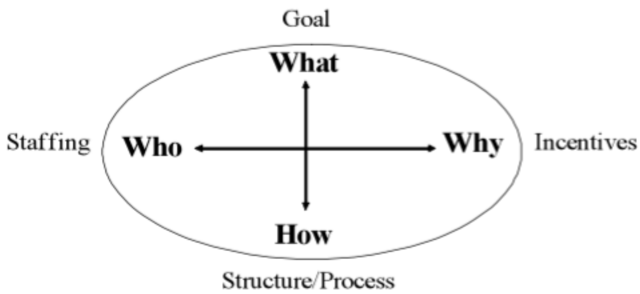
Yet, there is other mechanism that is categorized in *moral suasion* (to borrow a term from [Ledyard, 1995]). "Meritocratic group based matching" [Gunnthorsdottir et al., 2010] or Assortative matching is a theory that shows positive signs in solving the problem of free-riding. With "assortative matching" 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 whole players (community) and also increased contribution of the players. In fact, in group-based merit or assortative matching (as relaxing mechanisms) game players can show *higher level of contribution* [Nax et al., 2014]

In our research, we will explore the Assortative matching theory using agent-based modelling to study the effect of "grouping mechanism" on the citizen contribution into the shared resources. The idea is to find a mechanism that can stimulate citizen contribution in collective action by enabling, and not by enforcing.

## 3.4 Motivation Factors in Collective Actions

In this research we also use the insights from "collective intelligence", defined very broadly as groups of individuals (families, companies, countries, citizens, etc.) doing things collectively that seem intelligent in terms of reaching to common goal [Malone et al., 2009]. Wikipedia is a good example of such actions, where people from around the world (contributors) have collectively created the largest encyclopedia in the world, and the people who do all this work are volunteers who are not paid. So, the question now is that : what is their motivation in joining such activities? Malone et al. [2009] in their paper present a framework to answer the questions of: Who is performing the task? Why are they doing it? and What is being accomplished? How is it being done? Figure 13 show the framework and its building blocks referring to the mentioned questions.

Figure 13: Elements of collective intelligence building blocks. *Source* [Malone et al., 2009]




The incentive factors regarding the ”Why” dimension of the framework is interesting in collective action in cities where the citizen participation play an important role. So, the collective action in cities is very similar to the collective intelligence in term that both of them are trying to collectively reach an ultimate goal. But the interesting question is: What is the motivation of people joining in such collective actions? Questions about human motivation have been central in many fields such as philosophy, literature, economics, and psychology for centuries. However, Malone et al. (2009) introduce three basic ”why building blocks” or ”motivation factors” that lead people in collective intelligence systems, that are: *Love, Money*, and *Glory*.

This research is based on 250 web enabled collective intelligence, yet the writers emphasis that the finding (framework) is useful in designing *any* system for collective action. In our research, we use the insights of this framework and these motivation factors in designing the institutions governing the resource system in BSH. Generally, ”Love” factor is interpreted as the extent of citizens’ concern of having sustainable and green neighborhood. ”Money” is interpreted as the availability of subsidy for implementing technical interventions and connection into the resource system, and the amount of money the citizens could save by: local energy production and water and waste recycling.

"Glory" factor is used along with the theory of Assortative matching in proposing our institutional design that can enable citizen contribution in collective action around shared resource. Citizens are recognized based on their level of contribution into the resource system (interpretation of Glory), and they interact within groups of most similar contributors (e.g. in form of associations). Glory factor shows the benefit of recognition of individuals for their contribution into collective action, and the Assortative matching shows the possible benefits of group-based interactions among them. We also use ABM to explore the theory of Assortative matching (demonstrate the theory in an agent-based model) in more details, and test its functionality in an abstract resource system, which validates the effectiveness of our proposed institutions in enabling the citizen participation.

Our institutional design is also used in the MAIA framework which helps us to develop a conceptual model of BSH. In this model we use another theory that introduces the success factors in sustainable transitions. The following section presents the explanation of the theory and its relevance to the case of BSH in this research.

## 3.5 Success Factors in Sustainable Transitions

As a result of a cross-case study among four cases of small-scale communities in the U.K, some factors are recognized that show significant effects on sustainable transitions. It means, this analysis leads to recognition of some success factors that can be important for successful transition processes with sustainable intervention outcomes [Forrest and Wiek, 2015]. The success factors are recommended to be considered in sustainable transitions. Therefore, similarly in our case of BSH, where a big sustainable transition is going to happen, we find using such factors very helpful in designing our institutions and developing a conceptual model of BSH.

The list of contextual success factors are presented below:

- 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.

The concept of these factors and the factors from the Adaptive institution framework are interchangeably used in designing the institutions. The success factors are also used in the conceptual model of BSH; they are applied in a multi criteria decision making (MCDM), which influences the level of inhabitants' participation in BSH (see chapter 7).

To conclude, in this chapter, we introduced the theories and frameworks used in this research. The relevance of them to our research and the reason behind their choice are also elaborated. Besides, figure 1 in the first chapter gives an overview of the contribution of this chapter in the rest of the chapters in this thesis (see the arrow from chapter 3 to chapters of 5, 6, and 7).

# 4 Literature Review

In this chapter we present an overview of the history of CPRs and their governance in the first section. We also elaborate on the literatures about the community-based collective actions and more specifically about community energy in the second section.

## 4.1 Literature on Governing the Commons

### CPRs in rural and urban communities

Common Pool Resources (CPRs) and their management have been traditionally studied in rural communities such as forests, fisheries, and agricultural practices. For instance, Researchers looked at collective management of fishing [Acheson, 1989, Acheson and Brewer, 2003, Berkes, 1992], hunting practices[Beckerman and Valentine, 1996], irrigation systems [Singleton and Taylor, 1992]. More recent research are focused on CPRs in urban area, and they are called Urban Commons [Foster and Iaione, 2015]. Urban commons are shared urban spaces such as urban gardens [Barthel et al., 2010].

### Bottom-up Governance

Governing common pool resources has a long history from *state intervention* and *privatization* that try to avoid the tragedy of commons [Hardin, 1968] to Ostrom's theory on governing the commons through *institutions* [Ostrom, 1990b]. Pure control of the state/government (through international and national policies, for instance) and privatization are top-down approaches in governing the commons. Such governance structures eliminate user self-governance, and may lead to resource depletion [Feeny et al., 1990, Ostrom, 1990b, 2010].

Bottom-up forms of governance and local initiatives are gaining more attention from the scholars. Bottom-up governance in form of collective citizen actions is showing considerable outcomes comparing to the pure top-down governance structures in case of emission mitigation, for instance [Bulkeley and Moser, 2007]. Bottom-up governance takes place when the local effort of individuals in a community collectively leads to managing or solving a problem in the community through collective action in the form of Cooperatives for instance [Chaudhary et al., 2015, Huybrechts, 2013]. In the top-down approach of governance, there is a hierarchy of state actors in a coordinated system. However, in bottom-up forms of governance with inclusion of a greater number of actors, there is a network form of governance among non-state and state actors. These actors influence and are influenced by multiple centers of decision making which is referred to as polycentric governance [McGinnis, 2005, Ostrom, 2010]. Polycentricity is mainly observed in metropolitan areas where there are various forms of collective action [Ostrom, 2008]. Therefore, governance is a joined up system [Bulkeley and Moser, 2007]. The existence of such network brings complexity in the governance as each of these actors has different perspectives and interests over the problem/situation.

### Governing the Commons through Institutional Arrangements

Back to the governance of the commons, research have shown that user self-governance through *institutional arrangements* can better address the tragedy [Cavalcanti et al., 2013, Feeny et al., 1990, McEvoy, 1990, Ostrom, 1990b, 2010]. Self-governance of common pool resources is a pure bottom-up structure though institutional arrangements, with eliminating the role of some authorities. However, in this research we also impose institutions from authorities (can be municipality or government or the core group in BSH). In our design we also try to create arenas that citizens can interact and self-organize the resources. Therefore, our governance structure is through institutional arrangements that are neither purely bottom-up nor top-down.

### Four Layers of Institutions

To be more specific about the type of institutions that are going to be designed in this research, we should mention four layers of institutions by Williamson [1998]. At the lowest layer there are operational rules that are constantly changing. Then, there are agreements and contracts that change between 1 to 10 years. The institutional environment in forms of formal laws and regulation change between 10 to 100 years, and in the higher layer there are informal institutions i.e. norms and culture that change between 100 to 1000 years. Our research is designing institutions in the two lowest layer: institutions that can change very often by the citizens and the institutions that are imposed to the citizens like official agreements and contracts.

## 4.2 Literature on Community Energy

### Community-based Collective Action

Community-based collective governance is happening worldwide. As some cases in point, we can mention "Labgov" project and "participatory budgeting" in NYC [2], Transition Town [Hopkins et al., 2008], low carbon communities [Moloney et al., 2010], and eco-village [Dawson, 2006]. Beside, as Forrest and Wiek (2014)

[2] see nycreic.com for more information

mention , there are a thousand or more active community-based collective actions, most commonly in post-industrial countries (there are 472 registered active Transition Towns alone in November 2014 [3]). All of these activities in cities or neighborhoods have been showing effective results in term of making changes toward having a higher quality of living and more sustainability in their communities.

### Community Energy

Community based sustainable transitions which are based on collective citizen effort is happening in diverse approaches such as promoting household energy efficiency or establishing community energy, and in different scales (urban, village, neighborhood, etc.). They all are sharing the general description of *collective action*, aimed at bringing sustainable changes [Forrest and Wiek, 2014].

Bulkeley and Moser [2007] indicate the results of two case studies in their paper: (1) renewable energy in the UK, and (2) carbon management projects in the US. The cases show how non-state actors are in some instances getting ahead of state actors and how non-governmental and hybrid organizations are simultaneously involved in governing GHG emission mitigation. The case of renewable energy source cooperatives (REScoops) in the EU [Huybrechts, 2013] also shows the role of bottom-up initiatives engaged in a cooperative network process in reaching main goals of transition to a sustainable future.

Besides, the other similar case in community energy and collective challenge is: carbon neutral village, in which small activities at household level and community level lead to 20 percent energy use reduction over four years [4]. In addition, a cross case study of four sustainable transitions of small-scale communities in the U.K: Ashton Hayes, a small village in Cheshire, England; BedZED, an urban housing complex in London; Forres, a small Scottish town; and the Isle of Eigg, a remote Scottish island, identifies success factors in sustainable transitions in small scale communities [Forrest and Wiek, 2015]. We consider identified success factors that can be critical in sustainable transitions in designing our institutional arrangements.

[3] see the website of Transition Network for more active transitions happening in the world: https://www.transitionnetwork.org/initiatives/by-number

[4] Ashton Hayes Going Carbon Neutral 2010 Survey. University of Chester, Retrieved from: http://www.goingcarbonneutral.co.uk/village-footprint-survey-2010/

# 5 Analysis of BSH as a Technology Driven CPR System

## 5.1 Introduction

The goal of this chapter is to study the case of BSH, identify its technology-driven urban commons, and theoretically analyze them by means of SES framework. This chapter consists of two main sections in which two of our research sub-questions will be answered. In the first section we address the first sub-question of: ”What are the technology-driven urban commons in the sustainable neighborhood of BSH?”. Desk researching through the main report of BSH and information gathered through the interviews, help us to gather enough information to answer the question. Identification of the shared resources in BSH paves the way to provide analysis of the whole resource system and institutional system in BSH, which will answer the second sub-question.

Then, we will address the second sub-question of: ”How can a technology-driven resource be systematically and institutionally analyzed with a commons perspective?” through theoretical analysis of BSH. We will adopt the SES framework to analyze technical and institutional system in BSH, and to identify the main components of the system in the SES framework. The analysis of the system with technology-driven urban commons using the SES framework, gives us insights in the main sub-systems of: (1) technical sub-system, and (2) institutional sub-system. We also highlight some differences in using the SES framework in systems with technology-driven urban commons (socio-technical systems) with the social ecological systems. Identification of the institutional system in BSH in this chapter leads us toward more analysis and exploration of the institutional system and designing the institutions in the next chapter.

## 5.2 Technology-driven Urban Commons in BSH

### 5.2.1 Technical Interventions for EMW Implementation in BSH

Technical interventions in form of infrastructures are needed to realize local renewable energy production, circular material flow , and recovery from waste water in BSH. In order to recognize the right infrastructure, first we need to understand the exact future practices in domains of energy, material, and water. Then, we propose a list of interventions that can lead to the realizations of EMW system.

First, in case of **Energy** and except from the demand reduction, BSH wants to:

1. 100 percent of the remaining energy demand is met with renewable energy production

2. have a smart energy management system (including monitoring, feedback, and a local smart grid)

therefore, there is a need for a local production of renewable energy by means of solar panels, for instance. The "renewable electricity production plan" in BSH also needs more systematic infrastructural support in form of a local smart grid with monitoring and feedback options and possibility of electricity storage.

Second, in case of **Material**, and except from the demand reduction, BSH wants:

1. Reuse and recycling material waste and waste-water (such as organic waste in the kitchens)

In this case, BSH needs to have the bio-refinery, organic waste collection in the kitchens (kitchen macerator), and a collection system of organic wastes.

Third, in case of **Water**, set of ambitions based on the report of BSH Gladek, van Odijk, Theuws, Herder [2014] are:

1. All rainwater is managed above ground with rain water harvesting system.
2. Heavily polluted water (black water) is source separated from lightly polluted water (yellow water).
3. Waste water is recovered into the total nutrients and other resources in the bio-refinery
4. Most of the micro-pollutants from waste-water are fully removed

The above ambitions recall for a urine separation, rainwater collection, and again a bio-refinery. In fact, the bio-refinery recover the waste water into energy and low grade water (for irrigation use). Figure 14 presents the technical intervention in each field of Energy, Material, and Water

After proposing EMW framework and its technical infrastructures, we propose a technical system that shows the components of the system including the shared resources of Energy and Water. As shown in figure 15, the EMW system (interconnected 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 smart grids of energy (produced by solar panels and through the bio-refinery) and water (collected from rain water and recycled through the bio-refinery) embedded in the EMW technical system.

Figure 14: Proposed technical interventions in EMW technical system

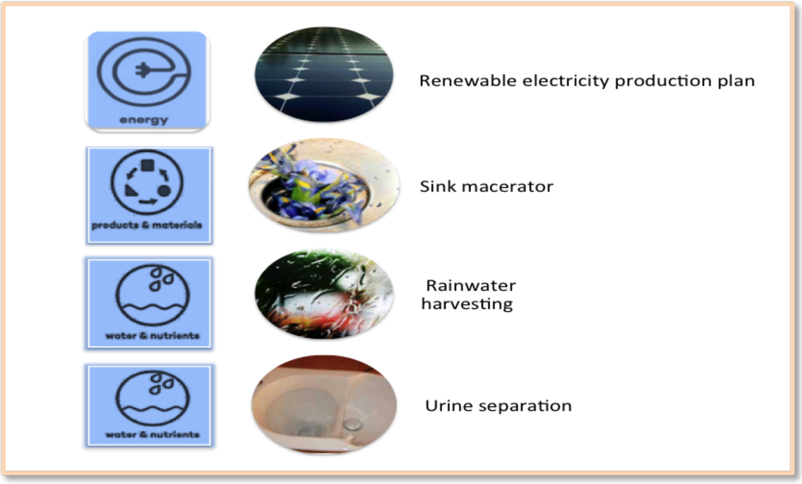



Figure 15: Resource system of EMW in BSH

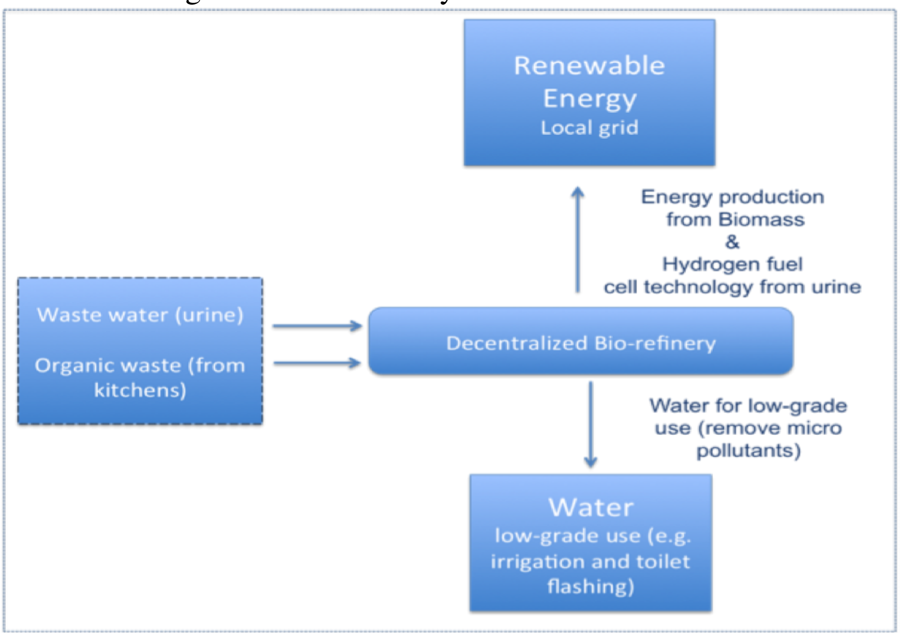
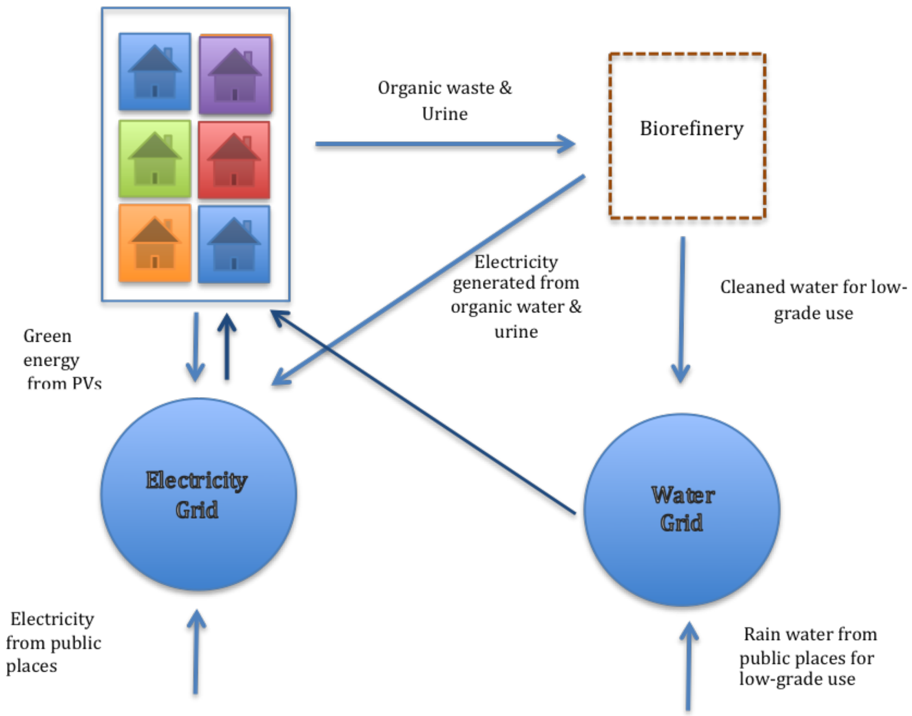


Figure 16: The technical system of EMW with the technology-driven urban commons of Electricity and Water



In this section we answered the first sub-question. Energy and Water are the technology-driven urban commons in BSH. In figure 16, we presents the technical system of EMW with its technological shared resources (urban commons) of Energy and Water. Except from the technical side, there are some other important components of the EMW system, which will be pointed in the second sub question. In the next section we will continue the analysis of EMW system with more theoretical focus employing SES framework.

## 5.3 Theoretical Analysis of BSH Using the SES Framework

In this section, we identify the four subsystems in the SES framework, which are categorized into two main parts of (1) technical: resource system and resource units, and (2) social: governance system and users. After the identification of them, we will present the SES framework with the placement of the subsystems in the socio-technical system of EMW in BSH.

### 5.3.1 The Technical and Social Subsystems in BSH

We employ the SES framework in order to analyze the EMW system in BSH. 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 framework) (see figure 9). The following subsections provide a comprehensive analysis of BSH and recognition of its sub systems using SES framework. And, we propose an adaptation of SES framework to the case of BSH. Finally institutional system of EMW will be presented.

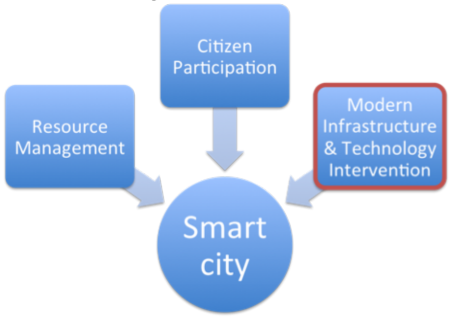
BSH wants to maximize social and environmental capital through three factors: (1) Use of modern infrastructure and technical interventions, (2) Highly efficient resource management, and (3) Active citizen participation[Gladek, van Odijk, Theuws, Herder, 2014] (see 17). Satisfaction of these three elements will make BSH to be smart and circular, so these three elements are also considered along with our theoretical analysis of EMW in SES framework.

### 5.3.2 Technical Subsystems of BSH

#### Resource System (RS) of BSH

Unlike the natural resource systems such as lakes and jungles, man-made resource systems in cities require modern infrastructure and technical interventions. As it is shown in figure 17, having modern infrastructure is one the main elements in smarticizing cities. The proposed EMW system in BSH with its technical interventions is the infrastructure that provide circularity of resources in BSH.

Figure 17: The importance of modern infrastructure and technology intervention in BSH as a smart and circular neighborhood

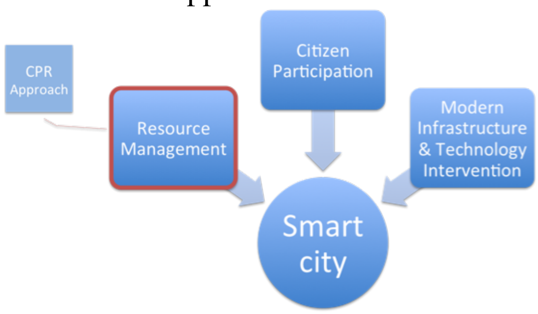



Therefore, as presented in figure 15 ***technical system of EMW*** , is the *resource system* in the SES framework.

**Resource Units (RU) of BSH**

The importance of resource management in smart cities are shown in figure 18. Creating a CPR approach in managing the resources has been gained so much attentions in the cities, and the concept of urban commons has been introduced in cities. Urban commons are natural or man-made CPRs in cities. Natural commons such as collected rain water or man-made commons such as produced electricity are shared resources in the community and have two main characteristics of: being non-excludable and subtractable.

Figure 18: The importance of resource management in BSH as a smart and circular neighborhood with a CPR approach




in the EMW system, Energy and Water are the shared resources that are locally produced and consumed (see figure 15). They also have the two mentioned characteristics : First about the subtractebility, if one of the inhabitants/users consumes the shared energy or water (resources), then that amount is subtracted from the rest of the resource and the other users only can consume what is remained, so one user extraction of the resource negatively leads to another user extraction. Second, it is difficult (costly) to exclude people from using resources, so they are non-excludable.

Therefore, both ***Energy*** and ***Water*** are recognized as resource units of SES in the proposed resource system of EMW. In fact, regarding the technical aspects of SES framework, we are proposing a resource system with *two* resource units: EMW resource system that interconnects energy, material, and water through a local bio-refinery, with two resource units of energy and water.

### 5.3.3 Institutional/Social Subsystems of BSH

#### Governance System (GS)

The role of citizen participation in smart city is very important; figure 19 implicitly shows the importance of this subject as one of the three elements that lead to having a smart city. In the case of BSH, the realization of future ambitions depends on the extent of citizen cooperation in the community ( Muller, personal communication, 14 December, 2015).

Citizens can collectively participate in community-based actions in order to govern their commons (see some practices on labgov.it). The action and interactions of the citizens in the community are actually managed through some institutions. Such institutions in case of BSH need to be designed as BSH is still under the redevelopment plans due to 2035.They can also be emerged as patterns of the interactions of the inhabitants who try to collectively manage their resources.

The technical aspects of BSH has already analyzed through the recognition of EMW as the resource system with two resource units of water and energy. The institutional aspects of BSH is where the prosumers need to collectively manage interacting with themself and with the technical aspects.

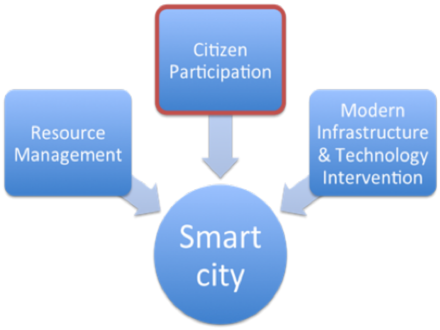
Therefore, the governance system of BSH is a **community based governance** through systematic interventions (e.t. designing institutions).

#### Users

"Users" is one of the subsystems of SES framework. Users can be fishers in a coastal fishery, resource system, who only use/consume the resource units, lobsters for example. However, in case of BSH as a "smart and circular city-to-be", the resource units of energy and water are not only being consumed but also produced by the users. Combination of resource production and consumption, brings the new concept of ”prosumers” instead of ”users” Prakash et al. [2015].

Therefore, the **inhabitants** of BSH who, both produce and consume the recognized resources of energy and water are the users in SES framework. In case

Figure 19: The importance of citizen participation in BSH as a smart and circular neighborhood




of energy, they produce renewable energy through the solar panels on their roofs, and their organic waste collected in their kitchens are returned into energy through the bio-refinery. In case of water, inhabitants/prosumers produce low-grade water from the waste-water (urine).

To conclude, the main four sub-systems of SES have been elaborated and analyzed in the last sub-sections. As figure 20 shows, each four sub-systems of resource system, resource units, governance system, and users in BSH are:

1. Resource system: interconnected technical system of EMW in BSH

2. Resource units: locally shared technology-driven resources of water and energy (electricity) that are connected through the bio refinery

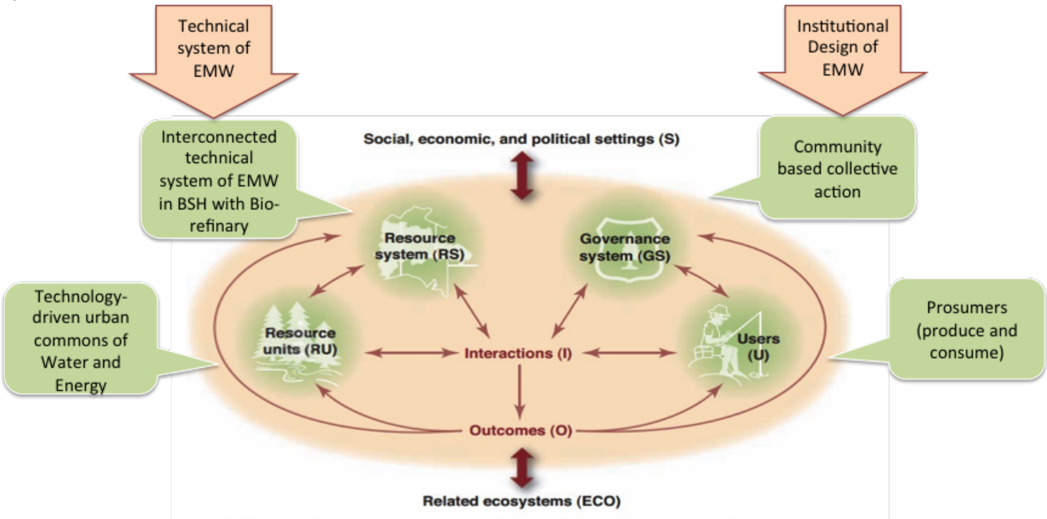
3. Governance system: community based collective action

4. Users: prosumers (inhabitants who produce and consume the resources of water and electricity)

**Requirements for Institutional System of EMW**

The technical system of EMW has been already identified and analyzed (see figure 15). The information gathered through the main report of BSH and interviewing the experts in BSH (S. Muller, personal communication, 14 April, 2016) shows that, apart from the well defined technical developments, there is a need to investigate and study the possible social engagement and institutional arrangement in the community-based governance system in BSH. Therefore, as it is shown in figure 20 governance system of EMW in BSH needs institutional design, which will be addressed in the next chapter.

Figure 20: 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.




## 5.4 Conclusion

In this chapter we answered the two sub-questions of his research: (1) ”What are the technology-driven urban commons in the sustainable neighborhood of BSH?” and (2) ”How can a technology-driven resource be systematically and institutionally analyzed with a commons perspective?”

First, we presented the technology-driven urban commons of Water and Electricity in the technological system of EMW in BSH. We also showed the interconnectivity of Energy, Material, and Water in the resource system of EMW (see figure 16).

Second, we employed SES framework in analyzing the EMW system with its two technological shared resources. We presented a SES analysis where the technical and institutional systems of EMW along with their urban commons (water and electricity) and prosumers are recognized as the main components of the SES (see figure 20. The main findings of the SES analysis are:

1. The SES framework has been mainly used to analyze ecological systems such as forest, yet in this research we applied the SES framework in analysis of a *urban technical system*. Our main contributions are:

    - We show that the resource units can be interconnected: interconnected resource units of water and electricity as two technology-driven urban commons are connected through the bio-refinery in BSH.

- we presents that the users can not only consume, but they also produce the resources: users in the EMW system in BSH are ”prosumers”.

2. The SES analysis recognized the gap for the institutional arrangements in the social / institutional system of EMW, which will be addressed in the next chapter.

# 6 Institutional Design for the EMW Resource System in BSH

## 6.1 Introduction

In this chapter, we investigate the third sub-question of: ”What institutional arrangement can be designed to govern collective action around technology-driven urban commons in BSH?”, so the aim is to design the institutions that govern the behavior of the citizens in BSH practicing collective action around the technology-driven commons of water and electricity in the EMW system. We will formulate the institutions in ADICO tables. ADICO is a tool helps formalizing the institutions of our socio-technical system of EMW in BSH. Theoretical analysis through the IAD framework, the Adaptive institution framework, and the success factors in sustainable transitions, helps us to design the institutions in this chapter. We are also inspired of the theories of Assortative matching and the theory of motivation factors in collective action, in the process of designing the institutions.

The institutional design in this chapter is used in the next chapter in developing two models. First, main part of the proposed institutional design will be tested through an agent based model in the next chapter. Second, the institutional design in this chapter will be used in developing a comprehensive conceptual model for BSH. The institutional design also benefits from the insight and added values gained in developing these two models.

## 6.2 Institutional System Design of EMW

We use the IAD 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 figure 10). 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 (AS) of:

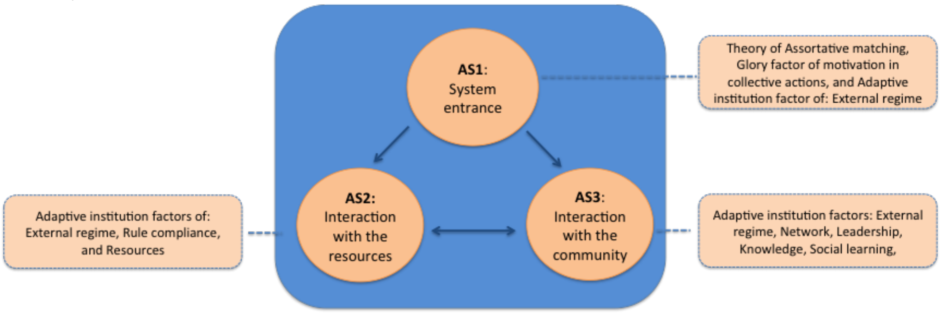
1. AS1: System entrance, in which inhabitants enter the system,

2. AS2: Interaction with the resources, in which inhabitants prosume (produce and consume) the urban commons of electricity and water,

3. AS3: Interaction with community (social interaction), that includes the social interaction of the inhabitants.

As figure 21 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 is 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. These theory and framework have been already introduced. They will be explained more in details with their connection and relevance to our institutional system in the following sections.

Figure 21: 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




### 6.2.1 Conceptualizing Institutions Using: Adaptive Institution Framework and Contextual Success Factors

ADICO is a tool in stating the institutions, yet in order to identify and design appropriate institutions for social engagement in 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 has been taken in 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 lead 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 have been careful about having adaptive institutions that can adjust rules based on changes in the system.

The success factors 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 section of 3.5 in chapter 3. We use the success factors in our case as SBH is facing a big sustainable redevelopment including transitions in energy production and material and water recycling.

The theoretical analysis in the next sub-section provide our institutional design with more theoretical background. We will indicated that the theory of Assortative matching in game theory can show some signs of solution in collective action problem by enabling more citizen contribution.

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

After the theoretical analysis of the case, the governance in BSH is recognized to be a community based collective action which seeks citizen participation. It should be mentioned that the importance of this matter is also recognized through interviewing Saskia Muller (one of the main core group members in BSH). She specifically points it out about this matter of citizen participation: ”We are really interested to see the level of inhabitant participation in BSH”. She also mentioned that the realization of future ambitions in BSH is highly dependent on the extent of inhabitants’ contribution.

The important factor of *citizen participation* has been recognized in smart cities or in any collective action toward a sustainable goal in the neighborhoods. In our case of BSH, we are interested to enable citizen contributions in collective action around electricity and water. Therefore, the main goal of our institutional design is *facilitating collective action* by *enabling citizen contribution* to the system.

Our institution design in action situation 1 is inspired from the theories of Assortative matching and the Glory factor of motivation in collective action (see figure 21). These two theories show signs of solution in facilitating 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 show more contribution of the players. This theory is explained more in details later in this section, (2) the other theory claims the importance of the Glory as a motivation factor in collective actions, meaning that the actors in a collective action show more participation when they are recognized for their contributions in the collective action. More explanation of this theory is also presented later in this section.

In fact, 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 table 2). It means that each inhabitant chooses a smart-label that shows the level of his contribution to the EMW system [5] .

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 form of associations in action situation 3). More explanation about the Labeling and Group-based institutions are presented in the sections of institutions in AS1 and AS3.

In general, the recognition of the citizen contribution through their smart-labels and their interactions in different groups of associations 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.

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

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

[5] Labeling institution is *different* from the energy labels of houses representing the level of their sustainability in the energy consumption

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 is form of group interactions in action situation 3 (see the ADICO tables in AS3). Therefore, our proposed institutional design could work as group-base matching mechanism paving the way for more contribution of individuals in the community.

**Motivation Factor of "Glory" in Collective Actions**

Besides, second source of our inspiration in designing the institutions is: the importance of *"glory"* factor. It is 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 in the following section of ADICO tables of institutions for the three action situations.

## 6.3 ADICO Tables of Institutions

The designed institutions in each action situation are formalized in ADICO tables which are presented in the following sections. ADICO (Attribute, Deontic, aIm, Condition, Or else) is a tool in order to formalize institutions. It helps to explain the institutions of a socio-technical system like our technical (resource system) and social (institutional system) as a whole. More specifically, ADICO assists in clarifying the institutional statements of such system [Crawford and Ostrom, 1995] (see figure 8 for examples and more explanation).

### 6.3.1 Institutions in Action Situation 1: System Entrance

First action situation works as a base to the other two action situations, and it gives a concrete context to the EMW institutional system. The actors (inhabitants) choose their smart-label and follow their further interactions based on the selected label. After choosing labels in this action situation, inhabitants interact in the two other action situations mainly based on their selected smart label. First, we explain the Labeling institution and then we present the ADICO table in this action situation.

#### Labeling Institutional in Action Situation 1

Inhabitants can choose five different smart-labels in five different colors. The colors are representing the type of the smart labels. In fact, inhabitants must choose a smart-label when signing a contract for renting or buying a house in BSH. These labels shows the level of inhabitants contribution to EMW system. There are five types of smart-label:

1. Green: including all the three facilities in the house (having all three technical interventions of solar panel, urine separation, and sink macerator)
2. Blue: including two of the three facilities in the house (combination of having solar panel and urine separation )
3. Violet: including two of the three facilities in the house (combination of having solar panel and sink macerator) [6]
4. Yellow: including one of the three facilities in the house (like the solar panel as it is most practiced one among the other two ones)
5. Red: none of the facilities (because there is no obligation in installing the technical interventions of solar panels, urine separation, and kitchen macerator)

All the inhabitants have access to the both CPRs (electricity and water), even a house with red label could benefit from them by changing its label or buying electricity or water from the grid. Therefore, there is no force of contribution to

[6] Solar panel facility is assumed to be a more common technical intervention comparing to urine separation and sink macerator, as it has been used in much more extent comparing to the other ones. Therefore, in blue and violet label, the option of solar panel remains.

the system. Inhabitants with green label have the highest level of contribution in the system. It is a collective action situation where inhabitants can collectively produce and use the shared resources of electricity and water. And, we expect that the green label owners who contribute the most, also benefit more that the other inhabitants. This is another added value of the Labeling institution that can eliminate the problem of free-riding. The smart-labels chosen by the inhabitants clearly show the level of inhabitants' contribution in EMW system and it is a starting point in proposing solutions to the problem of free riding. So, every one is expected to benefit from the resource based on his smart label. This is, in fact, the interaction of the inhabitants with the resources based on their smart label which is elaborated in action situation.

**ADICO Table in Action Situation 1**

In order to identify and explain the institutions in each three action situations, we use tables in the format of ADICO. Every row of the tables show an institution which is designed based on the factors of adaptive institution [Koontz et al., 2015] and success factors of sustainable transition [Forrest and Wiek, 2015], and the columns show the building blocks of ADICO. In this action situation, the factor of "external regime" from the adaptive institution framework is used (see figure 22).

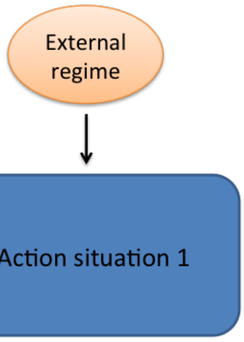
We also found the factor of "External regimes" [Koontz et al., 2015] carrying very similar concept of external influence of "providing crucial resources in form of *funding, information, and training*" [Koontz et al., 2015] (p. 146) that help in long lasting collective action. In this action situation, we are considering this factor in form of subsidy by the government (funding), yet the other forms of external support is elaborated in the third action situation (e.g. providing information and training see table 6).

External regime in forms of: funding, information, and training, are interpreted in the first and third action situations as:

- a subsidy in form of different color packages of subsidies in AS1
- information and training in forms of workshops and online platforms in AS3 (see table 5)

The table 2 lists the institutions in action situation 1. Yet, before the table we list the general assumptions in this action situation, so we do not consider these issues in our institutional design. For instance, we assume that the inhabitants only buy their houses so that have to choose the smart-labels. The list of assumptions are:

Figure 22: Adaptive institution factor used in action situation 1




1. Inhabitants buy their houses
2. There are five types (colors) of smart-labels
3. Inhabitants can select a red label meaning no technical infrastructures in house; no contribution to the system of EMW [7].

[7]enforcing the citizens in sustainable activities is not possible, so the citizens can also choose a red label. see: http://citiscope.org/story/2016/how-amsterdam-turned-polluted-industrial-site-its-most-interesting-neighborhood

| 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 2: ADICOs of Action situation 1

Another action situation happens after the inhabitants decided about the extent of technical infrastructures in their houses (level of their contribution) by choosing smart-labels. The second action situation address the interactions with the technical part of EMW: resource system and resource unit, which is explained in the following section.

#### 6.3.2 Institutions in Action Situation 2: Interactions with the Resources

The institutions in this action situation is related to the social arrangements regarding the production and consumption of the urban commons. So, it is about the interaction of the inhabitants with the electricity and water grid, or generally between the social (prosumers) and technical (resource system and resource unit) part of the system. Below are the list of assumptions that are taken before designing the ADICOs in this action situation. It means that the issues related to the storage of the excess energy produced in the community are excluded from our institutional system. In fact, the institutions in our institutional system are aligned with the main goal of enabling citizen contribution into the system, so the issues of storing and maintenance of the system are excluded from our design. The list of assumptions are:

1. The inhabitants can always switch to using electricity from main grid.
2. The maintenance cost of the resource system of EMW system is not included.
3. The amount of shared resources of electricity and water is dependent on the seasons (level of sun and rain).
4. The excess electricity can be stored in batteries or be used by cars, or be sold to the market or any other potion which is excluded from our system.
5. Produced energy from the solar panels and from the bio-refinery first go to the shared energy grid, and then EMWers (inhabitants who join the EMW system) can use them based on the institution in the following table.
6. Produced water from the collected rain water and from the bio-refinery first go to the shared energy grid, and then EMWers (inhabitants who join the EMW system) can use them based on the institution in the following table.
7. We assume that the system has a sophisticated technical monitoring system that can block the cheaters from overusing, so the cheating is not possible, and the technology is assumed to limit the overusing.

The table 3 list the ADICOs designed based on the factors in adaptive institution framework: resource, rule compliance and external regimes (see figure 23)

**Factors:**

- Resources: based on the factors of adaptive institutions [Koontz et al., 2015], Resources is an important factor in our case. There should be institutions that manage the access to the resources. In our system, every household has a smart-label showing their level of contribution to the system (the extent they produce electricity and water), which in turn indicate the level of their consumption from the resources.

  The *first* main reason behind the ADICO of resource is that inhabitants should get the benefits (using shared electricity and water) of the system based on their level of contribution, so we are eliminating the problem of

Figure 23: Adaptive institution factors used in action situation 2


| 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 3: ADICOs of action situation 2

"free riding" through technological interventions. It means that all the inhabitants have benefits from the shared electricity grid based on their smart label (for instance, red label owners have no benefit from the shared electricity).

- External regime: government (in form of Amsterdam municipality) can provide fund to EMWA for monitoring the system regarding the proportion of produce and use of the prosumers in the EMW system otherwise the recognition of the cheaters is not possible, for instance.

- Rule compliance: monitoring and sanctioning encourage compliance.

  Ostrom (1990) shows that user groups can devise and monitor their own rules. Although such rules create positive collective outcomes, the temptation to break them increase when others break them without any consequences. therefore, institutions may break-down in case of lack of rule compliance [Koontz et al., 2015]. Such institutions are morally contested and it is also in contradiction with collective action, where the citizens collectively make some changes in their community. In our case, citizens are not forced to participate, so monitoring and sanctioning institutions are not applicable. In BSH, we aim at enabling citizen participation, and not enforcing them to participate. We add this institution in the ADICO table to ensure the importance of the "rule compliance", as an important factor of adaptive institution" in our system. our main institution of labeling is a moral one expecting manifestation of contribution of the inhabitants, which will be elaborated in the last sub-section.

### 6.3.3 Institutions in Action Situation 3: Interactions with the Community

This action situation has the most dedicated ADICOs in terms of a collective action situation. Here in this context of institutional design, we are designing institutions that collectively provide solutions to collective action problems. As Ostrom (1990) argues "*institutions* may provide more effective solutions" to such collective action problems than the privatization, as they develop *local knowledge*, *better adapted rules*, *lower enforcement cost*, and *involvement of participants*. This action situation is considering the interaction of the inhabitants with each other and not with the resource (ADICOs related to the resources are in table 3).

Below are the list of assumptions that are taken before designing the ADICOs in this action situation:

1. Based on the insights taken from the case, there is a core group of three persons cooperating with Amsterdam municipality and some companies (such

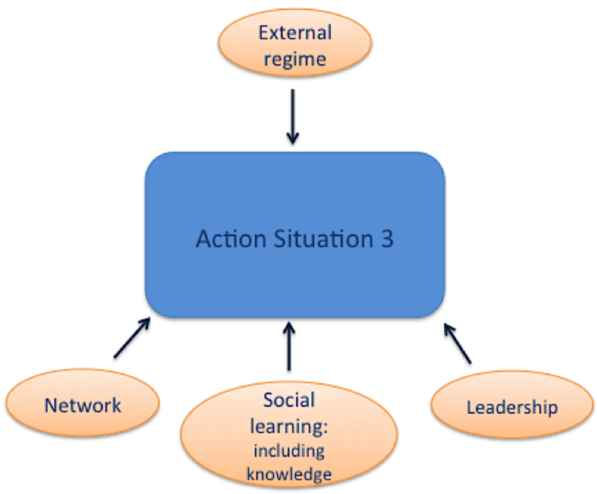
as Metabolic). These three persons can be seen as one of contextual success factors: ”core group and leadership” [Forrest and Wiek, 2015]. The concept of ”leadership” is also considered in the adaptive institution framework [Koontz et al., 2015] and it is among the subset of SES variables: U5 Leadership/entrepreneurship [Ostrom, 2009]. Therefore, we assume that in the institutional design of EMW, there is a core community of EMW called EMW Association (EMWA).

2. Inhabitants have smart-labels that show their level of contributions to the EMW system. For instance, green label owners (having solar panels, urine separation, and kitchen macerator) are contributing in both electricity and water production, while the yellow label owners (having solar panels) are only contributing in electricity production. We assume that the inhabitants make groups based on their smart-labels. This groups can be in forms of associations. So, our institutional system of EMW has Energy Association (EA), Material Association (MA), and Water Association (WA).

3. Based on the recognized success factor of ”Resources” [Forrest and Wiek, 2015], we assume that there is facilities for communications (e.g. meeting rooms) and sharing information and updates (e.g. on-line platforms).

The table below list the ADICOs designed based on the three factors of: leadership, network, and external regimes in adaptive institution framework (see figure 24).

Figure 24: Adaptive institution factors used in action situation 3



| **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 4: ADICOs of action situation 3, first part

Here we explain the institutions in more details:

### Leadership Institutions

The success factors in sustainable transition [Forrest and Wiek, 2015] and adaptive institution factors from the adaptive framework [Koontz et al., 2015] are taken while defining the ADICOs of leadership-1 and leadership-2. Based on the comparative study of Forrest et al. (2015) among three different sustainable transition practices, there are success factors of: *"community governance"* and *"organization and management"*: the former factor ( that can be as village council for instance) provide "legitimacy and administrative support" [Forrest and Wiek, 2015] which pave the way for promoting transition initiatives in a open, transparent and trusted way in the communities. The later factor of "organization and management" shows that existence of some kind of core group of people having organizational structure (formal and legally recognized entity like a local government body and limited company).

Besides, "leadership" itself has been identified as playing a key role in creating adaptive institutions (see the adaptive institutions framework 12). In fact, leaders help to "build trust, make sense, manage conflict, compile and generate knowledge, communicate information, and mobilize broad support for change" [Koontz et al., 2015] (p. 146).

### Network Institutions

Network-1: establishing *arena* ensure that individuals get opportunity to interact, which prevent *institutional fragility and failure* Koontz et al. [2015] (p. 142). As a case in point, we mention the example of a Turkish in-shore fisheries [Ostrom, 1990a]. This case had institutions suitable only for limited number of fishers who were incapable of addressing the increase demand of fishing among themselves due to lack of network (regular arena for collective choice discussions) for interactions. The Network-2: fitting population is designed in order to prevent institutional fragility and failure. So, there is a population threshold that call a new institution to address this change in the system.

Network institutions are also closely related to the learning ones, as it is within the networks that individuals get opportunity for interactions in arenas which are necessary for social learning [Ison et al., 2013]. The learning institutions are in the following table 6.

| **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, 1990a] |
| 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 5: ADICOs of action situation 3, second part

### External Regime Institution

External regimes can provide ”crucial resources in the form of funding, information, and training that can aid in adjusting institutions” [Koontz et al., 2015] (P. 146). As a case in point, examination of 20 NGOs active in the field of forest governance in India shows the long lasting collective action through awareness building,training and capacity building activities [Barnes and van Laerhoven, 2015]. Another relevant example is when external regimes are involved in monitoring and evaluation of the current policies, which help in identification of current policy effectiveness. This way lead to more accountability and transparency for managing policies in systems [Nikolic and Koontz, 2008].

### Learning Institutions

In the previous table, the Network institutions create arenas for individual interactions which can lead to learning. Here, we design learning institutions. First, the importance of required institution that ensure knowledge production is identified through the term of ”institutional linkage”, which avoids institutional gap [Olsson et al., 2006]. In fact, we create this institution between the ”network” and ”learning” institution in order to ensure enough support to create knowledge sharing. In learning-1: institutional linkage, Knowledge is produced at one level of institution, so critical knowledge is available to make required changes in the next level of institution (Learning-2) [Olsson et al., 2006].

Learning-2 : knowledge acquisition and accumulation ensure fostering accumulation of knowledge through local experience [Koontz et al., 2015]. Such knowledge can lead to social learning. In fact, 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 is based on the idea taken from the framework of ”Elements of collective intelligence building blocks” by [Malone et al., 2009] (see figure 13). They recognize ”glory” as one of the important motivator of harnessing the crowd where the actors in a collective intelligence system desire to be recognized by the peers for their contributions.

In this section we designed institutional arrangements in collective actions around the electricity and water in the institutional system of EMW in BSH. In our case, citizens are not forced to participate, so the institutions are aimed in manifesting the collective action.

| 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 6: ADICOs of action situation 3, third part

## 6.4 Conclusion

In this chapter the third sub-question of: ”What institutional arrangement can be designed to govern collective action around technology-driven urban commons in BSH?” was explored. Our institutional system design presented in figure 21 shows the three action situations and the theoretical background in designing the institutions. The main institution in the first action situation is the Labeling institution which is inspired form the Assortative matching theory and the Glory factor of motivation in collective actions. The other institutions in the second and third action situations are designed based on the factors of the Adaptive institutional framework. The ADICO tables presented in this chapter are the **results of our exploration** into the institutional system of EMW in each action situation. In fact, we proposed our institutional design in form of ADICO tables. Our proposed Labeling institution enables the citizens to interact with the resources based on their level of contribution in action situation 2. Besides, the Labeling institution facilitates group-based interaction of the citizen in associations in the community (e.g. Energy Association). Furthermore, the rest of our main findings in this chapter are listed as follows:

- The Labeling institution gives a smart-label to each house in the EMW system in BSH. The label shows the level of the contribution of the label-owner to the EMW system through renewable Energy production, Material recovery, and Water recycling practices. These labels give **transparency** to the system as every one has a label which indicates its contribution. The labels also **eliminate the problem of overusing**, since the interaction of the inhabitants with the resources is based on their label color (for instance, those with red label do not produce and consume from the shared resources). Besides, the labels can create the **opportunity for advanced monitoring** of the production and consumption of the resource.

- Leadership institution provides the system with **legitimacy**, which creates an open, transparent, and trusted community. It means that existence of some kind of core group (formal and legally recognized entity) brings legitimacy and trust within community, which also promote and support changes in the community.

- Network (group-based) creates **groups of label owners**, who have similar interests, values, and practices. They can share their knowledge and experience with each other. The **knowledge flow** created in this groups paves the way for **social learning** (Learning institution). In fact, social learning happens through **producing knowledge** within the community.

- External regime institution can **strengthen collective action** by affording support and resources in forms of funding, information, and training. For instance, municipality can organize some workshops to increase the awareness in the community, or create an on-line platform which provide information about the current practices, possible changes, or future plans.
- We also find out the importance of "**institutional linkage**" between the Network and Learning institutions. Social *learning* happens through social *networks* with knowledge sharing. Our Learning institution (support social learning) requires an arena for knowledge generation, which is provided by the Network (group-based) institutions (create groups for social interactions).

Based on our findings, the institutional system design of EMW can stimulate citizen participation within the community and increase their contribution to the resource system of EMW. The institutional system design in this chapter will be used in the next chapter to develop two models of: 1) an abstract model that demonstrates the functionality of the theory of Assortative matching in an abstract resource system. This model can replicate the theory and show the influence of this mechanism on the contribution of the actors independent to the case of BSH. This way we can explore our main assumption of the Labeling institution in the first action situation through an agent based model (2) a detailed conceptual model of BSH that can capture the dynamic of the whole socio-technical system of EMW in BSH (a case specific model).

# 7 Modeling of the Institutional System Design

## 7.1 Introduction

### 7.1.1 An Abstract Agent-based Model

In this chapter we first develop an abstract model (independent to BSH) to explore the functionality of the Assortative matching mechanism regardless of our case of BSH in an abstract resource system through an agent-based model. The reasons behind developing this model is:

1. the theory of Assortative matching is a big *choice* in our proposed institutional system design as a mechanism that can influence the citizen participation instead of the choice of other mechanisms of monitoring and sanctioning. Therefore, implementation of this theory needs more understanding and exploration,

2. this model can find out the correlation between the Assortative matching as a mechanism in a collective action and the level of citizen contribution into the resource system,

3. this theory is the source of our *inspiration* in designing the Labelling institution in the first action situation. The Labeling institution has importance in the designed institutional system as the interactions in the other two action situations are influence by the Labelling institution. In fact, the interaction of the citizens with the resources in action situation 2 and their interactions with the community in action situation 3 are based on their level of contribution which is shown with their smart-labels. Therefore, considering the significance of the Lebelling institution in our institutional design, we will explore the theory behind the labeling institution.

We explained about the theory of Assortative matching (group-based matching) [Gunnthorsdottir et al., 2010] in the voluntary contribution game and the consequences of this mechanism on the game: new equilibrium emerge that can have a better payoff for whole players (community) and also *increase the contribution of the players* (see section 6.2.2). Here, we intend to evaluate the implementation of the Assortative matching theory (as a mechanism in a collective action ) around a shared resource, and investigate if this mechanism can facilitate citizen contribution into the resource system. Then, we are able to answer the fourth sub question of: How can citizen participation in a collective action be increased? We develop a preliminary agent-based model in order to animate the theory and explore the effect of grouping mechanism in the level of contribution of the agents (resource prosumers) in an abstract resource system.

### 7.1.2 A Conceptual agent-based model

Second, after exploring the functionality of the Assortative matching mechanism in a collective action around an abstract resource system (regardless to the case of BSH), we will develop a conceptual model for our case of BSH. This model is a case specific model which can capture the dynamics of the institutional system in the EMW resource system. The two technical and institutional systems of EMW show how the technological urban commons can be governed through the institutions that can enable citizen participation. Yet, in this chapter, we step forward in understanding about how the dynamic of such collective action in the socio-technical system of EMW can be studied. So, we recall the last sub-question of this research: "How can the dynamics of collective action around technology-driven urban commons be studied?"

We use MAIA (Modeling Agent systems based on Institutional Analysis) [Ghorbani et al., 2013] in order to develop a comprehensive conceptual model of BSH that contains institutional arrangements and social engagements embedded into the technical resource system of EMW. MAIA is very helpful in sense of structuring knowledge and organizing concepts about our technical systems and also social system with a comprehensive institutional analysis.

This model is also an agent based meta model, (a meta model is used to define the syntax of a modeling language at an abstract level [Kent, 2002]) which helps to build an agent-based model of a socio-technical system [Ghorbani et al., 2013]. So, the analysis in this part also helps in building an agent-based model of BSH in the future when the neighborhood is occupied by the citizens and enough data is available. Currently, we do not have sufficient data of BSH to draw reliable conclusions out of the model. Besides, lack of data makes verification and validation of the model unfeasible. Apart from the data limitations, it is out of the scope of this thesis to build a concrete model of BSH. However, we create a conceptual model, that can later be used with valid empirically valid data for building an agent-based model.

## 7.2 An Abstract Model (Agent-based Model) of the Theory of Assortative Matching (Group-based Matching)

In order to test the theory we build a computational model [Sterman, 1985]. The goal of the model in this section is to *test* "meritocratic group based matching" theory [Gunnthorsdottir et al., 2010] in voluntary contribution game with a computer simulation model of ABM, which enables modeling individual behaviors and interactions in the system. The reason behind the choice of ABM is:

1. It can observe the collective impacts of agent behaviors and interactions

[Macal and North, 2010]

2. It captures emergent patterns from bottom-up individual interactions [Macy and Willer, 2002]

3. It represents the system based on individual interactions and its affects on the system as a whole [Bonabeau, 2002]

4. It can embody adaptive behavior and heterogeneity of the components of the system [Balbi and Giupponi, 2009]

The developmental steps of this theoretical model are based on the ten steps of model development [van Dam et al., 2012] which are presented in the below subsections. These steps are very useful in gradually leading the modeller from the first step of "problem formulation and actor identification" to the middle steps of "concept and model formalization" and finally to the "implementation into Netlogo and data analysis" and "model use". It should be mentioned that the complimentary information in some of the ten steps are presented in the Appendix of this research.

### 7.2.1 Problem Formulation and Actor Identification

Collective action problem have been explored by several ABMs. For instance, the effect of communication on cooperation of the users were first modeled by Deadman et al. (2000). Our model is a theoretical model that discovers the effect of Assorative matching in collective action.

This model is inspired with the model of "A Simple Model of the Emergence of Institutions Through Collective Action" presented in a paper by Ghorbani and Bravo [2016]. In their model, they show "that institutions favoring CPR management can *emerge* through collective behavior even without assuming advanced cognitive capacities for the agents" [Ghorbani and Bravo, 2016] (p. 201). In our model, with some contributions to their model of institutional emergent, we are emphasizing on testing the theory of group-based matching as a mechanism contributed to the sustainable management of the common pool resource system through increasing the contribution of the prosumers in the system. Therefore, *we are interested to see if grouping mechanism can increase their contribution to the CPR (urban commons).*

Prosumers act either in their neighborhood or group producing and consuming resource units. They can select a set of behavioral strategies, yet the dominant strategy is "free-riding". The reason behind the dominant strategy of being free rider is that this model is based on the voluntary contribution game in which the actor/players 's dominant strategy is "free-riding". Free-riding in our model means that prosumers always give (produce) smaller unit of the resource comparing to the unit of resource they take (consume). In fact, the prosumers always consume more units than the units they produce, so they are always acting as a free-rider. This behavioral strategies of agents will be explained more in details in the following sub-sections.

**Modelling Questions**

The aim of this model is to compare two scenarios of (1) prosumers interacting in neighborhood, (2) prosumers interacting within groups. In both of these scenarios, agents represent prosumers who are free-riders with a set of behavioral strategies that can be changed during the model. Agents can be affected by the other agents (prosumers) in their neighborhood or group.

The scenario ”without grouping” is our base scenario, in which the agents interact in their neighborhood. The scenario of ”with grouping” is the situation in which the ”grouping mechanism” is implemented. The behavior of the agents (taking different strategies) in these two scenarios can emerge patterns that collectively can lead to different states of the system regarding the resource and the level of agents’ contribution.

We are interested to know the emergent behavior of the agents under the grouping mechanism (based on the theory of group-based matching). Therefore, the main model question is regarding a comparison between the two scenarios of ”with grouping” and ”without grouping” on (1) the average contribution of actors to the shared resource after each run, and (2) the state/well being of the resource (average resource remained after each run).

Therefore, the questions to be answered by this model are:

1. What is the effect of ”grouping mechanism” on the level of contribution of the actors to the shared resource?
2. What is the influence of parameters of the model on the level of contribution of the actors to the shared resource?

### 7.2.2 System Identification and Decomposition

We are modeling an abstract CPR system. The ”Prosumers” of the CPR are modelled as agents. These agents produce and consume the resource by respectively giving and taking certain amounts of resource units and in turn loosing and gaining ‘energy’ from their production and consumption respectively. We assume that agents energy of one unit is equal to one unit of resource.

Agents can select an individual strategy that shows the amount of units they ”give” to the resource and ”take” from the resource. There is also ”condition” in which agents can change their strategy. Therefore, each individual strategy of the agents composed of three elements: ”give”, ”take”, and ”condition”.

As it is mentioned the agents (prosumers) having a dominant strategy of being ”free-rider”; it means that they always ”take” more units from the resource than ”giving” units to the resource. To model this strategy, we make a list of actions (”give” and ”take”) and a list of condition from which the agents can choose. Therefore, their individual strategy is formed by combination of their selected give and take action plus the condition. For example, strategies can be in form of “Consume 5 resource units and produce 3 resource units when my energy is lower than zero” or “Consume 10 resource units and produce 7 resource units every 20 time steps”.

Agents can select their strategies in two different ways: (1) randomly (based on random proportional probability) choosing new strategies, or (2) copying the strategy of the agent with highest level of energy (most successful one) in their neighborhood. Yet, If they are in group, then their selected strategy is affected by the average contribution of the group (average ”give” number of the agents in the group). And for the amount of resource unit consumption (”take” number) and the ”condition”, they just copy the most successful prosumer.

The concept of average contribution is showing that within the groups there is more interaction and influence, so the agents contribution is affected by all the group-mate and not only the most successful one. The grouping is happening based on the *level of agents contribution* to the resource which is represented by the unit that they produce (”give” number ).

In order to make groups, first agents are ranked based on their ”give”. Then, they are placed in groups with their most similar agents in the list. Apart from the ”condition” for changing the strategy, agents can change their strategies when their energy level is decreasing (i.e. their present level of energy is less that their energy level of the previous time step). It means that the subtraction of their unit of resource consumption and production does not meet their “livelihood needs” (their daily energy consumption). The logic here is that the agents are not happy when their energy level drops (they are performing poorly), so they try to improve their welfare either by copying others or by innovating a new strategy (a random choice).

In the model we have regular time intervals in which agents, in case of having groups, have the opportunity to change their groups. Therefore, the groups are dynamic and agents can change their groups based on the same logic of making groups (i.e. agents are ranked based on their level of contribution to the resource). This change only takes place if the number if unhappy agents with their current situation (i.e agent with negative energy) is higher than a certain threshold.

More explanation about the components of the model are presented in the Appendix.

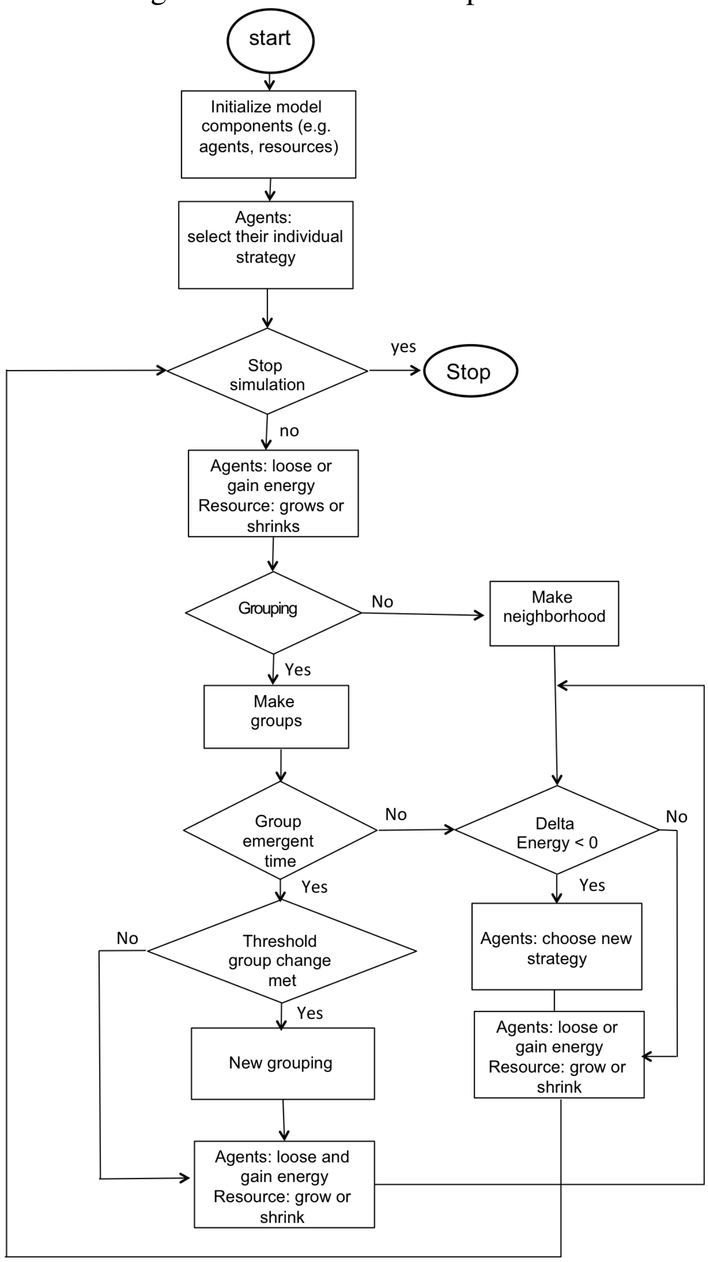
### 7.2.3 Concept Formalization

In order to give an overview of the model, we build a flowchart that clearly show the whole concept of the model along with its simulation procedures. As it is shown in figure 25 the model starts by initializing the agents and the single resource. The resource take an initial amount and a growth rate. The agents consume energy (daily consumption) from the resource and they also produce energy and give it to the resource (their contribution to the resource system), and in turn the resource can grow or shrink. Therefore, in the flowchart we show these dynamics of the resource (repetitive increasing and decreasing of the resource units) and the agents (repetitive increasing and decreasing of energy units) by stating: ”agents: lose and gain energy” and ”resource: grow and shrink”. Then an important critical event in the model is the *grouping*. If we have grouping then the agents follow their interaction within groups otherwise, they make network with their neighbors. Grouping is dynamic, given the *grouping emergent time* that occurs at regular time intervals, regrouping can only happen if the number of agents with negative energy level is higher than a certain *threshold for group change*. Group change only takes place if a certain majority of the agents are dissatisfied with their group (*threshold for group change* ).

The simulation, shown in figure 25 is described below:

- Initialization:
  1. Agents are created, and the number of agents is a variable determined by the modeller.
  2. The resource is initialized to the carrying capacity of (k) that is a variable determined by the modeller, with a growth rate of (r), that is also a variable.
- Individual strategy initialization: Agents randomly select their individual strategy that is a combination of one random action-take, one random action-give, and one randon condition.
- Procedure accuring in every time step:
  1. Agents loose and gain energy
  2. The resource grows and shrinks
  3. Action execution by the agents: The agents can execute the following type of procedure (i.e. individual strategy in neighborhood or in group, or changing grouping):

Figure 25: The simulation procedure



- Individual-based action in neighborhood: (a) agents gain and loose energy by producing into the resuming from the resource according to their own strategies; (b) each agent compare its current energy level with the energy level from the previous time step (energy delta); if it is below 0, the agent chooses a different strategy/action condition combination for the next time step (iteration) based from the following two options:
  - innovation: with a given probability that is a variable determined by the modeller, the agent randomly chooses a new ”action- take, action-give, and condition” similar to choosing the initial strategy;
  - copying: otherwise, if the agent is not innovative (given the probability) it instead chooses the strategy of the most successful agent (i.e., one with highest energy) *in its neighbourhood*.
- Individual-based action in groups: (a) agents gain and loose energy by producing into the resuming from the resource according to their own strategies; (b) each agent compare its current energy level with the energy level from the previous time step (energy delta); if it is below 0, the agent chooses a different strategy/action condition combination for the next time step (iteration) based from the following two options:
  - innovation: with a given probability that is a variable determined by the modeller, the agent randomly chooses a new ”action- take, action-give, and condition” similar to choosing the initial strategy;
  - copying :otherwise, if the agent is not innovative it chooses only the strategy of the most successful agent (i.e., one with highest energy) in respect to take (the amount of resource unit it presumes) and the condition, yet the give strategy (the amount of energy unit it produces) is affected by the whole group mates. It means that the average ”give” of the group is copied.
  - grouping emergence and changing groups: If it is the time for group change shown be *group emergent time* and if a certain proportion of agents which is modeled with: *threshold for group change*, has negative energy level ,there is a call for group change/ regrouping. The agents are ranked based on their give number (level of their contribution to the resource) and they are regrouped (group size is equal to the number of

agents divided by the number of groups).

- The simulation ends after 2000 time steps or when the resource is deployed.

The next step of "Model formalization" is presented in the Appendix (see Appendix 10.2.3).

### 7.2.4 Implementation in Netlogo

This model is implemented in Netlogo [Wilensky and Evanston, 1999]. It is a software platform for agent-based modelling. It benefits both educational and research purposes in the fields of social and natural sciences [8].

### 7.2.5 Model Verification

This step is performed to ensure that the model does what it is supposed to do according to the model formulation. The model verification is following the four main parts introduced in the book of "Agent-based modeling of socio-technical systems" [van Dam et al., 2012]: agent behavior, single-agent testing, interaction testing, and multi-agent testing. During the verification process, some tools are used to record and track agents behavior such as "plots" and "monitors". They help in checking the expected trend of the variables. We also used "Command center" and "print" to check the variables of the model during the run and check if they are taking a valid value. An example of the steps that are taken in this process is shown in the appendix.

### 7.2.6 Experimentation

This preliminary model is aimed at comparing the outcomes of the system under the "with grouping" and "without grouping" conditions. Table 7 shows the experimental setup, contains the parameters (introduced in the previous sub-sections of concept and model formalization) with their used values. The parameter of "mutation rate" (0.1, 0.5, 1) represents the ratio of agents innovating instead of copying others. If the proportion of dissatisfied agents (agents with negative energy) is more than "threshold group change" (0.35, 0.65) and the repetition of the simulation time is a factor of "group emergent time" (50, 100) the group change procedure is activated. The parameter of "number of link" (2, 5) shows the number of links that each agent can make within the neighborhood (without grouping). The other parameter of the model not presented in the table are: the carrying "initial capacity" (K) and "growth rate" (r) of the resource, and "energy consumption" of

[8] see Netlogo website here: https://ccl.northwestern.edu/netlogo/

| Parameter | Values |
|---|---|
| Number of agents | 2, 5, 8 |
| Mutation rate | 0.1, 0.5, 1 |
| Grouping | ”True”, ”False” |
| Group emergence time | 50, 100 |
| Threshold group change | 0.35, 0.6 |
| Network | random |
| Number of links | 2, 5 |

Table 7: Experimental setup

the agents which take constant values of: k = 60, r = 0.27, and energy consumption = 3. The amount of initial capacity and energy consumption are selected based on the result of the sensitivity analysis. In this analysis we run the model for different (extreme) values of the parameters and checked the behavior of the resource (see section of the validation).

This simulation setup results in a total of 4320 runs. Half of them are the runs with grouping ”True” and the other half is when grouping is ”False”. For each run, the average contribution of the agents into the resource (average ”give number” of the agents), and average amount of remained resource are recorded.

#### 7.2.7 Results

The data gathered after running the simulation setup, is analyzed in this section with the focus in answering the modeling questions of: (1) What is the effect of ”grouping mechanism” on the level of contribution of the actors to the shared resource?, and (2) What is the influence of parameters of the model on the level of contribution of the actors to the shared resource?

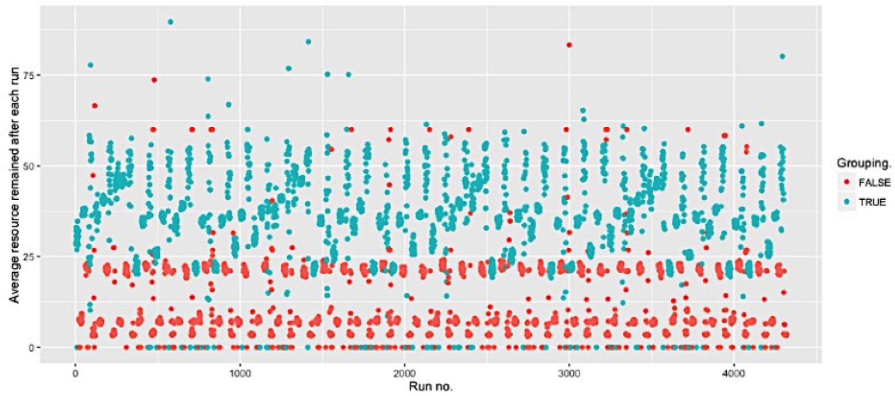
First, in addressing the first question, two following plots of 26 and 27 demonstrate the positive effect of the introduction of the ”grouping” on both variables of: “average resource remained after each run” and “average contribution of agents to the resource after each run”, respectively. In figure 26, the average resource remained when grouping is “False” has mainly the values around 0, 10, and 24 (see the red points in the plot which have a repetitive pattern during the 4312 runs), which are mainly smaller than the values of the variable in the question when the grouping is ”True” (see the blue points). Figure 27 is a box plot represents the difference between the values of the variable of “average contribution of agents to the resource after each run” in two scenarios of grouping ”False” and ”True”.

The blue box shows that 50 percent of the data when grouping is ”True” (data in the blue box) are bigger that the same amount of data in red box (when grouping is ”False”). This difference is statistically significant (see the table 9 for the statistical relation)

In order to gain more insights in the relation between the variables, we carry out multivariate regression analysis [9] by taking the parameters of the model as predictors in the regression model. Table 8 presents the results of the method of ordinary least square (OLS) [10], in which the relation (with its direction and degree) between the independent variables of: “average contribution of agents to the resource after each run” with the dependent variable of: ”number of agents” and ”mutation rate”, and ”grouping” (the general parameters) are presented.

As expected, the grouping positively affects the dependent variable. The finding that is consistent with the theory of Assortative matching in game theory, and it shows more contribution of the agents when they are grouped. The number of agents does not have a significant relation with the indicator, while the mutation rate has a negative significant effect on it. It means that the more agents copy in groups (and not innovate), agents contribute more to the resource.

Figure 26: Average resource remained after each run per run number when grouping is “False” (red points) and “True” (blue points)




### When grouping is True

The OLS shown in table 9 shows the relation of the parameters when grouping ”True”, and it gives answer to he second model question. The parameters that mat-

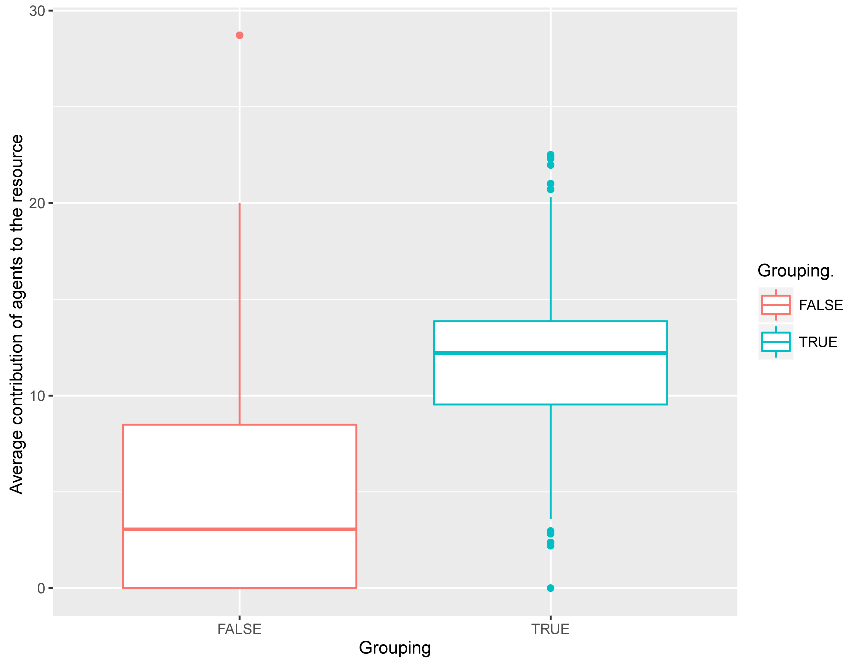
[9]By using multivariate regression analysis, it is possible to study the relation of a set of independent variables with one dependent variable.

[10]The method finding the coefficients that minimizes the sum of the squared residuals to find the best fitting linear regression line

| | *Dependent variable:* | |
|---|---|---|
| | Average contribution of agents to the resource after each run | |
| | (1) | (2) |
| Number of agents | | −0.001 |
| | | (0.001) |
| Mutation rate | | −1.014*** |
| | | (0.165) |
| Grouping | | 7.110*** |
| | | (0.121) |
| Constant | 7.902*** | 4.993*** |
| | (0.081) | (0.167) |
| Observations | 4,320 | 4,320 |
| $R^2$ | 0.000 | 0.446 |
| Adjusted $R^2$ | 0.000 | 0.445 |
| Residual Std. Error | 5.357 (df = 4319) | 3.990 (df = 4316) |
| *Note:* | | *p<0.05; **p<0.01; ***p<0.001 |

Table 8: OLS on average contribution of agents to the resource after each run

Figure 27: Comparing the average contribution of agents to the resource when grouping is False and True




ter in grouping scenarios are: ”number of groups”, ”threshold of group change”, and ”group emergent time”. The emergence time and number of groups have negative significant influence on the average contribution of the agents. It means that, agents in bigger group size have more contribution to the resource. Smaller time interval for group change (group emergent time) shows better contribution of the agents.

| | *Dependent variable:* | |
|---|---|---|
| | Average contribution of agents to the resource after each run | |
| | (1) | (2) |
| Group emergence time | | $-0.007^{*}$ |
| | | (0.003) |
| Threshold group change | | $-0.312$ |
| | | (0.480) |
| Number of groups | | $-0.228^{***}$ |
| | | (0.029) |
| Constant | $11.457^{***}$ | $13.251^{***}$ |
| | (0.073) | (0.362) |
| Observations | 2,160 | 2,160 |
| $R^2$ | 0.000 | 0.030 |
| Adjusted $R^2$ | 0.000 | 0.028 |
| Residual Std. Error | 3.396 (df = 2159) | 3.347 (df = 2156) |
| *Note:* | | $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$ |

Table 9: OLS on the average contribution of agents to the resource after each run when grouping is True

#### 7.2.8 Validation

There are four methods of model validation in the book of "Agent-Based Modelling of Socio-Technical Systems" [van Dam et al., 2012]: historic replay, model replication, face validation through expert consultant, and literature validation. Because our model it not a model based on real data, the methods of historic replay and literature validation, in which the model is compared with real world situation, are not applicable. Model replication requires creating a second model with different system decomposition, which is irrelevant to our model, as it is a theoretical model. Validation through expert consultant is also not applicable in this model as we do not have any problem owner. Therefore, the validation of this model is an internal validation in which the behavior of model is checked through some extreme value testing or sensitivity analysis. In this method, it is very important to know the purpose of the model and investigate if the model is replicating the expected results.

Resource behavior is tested under two conditions of (1) big value of K, small number of agents, and small amount of energy consumption, and (2) small value of K, big number of agents, and big value of energy consumption. Running the model under the first condition led a very stable state of the resource, yet the second condition resulted in a fast drop of resource, and negative energy for the agents. These model behaviors are valid and expected. In case (1), resource has a big initial capacity with very small resource prosumer (number of agents), so the state of the resource would not change dramatically, yet in case (2) the resource is initially small and with big number of prosumers, so the interaction between the agents and resource is high and the resource would show a dramatic drop.

### 7.2.9 Model Use

This theoretical model provides us with insights in the relation of the parameters of the model (see table 8 and 9). We explored that grouping the agents leads to increasing their contribution to the resource. This main fining demonstrates the Assortative matching theory in voluntary contribution game, and it also validates our proposed institutional design in the previous chapter. The Labeling and group-based institutions in designed institutional system are inspired of the Assortative matching theory, and the exploration carried out in this section demonstrates the theory and shows the correlation between the Assortative matching (group-based) mechanism and the contribution of the agents. The model presents that the functionality of this mechanism in a collective action in a resource system increases the contribution of the agents into the resource system.

The model provides a test bed for further exploration and comparison analysis. For instance, the insights of this model can be compared with empirical data of grouping people in the real world. In case we have the data, the comparison could also empirically validate the model and provides us with a three comparison analysis of the model, empirical data, and the theory.

After exploration of the Assortative matching theory in the abstract model (independent of the case of BSH) explained in this section, we will develop a detailed conceptual model for BSH (case specific model) that can capture the dynamic of the technical and institutional system of EMW in BSH.

## 7.3 Capturing the Dynamics of EMW System in BSH through a Conceptual Model

In this section we develop a detailed conceptual model of BSH which can capture the dynamic of the technical and institutional system of EMW. We will address the final research sub-question of ”How can the dynamics of collective action around technology-driven urban commons be studied?". This conceptual model of MAIA can be used to develop an agent-based model in the future, when there are sufficient data in BSH to draw empirically valid results. All the presented tables in this section are MAIA tables, which are the output of developing a conceptual model (MAIA model).

Besides, developing the conceptual model of BSH forces us to think more in detail about the system, so it gives us more added value and insight about the system of EMW in BSH (see the MAIA tables in this section). The gained insights are used to refine the institutional system in the previous chapter. The conceptual model also shows the functionality of our institutional system design embedded in the technical system of EMW (see the operational structure). The structure of this section is based on MAIA's four structures that hold related concepts:

1. Collective Structure: actors of the system and their attributes.
2. Constitutional Structure: the social context of the socio-technical system.
3. Physical Structure: the physical aspects of the socio-technical system.
4. Operational Structure: the dynamics of the system.

### 7.3.1 Collective Structure

Collective part of MAIA represents all the possible agents in the system including individuals, state, and non-state bodies that make decisions, act, and interact in the socio-technical system of EMW. Table 10 presents the agents in the system with their possible properties and behavior in the system.

| Name: agent type | Property | Behavior |
|---|---|---|
| Inhabitants | Population, have different type of smart-labels, age, income, education, history of living in a house with smart facilities (skill and experience), information about subsidies | Buy or rent a house, select smart-labels, choose to join the community, initiate a cooperative, initiate partnership with citizens and politics/government, interact within community, produce energy and water, use energy and water, increase their smart-label, apply for subsidy, cheat, follow the rules, take individual strategies, learn from each other, explore new possibilities, be satisfied or unsatisfied from their current activities, overuse the CPRs, need energy and water |
| Government body | Have subsidies | Give subsidies to inhabitants, give subsidies to developers |
| developers of EMW | Have expertise, have money, have information about subsidies | Run projects in BSH, apply for subsidies |

Table 10: Agents, their properties and behavior

### 7.3.2 Constitutional Structure

The institutional system of EMW holds the social context of the system. In each of the three action situations presented in chapter 6, we presented ADICO tables. The tables contain the institutions that govern citizens' behavior. Therefore, the ADICO tables show the social context of our system (see the ADICO tables of 2, 3, 4, 5, and 6.

#### MCDM of Selecting Smart-labels in Action Situation 1

The main action in this action situation happens when the inhabitants make decision about their smart-labels in a MCDM (Multi Criteria Decision Making) shown bellow. In fact, each of the inhabitants have to select a smart-label, and his decision is affected by three factors of:

1. **Skills and experience** ("skill-experience" in MCDM) factor is intending the importance of the background of the inhabitants (potential label-owners) in BSH. In fact, those who already gained skills and experience in green or sustainable activities or those who already have had experience in living in a green house, care more about being sustainable ,and they are willing to more contributions by choosing a better smart-label.

2. **Funding opportunity** ("subsidy" in the MCDM) in form of subsidy from the government. the amount of the subsidy is based on the color of the smart label ranging from the green-label subsidy to the lowest level of yellow-label subsidy (see ADICO table 2). So, the more chance of having subsidy, the more chance inhabitants select a smarter label (they can select red smart-label which means no contribution and no subsidy). In BSH, the municipality has also taken some policies regarding this matter, so the inhabitants will receive subsidies by implementation of sustainable changes in their housed.

3. **Core group and leadership** ("core-group" in MCDM) is recognized to be an important factor based on Forrest and Wiek (2015) research. The existence of a core group of volunteers can lead to a better sustainable transition. The original core group play an important role in feeding the right information that support the decision making of the potential smart label owners. In the case of BSH, such core group exist. A group of three main volunteers who steer the redevelopment of the region along with some companies such as Metabolic.

The three factors are selected from the three contextual success factors in sustainability transitions [Forrest and Wiek, 2015] of: (1) Skills and experience ("skill-experience" in MCDM), (2) funding opportunity ("subsidy" in the MCDM), and (3) core group and leadership ("core-group" in MCDM). The selection of these factors are based on their relevance to this decision making and to our case of BSH, which are explained in the previous paragraphs. The extent of these factors have influence on the labels selected by the inhabitants, and the weights show the influence of the factors in the MCDM.

$$MCDM-in-choosing-smart-labels = (skill-experience*weight-of-skill) \\ +(subsidy*weight-of-subsidy)+(core-group*weight-of-core)$$

We are also aware of the other possible factors influencing the MCDM such as income. They are considered as assumptions of the MCDM in the first action situation (see the assumptions in AS1 in chapter 6: Level of income and education are assumed to be fixed and are excluded from the MCDM).

### 7.3.3 Physical Structure

Physical structure are the components of the non-social environment in which the agents interact [Ghorbani et al., 2014]. The information related to the physical aspects of the system are presented in table 11.

It should be mentioned that the physical structure presented in the table 11 assumes the existence of some basic infrastructures such as monitoring system, waste grid from the kitchen to the refinery, and separate sewer system. They are assumed to be excluded from the conceptual model for the sake of simplicity.

### 7.3.4 Operational Structure

All the interactions take place in the operational structure. Agents interact in the action arena which is influenced by the physical and social setting of the system. The action arena contains all the action situations (in this case three action situations) with all the entity actions that can execute during the simulation [Ghorbani et al., 2014].

The model takes ADICO sequences assigned in three action situations, so the agents interact in the main action arena consists of the three action situations. The elaborated grammar of institutions (ADICO) are used as a starting point to allow institutions to emerge and evolve in our proposed EMW system. There are some contributors and non-contributors as smart-label owners in the EMW system, who are the agents in the model. The level of their contribution is depending on the color of their label. In fact, they either act as prosumers (contributors) having a label of green, blue, and yellow or they are non-contributors holding a red label. Therefore, we have different kind of agents which has different label-colors.

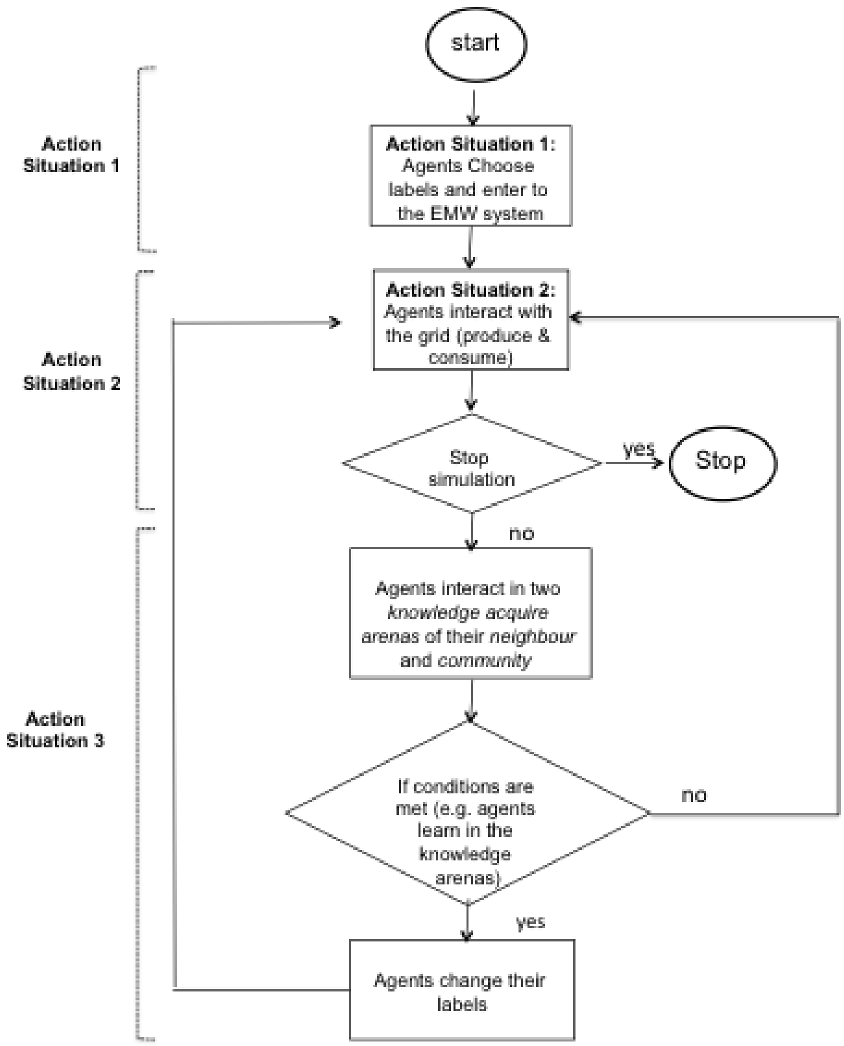
The dynamics of the system is shown in a flowchart in figure 28. The flowchart composes of three action situations presented in chapter 6. In action situation 1, agents choose smart-labels and enter to the system of EMW (Labeling ADICO in action situation 1). In action situation 2, the agents start interacting to the shared resource based on their smart-labels (Resource ADICO in action situation 2). Action situation 3 shows the interaction of the agents in their neighborhood and in their community. The communities can be the different associations in EMWA such as Energy association. Agents form such community-based groups based on their smart-labels. It means that the inhabitants with green and blue labels who are contributing in energy production, can establish the Energy association. Beside, all the inhabitants who do not have a red label are members of a bigger community of EMWA (see ADICO in action situation 3).

| Name | Property | Behavior |
|---|---|---|
| Houses (private) | Have smart labels, cost (price), location, connection to the grids | Gets old, need maintenance |
| Bio refinery (public) | Have inputs and outputs, cost (price), benefit, location, capacity, technology | Turn organic waste to enery, turn urine to energy and low-grade water, add energy and water to CPRs |
| Energy grid (community-owned) | Have a number of connections, has input and output, cost, benefit, locatio, capacity, maintenance cost, | Connect the green energy community in BSH, give energy to inhabitants, can be overused, can be depleted |
| Water grid (community-owned) | Have a number of connections, has input and output, cost, benefit, location, capacity, maintenance cost, can be depleted (over use) | Connect the low-grade water community in BSH, give low-grade water to inhabitants, can be overused, can be depleted |
| Solar panels (private) | Have cost, location, benefit, connection to energy grid | Turn solar energy to electricity, give energy to the energy grid |
| Urine separation (private) | Have cost, location, level of comfort in installing and use, benefit, connection to bio refinery | Separate organic waste in the kitchens, give waste to the bio-refinery |
| Rainwater harvesting system (public) | Have cost, location, connection to water grid | Collect rain water, prevent water disaster, give water to the water grid |
| Renewable energy from public places (public) | Have cost, benefit, connection to energy grid | Produce green energy, give energy to the energy grid |
| Storage system (community-owned) | Have cost, benefit, connection to energy grid | Store the possible exceed energy |

Table 11: Physical structure of EMW system

The group interaction and communication of the agents take place in the context of knowledge acquire arena where agents exchange their knowledge and experience (see ADICOs in action situation 3). If such communication of agents leads to some learning, then the inhabitants might change their label (increase their contribution in the resource). To be more specific about the operational structure of the model, we will present the general assumption and detailed assumptions in each action situation in the following sub-section.

Figure 28: The dynamic of the system



### 7.3.5 Model Assumptions

#### General Assumptions

After knowing the dynamic of the model through all the entity actions, it is also very important to know about the assumptions of the model. Assumptions are made in social and physical aspects of the model e.g. about the physical structure of the model and about the behavior and characteristics of the agents. The tables of 12 and 13 show the general assumptions and the reason behind each of them . The general assumptions are related to the model setting, type of agents, type of resource, and some general characteristics of the agents, which are all presented in the following tables.

#### Assumption in Action Situation 1

The assumptions in this action situation are presented in table 14. They are about the factors of decision making of the agents selecting a smart-label (see the subsection of MCDM in Action Situation 1). Besides, we consider the two small (neighborhood) and big (EMW Association) groups of interactions. It means that the agents will exchange knowledge, experience, tips about their sustainable practices with their group-mates. The effect of such group-based interactions are shown in ”neighborhood” and ”community” effects, which can lead to ”learning” (see Learning ADICOs in action situation 3).

#### Assumption in Action Situation 2

This action situation cares about the resource, so the assumptions are related to the production of energy to the resource (electricity grid), and consumption of energy from the resource (see ADICO in Action situation 2). As it is presented in tables 15, We also assume that the energy consumption of the agents has a normal distribution, yet it is also proportioned to a factor of ”learning”. It means that the ”neighborhood effect” and the ”association effect” might lead to ”learning”, which influence energy consumption of the agents.

#### Assumption in Action Situation 3

The list of assumptions in this action situation is presented in table 16. Regarding the ADICO of ”network-1”, citizens establish arenas. In this model, agents are placed in two groups of: neighborhood and community (EMWA). We also assume that their interaction (e.g. knowledge accumulation) may lead to ”learning” (collaborative learning through knowledge sharing [Różewski et al., 2015].

| **General assumptions of the model** | **Reason** |
|---|---|
| We assume that the model runs from the year 2035 when all the technical interventions are completed. | The interest of this model is to study the institutional development within the institutional system of EMW regardless of the infrastructural development of the technical system of EMW, so we assume that the technical implementation of EMW system is feasible, and the model starts from 2035 when all the interventions are available in BSH. |
| Running time of the model is 20 years. | As the technical development of BSH is taking 20 years from 2015 till 2035, we keep the same period of time for running the model and see the institutional development. |
| Four labels of green, blue, yellow, and red are included in the smart-labeling system. we assume that the labels of blue (having solar panel + urine separation) and violet ( solar panel + kitchen macerator) are the same. So, the both labels are represented as the blue label in the model. | Because the characteristics of these two labels are assumed the same: average *cost*, the level of produced *energy* in the grid, and produced low-grade *water* for these two labels (blue and violet) are equal in average. |

Table 12: General assumption of the model, part 1

Furthermore, we assume that the learning of the agents can show itself in changing of their behavior, and their behavioral change happens through changing their smart-labels.

| General assumptions of the model | Reason |
|---|---|
| The assumption of including only the energy grid and not the water grid, and having one common resource of electricity in the model. | The analysis of the outputs of the model is based on the institutional adaptability and social willingness in contributing in BSH which is not making differences by having one or two common resources. So, for the sake of simplicity we can only consider the electricity in the model. It should also mention that the data limitation regarding the production and consumption of these resources exists. |
| The maintenance cost and the cost for underlying infrastructures (infrastructures needed for a running EMW system e.g. biorefinery, grids, and connections) are excluded from the model. Only the cost of the private infrastructures (e.t. solar panel or kitchen macarator) are included. | The focus of the model is on the dwellings with smart labels and their reactions in the proposed institutional system (EMWA) in BSH. |
| The amount of energy consumption of each dwelling per month has a normal distribution with a average consumption. | This way we are considering that the dwellings have different energy-saving actions (e.g. turning off the lights when it is not needed) rooted in different consumption behaviors. Beside, this way the agents are more heterogeneous that leads to more emergent behaviors. |
| The demographic characteristics such as age and income of the inhabitants are not influencing in our model. | The age and income of inhabitants of BSH are assumed to have not much diversity. |

Table 13: General assumption of the model, part 2

| **Assumptions made in action situation 1** | **Reason** |
|---|---|
| Initial subsidy (1): all the dwellings regardless of their smart-label (except the red ones) will have the *same percentage* of the whole cost from the government (e.g. 20 per cent of the cost will be covered by subsidy) while the opportunity of having the subsidy may very (see the next assumption). | We want to impediment a labeling system which has an overall amount of subsidy for all the labels. This way, our labeling settings are independent form the subsidy settings (regulations) in the government/municipality. |
| Initial subsidy (2): the opportunity (level of subsidy) of having subsidy from the government is not fixed (e.t. it is taken as a variable shown by a slider in the model). | We are interested to see the effect of this factor (external regime) in the level of inhabitants' contribution and their willingness to participate (this is consistent with the factor of "external regime" in ADICO table in action situation 1. |
| "Level of Skills and experience" is one of the factors of decision making (MCDM) in choosing smart label, and the level of this factor is assumed to be different for any of the inhabitants who choose their smart label, so it is a random number. | Inhabitants have different background, so the level of skill and experience is not the same. |
| The two other factors of decision making (MCDM) in choosing smart label: "Core group and leadership" and "subsidy", have the same amount for all the inhabitants in every simulation of the model. | The effect of existing a core group of volunteers and subsidy is equal for all the inhabitants and it is independent of their personal values. |
| Each dwelling with a smart label is placed in a small world network of neighbors , this is considered as a group where agents interact. The size of the neighborhood can be a variable | This way we are including the effect of interactions among a small group of neighbors. We assume that the dwellings within such small community/group of neighbors will exchange knowledge, tips and experience of practicing green activities (depends to their smart label). This effect is known as *"neighborhood effect"* used in the table of formula. Dwellings are also learning from the bigger community of EMWA, which is known as "association effect" introduced the assumptions in action situation 3. |

Table 14: Assumptions made in action situation 1

| **Assumptions made in action situation 2** | **Reason** |
|---|---|
| Dwellings have a fixed production and consumption of energy to and from the energy grid (urban common), which is based on their level of contribution show by smart labels | Regarding to the ADICO designed for this action situation 2 (see ADICo table 3, interaction of the dwellings with the shared resources (urban common) is based on their level of contribution |
| Monthly energy consumption of each dwelling is coming from a normal distribution as it is already mentioned in the table of general assumptions, but it is proportioned to a factor of ”learning factor” | We assume that the consumption of the dwelling is affected by two types of interactions: dwellings with their neighbors (”neighborhood effect” and with the EMW association (”association effect”). |

Table 15: Assumptions made in action situation 2

### Main Model Formula and Information

In this sub-section, we show some of the data gathered during this research. However, the model seeks much more data to be built, so developing a valid agent-based model is the work of the future (when there are empirical valid data on the case of BSH). Table 17 and table 19 demonstrate some of data on electricity consumption and some assumed cost of the smart-labels, respectively.

We could gather some data about the expected population in BSH. Based on the report of Circular Buiksloterham there are currently 252 registered residents, and the number of residents is foreseen to rise up by approximately 25-fold Gladek, van Odijk, Theuws, Herder [2014]. So, we will have 6300 residents. Considering the average size of the families in the Netherlands (2.3) [Ingrid et al., 2003], we assume that there are approximately 2700 houses in BSH. Based on the other source of information, there would be 2700 dwellings in BSH [11].

Besides, the table of 18 explains two main formulas in the model: (1)Investment cost for smart labels, which depends on the level of subsidy and the cost of the label. (2) Energy consumption of the dwelling per month , which is affected by the smart label, learning effect, and the monthly consumption coming from a normal distribution.

[]

[11] see http://urd.verdus.nl/upload/documents/FactsBuiksloterhamCaseStudy.pdf

| **Assumptions made in action situation 3** | **Reason** |
|---|---|
| Dwellings interact within a small group of their neighbors and a big group of the community (EMWA). | Regarding to the ADICO of ”Network 1: establishing arena” designed in ADICO table of the third action situation (see table 4), these two arenas are consider as the groups in which the dwellings will share their knowledge and start learning. |
| We assume that the interaction of the dwellings in the two arenas is through the knowledge acquisition and accumulation presented in ADICO of ”learning 2” (see table 5). And we assume that such interactions can lead to learning, which eventually can lead to changing the labels. | Collaborative learning can happen through social networks with knowledge sharing. [Różewski et al., 2015] |
| Learning of the dwellings leads to the action of changing their labels. | When dwellings learn, they show their new learning through changing of their behavior in the system. In this model, the changing behavior of the agents can happen through changing their smart labels. |

Table 16: Assumptions made in action situation 3

| Some information needed for modeling | Data gathered for modeling |
|---|---|
| Average electricity demand<br>per household in 2010 | 3480 kwh per year<br>290 kwh per month |
| Water demand per person | 127.5 liter per person<br>318.75 liter per household (average 2.5 family member) |
| Low grade water demand | 37 liter toilet flashing per person<br>92.5 liter toilet flashing per household |

Table 17: Table of some model information

| Some main formulas in the model | Explanation |
|---|---|
| **investment-cost for selecting a smart label** = (1-*subsidy*) * *average cost of the selected smart-label* | Investment cost of each dwelling is dependent to the level of subsidy and the cost of selected label. The subsidy covers some percentage of the cost; for example, if the subsidy is 20 percent, then each dwelling pays 80 percent of the cost. |
| **energy consumption for each dwelling per month** = *general energy consumption of the dwelling per month* (coming from a normal distribution) * *factor of "learning effect"* (coming from the two factors of "neighborhood effect" and "community effect") - *energy production of the dwelling* (coming from the smart label) | Each dwellings has a random general energy consumption (it is random because dwellings have different consumption behavior) which is affected by his learning form its neighbors and community (EMW association). Besides, each dwelling has a label that shows the level of energy production per month, which is reduced from the general energy consumption. It should be mentioned that the learning effect could either positively (if it is bigger that 1) or negatively (if it is smaller that 1) affects the general monthly energy consumption of each dwelling. |

Table 18: Table of some model formulas

| Smart-labels in the model | Average cost in Euro |
|---|---|
| Green (solar panels + urine separation + kitchen macerator) | 500+200+200=900 |
| Blue (solar panels + urine separation/kitchen macerator) | 500+200=700 |
| Yellow (only solar panels) | 500 |
| Red (no technical intervention in house) | 0 |

Table 19: Table of model information on smart-labels

## 7.4 Conclusion

In this chapter, we develop two agent-based models of: (1) case independent model of the implementation of the Assortative matching theory in a collective action around an abstract resource system, and (2) case specific conceptual model of the EMW system in BSH. These two models are the other outputs of this research along with the institutional system design of EMW.

### Agent-based Model of the Assortative Matching Theory

First, the theoretical model attempted to answer the sub question of: "How can citizen participation in a collective action be increased?". The findings and insights of the model show the positive influence of the grouping mechanism on the contribution of the agents. In fact, the theoretical model in this chapter is developed based on the theory of Assortative matching in voluntary contribution game. This theory shows signs in solving the "social dilemma" [Ostrom, 1990b] in collective actions. It is a dilemma as the collective would benefit from high contributions, yet the agents have strategic intensive to contribute less. The model explores the theory of Assortative matching in a collective action around an abstract resource system using ABM. The results of the model:

- Show that grouping the agents has a positive influence on the contribution of the agents to the resource system.
- Replicate the theory of Assortative matching .
- Validate our proposed institutional design (Labeling institution). the Labeling institution provides the opportunity for group-based interaction among the citizens with the most similar smart-labels.

Some more detailed results based on the grouping mechanism in the model are: (1) agents who are affected by their group-mates make more contribution to the resource than the agents who are not affected by their group-mates (innovative agents), (2) agents in bigger groups show more level of contribution to the resource. Furthermore, the Labeling institution (inspired by the theory of Assortative matching) in BSH is the main assumption in our institutional system design that is now relaxed through our insight from the results of the theoretical model. Therefore, this model also verifies the "labeling" and "group-based" institutions through he positive effect of grouping mechanism in the collective action.

### Conceptual Model of the EMW System in BSH

Second, the conceptual model attempt to answer the final sub question of: "How can the dynamics of collective action around technology-driven urban commons be studied?". With MAIA we built the conceptual model of our EMW socio-technical system. We developed our conceptual model in four structures of: collective, constitutional, physical, and operational. After organizing of information regarding the agents (collective structure) and the physical components of the system (physical structure), we used ADICOs (constitutional structure) designed in chapter 6 in order to show the interactions of the agents in a flowchart (operational structure). The flowchart shows the dynamic of our MAIA model of collective action in the EMW system. It is as a result of more detailed and practical thinking in our proposed institutional system. It is consistent with the three action situations presented in chapter 6, and it is developed based on our tables of ADICO.

The MAIA model conceptualizes agents (inhabitants) interaction in two *groups* of neighborhood and the community of EMWA (see ADICO of "Network-1" in table 5). Interactions of the agents in the groups happen through "knowledge acquisition and accumulation", which can lead to "learning" (see ADICO of 4). We showed that knowledge exchange and experience sharing can realize collaborative learning in the two groups. The result of such learning (in groups of neighborhood and the community of EMWA), can be presented by agents who change their smart-labels.

The main finding in this chapter is capturing the dynamic of collective action in BSH through detailed and practical thinking in the system of EMW, which shows:

- The effect of two types of group interactions in two types of: **neighborhood effect** and **community effect**. They represent the **effects of knowledge production** in the social groups of inhabitants in BSH. The effects can lead to learning, which represents the social learning happens in social groups with knowledge flow.

- Learning of the inhabitants **changes their behaviors** in energy consumption and production. It means that the inhabitants who learned (e.g. care more about the sustainability in their community) can consume less energy and produce more to the shared resources (e.g. produce more renewable energy). More energy production can happen when they improve their smart-labels.

To summarize, the developed MAIA model in this chapter:

1. Is a complete and detailed conceptual model; it is one of the research outputs, and it can be used as a product in building an agent based model for BSH in future research.

2. Gives us learning and insights about the functionality of the system in BSH. These learnings are presented in the chapter of conclusion (see the societal contributions: ”Lesson learned for BSH”). In fact, the development of MAIA tables forced us in more practical thinking about the system, which provides us with more insights about the functionality of the socio-technical system of EMW in BSH.

3. Creates a two-way relationship between the conceptual agent-based model and the institutional system design. We used the institutional design (the ADICO tables in the three action situation) to develop the conceptual model, and the details and insights gained in developing the conceptual model are used to refine the institutional design of EMW. In fact, developing the MAIA model has improved our institutional system design in an iterative process (e.t. a loop between our institutional design and MAIA), which finally leads to more specific and detailed institutional design for EMW in BSH.

# 8 Discussion and Conclusion

## 8.1 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. Our research objective motivates us in formulating our research question as:

*"What form of institutional arrangement can facilitate citizen participation in collective action around technology-driven urban commons in the neighborhood of Buiksloterham?"*

The short answer to the research question is our institutional design presented in chapter 6 (see figure 21 for an overview to the institutional system composed of three action situations, and see the institutional arrangements in ADICO tables of 2 in AS1, 3 in AS2, and 4, 5, and 6 in AS3). This institutional system 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.

This question has been answered through theoretical analysis of the socio-technical system of EMW in BSH. Then, with simulation (ABM) we animated and replicated the theory of Assortative matching used in designing our proposed institutions. And, the model also further explored the validity and potential of our our proposed institutional design of the EMW system. Finally the MAIA framework helped us building a conceptual model of BSH, which gave us insights in refining our institutional design.

This research has three deliverables: (1) the institutional design of EMW in BSH, (2) the theoretical agent-based model, and (3) the conceptual agent-based model of EMW in BSH. The main outcome of this research is our institutional design, that is validated by the theoretical model, and it is refined through developing of the conceptual model.

In this chapter, we first give answer to the main research question more in details. Then, we answer to the sub-questions in the following sections. We will also explain the scientific and societal contributions of this thesis. Finally, limitations of this research are presented in section 8.5, which is followed by the future work in this thesis elaborated in section 8.6.

## 8.2 Research Questions and Answers

In this research we showed that our proposed EMW institutional system which is composed of the three action situations and the institutional arrangements (e.g. Labeling, Network, Learning, etc.) enables citizen participation in the socio-technical EMW system in BSH. The citizen participation is in form of a collective action governance of the two technology-driven urban commons of electricity and water in BSH.

The institutional arrangements in BSH starts with "Labeling institution" in action situation 1, in which the inhabitants have to choose smart-labels in different colors. The labels indicate their level of contribution to the resource system of EMW in terms of electricity and water production and consumption. This labeling institution paves the way for interactions of the inhabitants: (1) with the shared resources in action situation 2, and (2) in different groups within the community in action situation 3. The verification of our main institution of Labelling have been carried out through the agent-based model. And, more detailed analysis of the whole institutional design have been done through the conceptual model of EMW in BSH. Bellow we will answer the sub-questions of the research one by one.

**What are the technology-driven urban commons in the sustainable neighborhood of BSH?**

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 15) 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. The systematic and institutional analysis of these two urban commons are the subject of the second sub-question.

**How can a technology-driven resource be systematically and institutionally analyzed with a commons perspective?**

This question required the identification of social (institutional) part of the 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 16).

The main components of the system that require in depth analysis is the community-based collective action shown in figure 20. In order to enable collective action we proposed an institutional design for the EMW system which is embedded in the resource system of EMW. The whole institutional system design of EMW is addressed in the next question.

**What institutional arrangement can be designed to govern collective action around technology-driven urban commons in BSH?**

To answer this question we adopted theoretical frameworks for institutional design: IAD and adaptive institution frameworks. 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 21).

Formalizing institutions in the three action situations (ASs) were illustrated in ADICO tables (tables of 2 in AS1, 3 in AS2, and 4, 5, and 6 in AS3). In the first action situation, inhabitants have to choose smart-labels (Labeling ADICO) and they can apply for subsidy (Extenal regime 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).

Therefore, our designed institutional system (shown in figure 21) includes the institutions presented in the ADICO tables, which can enable the citizens to interact based on their level of contribution, and it also can facilitate group-based interactions in the associations of EMW system (e.g. energy association). 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 holds the Labeling institution. This theory can solve the social dilemma in voluntary contribution game through increasing the actors' contribution when they are grouped based on their level of contribution. Since the Labeling institutions (inspired from the theory of Assortative matching) is a big assumption in our institutional design, we decided to further explore the functionality of this theory using an abstract agent-based model. The next sub-question explored the verification of the theory by means of ABM. Besides, the designed institutions have been also refined through the conceptual agent-based model of EMW in SBH (see the conclusion to the final sub-question). The conceptual model forced us in more detailed and practical thinking in the functionality of the EMW system in BSH, which led to added values and additional insights into the proposed institutional system of EMW in BSH.

However, our proposed institutional design provided us with some insights below the main finding:

- 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.

**How can citizen participation in a collective action be increased?**

As it is mentioned in the conclusion regarding the previous sub-question, the theory of Assortative matching is the source of inspiration in designing the Labeling institution. The theory of Assortative matching is a big choice in our proposed institutional system design as a *mechanism* that can influence the citizen participation instead of the choice of other mechanisms (e.g. monitoring and sanctioning). Therefore, using ABM, we built a preliminary model based on the theory of Assortative matching. This model showed that the assortative matching/grouping mechanism significantly increases the contribution of the agents in as abstract resource system. The main finding of the model are listed below:

- It showed the positive effect of grouping mechanism on the contribution of the agents.
- It demonstrates the theory and shows the functionality of the theory in an abstract resource system.

Therefore, to get back to the case, we feel more confident that group-based institutional design in BSH can enable citizen participation.

**How can the dynamics of collective action in the context of BSH be studied?**

To answer the last sub-question, we continued our analysis in BSH by developing a complete and detailed conceptual agent-based model of BSH based on our insights and findings gathered in answering the previous sub-questions. We organized our findings in the MAIA framework, and through more detailed and practical thinking we could develop an operational structure for the *dynamic* of our MAIA model (see the flowchart in figure 28). This is presented in a flowchart that consists of three action situations of the institutional system of EMW. Agents follow institutions in the ADICO tables in the three action situations. They interact in two different types of group: neighborhood and community (e.g. energy association). Inhabitants in their neighborhoods or in groups are affected through knowledge accumulation and acquisition, which can lead to social learning. This learning could end up in changing smart-labels (increasing contribution to the resource). Since we had insufficient data to populate our model, we did not build the simulation, but we believe that the conceptual model has enough details to lead to a simulation.

Therefore, the comprehensive conceptual model of BSH is the answer to this sub-question. Besides, the model has some other contributions in this research:

- It is one the research outputs, that can be used as a product in future research in BSH for building an agent-based model.
- Detailed and practical thinking about the functionality of the system in BSH paved the way to gain: (1) some lesson learned about the case of BSH, that are presented in following section of ”Scientific contribution”, (2) some insights in the type of data needed to build an agent-based model; MAIA tables showed that what kind of data should be collected.
- MAIA model improved the designed institutions in an iterative process by creating a two-way relationship between the institutional design and the conceptual model. We used the institutional design (the ADICO tables in the three action situations) to develop the conceptual model, and the details and insights gained in developing the conceptual model are used to refine and improve the institutional design of EMW.

Nonetheless, the conceptual model gave us some insight below the main findings:

- knowledge can be generated in social groups through communication of the inhabitants, sharing their experience, and knowledge exchanges among them. Therefore, we created two knowledge flows in the two social groups of: neighborhoods and community.
- Learning happens in social groups which create knowledge. And, learning pave the way for changing the behavior of the citizens (e.g. care more about the sustainability in their community), which can lead to improve their smart labels.

## 8.3 Scientific Contribution

### Collective Action Around Technology-driven Urban Commons

Researchers have done research on collective action around the urban commons such as urban space, urban garden, and urban housing. Yet, in this research we have studies the collective action around *technology-driven* urban commons of electricity and water grids in the case of BSH. We presented the technical resource system of EMW including the technological shared resources (urban commons) of electricity and water (see figure 16) , and we also demonstrated the institutional system of EMW that shows the collective action around the shared technical resources of electricity and water (see figure 21).

**Using the Social Ecological System Framework in a Social-technical context**

In this thesis, the SES framework is used in analysis of the *technical* resource system on EMW in BSH. Yet, it is has been traditionally used to analyze the social ecological systems like forests. The analysis of our urban technical resource system of EMW highlights the difference that need to be considered when using the SES framework for social-technical system: resource users in the EMW system can not only consume the resources but they also can produce them, so ”prosumers” are replaced by the ”users” in the framework (see figure 20), this means that the contribution of them to the resource needs more analysis.

**Theoretical Model**

Furthermore, animating the theory of Assortative matching is the other scientific contribution done in this thesis. We built a theoretical agent-based model which explored the theory in an abstract resource system. The model presented the functionality of the theory. The main finding is the increasing of the agents' contribution when they are placed in groups (grouping mechanism). The model also has contributions to the model of Ghorbani and Bravo [2016]: (1) through the implementation of grouping mechanism instead of emerging the institutions in an abstract resource system, and (2) the existence of the ”prosumers” instead of only the ”users”.

**Adaptive Institutions with Room for Institutional Emergence**

The commoners in neighborhoods act like a ”trial and error” process rather than following some based rules and regulations. They try to create, change, adapt, or remove some rules among themselves in order to reach their common goals. Therefore, we are able to see *emergence* of institutions in the real world practices. However, existence of some rules that can *support* emerging the institutions in a right direction is necessary. Therefore, we recommend an *adaptive* institutional design in which institutions can be created, removed, changed, but not broken, and learn through experience, which means *adaptive institutional design* with enough room for institutional emergence.

## 8.4 Societal Contribution

### 8.4.1 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 conceptual model of 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 (represents 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).
  - existence of a core group such as a group of main stakeholders from the municipality (gemeente Amsterdam), Metabolic, Aliander, etc., creates legitimacy and trust in the community.
- Social learning in social groups:
  - Creating 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.

### 8.4.2 Institutional Guideline for Similar Cases

Although BSH is a specific case with special inhabitants, the insights and findings gained in designing the institutions in BSH can be generalized. They can be used in other similar cases facing a sustainable transition. The reason is that our institutional design has taken not only the current characteristic of BSH and its inhabitants, but also the future plans and the potential inhabitants in BSH (which are addressed in manifesto signed in 2015, see chapter 2). Besides, our institutional design has taken the insights of best practices that allow for implementation of influential factors in adaptive institutions and successful factors in sustainable transition (see the column of ”best practices” in ADICO table of AS3). The other reason is that our main institutions are validated by the finding of the theoretical model claiming the positive effect of grouping mechanism in increasing citizen contribution in the collective action.

### 8.4.3 Policy Recommendations

#### Exogenous Factors in Institutions

Community governance in neighborhoods in form of collective action relies on citizen participation. Therefore, institutional engagements in BSH try to increase this matter through labeling and group-based institutions. Such institutions care about the endogenous behavior of the citizens in the groups or neighborhoods. However, the role of some exogenous factors (external support of the authorities), can also stimulate citizen participation. Such institutions can be in forms of providing subsidy, information and awareness, workshops, online platforms in the community. Therefore, consideration of both endogenous and exogenous institutions are recommended in facilitating citizen participation. It should be mentioned that such institutions are placed in the second layer of institutions [Williamson, 1998]; the institutions that are imposed to the citizens in forms of official agreements, and they are not including the institutional environment (in forms of law and regulations).

#### Raise Public Awareness of the Issue

In this research, we present the moral mechanisms of ”grouping” that can enable citizen participation. However, the significance of citizen motivation should be highlighted in facilitating their participation. BSH future plans after the manifesto (signed in 2015, see chapter 2) will include new citizens that may have less motivation comparing to the current citizens. Lack of motivation leads to laziness of the citizens which destroys collective action. In order to avoid this and not be too pessimistic about our institutional design, we should draw special attention to the motivation factor of the citizens.

Therefore, we recommend raising public awareness of sustainability and its practices in the neighborhoods. This could be realized through clear and simple campaigns or workshops about sustainable practices in the neighborhoods, which develop community support for changes in attributes and knowledge of the citizens. They may include events, websites, newspaper articles, TV and radio programs , or other creative ways of sharing information in a neighborhood.

## 8.5 Limitations

Similar to any other works, this research has some limitations.

#### Empirical Data on BSH

The main limitation is regarding the absence of empirically valid data in BSH, which does not allow for building an agent-based model for BSH. However, the developed comprehensive conceptual model of BSH in MAIA is very useful for future agent-based models of BSH.

#### Dynamic Incentive Factors in Institutional Design

In this thesis, we developed an institutional design and we are aware of the fact that no human institution is perfect [Ghachem, 2016]. We considered some motivation factor of love, money, and glory [Malone et al., 2009] in our institution design. These factors motivate people for joining collective actions. For instance, when people are recognized by their contribution (glory factor), they are more motivated to contribute. This factor is used in the ”labeling” institution, where inhabitance are recognized by their labels (labels show the level of contribution).

However, such motivation factors might not always exist, and inhabitants might have other motivations that affects their contribution. Therefore, our institutional design is missing involving the dynamics of motivations among the citizens.

#### Cultural Factors and Institutional Environment in Institutional Design

Generalization of our institutional design is possible when it includes cultural characteristics of the local context. In this thesis we designed institutions in the two lowest layer of institutions [Williamson, 1998]: institutions that can change very often by the citizens and the institutions that are imposed to the citizens like official agreements and contracts. Therefore, we missed tackling other two layers which include institutional environment (in form of law and regulations changed between 10 to 100 years) and informal institutions (e.t. norms and culture). Therefore, generalization of this institutional design should include the cultural and environmental contexts of the case.

## 8.6 Future Work

This thesis can be further developed in three area 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 which is duo to 2035. Therefore, study on the feasibility of the technical interventions used in EMW technical resource 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.

**Developing the Theoretical Model**

Future development of the agent-based model (theoretical model) in this thesis can study:

- The comparison analysis of grouping mechanism when agents can cheat (e.t. when agents do not act as it is expected and they do not make or change the groups, for instance). Besides, consideration of errors in grouping mechanisms. For example, the possible error can happen when the grouping goes wrong by mistaken ranking of the agents or other possible errors.

- The current model with ”grouping mechanism” can also be compared with ”sanctioning mechanism” in order to analyze the difference in the influence of the moral mechanism of ”grouping” and the morally contested mechanism of ”sanctioning” on the level of citizen contribution.

- The insight of the model can also be compared with the real world data (in case of having data on people interactions in groups). This analysis can explore the credibility of the model and the theory by doing a three comparison analysis.

**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.

# 9 Reflection

Any system with collective action requires the participation of its involved actors. There are actors who make small changes that accumulatively and collectively lead to big changes in their community. Such communities [12]in cities or neighborhoods already exists, and they have shown effective results in term of making changes toward having a higher quality of living and providing more sustainability in their communities.

## 9.1 Process Reflection

During the challenging and interesting time of doing this master thesis, I have gained some practical and theoretical insights. Apart from my research, I have attended three main events: (1) Lorentz center workshop in Leiden (Emerging Institutions: Design or Evolution? ), (2) Sheila Foster seminar in Amsterdam (master class on commons and co-governance), and (3) ESSA@work workshop on Agent-Based Modeling and Simulation (where I had the opportunity to present my theoretical model).

### From Institutional Emergence to Institutional Design

In the first phase of my thesis I was busy with understanding and analyzing the case of BSH using SES framework. During this phase I faced for the first time the concepts of institutional *design* and *emergence*. On one hand, the first version of my research question was about understanding the institutional emergence through the *self-organization* among the citizens of BSH in managing their shared resources, and on the other hand, I understood that the case is still under development and there are yet not enough of self-organization activities among the citizen. Because of this, I needed to change the research question and propose a constitutional system that can manage the future technical plans in BSH. It means that the approach of developing the socio-technical system of EMW and proposing the institutional design, was replaced by understanding the emergence of institutions in a self-governed system.

### Gaining Insights

In the second phase of my thesis I was dealing with (1) reviewing literature and doing desk research along with (2) getting to know experts, practitioners (commoners), scholars, initiators and other students researching on the same field.

[12]e.g. "Labgov" project and "participatory budgeting" in NYC, see nycreic.com for more information

Thanks to the Lorentz Center workshop in Leiden (Emerging Institutions: Design or Evolution? ), Sheila Foster's seminar in Amsterdam (master class on commons and co-governance), the proposal and final presentations of students at Amsterdam Institute for Advanced Metropolitan Solutions (AMS), and the opportunity of interviewing several people such as Saskia Muller and Frank Alsema (two of the main initiators and project leaders in BSH). All of these efforts and opportunities led me through knowing more about the similarities, differences, and the relevance of two concepts of institutional "design" and "emergence". Discussions during the Lorentz Center workshop and the master class of Sheila Foster have opened my eyes and provided me with a broader perspective about the commons and institutions as a whole. In the following paragraphs I reflect on my thesis work in the context of institutional design and emergence. Then I reflect on the manifesto of BSH and finally I explore the connection of this thesis to the master program of EPA.

## 9.2 Institutional Design or Emergence

People need to have institutions to manage their behaviors and interactions in a community-based collective action. Such institutions can *emerge* as a pattern of local interactions like the pattern of flocking birds. But institutions are sometimes *designed*, and sometimes a *combination of both emergence and design* happens (see the feedback links in the IAD framework).

Based on my information and knowledge gained during this thesis and with taking a realistic perspective after interviewing commoners, I believe that what is done in this thesis could be far from the reality. I proposed a constitutional system with a list of ADICOs that are assumed to be followed by the inhabitants of BSH. Yet, there is no guarantee that the inhabitants will act and interact based on such institutions. For instance, there are some questions such as: what if people have no interest to participate? or what if they are too lazy ("laziness of the commons")[13].

However, we need to consider the importance of some basic institutions that are *adaptable*. The institutions that are designed in this research have this characteristic, and we also cared about creating an arena where the inhabitants can create, remove and change rules among themselves. In fact, the institutional design can play an important role if it has the characteristic of being adaptive [14] by keeping some room for emerging institutions.

[13] Introduced by Virginia Dignum in a group work about institutional design or emergence in the Lorentz center workshop

[14] Definition of adaptive institutions from two scholars: "ability of the institution to bend, but not break, and to learn through experience" [Engle and Lemos, 2010] (p. 8). "Adaptive institutions are those that actors are able to adjust to encourage individuals to act in ways that maintain or improve to a desirable state" [Koontz et al., 2015] (P. 141)

### Dynamic Incentives of the Actors

Another point is about the incentives that people have in performing actions in a community. Incentives of people are not fixed and it is rather dynamic. It means that they might care about money if there is a crisis, so ”money” is a motivation factor in joining a collective action. Yet later, when the financial situation is more relaxed, they might care about the ”quality” of their life. Therefore, a dynamic characteristic of people's interests can show itself in an evolution process.

Whereas, by designing institutions in this research I assume some fixed motivations which are not compatible with the dynamic characteristics of the people's incentives. In my institutional design I include the motivation factor of ”glory” when people are recognized by their contribution. Yet this motivation factor might not always be there, and inhabitants might have different other motivations that affects their contribution. so, my design is lacking dynamics of motivations among the people.

To conclude, based on our information and knowledge gained during the interesting and challenging process of this thesis, I think that institutions that manage collective actions should mostly *evolve*. Besides, considering the dynamics of motivation of the actors involved in the process of collective action, designing institutions seems limiting and shortsighted. However, I think that some *basic* and *adaptive* designed institutions can help and stimulate emerging institutions. Therefore, even if our proposed institutional design is missing the mentioned characteristics, it hopefully creates some foundations for further institutional emergence.

## 9.3 Citizen Participation vs. Laziness of the Commons

Another important insight I gained during my thesis is about the behavior of citizens in a collective action situation. As Saskia Muller clearly mentioned, it is eventually people who are going to live in BSH and the realization of future ambitions of BSH is up to their contribution. Citizens are the ones who need to interactively engage in collective action, interact with their community, create new networks or arenas for interactions (meetings, online platforms, gatherings, or workshops), exchange knowledge, learn, make new rules of interactions, create incentives, etc.

Being aware of the importance of citizen participation mentioned in the last paragraph, the question is: what if people have no interest to participate? or what if they are too lazy (”laziness of the commons”)[15] to interact with the others? This is a big challenge in designing institutions; since it is people who need to practice

[15]Introduced by Virginia Dignum in a group work about institutional design or emergence in the Lorentz center workshop

the institutions and if they have no interest (if they are lazy), the designed institutions are not effective and useful. So even if we proposed an institutional design in order to manage the technical interventions (EMW system), I think that such institutions *loose their effectiveness* without enough *citizen participation*: people need to practice these institutions otherwise the whole systematic intervention would collapse; the importance of a "critical mass" or enough participants engaged in collective action. So as Virginia Dignum mentions during the workshop: "design is quite myopic most of the times" as it is too pessimistic about the reality.

## 9.4 The Manifesto in BSH

The sustainable transition of BSH in this research considered the future ambitions and visions that are presented in the manifesto signed among 24 people and 22 parties (local parties: several companies such as Metabolic, Waternet, de Alliantie, etc. and Alderman of municipality of Amsterdam). This manifesto is a turning point which gives a systematic approach to the future of BSH. It aims to turn BSH into a living lab with highly ambitious sustainable plans. However, I skeptically think about the feasibility of the future plans and small scale sustainability of BSH as a circular and smart neighborhood. In fact, even if the neighborhood has been practicing some sustainable transitions, the realization of the project (BSH as a circular neighborhood) is still a big question and it calls for more research (see the section of "future work").

Based on my information gained during this research, the manifesto is a symbolic point that gathers the stakeholders involved in the project. The manifesto holds high ambitions for sustainability, and it has challenged the stakeholders for innovative and cross disciplinary *ideas*. However, the manifesto and the BSH project might fail in practice.

## 9.5 Connection of This Research with the EPA Master Program

The master program of EPA (Engineering and Policy Analysis) is a multidisciplinary field of study. EPA students acquire the skills to deal with socio-technical problems and multi-actor systems for which there is not one best solution, yet there might be a most satisfying solution. The following paragraphs show the connection of this research to the EPA program.

#### Buiksloterham as a Multi Actor System with Different Perspectives

BSH as a future smart and circular neighborhood is a multi actor system with different stakeholders holding various perspectives. From the national policy perspective (e.g. the government), BSH can reduce CO2 emissions. From local policy perspective (e.g. the municipality), BSH can create local initiatives and increase the role of citizens in the sustainability plans of the city. From the perspective of the private companies involved in signing the manifesto (e.g. Metabolic), BSH can run new metropolitan projects in implementation of new technical development and infrastructures. And, finally from the citizens' perspective, BSH can be a neighborhood which provides them with higher quality of life.

#### Systematic Thinking and Analysis

EPA provides me with systematic thinking and analytical skills, which is used in this research: (1) The case of BSH has been systematically analyzed with identification of its technical and social parts of the system (institutional system embedded in the technical system), and (3) the institutional system of BSH has been analyzed more in detail by using modeling as an analytical tool.

#### Analytical Method in Dealing with Complex Problems

Modeling is another skill gained in the EPA program. Modeling helps in understanding and exploring complex problems such as the institutional system in BSH. Agent-based modeling helped to deal with the complexity of this system and understanding the citizens' interactions. The agent-based model in this thesis helps to explore the functionality of the theory of Assortative matching in an abstract resource system, and it also helps to compare the system with and without the ”grouping mechanism”.

#### Policy Recommendation

EPA aims at providing analysis and policy recommendation in solving socio-technical problems. In this thesis, similarly, I am somehow improving the policy process regarding the socio-technical system of BSH by proving a systematic analysis in BSH along with some policy recommendations for the public authorities and private sectors in BSH (see the policy recommendations in the chapter of conclusion).

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# 10 Appendix

## 10.1 Semi Structured Interview Using SES Framework

In this interview with Saskia Muller (one of the core members of the BSH project), we use the SES framework in designing the questions. In fact, the questions are categorized based on the sub-systems of SES. This way we make a methodological contribution in interviewing experts by using a theoretical framework. It should be mentioned that some of the questions have been answered while addressing the other questions, so in order to avoid overlapping and repeated answers and not exceeding the proposed time of the interview, we skip asking the unanswered questions.

**One general question:**

1. BSH has been gaining more and more attention from private sectors, now my question is that: Who is in charge of the whole redevelopment plan? Municipality? Government?

*Answer*: no body is in charge really. No one is and every body is! We had a manifesto signed in March 2015 by 24 people and 20 parties, and they are involved. They are no official body or governance officially. It is just a team of three people (Peter Dortwegt, Frank Alsema, and Saskia Muller), which I am one, who are trying to initiate things that are necessary to make the ambitions of manifesto close to reality, and we will do that of course with the help of housing cooperation, great operators etc. It all work as long as all the parties are in agreement with what it is going on, so it is also more a diplomatic process. Normally it is the city (municipality) who start a redevelopment plan of a city, but this case happens in a lighter way, so they let the initiatives to come form bottom ups.

**Questions based on the sub-systems and variables of the SES framework:**

Resource system (RS) (4Qs)

2. *Productivity of system*: What is the amount of renewable energy locally produced by much energy will be produced out of local waste per year? How much water will be saved using the rain-water collection system per year? How much of the waste water will be reused? 3. How much of the energy will be generated locally? And what are the sources of generation? 100 percent? Is it doable? *Answer*: This type of questions I really cannot answer! The only data that we have is in the report. We are actually working in the field of energy together with some people from Delft (Sabine Jansen, Richina Bokon) to develop a map for potential energy sources in the area, so we do not know. On the other side, it is all the theory and at the end it is people who are going to live there, and they will decide how to produce energy? How much? if they want to produce energy. If you want to know more about this, you need to contact Sabin Janson, she is one of the researchers at TU Delft.

4. *Clarity of system boundaries:* From the report it is clear that the BSH will be locally circular, so this neighborhood will locally create its own energy for example, is this statement true? *Answer*: it is the ambitious plan, that's what we want but we do not know if we will succeed. I think that you cannot provide all the energy needed in the area. I do not think that it is possible. But let see how far we can go.

5. If all the activities to close the flow of energy (waste to energy reactors, and renewable energy production) will be located locally? If the bio massed reactors are located in BSH? *Answer:* We try to close the circle at the level of as low as possible. As long as possible we make it locally circular. However, we are not an island are looking at the world, so it is stupid to close the circle in an inefficient and expensive way in BSH comparing to close the circle in a higher level is Amsterdam or metropolitan level. The circularity is an important issue but there are some other important issues like efficiently and cost. It is also something that we do not know, scaling the solution is an important issue in the whole project, there are very technical solutions identified but the we still need to found out the scale of their implementation (is it in the household, street, ...). For example, what is ideal for bio-refinery. But it will definitely not be all in the scale of BSH, people still drink coffee and avocado coming from other side of the world.

6. What would be the design of the new houses in BSH? How the energy can be produce locally and renewably? If all the houses will have the facilities to create energy? *Answer:* I think that it is not the rule! The rules in terms of EPC (Energy Performance Coefficient) you cannot have a EPC of zero if you do not have solar panel or what ever. From there you could say perhaps that all the houses should produce energy but it is not the rule as such.

Resource unit (RU) (4Qs)

7. In the report it is mentioned that the circular economy will be happening by "prioritizing" in "managing the resources", what are the resources? And what is the priority of these resources? *Answer:* I think the whole idea behind this sentence are to make it as large as possible, it means that any thing that you can consider as a resource in BSH which is either material, papers in offices, ... all these should be handled in such a way. In the report we want to sketch the ambition and from that we get down to earth. But it is clear that we cannot recycle every thing. We will see where we get. You should know that we want to make BSH a sustainable place for living and working but we do not know till how far we go. And it is a trial and error process as finally people will be living there and it would be up to them to make things happen. Now there are 200-300 people living there but in one year there will be 1000 inhabitants living there. Then the thing will be interesting to see what will people initiate. There will be people themselves who will be in charge of organizing the BSH. Every thing starts when people start to move in.

8. What kind of resources in the city of Amsterdam are in danger of depletion? 9. In the one of the online information (play the city company) I found out that BSH wants to close the urban material cycle, what do you mean by Urban Materials? Are energy, water, and waste included in urban materials or it is only referred to waste? Is it the same as the meaning of “physical flow”? 10. How the new building principles can ensure the closure of material (short, medium, long) in BSH? For example I read that the construction materials will have a passport, so this will lead to closing the long term materials (circular building). But what about the short term ones? Like the household waste (how exactly)?

Users (U) (5Qs)

11. Socio-eco attribute of the users: What is the social attribute of the potential inhabitants? (Report: low-income, ¡40 years, and non-migrate) *Answer:* Form the report you can see that the spatial plan is till 2034 and it is 20 years of building, so we do not know who will be living there in 2030 of course. 12. Leadership: I think that Dutch people are very open and willing in joining into collaboration activities and they like benefiting from collective actions (like the case of Dutch paper collection). What is your opinion about the initiative approach of the inhabitants regarding the establishment of some organizations or communities to self-organize resources in BSH? Is there any rule regarding such activities? Are they obliged to do so? Or it would be voluntarily? *Answer:* People themselves will be in charge and about the rules you can check the “wetbuurt”.

13. Who will be the possible leaders in leading the citizens in self-organizing their local resources? *Answer:* people themselves. 14. Is there any future plan in building the capacity for self-organization in BSH? Possibility of people gathering? Or any online platforms? *Answer:* Yes! 15. Norms/social capitals: I have read in the report that the BSH will be circular in future, my question is that except the infrastructure support, who will be in charge of monitoring BSH, for example: who will check if the citizens are saving and using the rain water, or if they are participating in waste to energy project etc.? Municipality is the one in charge or there are some other organizations? *Answer:* The public facilities will be monitored by the municipality, but at the same time people can do things on their garden, balcony, and this is up to people who run the facilities. There is no one answer to this. There is no plan for such activities yet, the plan is for sustainability but how it will be implemented is not up to us, it is up to people. Theoretically it is possible but practically we do not know! As people will move to BSH we will see how they will practice sustainable actions.

Governance system (GS) (5Qs)

16. Collective-choice rules: In my model, I want to give freedom to the residence in making some locally established rules and regulation in managing their resources (urban commons such as energy), What do you think about the application of this in reality? *Answer:* there are quite lot of experiments going on in

the Netherlands. Things are happening but they are on the experimental basis and the "buurtwet" (it is a legal experiments come from the Hague, national government) 17. There should be some specific rules applied for BSH and this region will be governed separately than Amsterdam. My question is that how can I gain these rule and regulation of BSH? For example, how can I gain more information about the new design of houses (design principles) in BSH? *Answer:* For this you can look at the website of city of Amsterdam and look at building regulation. Tafel Passport, to find the requirements for each of the houses. You can find more information about sustainability requirements. In some cases the rules will be different that the rules in Amsterdam. However, there are some limitations applied by the government that you are not free to set some specific rules for some area of the city. Based on some published policy you can do some things but as I said the room is limited. 18. Government organizations: except the local municipalities, is there any organization in leading/governing the neighborhood of BSH? *Answer:* No there is no organization, it is only three people (Frank, Peter, and me) who work as lay the basis for the whole development. We try to initiate thing but we cannot decide as we do not have power. Nobody has the power, the city has some power but they even cannot say that your house have to collect the rain water or produce energy. It legally forbidden. So we cannot force people to do it, and we only can stimulate and motivate people to do it. 19. Property-right systems: If the facilities related to energy, water and waste are public or private? For example the waste-to-energy reactor is owned by public or private? Or if the facilities at each household (solar panels and wind plants, water reservers) are private or community owned? *Answer:* it depends if the house is bought or rented. If the house is rented then the solar panels can be leased or in case of a public building the roof can be leased by a foundation or cooperation. . When it is a public house, there might be a cooperation who lease the roof and use the panels and the energy that comes from it and sell it to people who do not have a roof, people living in apartment. There is many different ways of organizing that, this again is one the things we are looking at, we do not how this will be. The situations are always different. Different situations demand different solutions. The same goes for waste water and waste collection, etc. So that will be something interesting in my model to look for different future scenarios? *Answer:* Yes, but also about the business cases! 20. Operational rules: What are the rules for each household living in BSH? Is there any specific rule in using energy, water, and material? What is the rule of "use and share" (no possession) in the play the city website? Are there any related rules in using water or energy for exam

Interaction (I) (1Q)

21. Information sharing among users: Will the neighborhood receive any infrastructural facilities for citizen communication or possible cooperation such as online platform, or building to facilitate communications? *Answer:* Yes there are,

we built a web site for people to find each other and post their new projects, so they know what they are doing.

## 10.2 Agent-based Model of the Theory of Assortative Matching

### 10.2.1 System Identification and Model Decomposition

After giving a general overview of the model, we can summarize the model components into:

- Agents: They are the prosumers in our model who can take different strategies in producing into the resource and consuming from the resource, yet they are always free-riders. It means that their level of resource consumption is always more than their level of resource production. They have produce and consume the resource by respectively giving and taking certain amounts of resource units and in turn loosing and gaining 'energy' (the same unit of their production and consumption respectively). We assume that agents energy of one unit is equal to one unit of resource. The taken strategy of agents is changed by themselves when they are not satisfied (i.e. their level of energy is dropped comparing to the one of the previous time step). In fact, energy of the agents is an abstract representation of their welfare [Ghorbani and Bravo, 2016]. Final point about our agents is that they are interacting either in their neighborhoods or within groups. The groups are made based on ranking of the agent according to their level of resource production (their contribution to the resource system).

- Resource: The resource in this model is a single common pool resource that is shared among the agents (prosumers). It is changing through the interaction of the agents taking and giving resource units depending on their strategy. Our resource has initial value and a self production rate that is representing the amount of resource units that can be produced through the public spaces. For instance, in case of electricity, this can be the amount of electricity produced through the solar panels in the public spaces.

When agents are interacting in their neighbors and copy their most successful neighbor's strategy, they are indeed in a social network that defines their neighbor. The network can take two different structure of:

- Random network: in this network each node (nodes are representing the agents) is randomly connected to some other nodes which is defied as a slider in the model (number of links) interface and can be changed by the modeller.

- Small-world network: The idea here is that the agents make local connections with close neighbors. Yet, a few nodes hold "long distance" connections in order to allow relatively short path lengths between the node couples that are randomly selected[Watts and Strogatz, 1998]

### 10.2.2 Concept Formalization

Prosumers are the agents in our model. They have some properties (what they have) and attributes (what they do) that are listed below. The main goal of our agents is that they want to keep themselves satisfied by changing their strategy when they are performing poorly (when their energy level is dropped), **they have**:

- energy [energy unit]
- strategical behavior composed of:
  - action take list [integer]
  - action give list [integer]
  - condition list [string]
- group id (the number of the group in which the agent is grouped)[integer]
- give number (the resource unit of production, which is the level of contribution to the resource system) [integer]

They can:

- choose strategy
- change strategy
  - choose another strategy in their neighborhoos or group
  - randomly choose another strategy
- make network with neighbors
- make groups
- change groups

Besides, we have a single resource. It has:

- initial capacity (k) [integer]
- renewal rate (r) [integer]

It can:

- renew itself with renewal rate of "r"

### 10.2.3 Model Formalization

**Agent: prosumers**

- choose strategy: randomly choose form three different lists of:
  - action take list (the amount of resource unit produced) [take 10, take 20, take 30, take 40, take 50, take 60, take 70, take 90, take 100]
  - action give list (the amount of resource unit consumed) [give 10, give 20, give 30, give 40, give 50, give 60, give 70, give 90] it should be mentioned that the give number is always smaller than the take number to follow the free-riding dominant strategy.
  - condition list (time and energy condition) [" every three time steps " " every two time steps" " when energy is negative " " every 20 time steps " " every 250 time steps " " always "]
- change strategy
  - innovation: with a given probability (mutation rate) that is a variable determined by the modeller, the agent randomly chooses a new "action- take, action-give, and condition" similar to choosing the initial strategy;
  - copying: otherwise, if the agent is not innovative (given the probability) it instead copies the strategy of the most successful agent (i.e., one with highest energy level) in its neighbourhood. If the agent is in a group, he copies the "average give number" of his group-mates, while he copies "take" and "condition" from the most successful group mate.
- make network with neighbors
  - random network: in this network each node (nodes are representing the agents) is randomly connected to some other nodes. The number of links is a variable: *number of links* which is defied as a slider in the model interface and can be changed by the modeller.
  - small-world network: The idea here is that the agents make local connections with some *close* neighbors based on the variable of: *number of link*. Yet, a few nodes hold "long distance" connections in order to allow relatively short path lengths between the node couples that are randomly selected[Watts and Strogatz, 1998], which is determined by the varaible of: *rewire-prop*.

- make groups: agents are ranked based on their level of contribution (their action give number) and grouped in *number of groups*, a variable defined by the modeller. So, the groups size is equal to the number of agents divided by the number of groups.
- change groups: this function is happening only if two following conditions are met: when the time step is equal to the *grouping emergent time* (this time occurs at regular time intervals), and regrouping can only happen if the number of agents with negative energy level (energy level ¡ 0) is higher than a certain threshold *threshold for group change*.

**Resource**

- resource: The resource is taking an initial capacity of $K$ with a renewal (reproduction rate of $R$.The resiurce is subsequently changing depending on the amount taken (harvested) by agents, given by agents, and on the following equation (1). In each time step it regrow with the equation (1). K is representing the carrying capacity of the resource. The resource also provide resource units to agents (agents gain energy units).

$$\Delta R = rR\left(1 - \frac{R}{K}\right)$$

### 10.2.4 An Example of Model Verification

In case of no error, the process is confirmed, yet if there is an error, the error is fixed, validated, and confirmed.

- When setup, each prosumers should have their own action and condition list. **Confirmed**. The initial action take and give should change the energy level of the prosumers. **Error found, fixed, re-validated, Confirmed**. Prosumers' energy level should decrease through the daily "energy consumption". **Confirmed**. The value of take and give should be equal to amount of energy gain and lose of the prosumers. **Confirmed**. In every time step, first the energy of each prosumers should be zero in order to make a valid calculation of its energy level in that time step. **Error found, fixed, re-validation, Confirmed**.
- In every time step, dEnergy ¡ 0 (dEnergy = energy - previous-tick-energy) should be the condition of calling the function of "choose-new-action" . **Error found, fixed, re-validated, Confirmed** . When setup, resource should

take an initial k capacity and their capacity should change in every time step.**Confirmed**. When setup the initial energy of all the prosumers are zero. **Confirmed** . When setup, the number of created prosumers should be equal to the number selected in the slider of ”number-of-agents”. **Confirmed**.

## 10.3 Conceptual Model of BSH (MAIA Model)

### 10.3.1 Expected Outcome and Possible Scenarios of the MAIA Model

Some interesting outcomes of the model:

- The ultimate percentage of ”green” labels independent of its extent in the beginning.
- The difference between the percentage of the initial and final amount of the green labels (focus on the green label as the most sustainable label)
- The difference between the percentage of the initial and final amount of the red labels (focusing on the red as the least sustainable label).

Some possible scenarios:

1. start the model with all red labels.
2. start the model with another label: yellow that shows there is some initial level of participation. There is the possibility that in a scenario that the majority having yellow label (so the level of subsidy is not that high), the system shows better results than when the system starts with the green majority of label.