Facilitating energy transition through energy commons

An application of socio-ecological systems framework for integrated community energy systems

Acosta, Cristina; Ortega, Mariana; Bunsen, Till; Koirala, Binod Prasad; Ghorbani, Amineh

DOI
10.3390/su10020366

Publication date
2018

Document Version
Final published version

Published in
Sustainability

sustainability

MDPI

Article

Facilitating Energy Transition through Energy Commons: An Application of Socio-Ecological Systems Framework for Integrated Community Energy Systems

Cristina Acosta [1], Mariana Ortega [1], Till Bunsen [1], Binod Prasad Koirala [1,2,*] and Amineh Ghorbani [1]

1 Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, 2628 BX Delft, The Netherlands; cristina.acosta.pisciotti@gmail.com (C.A.); mariana.ortegar@gmail.com (M.O.); tillbunsen@gmail.com (T.B.); A.Ghorbani@tudelft.nl (A.G.)

2 Department of Science, Technology and Policy Studies, University of Twente, Drienerlolaan 5, 7522 NB Enschede, The Netherlands

* Correspondence: b.p.koirala@utwente.nl

Received: 9 November 2017; Accepted: 30 January 2018; Published: 31 January 2018

Abstract: Integrated Community Energy Systems (ICES) are an emerging local energy system focusing on the collective use of distributed energy resources (DER). These socio-technical systems (STSs) have a high potential to advance the transition towards socially inclusive, environmentally-friendly energy systems and to stimulate the local economy. While there is an analogy between energy in ICES and other common goods such as natural resources, it is not clear to what extent the existing theoretical framework for Socio-ecological Systems (SES) on the commons accounts for the specificities of common resources in ICESs and other STSs. This research explores the applicability of the SES framework to energy commons that are firmly embedded in STS with reference to the DE Ramplaan ICES in the Netherlands. The formation process and governance characteristics of this ICES are revised, further aided by stakeholder interviews. A framework and a strategic plan that can be used to design and implement an ICES are proposed.

Keywords: common pool resources; socio-technical systems; energy transition; distributed energy resources; renewable energy; self-governance; community energy

1. Introduction

The electricity sector is undergoing profound changes through the liberalization and integration of electricity produced from renewable energy technologies (RET). The International Energy Agency (IEA) stresses that system transformations are needed to integrate intermittent RETs in the electricity sector, in which economic, technical, and institutional requirements of these technologies must be accommodated [1]. There is a need for a system design in which the technical and institutional coordination of this socio-technological system is well aligned in order to safeguard its performance [2]. These requirements provide new opportunities to create smarter, flexible, integrated, and local systems such as community energy systems (CESs), creating value both for whole energy systems as well as the end-users [3–5]. CESs provide new roles for local citizens and communities, putting them at the center of the energy system [3,6]. The acceptance, support, and participation of citizens is essential to successfully manage these ongoing energy transitions [7–10].

Koirala et al. (2016) claim that the emergence of Integrated Community Energy Systems (ICES) along with the social-technical transition of the energy system provide major contributions to the sustainable development [11]. They define an ICES as a collection of distributed energy resources

(DER) supported by demand-side management and storage that are managed at a community level to generate and satisfy the local energy needs.

The need to align technical and institutional coordination is analogous to the alignment between ecological and social systems. This latter alignment is carried out through the social-ecological system perspective by Ostrom (2009) and others [12]. Social-ecological systems are dynamic systems that constantly change due to their interaction with different actors, institutions, and resources that are limited and formed by a given social-ecological setting [13,14]. However, the ICES concept goes beyond the notion of a social-ecological system as it is implemented in a socio-technical system (STS). STSs are also dynamic but are based on the interaction of humans and technology in a socio-technical setting which includes economic, political and social factors [15].

Within an ICES, the main common resource is energy, and therefore needs to be governed so that its benefits are fairly distributed among members. Due to its self-organization nature and diverse characteristics, each ICES has to develop a tailored governance system. This is an extensive time-consuming process of trial and error which can slow down the development and growth of an ICES. Ostrom (2009) provides a general framework called SES to analyze the sustainability of social-ecological systems that could potentially be applied to solve the ICES governance problem [12]. The SES framework provides a systematic way to analyze the degree of self-organization among the users of a common-pool resource (CPR) and to manage the resource efficiently for a long lasting common benefit [12]. This framework has been largely used to test the community management of natural resources like fisheries and forests [16]. STSs in general lack research on system governance from a perspective which focuses on common goods. Therefore, the SES framework can be useful for the study of the governance of common technological resources in STS [17].

Several scholars have studied the governance problems in STS from an SES perspective, as both face similar problems [17,18]. Within community energy, some research has been done using a commons perspective. Bauwens et al. (2016) apply the SES framework to review the emergence of wind power cooperatives in four countries, yet do not focus on the technical operation of local energy systems [8]. Melville et al. (2017) address the operational level of local energy systems, in which they use Ostrom's design principles to assess challenges and opportunities arising in an ICES in the UK [19]. Wang & Hunag (2016) propose an optimization framework to determine the most cost-efficient solution for implementing microgrids with PV and wind power generation. This study focuses on costs of microgrids and authors find that a cooperative planning approach across multiple systems can lower system costs [20]. To the best knowledge of the authors, there is no research focusing specifically on the governance aspect of ICESs to-date.

To assess the applicability of the SES framework to ICES, a case study is selected for analysis with the SES variables. The selected case of DE Ramplaan Cooperative in the Netherlands with only one RET being used has a low level of resource integration, yet, it is a successful example of ICES governance. Moreover, based on the SES analysis, a framework and a strategic implementation plan are proposed to support ICES facilitators to benefit from improved governance.

The following sections give context to this research by introducing the background information on ICES, and the DE Ramplaan case study in Section 2. Section 3 explains the research approach. Section 4 introduces the selected SES variables that can be used in analysis of ICESs. Section 5 introduces the proposed framework for the analysis of ICES and the obtained outcomes. Section 6 proposes a strategic plan for implementing ICESs based on the analysis framework. Finally, in Section 7, conclusions and recommendations are provided focusing on the practical relevance of our results for advancing the emergence of ICESs.

2. Integrated Community Energy Systems

According to Koirala et al. (2016), there is no single definition nor typology to describe ICESs [3,11,21]. In general terms, ICESs are tailored (in technology and size) to the respective community needs for efficient energy performance. This typically entails the integration of decentralized, small-scale RET applications as well as demand side and storage activities to a system which provides local energy security and reduces the dependency on the central grid. Further motivations of members to join an ICES are reduced energy costs and increased environmental performance. Criteria to assess and describe ICES include locality, modularity, flexibility, intelligence, synergic behavior, customer engagement, and efficiency [11]. Moreover, new market platforms emerge with the integration of local generation and demand, and members often trade energy in a local price setting which makes it possible to share costs and benefits from investments [22,23]. In fact, ICES stimulate economic activities at the local level and build social capital among community members. However, initiatives to establish an ICES often face barriers. There are especially difficulties to convince and recruit members, often due to hesitance to leave the comfort of central energy systems or a lack of financial, temporal, structural and natural resources. Other constraints can be lack of trust, incentives, and stability which discourages potential members, especially during the early initiation stage. Besides member recruitment, developing an effective governance system is challenging [18,24–26]. Related issues include potential free-riding behaviors, fair cost and benefit allocation, and the risk of for rebound effects which jeopardize energy savings.

DE Raamplaan Cooperative

There are more than 500 energy collectives in the Netherlands [3]. However, the country still lags behind most of the European countries concerning energy production from renewable resources: 5.9% in 2016 [27]. The creation of energy cooperatives has been referred as a niche innovation in early stages [28]. It is uncertain whether it will develop into a regime, but understanding the governance mechanisms of local energy initiatives such as ICESs, will gain importance as the country develops into a low carbon economy.

Each ICES is different in terms of the mix of technologies and how they become operational. DE Ramplaan energy co-operative is developed through a DE Ramplaan foundation consisting of the citizens in the local neighborhood. It was chosen as a case study, firstly, because it is recognized as a highly successful initiative with good governance practice. Secondly, the different potential business cases for the energy co-operative were well documented, which allowed for comparing the project design to the actual implementation. Although the techno-economic aspects were well described, little documentation was available regarding social and governance aspects. As discussed in the following sections, governance and social aspects of ICES are as important as the techno-economic aspects.

The energy cooperative DE Ramplaan unites household of the Ramplaankwartier, a neighborhood of approximately 1000 households in the Dutch city of Haarlem. This cooperative was initiated by DE Ramplaan Foundation (Stichting Duurzame Energie Ramplaan, Sustainable Energy Ramplaan) and under joint ownership operates a local PV installation with 1374 PV panels and 370.43 kWp capacity [29]. The PV installation is not directly connected to members' households. However, the retail partner Qurrent waives members parts of their electricity bill, thus, members use the locally produced energy indirectly. The DE Ramplaan is a successful case of community members who jointly engage in local energy generation with RET, and is suitable to evaluate the applicability of the SES framework to such systems.

The initiative to start an energy cooperative in the Ramplaankwartier gained momentum with the establishment of DE Ramplaan Foundation in 2011. The foundation's founding objectives are (1) to reduce energy consumption by 12.5 percent from 2012 to 2016; (2) to promote installation of PV panels on roofs; (3) to increase circular use of materials and products; (4) to study the applicability of sustainable technologies; and (5) to involve as many residents as possible in the foundations' activities [30]. The foundation in 2012 reached out to the owner of a local indoor tennis court with a roof surface of 6.500 square meters. Subsequently, preliminary quotations for a PV installation on this roof were collected (source: 2016 interviews).

The Haarlem municipality supported this initiative through commissioning of a technical-economic feasibility study on alternative technology scenarios (High-Level Business Case Energiecoöoperatie DE Ramplaan). The objective of this study, published in 2013, was to define a technology roadmap to produce sustainable energy in the neighborhood for the neighborhood, in which the pay-back period for investments should be no longer than ten years [31,32]. The results described two technology scenarios for which net present value (NPV), pay-back period, and GHG mitigation potential was evaluated. Firstly, an all-electric scenario suggested to locally produce electricity from RET and to electrify heating demand (space and water heating). This scenario was analyzed in two adjustments, namely with and without investments in building insulations. A second maximum sustainable scenario was proposed to extend the technology used in the all-electric scenario with applications to produce energy from waste and waste-water. The study considers PV, wind power, biodigesters, heat pumps, using waste heat from greenhouses, and combined heat and power (CHP) applications (source: 2016 interviews). Neither of the scenarios made it possible to invest with the envisaged pay-back period of ten years. Only the all-electric scenario (without insulation measures) was bankable with a pay-back-period of 13 years and an NPV of EUR 23 million. The recommended RET portfolio for the all-electric scenario included PV installations, a wind turbine, and production of electricity from biomass. Furthermore, use of heat pumps was suggested for heat generation [32]. This technology recommendation was not fully implemented by the DE Ramplaan Cooperative which today only features a PV installation. Nonetheless, the study supported the foundation's objectives and reinforced support from Haarlem authorities. Yet, modular development into multiple technology scenarios to efficiently meet the local energy demand in future cannot be neglected.

In 2014, the DE Ramplaan Cooperative was founded as a legal entity separate from the foundation with the objective to realize and coordinate a joint PV installation on the tennis hall roof. The foundation then rolled out a campaign to recruit members and the PV installation was erected in 2015 [33].

The project is embedded in a distinct organizational arrangement. DE Ramplaan Cooperative holds ownership of the PV installations. Membership in the cooperative is conditional upon the purchase of at least two shares in the project, in which one share refers to a generation of approximately 225 kWh per year (DE Ramplaan 2017d). The price of one share is EUR 325 (source: 2016 interviews). Upon commencing the project, a pay-back-period of 10 to 15 years was envisaged. This range is due to fluctuating electricity generation and uncertainty about permissible tax breaks due to regulatory uncertainties. Each member has equal voting rights in the cooperation regardless of the number of the shares ownership (source: 2016 interviews). All joining members conclude a contract with the cooperative and with the retail company Qurrent. Qurrent receives the generated energy and in turn, offers reductions on the electricity bill of members. The distribution system operator (DSO) Liander is responsible for distribution of electricity generated in DE Ramplaan. Members benefit from the Dutch Postcoderoos regulation which offers partial tax exemption for owners of RET assets who live in the postcode area of the project, or in a postcode area adjacent to project location.

Depending on the owned share of solar PV, each member gets a discount on their household energy bill. Community decision-making on the techno-economic operation of the energy system is reduced since both Qurrent and Liander handle operations and rules enforcement. The cooperative leaders convinced the neighbors to join the group as the project has economic incentives for the members.

Finally, it is worth emphasizing on the free-riding behavior and split incentives problem regarding ICES. Both are commonly referred in the literature as potential issues. However, this was not identified in DE Ramplaan. All work in the cooperative is voluntary, and although the project focused on achieving a feasible cost for the solar panels, there was no intention to profit from the ICES. In fact, the focus has been to get the installation going and recruit members, and no so much to monitor the financial operation. Indicators related to why and to what extent members were engaged, or by how much the energy bills have decreased are not available.

At the time of analysis, DE Ramplaan was at steady state, not actively looking for new members. For the future, members were conceiving the idea of expanding the system adding more solar panels on other collective roofs. At the same time, new projects for the area were also being developed in partnership with the university. Leading members acknowledge that undertaking complex projects could bring co-benefits for the neighborhood, but also foresee it as complicated since neighbors hardly want to deal with developments requiring additional effort.

3. Research Approach

Firstly, the DE Ramplaan case is analyzed theoretically using the SES variables, as outlined by McGinnis & Ostrom (2014) [16]. The framework consists of a set of subsystems (or top-tier variables): resource system (RS), resource units (RU), a governance system (GS) and actors (A). These subsystems interact (I) with each other and produce outcomes (O) [16]. Each subsystem includes second-tier variables which may have a positive or negative effect on the system, depending on the extent to which community members engage in self-organizing actions. In the first step, the applicability of these variables in the case of ICES is studied.

A feasibility study conducted on behalf of the Haarlem municipality and the cooperative is studied, in addition to expert interviews. Interviewees are the chairman of the organization's board, a member of the organization, and a former foundation member involved during the foundation's initiation stage. Also, an ICES expert was approached. The interviews are conducted in a semi-structured manner and focusing on self-governance in DE Ramplaan, as this information was not publicly accessible, unlike the technical data. Application of the SES and interviews are conducted iteratively. There are no attributes of statements to particular interviewees in this article, however, interview results are marked as such.

In the second step, based on the analysis of the Ramplaan case using SES variables and the insights from the interviews, those variables that are relevant for studying community energy system are selected. An ICES analysis framework is proposed by analyzing in retrospective how using the selected SES framework for ICES could have improved the creation of DE Ramplaan. Among the selected set of SES variables, a set of key variables are also highlighted given their importance for ICESs.

Finally, in the third step, an ICES strategic plan is formulated to provide a practical methodology for the implementation of the (key) variables of the ICES analysis framework.

4. Application of the SES Framework to ICES

In this section, the adjusted SES framework for ICES is presented as derived from applying the standard SES on the DE Ramplaan case. These adjustments were done to better accommodate analyses of ICESs and DE Ramplaan specifically, in which we focused on the most relevant variables of the original framework.

Table 1 presents the SES framework for ICES. It considers the same eight original groups or first-tier variables proposed by Ostrom: settings, resource system, governance system, resource units, actors, interactions, outcomes, and related ecosystems. However, in comparison to the original SES framework, several changes concerning the variables within the groups can be observed. Our SES adaptation for ICES eliminates nine second-tier variables from the original SES framework. They were discarded either due to irrelevance with regard to ICES or redundancy with other (modified) variables. Furthermore, our SES adaption for ICES includes twelve second-tier modified or relocated variables. These changes were made for three reasons: Firstly, for changing the name of variables to provide more detail and clarification with regard to ICESs. Secondly, for relocating the variable to another subsystem to increase its applicability to ICESs. Thirdly, for creating third-tier variables, either to group existing variables or to create new ones.

The colored variables portray the differences from the SES framework. The deleted variables are displayed in grey color with the reasoning for being removed. The variables whose name was changed in order to provide more detail for ICESs are displayed in green color. The variables relocated to another subsystem are displayed in blue color. Finally, the variables that were created as a new addition or as a hybrid are displayed in purple color and are composed of third-tier variables.

It is worth emphasizing that for those not familiar with the SES framework, and probably more related to the technical side of RES, some original names for the variables could be confusing.

For instance, in relation to "size", it is more clarifying to state "size or capacity (RS2)" as we refer here to the RET in the ICES. The same goes for "network structure", where "social network structure (GS3)" speaks clearly to the governance system and not the energy network.

Table 1. Social-Ecological System Framework (SESF) for Integrated Community Energy Systems (ICES).

Social, Economic, and Political Settings (S)	
S1 Economic development, S2 Political stability, S3 Energy system: markets and technology Covered in actor subsystem: demographic trends; Irrelevant: media organization, other governance systems; Included in new variable: market incentives, technology.	
Resource systems (RS)	Governance system (GS)
RS1 Clarity of system boundaries	GS1 Government organizations
RS2 Size or capacity	GS2 Non-government organizations: internal and external
RS3 Naturally occurring facilities	GS3 Social network structure
RS4 Productivity of system	GS4 Property-rights systems
RS5 Equilibrium properties	GS5 Operational-choice rules
RS6 Storage characteristics	GS6 Collective-choice rules
RS7 Mobility (previously RU6)	GS7 Constitutional rules
RS8 Growth or replacement rate (previously RU7) RS9 Location	GS8 Monitoring rules
Redundant: sector (always energy)	
Resource units (RU)	Actors (A)
RU1 Interaction among resource units	A1 Number of relevant actors
RU2 Economic value	A2 Socioeconomic attributes
RU3 Spatial and temporal distribution	A3 Leadership/entrepreneurship
RU4 Predictability of system dynamics (previously RS7)	A4 Norms (trust-reciprocity)/ social capital
	A5 Knowledge of SES/ mental models
	A6 Importance of resource (dependence)
Redundant: number of units, distinctive characteristics	A7 Technologies available
	Irrelevant: history or past experiences
Action Situations: Interactions (I) -> Outcomes (O)	
I1 Harvesting of electricity	O1 Social performance measures
I2 Information sharing	
I3 Deliberation processes	O2 Ecological performance measures
I4 Conflicts among users	
I5 Investment activities	O3 Economic performance measures
I6 Lobbying activities	
I7 Self-organizing activities	O4 Externalities
I8 Networking activities	
I9 Monitoring activities	
I10 Evaluative activities	
Related Ecosystems (ECO)	
ECO1 Climate patterns, ECO2 Pollution patterns, ECO3 Flows into and out of focal SES	

In the case of the relocated variables, when analyzing the energy system we came to the conclusion that for the community energy systems, some of the variables from the resource unit fitted better when considered as part of the resource system. In our reasoning, the resource unit (RU) is energy from its different potential sources (only solar in the case study). And the resource system (RS) is made from all tangible installations which collect, transform and transmit the energy. Thus, variables like mobility and growth fit better to the resource system than to the resource unit variables.

Lastly, added third-tier variables such as internal and external government organizations (GS1) were needed because of the specific circumstances of the case of study DE Ramplaan because, besides the internal organization (the cooperative members), other external energy system actors are also important.

Key Variables

All variables in the SES-ICES framework are useful for describing a community energy initiative. While analyzing the DE Ramplaan case with this framework, very little emphasis on the governance system was noticed in the existing literature on community energy systems. Later, with the analysis of interviews, it became clearer that if some governance variables were more exercised or discussed in parallel to developing the technical side, this ICES could have advanced more rapidly. Based on the interviews and a thorough analysis of the case, as well as SES-ICES framework presented in Table 1, fifteen variables were chosen as presented in Table 2. They are considered the most important ones for analyzing an ICES in the design and implementation phases of the ICES analysis framework presented in the following section.

Table 2. Selected key variables for ICES analysis framework.

Communication Variable		Information Sharing (I2)
Design phase variables	Soft variables	Norms/social capital (A4) Knowledge of SES/mental model (A5) Social network structure (GS3)
	Hard variables	Constitutional rules (GS7) Productivity (RS4)
	Decision-making variables	Importance of the resource (A6) Equilibrium properties (RS5) Storage characteristics (RS6) Predictability of resource dynamics (RU4) Operational choice rules (GS5) Collective choice rules (GS6)
Implementation phase variables	Soft variable	Investment activities (I5)
	Hard variable	Monitoring activities (I9)
	Search for improvement variable	Evaluative activities (I10)

As a starting point, it is worth explaining the information sharing variable, as it influences both, the design and implementation phases of an ICES. Findings from Janssen et al. (2012) explain the importance of communication, implying that resource management can be influenced more by communication and trust than by the rules crafted around it [34–36]. Building trustworthy relationships within the community for successful and efficient implementation is essential and was in fact mentioned during all the interviews conducted in this research.

The variables in the design phase are classified into three types: (1) soft variables which are related to the community aspects of the system; (2) hard variables which are related to the formal governance structure and (3) the decision-making variables. Three soft variables in the design phase were selected as key variables: *social capital*, *mental model*, and *social network structure*. The reason is that the outcome of this phase is a shared *mental model* based on the *community's social capital* that can then give rise to a strong *social network structure*. Such structure should be regarded as key to share information and make decisions. Social norms marketing campaigns could be useful as a tool for advancing communication, although this has yet to be tried for the DE Ramplaan. Only pamphlets and speeches given during gatherings at church or schools, along with neighbor to neighbor communications were used to create a social network structure, but this was key for every step of the process.

The key variables for the hard side of the design phase are *constitutional rules* and *productivity*. Constitutional rules set the possibilities for the business case, and based on these rules lobbying activities might be of importance. For the DE Ramplaan, taking advantage of the Dutch Postcoderoos regulation helped the project to gain force and take off. The Dutch Postcoderoos regulation promotes DER penetration and local balancing through offering partial tax exemption for owners of RET assets who live in the postcode area of the project, or in a postcode area adjacent to project location [37]. *System productivity* is another variable that can be used to set a clear objective for the ICES. And in fact, defining the desired productivity is also related to the incentives of the people for joining the initiative.

The decision-making variables in the design phase include: *importance of resource*, *equilibrium properties*, *storage characteristics* and *predictability of system dynamics*. Based on these four variables, the rest of the technical decisions can be made, thus they are used in defining the business case. Furthermore, *operational* and *collective choice rules* are considered crucial, but to our best knowledge have not yet been studied in ICES, and the case study did not rend much information about it. We believe that collective choice rules in ICES require further research work, while the available research on social norms can be useful for facilitating ICES. Although for the DE Ramplaan case, these decision-making variables did not create any difficulties and did not render relevant discussions during the interviews, the reason might be this ICES is a simple one with only one centralized RET. Other more complex ICES might need to pay closer attention to these variables.

Finally, the key variables selected for the implementation phase are divided into three types. The third one differs as in this phase as a search for improvement is needed to evaluate the operation of the ICES. Investment activities seem to greatly draw from the design variables. Overall, investment activities are needed for the ICES to take place. Meanwhile, monitoring and evaluative activities are key for further adjustment and improvement of the system. However, these last two variables were mostly neglected in the DE Ramplaan case. The produced energy is not measured by the organization nor any other sort of indicator which could respond to what they would want to achieve. As with the collective choice rules (from the decision-making variables), further investigation is needed, especially in connection to the ICES, and to the innovation in the energy sector.

These key variables will be also discussed in the next section as they are part of the ICES analysis framework we propose for the development of ICES.

5. ICES Analysis and Design Framework from Commons Perspective

Based on the extended interviews with stakeholders in DE Ramplaan and the analysis of the case with the SES framework, we propose a framework to exemplify how the DE Ramplaan cooperative could have potentially increased distributed energy technologies (i.e., not just solar) and member numbers during the initiation stage. This method uses the selected system variables within the SES framework. The case study is used as a reference to explain how governance efficiency can be improved by applying the selected variables from the SES framework. We call this set of variables the **ICES analysis framework**, as it helps determine governance steps to follow on an ICES.

As shown in Table 2, the development of an ICES project follows two main phases: design and implementation. We add an additional phase called the initial phase where the project is viewed in the context of all variables, providing a general overview of starting conditions. During the initial, design and implementation phases, the ICES project will be in a different status of development:

1. System creation. It involves initial actions like: actor gathering, potential technology analysis and investment. Choices, rule establishment and decision-making are central here.
2. Implementation and stability. Period where the ICES starts to settle down.
3. System innovation or adjustment. Moving from an evaluation phase to system adjustment, which is affected by the acquired experience as well as use and articulation from the involved actors.

We believe that the variables in the SES framework hold different degrees of importance depending on the development status the ICES is at. Within the development status of ICES, three building blocks integrate the variables, as illustrated in Figure 1.

A methodological pathway is defined using the variables of the SES framework for ICES. From the case analysis, it was possible to define different degrees of importance for the variables depending on the stage of development of the ICES. The three identified phases were taken as the starting point for proposing a pathway composed of steps withholding all the variables. For each step, the most important variables were selected.

The **initial phase** sets the context by looking at all the enabling context variables from the social, economic and political settings (S variables in the SES framework in Table 1) which are analyzed and qualified as appropriate. In the initial phase, before any development away from the status quo of an area can be achieved, it would be important to detail the preconditions that mark the boundaries of the potential ICES. By analyzing all the variables of the social, economic and political setting (S, Table 1), the initiators can clarify the current status of the larger system that could shape their local community energy system. The key variable in this case would be the *energy system* (S3, Table 1). Having the energy system as framework, a *social network* (GS3, Table 1) should be fostered with a shared objective: depicting a concrete idea for the ICES, and then establishing a governance system for it.

In the DE Ramplaan case, the solar PV roof idea was first developed, and only afterwards the energy cooperative started recruiting members to join the project. In contrasts, our method proposes the founding members should have started by setting up a strong social network and only later decide upon the project's technicalities and business model best appropriate to the local conditions.

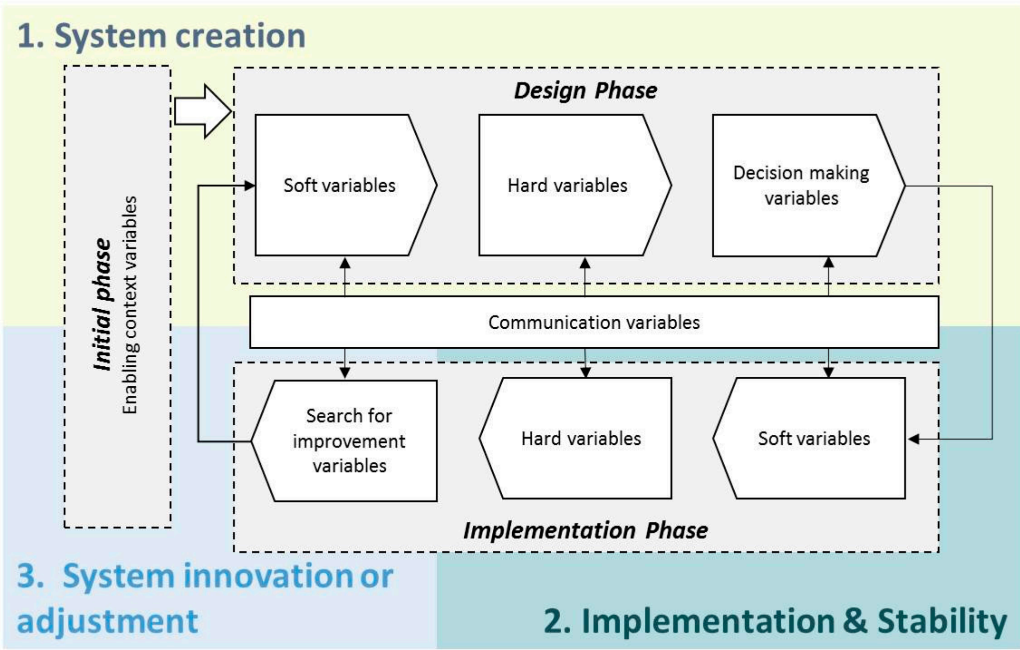

Figure 1. Status points of development and phases in the ICES analysis framework.

The **design phase** is composed of three types of variables: soft variables, hard variables and decision-making variables. The first two types can be iterative and influence each other. The social/community aspects of the ICES that have to be considered according to the SES framework are grouped into the type called *soft variables*, as these are not easily quantifiable and subjective. The *hard variables* contain the more quantifiable ones. This phase is concerned with looking at all the possible energy technologies and its potential combinations for fitting the community's needs and wants, available space, and available investment. In the end, the hard variables define constitutional rules and desired productivity metrics. To arrive at the third type, *decision-making variables*, there should be effective communication between the actors who participate (as leaders and as community members) in the soft variables. A strong social network with a shared mental model on a community energy system must be achieved. For this, the potential ICES has to be understood; that means the hard variable analysis has to be communicated and discussed among the community members and the rest of the network that has been established in the soft variables. The decision-making variables should be applied after the soft and hard variables have been analyzed and determined.

The use of the soft and hard variables during the design phase is likely to occur in parallel, while the communication variables have to be constant throughout the whole process. By doing so, the ICES would probably reach a moment when *decision-making* starts happening organically, creating a system where change is gradual, automatic and slow rather than enforced. Hard and decision-making variables are highly interlinked (see Figure 2). The outcome should be a business case document that communicates the agreed definitions and values for the soft, hard and decision-making variables along with the proposed business model.

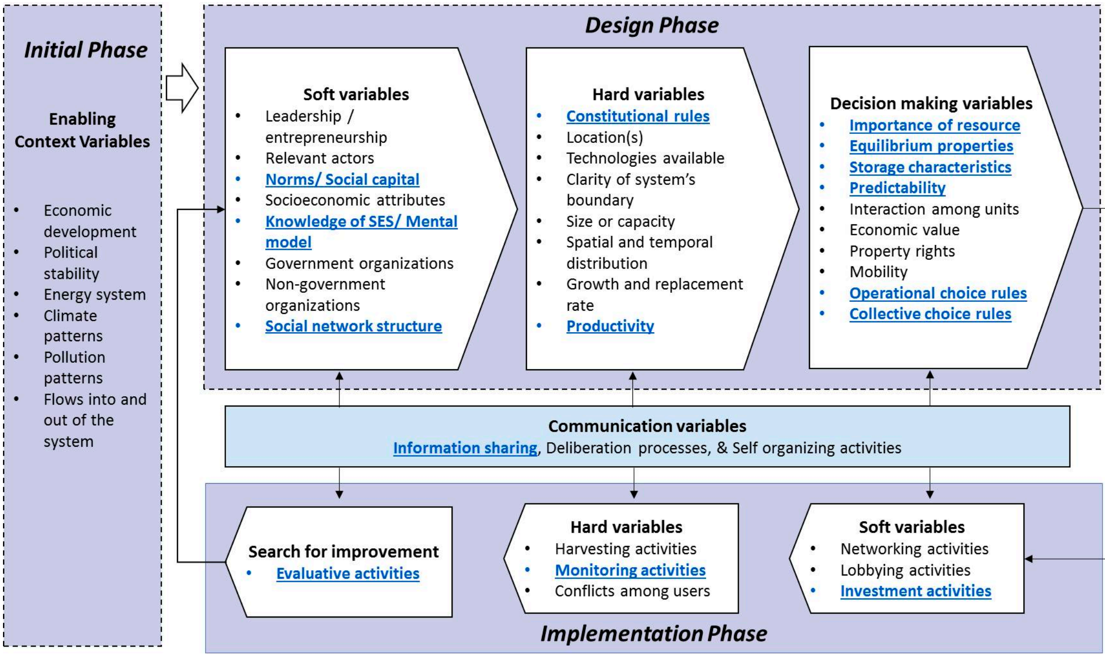

Figure 2. Variables from the SES framework for ICES involved in each step of the ICES analysis framework.

Once the governance system is in place and the business case based on the community's needs and wants is established, implementation can follow. Governance is crucial in the design phase: "[arbitrary] interference from outside is no good. It is also important to engage all the local players: that everybody who uses the common is genuinely involved in how it is run" (Hermansen and Nørretranders 2013, Chap. 4).

The **implementation phase** starts with a group of *soft variables* as a first type. They include networking, lobbying, and investment variables. It is believed that once all the members from the community are included and recognize themselves in terms of how they can individually contribute to the project, the soft side of implementation should develop organically through self-organization. But to advance this phase as fast as possible, it is believed that building of the shared mental model with a governance approach is crucial. For members to make the decision and invest, they would have to trust the community initiative and take part in designing its shared goals. In fact, this was a problematic issue for DE Ramplaan, since the shared mental model wasn't built from the start.

After the soft variables are attained, the second type of variables, *hard variables* relate to actual results from implementation. They include energy production/consumption (harvesting) and monitoring activities. Possible conflicts among users might occur when dealing with production and consumption. ICES literature mentions potential free-riding behavior and split incentives as expected barriers in these systems [3]. However, this wasn't found in the DE Ramplaan case, nor in other revised community energy initiatives. When interviewed, both representatives from these cases confirmed that as members of the community the goal is not to be protective of whatever has been achieved. Rather, it is desired to share and expand the energy project benefits instead. The goal of an ICES is not to make a profit and the benefit comes in terms of valuing what a community can achieve. This clearly distinguished ICES from profit-driven energy systems (source: N2016 interviews). One interesting finding from this research is that apparently, the functioning of energy communities relies to a great extent on good will, and that success comes with a mixture of enthusiasm, sufficient expertise and effective organization. For DE Ramplaan case, the *conflicts among users* variable from the

SES framework was considered not relevant for the case study, although it should be kept in mind for further research in other cases.

The final set of variables of the implementation phase is *search for improvement*. Change can only follow a necessary period of *harvesting and monitoring activities*. Here is where any member's voice can be raised for change at any scale, big or small. Search for improvement could not really be observed in the DE Ramplaan case. Currently, the future activities are uncertain and stakeholders explore different ideas: merging with bigger cooperatives, going off the gas grid, becoming a fully decentralized system, or maintaining connection with the grid (source: 2016 interviews). This showed that even in a successful ICES like DE Ramplaan, shared mental models need constant work on communication. The proposed ICES analysis framework follows a Plan, Do, Check, Act cycle, as an interactive process.

6. ICES Strategic Plan

We devise the ICES strategic plan as a practical approach that is recommended for the application of the ICES analysis framework, as the latter might pose difficulties to grasp the links between its status points, phases, and variables. The main aim of this plan is to provide enough structure but also enough flexibility so that it can be adapted to the needs of other ICESs. This plan is an adaptation of the business plan structure presented in Wolk (2008), which provides an orderly process to obtain social objectives, like the main benefits an ICES provides [38].

This outline aims at providing guidance in using our proposed application of the SES variables for ICES, and at which phases they can be supportive. This can be particularly valuable in the ICES articulation phase, to avoid overlooking important elements of ICES development. All the variables in the ICES analysis framework should be applied when applying this strategic plan. However, to exemplify and identify in which situations of the development of an ICES will the SES selected variables be mainly needed, the use of the key variables has been emphasized on, in the three phases.

As shown in Figure 3, the ICES strategic plan is composed of three phases: preparation, ICES articulation, and execution. Before beginning the plan, it is necessary to consider the first steps that should be done, which is what the preparation phase does. This phase will set the pillars for the development of the ICES's organizational plan. The outcomes from this phase will be further developed and detailed in the other two phases. The main variables in the preparation phase are information sharing and social network structure. The former ensures the constant flow of organized communication through established channels like meetings or online forums. The order of communication is determined by the social network structure.

During the second phase, the most relevant variables are: norms, mental model, productivity, monitoring and evaluative activities and information sharing. In this phase, norms are developed while productivity and monitoring and evaluative activities are assessed for the development of the strategy and future indicators. This is used to model the desired structure and approach of the ICES to describe how it will make an impact on the community energy management, which will explain the importance of the ICES for the community (and other stakeholders).

The third phase is the execution of the previous one, so the strategies in the ICES articulation are developed further and in more detail. In this way, all previous gaps are covered and resolved before the strategy is fully operational. The principal variables that need to be used in this phase are: collective choice rules, constitutional rules, productivity, importance of resource, storage characteristics, predictability, operational choice rules, investment activities and information sharing. It is important to note, that even if it is a strategic plan, it does include variables that in the ICES analysis framework are noted for the implementation phase, as the implementation needs to be also planned, discussed and analyzed strategically before putting the plan into action.

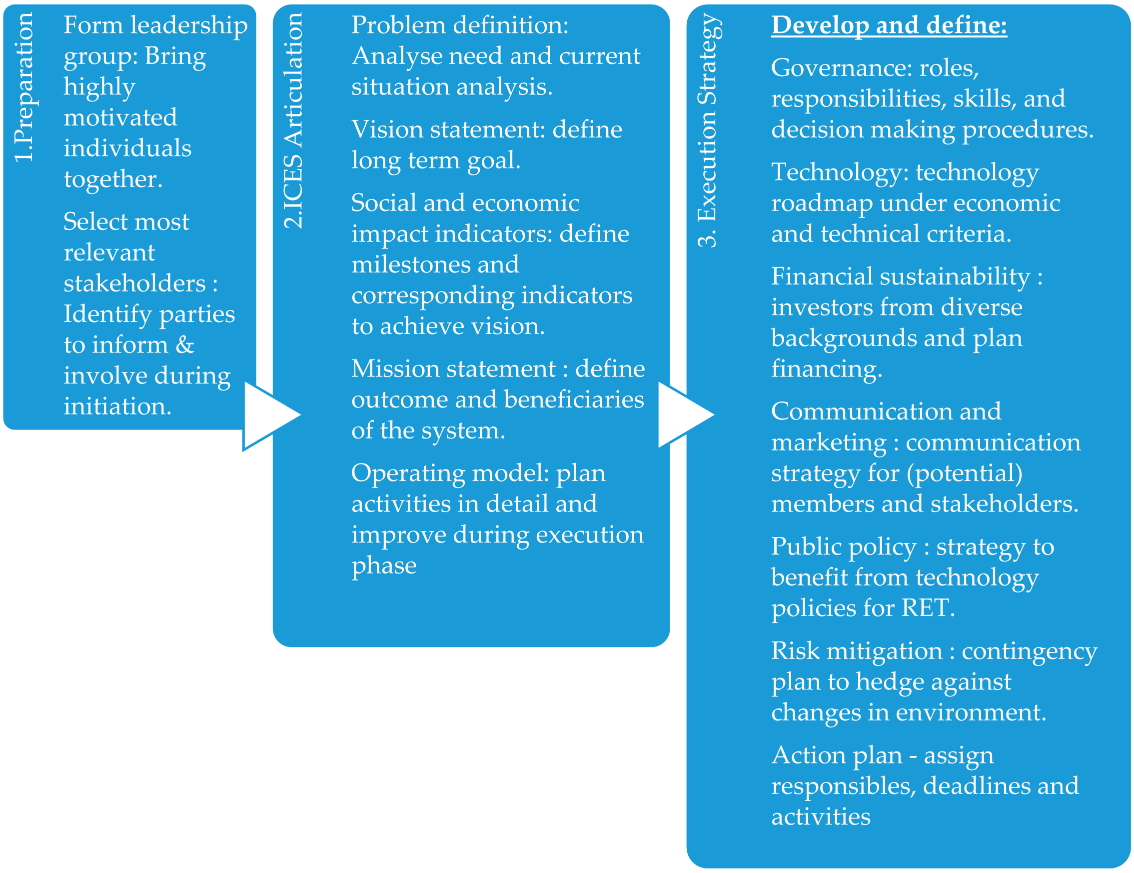

Figure 3. ICES Strategic Plan.

7. Discussion

In this research, the SES framework is used to analyze ICES from a common-pool resource perspective and collective action in general which is so far mainly applied to ecological systems. Given the highlighted importance of the variables in our interviews and analysis, the SES framework can indeed benefit the design and implementation of community energy projects and facilitate their success.

As such, we stepped further to define a specific framework and strategic plan based on the SES framework to support the implementation of ICES. However, it is important to note that our proposed framework and strategic plan for ICES were developed mainly based on the empirical analysis of a Dutch case (DE Ramplaan) and literature review of other cases. DE Ramplaan is embedded in a specific socio-economic and technical environment which influences the prospects for the emergence of ICES. The organizational arrangement and technical system integrates into an existing electricity system with distribution network, retailer, and DSO as major institutional and technical agents. The implementation of ICES in areas without existing grid may face challenges which do not arise in DE Ramplaan. Moreover, the taxation levels for electricity and support for renewable generation through the postcode-roaster creates different conditions than in countries with subsidized electricity tariffs and without fiscal support for renewables. Lastly, the socio-economic conditions in the Netherlands allow potential members to make investments with long payback period and there is credible protection of property, which endorses conditions for the emergence of ICES. The formulation of the presented framework takes DE Ramplaan as reference and our results are applicable to ICES with similar circumstances. Adjustments of selected steps may be necessary to accommodate analyses of ICES in very different socio-economic, regulatory and market environments. For example, there was no evidence for conflicts among users in the studied case and the corresponding SES variable was not adopted. This may not hold universally.

8. Conclusions

In this research, it has been demonstrated that the SES framework extends well to socio-technical systems and enhances future analyses of the governance of common resources in ICES. Through the proposed method and the ICES strategic plan, the variables of the SES framework were used to diagnose and analyze existing ICESs, and to design new ones. For existing ones, the adapted SES framework for ICES could show the adjustments that an ICES needs to implement in order to optimize its self-governance. In the case of new ICESs, the proposed method can simplify effective implementation and offer an adaptable, yet sound strategy plan from the beginning. As a broader implication, this is meaningful for climate change mitigation, as understanding ICES dynamics can lead to more efficient energy use and reduction of GHG emissions [24].

After analyzing the interviews with the ICES implementers, the adoption of these systems could greatly benefit from taking into account a social science approach in parallel to the strictly techno-economic approach, as advocated in the proposed SES-ICES framework. Interested researchers may be able to apply these results to improve the general viability of the proposed ICES analysis framework from the commons perspective. By giving the same weight to designing the economic case as creating social awareness and social cohesion, countries could more rapidly leapfrog to full RET adoption, and achieve the 2030 sustainable development goals.

Moreover, the results could extend to other socio-technical systems with common goods characteristics whose functioning relies on effective governance. These may gain relevance, for instance, with increasing digitalization and electrification of the transport sectors and emergence of shared fleets of autonomous electric vehicles.

Future research based on this work includes applying our framework to more case studies. This would allow us to further validate the findings and improve the proposed SES-ICES framework adaptation. The applicability of the proposed framework on ICESs with different conditions, for instance in urban or rural areas of the developing countries, may be further tested. This will provide more insights on the general validity of the selected key variables for the success as well as of the framework as such. Lastly, the ICES strategic plan can be applied to the new ICESs in other countries to test its usefulness and to what degree it can be implemented. Results of these studies could strengthen our contribution to contextual variables of the framework to study common goods in STSs.

Acknowledgments: The authors would like to acknowledge and thank all those involved in the research process: Jessie van Hattum and Freek Zuiderveen Borgesius, the members of DE Ramplaan Cooperative that were openly willing to talk to us and ICES expert Søren Hermansen, director of Samsø's Energy Academy.

Author Contributions: The authors contributed equally in research design, data collection, fieldwork and manuscript development.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. International Energy Agency (IEA). *Status of Power System Transformation 2017*; International Energy Agency: Paris, France, 2017.
2. Scholten, D.; Künneke, R. Towards the Comprehensive Design of Energy Infrastructures. *Sustainability* **2016**, *8*, 1291. [CrossRef]
3. Koirala, B.P.; Koliou, E.; Friege, J.; Hakvoort, R.A.; Herder, P.M. Energetic communities for community energy: A review of key issues and trends shaping integrated community energy systems. *Renew. Sustain. Energy Rev.* **2016**, *56*, 722–744. [CrossRef]
4. Mendes, G.; Loakimidis, C.; Ferraro, P. On the planning and analysis of integrated community energy systems: A review and survey of available tools. *Renew. Sustain. Energy Rev.* **2011**, *15*, 4836–4854. [CrossRef]

5. Xu, X.; Jin, X.; Jia, H.; Yu, X.; Li, K. Hierarchical management for integrated community energy systems. *Appl. Energy* **2015**, *160*, 231–243. [CrossRef]
6. Nature Editorial. The role of society in energy transitions. *Nat. Clim. Chang.* **2016**, *6*, 539. [CrossRef]
7. Kalkbrenner, B.J.; Roosen, J. Citizens' willingness to participate in local renewable energy projects: The role of community and trust in Germany. *Energy Res. Soc. Sci.* **2016**, *13*, 60–70. [CrossRef]
8. Bauwens, T.; Gotchev, B.; Holstenkamp, L. What drives the development of community energy in Europe? The case of wind power cooperatives. *Energy Res. Soc. Sci.* **2016**, *13*, 136–147. [CrossRef]
9. Walker, G. What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy* **2008**, *36*, 4401–4405. [CrossRef]
10. Walker, G.; Devine-Wright, P.; Hunter, S.; High, H.; Evans, B. Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy* **2010**, *38*, 2655–2663. [CrossRef]
11. Koirala, B.; Chaves Ávila, J.; Gómez, T.; Hakvoort, R.; Herder, P. Local Alternative for Energy Supply: Performance Assessment of Integrated Community Energy Systems. *Energies* **2016**, *9*, 981. [CrossRef]
12. Ostrom, E. A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science* **2009**, *325*, 419–422. [CrossRef] [PubMed]
13. Holling, C.S. Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems* **2001**, *4*, 390–405. [CrossRef]
14. Schlüter, M.; Hinkel, J.; Bots, P.; Arlinghaus, R. Application of the SES Framework for Model-based Analysis of the Dynamics of Social-Ecological Systems. *Ecol. Soc.* **2014**, *19*, 15475–15487. [CrossRef]
15. Geels, F.W.; Schot, J. Typology of sociotechnical transition pathways. *Res. Policy* **2007**, *36*, 399–417. [CrossRef]
16. McGinnis, M.; Ostrom, E. Social-ecological system framework: Initial changes and continuing challenges. *Ecol. Soc.* **2014**, *19*. [CrossRef]
17. Kunneke, R.; Finger, M. The governance of common pool problems in liberalized infrastructures. In Proceedings of the Fourth Workshop on the Workshop (WOW4), Bloomington, IN, USA, 2–7 June 2009.
18. Cayford, T.; Scholten, D. Viability of self-governance in community energy systems: Structuring an approach for assessment. In Proceedings of the 5th Ostrom Workshop, Bloomington, IN, USA, 18–21 June 2014; pp. 1–28.
19. Melville, E.; Christie, I.; Burningham, K.; Way, C.; Hampshire, P. The electric commons: A qualitative study of community accountability. *Energy Policy* **2017**, *106*, 12–21. [CrossRef]
20. Wang, H.; Huang, J. Cooperative Planning of Renewable Generations for Interconnected Microgrids. *IEEE Trans. Smart Grid* **2016**, *7*, 2486–2496. [CrossRef]
21. Koirala, B.P. *Integrated Community Energy Systems*; Delft University of Technology: Delft, The Netherlands, 2017.
22. Koirala, B.; Hakvoort, R. Integrated Community-Based Energy Systems: Aligning Technology, Incentives, and Regulations. In *Innovation and Disruption at the Grid's Edge*; Elsevier: Amsterdam, The Netherlands, 2017; pp, 363–387, ISBN 978-0-12-811758-3.
23. Koirala, B.P.; Hakvoort, R.A.; Ávila, J.P.C.; Gómez, T. Assessment of Integrated Community Energy Systems. In Proceedings of the 13th International Conference on the European Energy Market (EEM), Porto, Portugal, 6–9 June 2016; pp. 1–6.
24. Avelino, F.; Bosman, R.; Frantzeskaki, N.; Akerboom, S.; Boontje, P.; Hoffman, J.; Paradies, G.; Pel, B.; Scholten, D.; Wittmayer, J. *The (Self-)Governance of Community Energy: Challenges & Prospects*; DRIFT: Rotterdam, The Netherlands, 2014.
25. Gui, E.M.; Diesendorf, M.; MacGill, I. Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1355–1365. [CrossRef]
26. Ostrom, E. *Understanding Institutional Diversity*; Princeton Paperbacks; Princeton University Press: Princeton, NJ, USA, 2005; ISBN 978-0-691-12207-6.
27. CBS Share of Renewable Energy at 5.9% in 2016. Available online: http://www.cbs.nl/en-gb/news/2017/22/share-of-renewable-energy-at-5-9-in-2016 (accessed on 15 December 2017).
28. Hufen, J.A.; Koppenjan, J.F. Local renewable energy cooperatives: Revolution in disguise? *Energy Sustain. Soc.* **2015**, *5*, 18. [CrossRef]
29. DE Ramplaan. DE Ramplaan Dashboard. Available online: http://public.solarmonitoring.net/dashboard/system/A67YY/vDHnjRrbmQ (accessed on 9 November 2017).
30. DE Ramplaan. Onze Doelstellingen DE Ramplaan. Available online: https://deramplaan.nl/over-de-ramplaan/ (accessed on 9 November 2017).

31. DE Ramplaan. Business Case Gepresenteerd | DE Ramplaan. Available online: https://deramplaan.nl/2013/04/15/test-artikel-titel/ (accessed on 9 November 2017).
32. Jansen, G. *High Level Business Case Energiecoöperatie DE Ramplaan*; Energy Transtition Group: Harleem, The Netherlands, 2013.
33. DE Ramplaan. Akte Van Oprichting en Statuten | DE Ramplaan. 2014. Available online: https://deramplaan.nl/zonnecentrale-fablohal/akte-van-oprichting-en-statuten/ (accessed on 15 December 2017).
34. Janssen, M.A.; Bousquet, F.; Ostrom, E. A multimethod approach to study the governance of social-ecological systems, Abstract. *Nat. Sci. Soc.* **2012**, *19*, 382–394. [CrossRef]
35. Poteete, A.R.; Janssen, M.; Ostrom, E. *Working Together: Collective Action, the Commons, and Multiple Methods in Practice*; Princeton University Press: Princeton, NJ, USA, 2010; ISBN 978-0-691-14603-4.
36. Bamberg, S.; Rees, J.; Seebauer, S. Collective climate action: Determinants of participation intention in community-based pro-environmental initiatives. *J. Environ. Psychol.* **2015**, *43*, 155–165. [CrossRef]
37. Visbeek, S. Post Code Regulation: Regulation for Reduced Energy Tax. Available online: http://www.postcoderoosregeling.nl/ (accessed on 21 October 2016).
38. Wolk, A.; Kreitz, K. *Business Planning for Enduring Social Impact: A Social-Entrepreneurial Approach to Solving Social Problems*; Root Cause: Cambridge, MA, USA, 2008; ISBN 978-0-615-18284-1.