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# 1 Table of Contents

# 0 Executive Summary

The overall objective of this deliverable is to introduce an analytical framework for the ex-post evaluation of the socio-economic changes in the local energy systems demonstration sites.

We are striving for a systematic evaluation of the socio-economic change and effects in the local energy systems in the demonstrator sites, with explicit criteria based on a valid evaluation research design and research choices. Therefore, this deliverable formulates an analytical framework that defines the evaluation concepts, criteria, and basic steps of the evaluation. It is not a detailed guideline for the local energy system evaluation in the individual demonstrator site, but instead, it discusses the common concepts, steps, and socio-economic evaluation criteria.

We introduce here a framework for an evaluation to determine the socio-economic local energy system changes and attribute these change to the socio-economic interventions (social innovation). The main goal is to understand the attribution of social factors that affect technical system changes. The analytic framework provides the key social, economic, and regulatory variables to help understand (1) in how far social factors contribute to technical innovations changing the local energy system in the demonstrators, and (2) how social innovations themselves contributed to the envisioned low-carbon citizen-centred local energy system changes.

The purpose of the evaluation of the local energy system is to establish the progress in socio-economic system change in the demonstrator sites at the end of the project. Therefore, it is focused on a classical evaluation of effects of interventions in the system. We evaluate the processes and substance of the innovations that are used to explain the successes and failures of the interventions.

We follow a mixed-method approach based on the idea of a systemic evaluation, bringing different evaluation components in terms of criteria and methods together in one system.

Section 1 discusses socio-economic local energy system changes in relation to socio-economic interventions (social innovation), and the role of social factors in the technical system change. Section 2 presents an evaluation perspective on local energy system change in the demonstrator sites in relation to hard and soft system change and different perspectives on evaluation. Section 3 sets the evaluation object and focus within the local energy system in the demonstrator sites as either the effect of specific innovations or system change as a whole. Section 4 discusses the evaluation criteria with a strong focus on the goals of the intervention in the system (technical and social innovations). Section 5 discusses measuring socio-economic SERENE demonstrator progress and impact, which is about different socio-economic criteria (socio-economic key performance indicators, socio-economic changes, innovation activities and transition metrices). Section 6 addresses the issue of effectiveness, particular the role of intervention theories on how the technical and social interventions in the system are supposed to achieve system impacts. The intervention theory for change in the local energy systems is based on the mechanism of changes through local niches and local experiments, based on the theory of strategic niche management (SNM). Section 7 discusses the steps necessary for a quantitative and qualitative goal achievement, and quantitative and qualitative approaches to effectiveness.

In the SERENE project, we make use of concepts related to SNM to evaluate the intervention theory. Using SNM takes us away from simply looking at a new innovation introduced to an existing market. Niches innovations are intentionally created and protected by public and private measures to be able to learn about these new technologies. Eventually, the new innovations should change the local energy system by presenting viable alternative pathways to a fossil fuel-based system. The local energy transitions are ultimately about influencing and changing the local energy system regime. The replication potential of the innovations to other sectors is secondary.

**Abstract SERENE project**

This deliverable is part of the SERENE project. This particular deliverable bridges the general work on factors influencing the local energy system and the use of the found factors and criteria in the evaluation of the demonstrator sites. The aim of the SERENE project is to develop and demonstrate sustainable, integrated, cost-effective, and customer-centric solutions for local communities. The idea is to integrate different energy system carriers and new renewable generation units in the local communities based on their social and technical status today to meet their energy needs in the coming years. The users must be involved in the changes to the energy system and be informed about different technical opportunities and business cases to make decisions about their participation. Depending on the actual site, the new energy system involves different storage technologies (battery energy storages, heat storages, water storage-systems), demand response systems to enhance the flexibility of the systems (activating for instance electric vehicle charging stations and heat demand supplies), electric transportation systems like electrical vehicles or buses, heating system improvements using heat-pumps and integration of new renewable generation sources mainly in form of photo voltaic. The SERENE project will establish demonstrations in local villages in three European countries - Denmark, the Netherlands, and Poland. The experiences gained at the demonstration sites will be analyzed and evaluated for replicability in Europe and beyond. Technical benchmark models and solutions will be set up together with their business models, and it is evaluated how different legal aspects from the involved countries will affect the possibility for replication. Further, the needed user involvement and their interest to join are evaluated based on geographic, social, environmental and economic conditions and characteristics.

# 1 Introduction

In the previous Deliverable 3.1 of the SERENE project we discussed the need to broaden the perspective on the role of social factors in the local energy system transition. A local system transition is not just about the technical change, but instead, social factors must be taken into account to achieve successful technical and societal innovations. In a 'technical change dominant perspective,' policies, regulation, and costs are seen as conditions which need to change and fit to the new technical systems. However, there are also many other social and cultural barriers facing renewable energy systems. Particular we must deal with a wider public discourse around energy systems and attachment to fossil fuels (Sovacool, 2009). We also need to deal with social acceptance problems, such as attitudes towards renewable energy, which are not always rational and are often driven by emotions and psychological issues (Lenoir-Improta, Devine-Wright, Pinheiro, & Schweizer-Ries, 2017). The local energy system transitions further ask for new active citizenship (Devine-Wright, 2007) and for new forms of cooperation between citizens, including peer-to-peer transactions.

Approaching the local energy system as a socio-technical system instead of a purely technical system also results in a different type of interventions needed to achieve system change. Socio-technical systems are 'interconnected, integrated systems that link social, economic, and political dynamics to the design and operation of technological systems' (Miller, Richter, & O'Leary, 2015). The idea of socio-technical improvement is to find the best possible match between the technical and social components of a system – a co-evolution of social and technical innovation to induce system change.

The previous Deliverable 3.1 of the SERENE project discusses that this co-evolution asks for different types of interventions that fit in the idea of hard and soft systems change rationality. Hard systems thinkers look for concrete problems and solutions for definable systems. When one sees a local energy system as a system with well-defined problems and a single optimal solution, a hard system approach matches.

However, in such an approach, technical factors will dominate. The technical innovations in SERENE, although implemented in a co-evolutionary way with complementary organizational social innovations, mostly fit in this hard systems perspective. In contrast, the social innovations in SERENE, which address public discourse, social debates, new forms of cooperation with and among citizens and social acceptability in the local community, aligns better with the soft systems way of thinking. Soft systems thinkers focus more on people and their perspectives of a given system, and how these people would cooperate to make improvements (Foster-Fishman et.al., 2007). The soft systems approach provides a framework which helps to make sense of unclearly defined problems. An example of social innovations would be information and awareness efforts and strategies. Why people do or do not accept certain innovations is not clear cut. The issue of social acceptability will be addressed in more detail in deliverable 3.5 of the SERENE project.

In this deliverable, we introduce a framework for ex-post evaluation to determine the socio-economic local energy system changes and attributes these change to the socio-economic interventions (social innovation) and to understand the attribution of social factors to the technical system change. The analytic framework provides the key social, economic, and regulatory variables to help answer two central questions:

1) In how far do social factors influence the possibilities of technical innovations to change the local energy system in the demonstrators with their different socio-technical system?
2) How do social innovations themselves influence the envisioned low-carbon citizen-centred local energy system changes in the demonstrators with their different socio-technical system?

# 2 Evaluating local energy system change in the demonstrator sites

The time span of the SERENE project and the transition literature must first be noted. The SERENE project focuses on a short time period and relatively short-term changes in the demonstrators. However, these changes are part of a much longer transition process. The transition literature as discussed in deliverable 3.1 of the SERENE project is about transitions over a long period of up to 30-40 years.

Therefore, although inspired by concepts from the transition literature, the purpose of the evaluation framework of the local energy system within this deliverable is mainly to assess the progress towards socio-economic system change in the demonstrator site by the end of the project. This of course, has to be seen in the perspective of the long-term transition. In other words, the evaluation of the short-term results is focused on a classical evaluation of effects of intervention in the system. Evaluation of processes and of substance of the innovations are used to explain the success and failure of the interventions and need to be seen in the much larger time perspective.

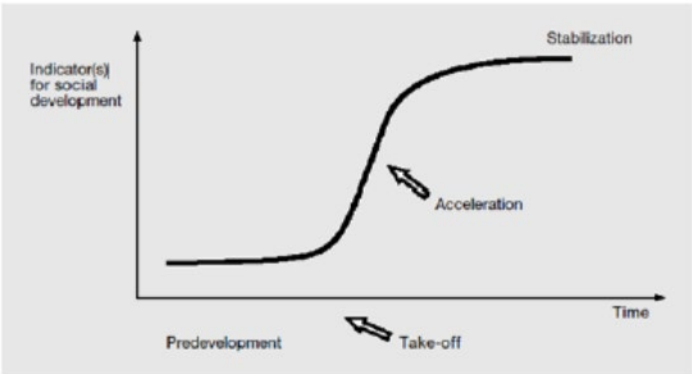


Figure 1. Transition phases. From "More Evolution than Revolution: Transition Management in Public Policy," by J. Rotmans, R. Kemp, and M. van Asselt, 2001, Foresight, 3(1), p. 17

The three demonstrator sites countries are in different phases of transition. The Danish demonstrator in the SERENE project is a rural area of Låsby and Hylke in Skanderborg Municipality. The overall objectives of the demonstrator is to carry out test and demonstration activities by working closely with local citizens, property owners, utilities and stakeholders for establishing the transition of existing heating supply from fossil fuel (natural gas and oil boilers) to electric heating from heat pumps in residential buildings, and increase self-consumption from renewables. Further, it's supplemented by e-vehicle mode of transportation, digitisation and smart control of integrated solar PV, battery storage, heat and EV systems to effect local demand side management, maximising self-consumption from solar PV and provide local grid support. The SERENE project will also include analysis on how the local electricity grid system is affected, possible bottlenecks and how the local rural energy systems and the local grid system can be optimized. The Danish demonstrator is strongly municipality lead. Although the demo sites start at the beginning of the SERENE project, the Danish energy transition is going on for quite some time and Denmark is considered a leading country in the energy transition and in sustainable development (Denmark Voluntary National Review 2021) and in the take-off phase of the energy transition. In the Skanderborg Municipality around 44% of the total energy consumption is covered by local renewable energy sources and around 55 % of the electricity consumption is from renewable energy source. This will increase to 100 % in 2030 because of national actions. Skanderborg Municipality has the goal of 70% CO2-reductions by year 2030 compared to 1990 for heating and electricity consumption, transportation and farming sectors.

Climate issues are high on the agenda for most people in Denmark, including Skanderborg citizens, where the education level is among the highest in Denmark. The local acceptance for solutions that will help the climate related innovations is high.

The demonstrator in the Netherlands involves two demonstration sites, the community Aardehuizen and the neighborhood Vriendenerf, both are part of the rural village of Olst, which has approx. 5500 inhabitants. Both sites are two recently built neighborhoods. The overall goal of the demonstrators here is to implement solutions to enhance smartening of the electricity grid in the area with electric boilers, electric vehicles, battery storage (Aardehuizen), and heat pumps (Vriendenerf). The neighborhood already has a community project that integrates solar PV systems and energy efficient buildings. The Aardehuizen neighbourhood is a unique community in which occupants built their own houses with help from volunteers from all over the world, according to circular and bio-based principles (the so called 'earth ship concept'), solar PV systems, wood boilers using local wood supplies, decentral water sanitation, own drinking water supply and plans to grow local crops for own food supply. The Vriendenerf neighbourhood consists of 12 houses (finalised in 2017) in which the residents (aged mostly above 50 years) formed a community project to jointly tender design and construction of the houses. The houses are built according to NZEB (Near Zero Energy Building) standards, utilizing the most recent standards in building insulation and installation technology: high level of wall insulation, triple glass windows, solar PV integrated roof constructions, ventilation with heat recovery and ground source heat pumps. The community works together on a joint garden, exploitation of a community house and has plans in the direction of EV sharing and a charging point. In the Aardenhuis and Vriendernerf already a lot of renewable energy and sustainable initiatives are taken. The communities are past the take off and already in the acceleration phase. This is not to say that this holds for the whole municipality of Olst or the Netherlands as a whole. Also in the Netherlands climate issues are high on the agenda for most people, including the inhabitants of Olst, but the inhabitants of these both demo communities, particular Aardenhuis, are national forerunners. The community received active support of the village council in order to successfully apply for exemptions to national building regulations, water sanitation requirements and drinking water supply requirements. Also, the Aardenhuis neighborhood successfully applied to become a pilot for electricity sharing according to the Dutch experimental electricity exemption regulation. This makes it possible e.g. to trade electricity within the neighborhood against own defined, dynamic price levels. Although supported by the municipality, the citizens initiatives in the demos Aardenhuis en Vriendenerf are in the lead.

Members of these demo communities also participate in the sustainable transition movement in Olst. Both communities are active in exchanging ideas and experiences with others in the Netherlands and international, and are an example how a community can work together and achieve common goals within a sustainable community and how to create regional exposure of ideas and experiences. The municipality and regional legislative body "Cleantechregio" support the project and want to create similar examples within the region, together with energy cooperatives, The province of Overijssel regards the demonstration as possible solution for current problems with solar PV projects due to expected grid congestion by the network operator and therefore supports the project. Besides that, both neighbourhoods have a long-term strategy to support activities of the local energy cooperation for neighbouring areas of the village to increase the amount of solar PV generation

In the Polish demonstrator, there are three demonstration cases applied in SERENE project. They are a school building, an industrial site and energy complexes (both public and community based blocks) located in the Przywidz municipality. Przywidz is a rural municipality in the Pomerania Voivodeship (Province). It has an overall area of 129 km2 with a population of 5800 inhabitants The overall goal of the demonstrator is to establish a first initiative to the concept of “Energy clusters” that is part of the Polish renewable energy policies. Based on the concept, the local counties and municipalities will involve local citizens and stakeholders in the creation of sustainable ‘energy nests’ to meet and manage the energy demand locally by utilising local energy resources, creating local entrepreneurship and enabling socio-economic-environmental benefits. Compared with the other country demos not only the municipality provides a strong lead together with the academic research institute, but also closely cooperates with the grid operator and local companies, which fits with the idea of energy clusters

The framework and research steps formulated here directly relate to the goals of work package (WP) 7 of the SERENE project. The objective of WP 7 is to establish the impacts of the technical and social innovations in the local energy systems as well as to create benchmark models. In WP7, we will combine the work of all previous work packages (WP2-WP6), but it particularly builds upon the results from WP2 and WP3.

The impacts of various innovations in SERENE have a technical and a social side. First, the framework can be used to show the starting point for the social perspectives, which can be used in the comparison of the demos, to show how country and demo specific social factors like different social cultures, institutional frameworks in the three demonstration sites maybe call for different kind of innovations and implementation and activation methods. The basis for this analysis can be found in the D3.1 and D3.3 and the social-cultural status will be further explored in the survey (see attachment).

Secondly, the assessment will verify the role and impact of smart energy and grid solutions to effectively combine and economically operate multi-carrier energy systems on the local level to utilize a maximum share of local sustainable energy resources. The role of socio-economic, regulatory and governance factors in these solutions needs to be evaluated.

Thirdly, the assessment will determine the extent to which the involvement of local energy users and the creation of energy communities have had an impact on local energy frameworks. This includes the engagement of local citizens in the acceptance of technical solutions and the evaluation of business models for local citizens. The final objective of WP7 is to develop benchmark models for the technical solutions and business models that can be replicated in other local regions, and are acceptable and attractive for local citizens. The demonstrator sites function as socio-technical innovation experiments (niches) from which lessons on impacts of technical and social innovations in the local energy system will be drawn. Based on the demonstrator site experiments, the project will create benchmark models for technical and social innovations, as business and incentive models for involving citizens in local energy systems.

We are striving for a systematic evaluation with explicit criteria, based on a valid evaluation research design and explicit research choices. Therefore, this deliverable formulates an analytical framework that defines the evaluation concepts, criteria and basic steps of the evaluation. It is not a detailed guideline for the local energy system evaluation in the individual demonstrator site, but rather it discusses common concepts, steps and socio-economic evaluation criteria. In a general sense, evaluation can be described as *the assessment of the representation or observation of a certain phenomenon (an existing situation or a change therein), based on certain criteria*. This general description is characterized by three elements. (1) any evaluation requires an observation and monitoring, which should be taken into account before the start of the project and after the completion of the project. (2) we need criteria or standards before we can evaluate. Assessment is the confrontation of an observation with a standard or criterion. (3) evaluation is related to an object. The object of evaluation may include the substance, process, and effects of system interventions.

The distinction between hard and soft system approaches has further implications for the evaluation of system change, related to differences in philosophical and theoretical origin. Central in the debate is the *causal explanatory model*, which aligns with the hard systems approach. Evaluation research based on a causal explanatory model is termed the rationalist methodology of evaluation research. The core of rationalist, ex-post evaluation research is the explanation of why certain effects do or do not occur, as assumed in the intervention or impact theory. This method investigates certain effects as they do (or do not) occur, and looks at whether they are caused (or not caused) by the conduct (or lack thereof) of interventions to change the system. It attempts to draw the probabilistically best conclusions about these sorts of relations.

Besides this rationalist methodology, there is also a hermeneutic methodology, which seeks an alternative to the causal explanatory model and focuses on 'understanding' rather than 'explanation.' The hermeneutic methodology is concerned with understanding the factors underlying the occurrence (perhaps only to a certain degree) of the effects of the system change activities. This fits with the soft system approach which recognizes that people have their own perspectives of a given system, and is about understanding unclearly defined problems.

The difference between 'explanation' and 'understanding' in evaluation research also relates to the difference between positivism and constructivism where the hard system and explanatory approach relies on the positivist idea that there is such a thing as the real-world system, which we can directly observe, and from which can derive facts about the system. The soft system approach and the understanding approach are more based on the constructivist idea that it is not possible to know for certain what the nature of reality and the real system change facts are, since all our observations are shaped and filtered through the human senses and the human brain.

# 3 Innovations and local energy system change as evaluation objects

The appropriate evaluation approach depends on the object of the evaluation. Within the demonstrator sites, as we have seen above, there is a range of possible objects to evaluate as part of the local energy system change. This includes the evaluation of individual innovations, such as technical installations, different processes or new activities, which might be evaluated with regards to the percentage of renewable energy in the local energy system, the role of the municipality in the transition (incentives, regulations), the process of creating a local energy community or meetings with citizens as an activity (personal circumstances, social readiness level). These individual elements of the local energy system can thus be technical or social interventions, which relates to the type of impacts we are looking at, such as system changes in terms of substance, process or effects.

In the case of technical innovations, we can look at the impact of a specific innovation on the system as a whole, where both the type of impact and the goals of the intervention are formulated in terms of effects. An example would be the introduction of photovoltaic (PV) panels on a block of houses. For the impact, we can then look at the increase in PV production within the system in absolute terms, the increased electricity from renewable energy sources (RES)of the whole system (kWh/year or %) or the reduced fossil fuel consumption for electricity in the area (kWh/year or %).

In the case of social innovations, the evaluation is less clear-cut. For instance, the start of a local renewable energy community is formulated in terms of process changes or a change in beliefs (substance). The goals that we are trying to contribute to with this intervention is formulated in terms of process effects and belief changes. The effect of this social innovation on the whole system is much more difficult to determine. For technical innovations, it is much easier to focus on a causal chain of effects. For social innovations, the contribution to the system might form a complex web of social relations and interactions which might be correlated or not which might be critical to the effects and the success of this initiative. In the case of people's behavior and interaction, it is much more difficult to attribute system change to behavior changes as the causes, making it more important to understand the larger system around the social innovation.

Social innovations might lead to process effects, i.e., doing things differently, as well as to system effects, like benefits for citizens. Social effects can be difficult to measure, for instance a grown 'sense of community,' and can be as much about the side effects of an intervention as about its original purpose. The creation of a local energy community might have citizen ownership of renewable energy production as its primary goal. Something like an increased sense of community is a side effect. Additionally, social innovation might be explicitly aiming at changing awareness and beliefs, such as (collective) ideas on renewable energy and climate, which are difficult to measure and attribute to a specific innovation. Attribution will be discussed in more detail in section 6.

Evaluating and understanding system change based on traditional evaluation methods and concepts alone is challenging, particularly in the case of social innovations. The combination of technical and social elements in the local energy system requires evaluation to think differently about the tools and approaches it uses to understand change. The evaluation needs to focus on broad system of interactions.

A connection can be made to our earlier discussion on hard and soft systems approaches, rationalist and constructivist approaches to evaluation, and the associated evaluation methods. The traditional way of evaluating a system assumes that specific parts of the system can be looked at in isolation in order to understand its operation and contribution to the end result. This fits with the hard system approach, i.e., looking at concrete problems and solutions for definable systems and evaluating if a single optimal solution works. However, not all system parts can be meaningfully evaluated in isolation. For some interventions, particularly the social innovations, we should instead think in more holistic terms. Impacts might result from an interaction between elements of the system, rather than from one element alone. For instance, the creation of a local energy community as a social innovation might make a collective energy project, like a neighborhood battery, possible. Put differently, the overall impact on the system might be greater than the sum of the interventions.

In the SERENE project, we use a range of methods and both quantitative and qualitative data to evaluate energy system change. Technical system changes can mostly be evaluated based on quantitative data. For the evaluation of social aspects, we also use some quantitative data, which can be collected through surveys and primary and secondary data analysis of existing documents and databases.

However, there are some limitations to the use of quantitative data for evaluation in our demonstrators, in particular small sample sizes, poor response rates from the surveys, entrance to process in the different demonstrators, difficulties to obtain or translate documents and difficulties in valid measurement. In addition, quantitative methods are inherently limited in explaining soft system changes. Quantitative data does not provide a sufficient understanding of the context of technical innovations and of the complex interactions related to social innovations. We therefore also need to use qualitative methods to better understand patterns and interactions within the local energy system, including both the social changes happening in the socio-technical system and the co-evolutionary processes of technical and social changes taking place together.

# 4 Goals and evaluation criteria

Evaluation criteria are used to determine the worth and significance of the system change, and are the basis for goals to be formulated. These criteria play a normative role, as we use them to express how we think the system *should/would* change.

Three main types of evaluation can be distinguished, based on different types of criteria: goal-based, process-based and outcomes-based. *Goal-based* evaluations measure if specific goals have been achieved. *Process-based* evaluations are about analyzing strengths and weaknesses of processes. We use process-based evaluations to understand why a goal has or has not been reached. Processes can also have clear goals by themselves. *Outcomes-based* evaluations examine broader impacts and often investigate what greater aim was served as a result of the program or project, like combatting climate change. For the evaluation of the interventions in SERENE, this is difficult due to the relatively short timeframe of the project.

Looking back at the two key evaluation questions we defined earlier, the first question, i.e., how far the demonstrators' social factors influence to technical innovations, is an effectiveness question: Social factors might or might not influencing to the functioning, and therefore goal attainment, of the technical innovation. Answering this question comes with two steps – we first need to determine if the technical innovation indeed achieved its goal. Then we can look at whether social factors reduced or improved effectiveness of the technical innovation.

Possible criteria for the evaluation of a specific technological innovation might be official intervention objectives, for instance the share of RES that needs to be generated. In general, looking at an intervention effectiveness from the perspective of its *official* objectives is not merely a way to evaluate it; in a democratic society, the official objectives also form the public justification for the proposal to apply certain innovations and use tax money for it. This means that the official objectives are also the most widely acknowledged measures against which a democratically chosen policy can be tested. There may be other goals besides the official ones, though. Every group or individual will look at interventions from the perspective of their own objectives. Sometimes we may want to judge interventions according to the objectives of one of the actors involved, e.g., a specific energy actor or local energy community, rather than according to the fixed official goals.

What we measure at the end of the project period are not necessarily end goals, which define the envisioned situation at the end of the transition. At the end of the SERENE project, we can look at the achieved or actual situation at that moment, and compare it to the baseline situation and the envisioned situation at the end of the specific intervention or at the end of the system transition. For many interventions, this will be an interim evaluation, not the end situation. This also means that we need to establish a baseline at the beginning of the project as a reference point. For quantitative goals, the progress made throughout the project is given by deducting the situation achieved at the end of the project from the baseline situation.

In the step of goal achievement, we determine the degree to which the evaluation criteria have been fulfilled, i.e., the degree to which the goals have actually been achieved. This should not be confused with effectiveness – goals can be achieved without interventions being effective if other factors have pushed the system in the desired direction.

In order to determine goal achievement, we need to gather and analyze data that allows us to compare the actual situation to the criteria. For this, we first need to *operationalize* the goals, so they can be measured. The measurability of a goal depends on whether it indicates a direction, can be quantified and is time-specific. Operationalizing goals means making concepts measurable. Some concepts with the local energy transition are relatively easy to operationalize, for instance the increased RES-electricity in kWh/year or the number of citizens who are members of an energy community. Many goals can best be measured if the goal can be operationalized in terms of 'hard' indicators, e.g., directly observable phenomena and characteristics like number of PV panels or number of electrical cars. For a concept like user-friendliness, this is far more difficult. We might also encounter problems if goals are defined in terms that can only be indirectly influenced by the SERENE project, like the market penetration of technologies.

If we cannot measure a goal directly, we will attempt to make it measurable by reformulating it in different terms with the help of actors in the local community. The involvement of local actors in this process is important because they often have more background information, such as the process that led to the goals being formulated in the first place, and because they thereby commit to the operationalization, thus increasing the acceptance of the evaluation outcome.

Goals can relate to various elements in the cause-effect chain, from innovation implementation activities to the ultimate effect. In principle, all elements in this chain can be operationalized or made measurable. To really understand what is happening in the local energy transition, the challenge is to not stay too close to the implementation activities, nor too far into the chain of processes occurring in the system. Measuring how much money is spent or how many man-hours are involved says nothing about whether the goal will be achieved. And if we assess the situation at the very end of the chain, we need to contend with all sorts of unrelated factors that might also have caused the system change effects we see.

# 5 Measuring SERENE demonstrator progress and impact

During the demonstration period, data will be collected to measure the impact of the individual technologies set up in the SERENE project. For WP7, data includes technical aspects such as increase in energy efficiency, but also social aspects like number of users involved, number of trained people, and other social impacts. The data gathering tools for the socio-economic analysis include community statistics, a population survey and innovations surveys. The community statistics give the basic demographic and socio-economic data for the demonstrator sites.

The goal of the population survey is to study the wider public discourse around energy systems, particular viewpoints on energy use and climate change, attitudes towards renewable energy, the respondents' energy use behavior, and the social acceptance of renewable solutions. The population survey further asks questions on new active citizenship and new forms of cooperation between citizens, including peer-to-peer transactions (see further below and in the attachment).

Innovation surveys are conducted to measure and monitor individual technology development in the SERENE project in the form of company and technology surveys throughout the project lifetime to track the progress of the technology towards commercialization. These surveys are formulated based on the widely accepted Oslo Manual and in accordance with the EU regulations on the creation and production of community statistics on science and technology. The surveys are used to monitor market opportunities and techno-socio-economic, legal, political and environmental factors that may influence the innovation potential of the solutions. It is also used to measure the exploitation and replication potential in other communities. These innovation surveys and indicators are part of WP 8 and involve insights from all other WPs.

## *5.1 Key performance indicators*

The SERENE proposal mentioned different key performance indicators (KPIs) to be measured for the countries and demonstrator sites (See Table 1). These indicators are outcome KPIs, and are used to define and evaluate how successful the project is by expressing its progress towards the overall project goals.

Table 1 *Key performance indicators mentioned in the SERENE proposal*

| **Key performance indicator** | **Measurement unit** |
|---|---|
| Increased RES-electricity | kWh/year; % |
| Increased RES-heat | kWh/year; % |
| Reduced fossil fuel consumption in electricity area | kWh/year; % |
| Reduced fossil fuel consumption in heat sector | kWh/year; % |
| Flexibility possibilities - movement of electricity from high to low load period | kWh/year; % |
| Exchange of households from coal or gas to electricity | total number |
| Exchange of fossil fuel cars by electric cars | total number |
| Increase of EV charging points in the area | % |
| Expected green transport | km |
| CO2 savings and other pollution | t/year |
| Expected economy (payback time) for investment | years |
| Impacts/replication in demo-district expected | total number |
| Number of citizens with awareness of green energy | total number |
| Impacts/replication expected locally/globally | total number |
| Job creation in energy market | total number |
| Job creation of small SME | total number |
| Number of training of local people, (students, and maintenance people for the new equipment) | total number |

## *5.2 Innovation activities and replication indicators*

Next to the KPIs in Table 1, in the project proposal some more qualitative key indicators were formulated to measure and reflect upon the SERENE project's innovation activities and replication potential:

- Increased market penetration;
- Levels of consumer acceptance and engagement;
- Collaboration with relevant target groups;
- New business opportunities and collaborations;

- Degree of novelty;
- Increased turnover and R&D spending;
- Acceptability from energy stakeholders;
- Increased channels and sources to develop innovations;
- Reduced obstacles for commercialization from macro-environmental forces;
- Reduced regulation and legal constraints.

These indicators ask for a different method to measure effects, and for a different approach to measure effectiveness based on actor's opinions (de Bruijn, Coenen, & Lulofs, 1996).

The aspect of changes to the market of energy technologies is an aspect of the SERENE project, because we consider the innovation activities and their replication potential in terms of new business opportunities, commercialization of the innovations and market penetration. However, for local energy system change, we look at a different function of introducing new innovations. In the SERENE project, we draw from the strategic niche management (SNM) approach. Using SNM takes us away from simply looking at a new innovation introduced to an existing market. Instead through the SNM framework we look at innovations in the demo sites as technological niches, which are use case within the demonstrators that are intentionally created and protected to learn about these new technologies (Geels, 2002). Protection can for instance be specific rules created for the innovation (exemption from law) or through subsidies to make the innovations possible or market competitive. The network of incumbent actors and new actors like energy active citizens and local energy communities play an important role here.

## *5.3 Socio-economic impacts*

The second key evaluation question in our assessment asks how social innovations themselves influence the envisioned low-carbon citizen-centered local energy system changes. To address this question, we need to know how far the social aspects of the system have been changed. Most KPIs mentioned in Table 1 are not related to socio-economic changes, and measuring societal change, e.g., the practices of legitimation and results of discourse and debates, cannot easily be translated into KPIs. An alternative is using an energy transition metric. The KPIs in Table 1 are individual measurements that quantify the results in the demonstrator. This does not really give an idea of the larger energy transition. Renewable energy or energy transition indexes are developed and used worldwide. An example are the the International Energy Agency (IEA)'s 'clean energy transition indicators' (Janoska, 2019). The Social readiness level is an indicator for actual readiness and willingness to participate in the green transition (see hereafter). Additionally for SERENE a survey is developed to assess social aspects of system change in terms of opinions on social effects and social benefits (see attachment).

# 6 Effectiveness and strategic niche management

Effectiveness can be described as the degree to which the interventions in the system contribute to achieving the goals of the system change. This implies that a goal may be achieved, even if the intervention itself may be deemed ineffective. Situations like this occur when a goal has indeed been achieved, but the actual measure of achievement (with intervention) is no better than the level of achievement that would have been reached, even in the absence of the interventions. In such cases the intervention is not effective and the goal has been achieved thanks to other factors.

Therefore, a judgement about effectiveness always involves an observation of the degree to which the goals of system change have been achieved, *and* an observation of the contribution made by the interventions. For the latter, setting the actual goal achievement (with intervention in the system) against the achievement in the absence of intervention reveals the intervention's contribution to goal achievement.

## *6.1 Intervention theory*

Intervention or impact theories outline how the technical and social interventions in the system are supposed to lead to the intended system impacts based on a collection of assumptions that underlie the envisioned system change. The theory contains hypotheses about the relation between certain interventions in the local energy system and their effects on the system, including both the achievement of certain goals and the presence of other side-effects. This collection of hypotheses is sometimes called ‘impact model’ (Freeman & Sherwood, 1970, p. 56).

Assumptions can be about how a certain intervention can achieve intermediate and ultimate goals and through which causal chains (cause-effect chains). Many factors influence the degree to which a goal is achieved and thus the relation between the goals and the chosen intervention. If the goals are not achieved after the implementation of the intervention, the question becomes what caused the failure. Were there erroneous assumptions in the intervention theory, and were the interventions in fact inadequate to achieve the goals? Were the interventions inadequately implemented, for instance due to lack of funding, knowledge or support by some actors? Were there relevant circumstances or pre-conditions that were ignored in the assumptions? These and many other explanations are conceivable when a goal is not or only partially achieved.

An intervention theory starts with the problem it addresses. The SERENE project is addressing several trends, ambitions and problems related to the energy transition, such as decentralized energy production from intermittent renewable sources and the multi-carrier energy system integration. Deliverable 3.1 provides more information on these issues and the way they are included in SERENE.

## *6.2 Technology Readiness Level*

The main intention of the SERENE project is to apply innovative technological, environmental, institutional and socio-economic solutions, and schemes to put efficient and reliable integrated community energy systems into practice. More specifically, according to the General Annex G of WP7, which focuses on benchmarking and replication of the innovations, the Technology Readiness Level

(TRL) of the project may be classified as TRL 5-8. The testing of various set-ups on the smart integration of multi-carrier components, its control and coordination and socio-economic schemes in local energy communities in the three demonstrators are applicable within TRL 5-6 - *technology validated/demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)***.** The integration of various cross-sector energy technology solutions and socio-economic-institutional schemes that are demonstrated in the local community energy systems with active consumer and community engagement qualify within the TRL 7 – *system prototype demonstration in operational environment*. The establishment of the active involvement of local energy consumers and stakeholders and the creation of energy communities, their enhanced socio-economic and technical outlook on local energy transition, and development of bench mark solutions and roadmap to standardisation of technical solutions and business models for low-carbon community energy systems is applicable to TRL 8 – *system complete and qualified*. Furthermore, the plan is to apply these demonstrated solutions to TRL 9, *functionally complete system is in place,* within a period of 1-5 years from the end of the project.

## 6.3 Social Readiness level

Societal Readiness Level (SRL) is a way of assessing the level of societal adaptation (Wullum Nielsen et. al. 2018). In case of the SERENE project the technological, environmental, institutional and socio-economic solutions, and schemes to put efficient of. If the societal readiness for the social or technical solution is expected to be low, suggestions for a realistic transition towards societal adaptation are required. Naturally, the lower the societal adaptation is, the better the plan for transition must be. SRL 1 is the lowest and SRL 9 is the highest level. Levels SRL 1 – identifying problem and identifying societal readiness SRL 2 – formulation of problem, proposed solution(s) and potential impact, expected societal readiness; identifying relevant stakeholders for the project. SRL 3 – initial testing of proposed solution(s) together with relevant stakeholders SRL 4 – problem validated through pilot testing in relevant environment to substantiate proposed impact and societal readiness SRL 5 – proposed solution(s) validated, now by relevant stakeholders in the area SRL 6 – solution(s) demonstrated in relevant environment and in co-operation with relevant stakeholders to gain initial feedback on potential impact SRL 7 – refinement of project and/or solution and, if needed, retesting in relevant environment with relevant stakeholders SRL 8 – proposed solution(s) as well as a plan for societal adaptation complete and qualified SRL 9 – actual project solution(s) proven in relevant environment Stages SRL 1-3 reflect the early work in a research project, which is not so relevant for the SERENE project. For SERENE the stages SRL 4-6, representing actual solution(s) and testing them in the demo and use case context in co-operation with relevant stakeholders, while keeping a focus on impact and society's readiness for the product, is more relevant. In these stages for the SERENE innovations expectations on the societal adaptation must be described in specific terms and, to the extent possible, be part of the test phase. The stages SRL 7-9, that relate more to the end stages of a research project, includes refining the solution(s), implementation and dissemination of results and/or solution(s), is also relevant for some innovations in the SERENE project. Here the plan for addressing the societal readiness on a practical level to gain impact, creating awareness, disseminating results, etc., will be carried out

## 6.4 Strategic niche management as intervention theory in the demonstrators

The intervention theory for change in the local energy systems in SERENE is inspired by the mechanism of change through local niches and local experiments in the theory of strategic niche management

(SNM). Schot, Slob, and Hoogma (1996) define SNM as learning about niches and developing the application rate of technologies through the creation, development and controlled phase out of protected spaces. It is thus about the development of niche innovations. We have chosen to use the SNM approach to study underlying processes of the innovations in the local energy system driving system change. For the SERENE project, SNM is relevant to explore how niches are best supported and can develop to become a part of the regime, i.e., the local energy system in the demonstrators (Temmes, Räsänen, Rinkinen, & Lovio, 2013).

We see the technical and social innovation in the demonstrator sites as ’experiments’ and niches in the regime of the local energy system. We are careful here to suggest that that experiments and niches in the demonstrator alone, although necessary, would be enough to induce a transition (Rip & Kemp, 1998, Hoogma, Kemp, Schot, & Truffer, 2002). In deliverable 3.1, we used the concept of local energy system change. In principle, a local energy system change is a transition, but the system change we are particular studying here spans a shorter project period in which we cannot see a full transition of the whole system. This full transition is still the background, depending on which phase the demonstrator transition is in (Loorbach and Rotmans, 2010) (see before fig 1). We do not expect to see the full development of niche regimes within the project time span, although this depends on the demonstrators.

In the SNM literature, technological niches are intentionally created protected spaces for learning about new technologies (Geels, 2002). This learning aspect fits very well in the SERENE project. Within the short time span of the project, the role of niches as an important tool for transition can only be studied to a limited extent, focusing on in how far experimentation with niche innovations influences the local energy system. Accordingly, in SERENE, we only focus on the first three of the four stages of regime transition within SNM, as described by Kemp, Schot, and Hoogma (1998): (1) the selection of an experiment, (2) the set-up of the experiment, (3) scaling up the of the experiment, and (4) breakdown of the protection of the experiment (the more the experiments mature, the less of protection in terms of subsidies an specific regulation they will need, which will only limited happed within the SERENE project timeframe). So for instance, if we experiment with subsidized heat pumps in the project, the subsidies is there during the project and we will not scale up to new experiments without subsidy (stage 4).

Geels and Raven (2006) have conceptualized how experiments and niches relate and develop over longer periods of time. They make a distinction between local experiments and a ‘global’ niche, and outline different forms of learning for different actors. Local niche development in this distinction relates to experimentation in local contexts supported by local networks and generating locally applicable lessons. This is where most of our evaluation work in the demonstrators lies. The so-called ‘global’ niche refers to a network of actors that is concerned with knowledge exchange transcending local contexts and interacting with the wider world (Geels & Raven, 2006). Here, actors outside of the demonstrator sites, such as industry platforms, user-groups and other intermediary organizations play a role (Grin, Rotmans, & Schot, 2010). The BRIDGE initiative can play such a role in the SERENE project.

With regards to learning processes, we take a somewhat limited perspective of leaning from the innovations for other settings and for actors outside of the demonstrator sites. WP7 will investigate the replication and scale-up possibilities of the SERENE innovation activities for the creation of benchmark models and innovation pathways.

The main goal of the SERENE project is to apply innovative technological, environmental, institutional and socio-economic solutions, and schemes for efficient and reliable integrated community energy systems. These innovations should also be citizen-centered and economically viable. In this sense, project viability goes beyond economic considerations to include criteria of social-acceptance, democracy, benefit sharing and energy security. We introduced these and other criteria in deliverable 3.1. As discussed above, given the short project time span, the question if the niches lead to viable competing socio-technical practice might be difficult to answer, as we can only study experiments in relation to short-term changes in the regime and landscape levels. Therefore, we ask in how far experiments are designed and supported by regime insiders or outsiders, in how far the niches were intentionally shaped by an intervention program and by whom, and in how far the new interventions are a break with the past.

Kemp et al. (1998) distinguished three steps in niche forming: (1) aligning expectations, (2) learning through sharing information and lessons learnt, and (3) forming networks. An important aspect of the idea of using local experimentation in SNM is the role of expectations and visions (Raven et.al., 2016). Niches show the possibilities of doing things differently than in the existing regime, in our case related to the switch from fossil fuels to RES. Articulating expectations reduces uncertainty in the innovation process (Schot & Geels, 2007, 2008). The vision allows mobilization of resources by other actors by providing them promises about future benefits (Geels and Schot, 2007). However, these niches will not bring about a radical change in the regime in the short term of three years.

Besides expectations and visions, another crucial element for niche development are networks (Raven, Bos & Weterings, 2010). Experimentation also aims to align the expectations of different actors in the system. In niche experimentation, social networks are considered important because the actors in the network provide necessary resources to sustain niche development. Further, actors in the network are important for the formulation of requirements and demands. Networks are also important for enabling learning and diffusion of lessons and experiences between network actors. Such networks might additionally include actors related to the larger regime, who might even be necessary in terms of resources and support. However, networks dominated by regime actors might lead to incumbent actors blocking the niche development.

The demonstrator sites provide the necessary protection for niche innovation. Although SERENE is ultimately looking for economically viable innovations, future profits or social benefits might still be uncertain early in the project. Unless actors want to invest in technological innovation without any direct commercial benefits, financial protection and support is important to facilitate investments in early applications. Eventually, however, innovations need to be selectively exposed to market pressures (Kemp et al., 2001). An innovation should not remain unnecessarily long in place if it shows that it lacks social acceptability and economic feasibility.

To summarize, a basic assumption in the intervention theory is that experimentation with niche innovation within an intentionally created protected space is a crucial step in maturing innovations. We can test this assumption in the demonstrator sites. The niche innovations have the inherent element of showing that things can be done differently. Experimentation is a way to help articulate and change expectations of actors of the benefits to expect from the innovations. Protected spaces are important because the existing regimes would otherwise reject those innovations as economically not viable or not socially acceptable, and prevent the innovations from becoming mature. What we cannot do in the

SERENE project, given the time span, is to see whether the current regime will be broken and replaced by a niche regime.

We use the SNM theory as inspiration for a number of evaluation questions:

- Who started the technological or social innovation initiative?
- Which actors are included in the network surrounding the innovation?
- In how far are the experiments designed and supported by regime insiders and or outsiders?
- In how far were the niches intentionally shaped by a policy program, and by whom?
- What kind of protections for the experiments are being used?
- How mature are the technological innovations in terms of their TRL level?
- How did the regime and landscape dynamics of the demo sites influence the experimentation?
- What was the role of expectations and visions in the initiative?
- In how far is the innovation a break with past practices?
- How ready are the demonstration site for the technical innovation (SRL)?
- Which limitations or obstacles influence the innovations?
- What is needed to make the innovations a success?

# 7 Evaluation methods

Determining causation and attribution of social system change and the role social factors play in technical system change is difficult due to the complexity of human systems and the interactions of social variables. Given that there are no evaluation methods specifically suited to address social aspects of socio-technical system change, we follow a mixed-method approach. Key to our approach is the idea of a systemic evaluation (Hargreaves, 2010), bringing together different evaluation criteria and methods.

As mentioned in section 1, we use quantitative and qualitative evaluation methods. Quantitative research is mainly concerned with a (quasi-)experimental research design with measurements made both in advance and ex-post, using quantitative indicators. Qualitative research is more concerned with qualitative descriptions of the situation prior to the introduction of the interventions, how the interventions are implemented, and the situation thereafter. It focuses on how the interventions (innovations) function and how they are viewed by different actors.

## *7.1 Quantitative goal achievement*

Goals are about effects we want to attain. Parts of the social change of the local socio-technical energy system can be quantitatively measured, particularly the KPIs and socio-economic change effects. Other effects, such as the 'level of energy discourse,' are more difficult to quantify, other than in terms of the share of the population that gained new insights. In order to measure quantitative goal achievement, we need to compare the baseline situation prior to the intervention, the envisioned situation in the future, and the achieved situation at the end of the relevant evaluation period.

The situation prior to the intervention can be described on the basis of the baseline survey, and compared with a description of the situation at the end of the evaluation period.

The population survey is aimed at the population of the demonstrator sites. Part of the wider community serve as control group. The survey in the demo sites is also conducted in other parts of the municipality of the demo sites. Because the population of the demo sites is rather small this also gives us a better idea of how people in the different country and specifically in the demo site municipalities think about energy and climate, their priorities and their energy related behaviour. The goal of the survey is to collect data on economic and political attitudes towards local, clean, and security of energy and to gather demographic data as background information. The survey will be repeated at the end of the project to see if attitudes and other socio-economic variables have been changed.

Survey questions focus on the following topics:

- Basic demographic questions (age, gender, occupation, place of residence, income);
- Housing situation (type of house, neighborhood);
- Questions related to energy use, energy carriers, application use, house heating, commuting to work, etc.;
- Prosumer situation;
- Political view and citizen or community organization membership;

- Energy themes discussed with neighbors; and the municipality
- Attitudes towards energy and climate issues.

## 7.2 *Qualitative goal achievement*

While quantitative goals are measurable and specific objectives, qualitative goals are generally subjective and non-measurable. They are more about progress in a certain direction, e.g., for the local community to move in a certain way and get all local actors involved. We plan to conduct interviews with project participants who are currently residing or will be residing in the demonstrator sites in the three countries in order to collect qualitative data that would complement the survey data, which is described above.

## 7.3 *Quantitative effectiveness*

An intervention is effective only insofar as it is actually responsible for the goal achievement. There may be other explanations for the degree to which the goals have been achieved besides the intervention, and these offer alternative, rival explanations. Such rival explanations can be ruled out by selecting a suitable research design.

We previously discussed the rationalist methodology of evaluation research based on a causal explanatory model. The core of rationalist, ex-post evaluation research is the explanation of why certain effects do or do not occur, as assumed in the impact theory. This method investigates certain effects as they do (or do not) occur and looks at whether they are caused (or not caused) by the interventions. The method attempts to draw the probabilistically best conclusions about these sorts of relations, e.g., it has been shown, with 90% probability, that intervention X has caused effect Y.

Comparing the state at the beginning and the end of the project period, I.e., a 'before and after' research design, allows us to be more objective about the system changes than with post-facto measurements only. However, this research design cannot determine whether the change can be ascribed to the interventions or to some other explanation, i.e., it cannot establish causality. Any statement about causality between a cause A (system innovation) and an effect B (system change) must meet several conditions. First, cause A must precede effect B in time. Second, cause and effect must be related. In other words, A and B must be covariable. And third, there must be no other explanation than the posited cause-effect relation. We must be able to establish that B is caused by A and by no other plausible cause. If we only use a before-and-after research design, there may be rival explanations for the system changes, such as:

- *Other events*: Maybe it was a very sunny year, so more solar energy was produced instead of more PV panels installed.
- *Independent development*: Maybe the number of PV panels installed has been growing for years. The growth during the research period might be part of this development.
- *Normal variations*: The year-on-year figures may fluctuate to such a degree that results are just a coincidence.

One way of ruling out these alternative explanations is looking at time-series observations, which allows us to make more confident statements than those based on individual observations alone. We can also distinguish between an abrupt introduction of an intervention and a gradual implementation.

Another way to gain greater certainty about whether the system intervention is responsible for the observed changes is to compare the group being investigated to a control group that has not been exposed to the intervention (experimental design). The probability of other events is reduced since these must have happened in both the experiment group and the control group. For instance, if a graph shows a declining trend in all geographical areas, but the decline is steeper in the experiment group, this effect is likely due to the intervention. In the demonstrator sites, we can use the technological niches. The experimentation in the niches can be compared with other places within the same local energy system and regime, but where energy generation takes place in a different way.

While this quasi-experimental research design can catch a number of factors influencing the validity of the causal explanation, there are also threats to the validity that cannot be caught. This includes the imitation of intervention effects as unrelated measures are adopted in the control group that result in similar effects, the rivalry between geographical areas or communities, where another area or community does not want to lose out to the experimental area and thus proceeds to implement its own measures, and the demoralisation among those who do not participate in the demonstrator site study (Cook & Campbell, 1976). So some inhabitants might get access to demand control schemes and subsidised heat pumps or energy storage facilities and others not.

## *7.4 Qualitative effectiveness analyses*

In qualitative approaches to effectiveness, we deal with the assumptions of the impact theory differently, making use of a subjective form of probability. Rather than using time series or experiments with control situations, we try to exclude rival explanations by means of qualitative descriptions of the situation prior to the introduction of the interventions, of how the interventions are implemented, and of the situation thereafter. This approach is more concerned with understanding how the interventions function and how they are viewed by different actors, including questions on the demonstrator sites like: What is the local energy system comprised of (activities, structures, processes)? Who is in the system? What role do different actors have in the system? How do members of the system interact? How do actors communicate within the system? Which external forces influence the system?

We apply Scriven's *modus operandi method* (Scriven, 1976) as a specific qualitative effectiveness analysis method to supplement the quasi-experimental design in quantitative evaluation. In general terms, the goal of the modus operandi method is to identify the cause (or causes) X of phenomenon Y.

Consider, for example, a car that does not start on a cold, winter morning. Sometimes we can find the cause of Y – the car not starting – by testing for the presence of causes X1 and X2. Suppose you know that the car not starting is nearly always caused by a problem with the fuel supply or the electricity supply. If you can verify that the high-tension supply is functional, e.g., by making a measurement at the spark plugs, then the only remaining reason is a problem with the fuel supply. The reasoning here is: nearly every Y (engine not starting) is caused by X1 (no fuel supply) or X2 (no voltage supply). Y occurs, with X1 present and X2 not present. Ergo, X1 (probably) causes effect Y in this situation. It is important to note that this is a probable cause, we do not in fact know whether our summary of causes is exhaustive, and it might be difficult to reliably measure the presence of all possible causes.

But it might well seem that several causes are occurring simultaneously. It is not necessary to find one single cause for the social effects, it is about the principle of sorting out what is an influence and what is not an influence in the demonstration sites, Even if it is a combination of a lot of factors, this is not a problem in demos. It is the principle about how to trace the effects. For instance in the above example, both the voltage supply and the fuel supply form a causal chain between cause and ultimate effect. The fuel supply, for example, may consist of no fuel, a blocked fuel supply line, a defective fuel pump, and a defective carburettor. Each of these factors can, on its own, offer a rival explanation for the effect 'no fuel supply'. The way the mechanic works is to conduct a systematic check to see if one of these factors is present. This means that they trace the causal path from the factor to the explanation. Some factors are associated with specific characteristics, e.g., a warning lamp indicating an empty fuel tank, that one can use to verify their presence.

The mechanic in this example is following the modus operandi method. Point-for-point, one can represent the method as follows:

1) What are the possible explanations Xi for phenomenon Y?

2) Which of these factors, which could supply explanations Xi, are (were) present?

3) Which characteristic properties display the causal path leading from Xi (where present) to Y?

4) Which characteristics of which Xi are (were) present, and to what degree?

The qualitative and intuitive aspects of this method are contained in the first step.

In order to identify factors that can lead to rival explanations in the SERENE project, we can use the insights on socio-economic, governance and regulatory factors developed in deliverable 3.1. Additionally, we will conduct interviews with stakeholders that can help identify other rival explanations.

## *7.5 Explaining success and failure*

Finally, we want to be able to explain the degree of effectiveness of interventions, which can also be seen as their success or failure within the pre-defined goals. We previously discussed impact theories that include assumptions underlying the results or impacts of the interventions. If these assumptions are incorrect, i.e., when the selected interventions are not appropriate to achieve the goals, the interventions can fail. However, we need to systematically describe and analyse the niche development of the intervention to establish whether explanation for failure could also be found in the way in which the selected innovations were implemented or operated in the field.

# 8 Framework

In deliverable 3.1 we discussed transition management. Transition management is about long term processes. We have seen in section 2 that the demonstrators are in particular phases of transition (Loorbach, 2010). In the SERENE project, we are focusing on a short period and relative short term changes in the demonstrator sites. We are not doing a policy (program) evaluation or are evaluating one (singled out) innovation, but instead, we are focusing on the interconnected components of system interventions in the local energy systems in the demonstrator sites. The key to our approach is the idea of a systemic evaluation, bringing different evaluation criteria and methods together, and the evaluation of niche innovations as the explanation steps, as part of an intervention theory, in the whole evaluation of success and failure of local energy system changes.

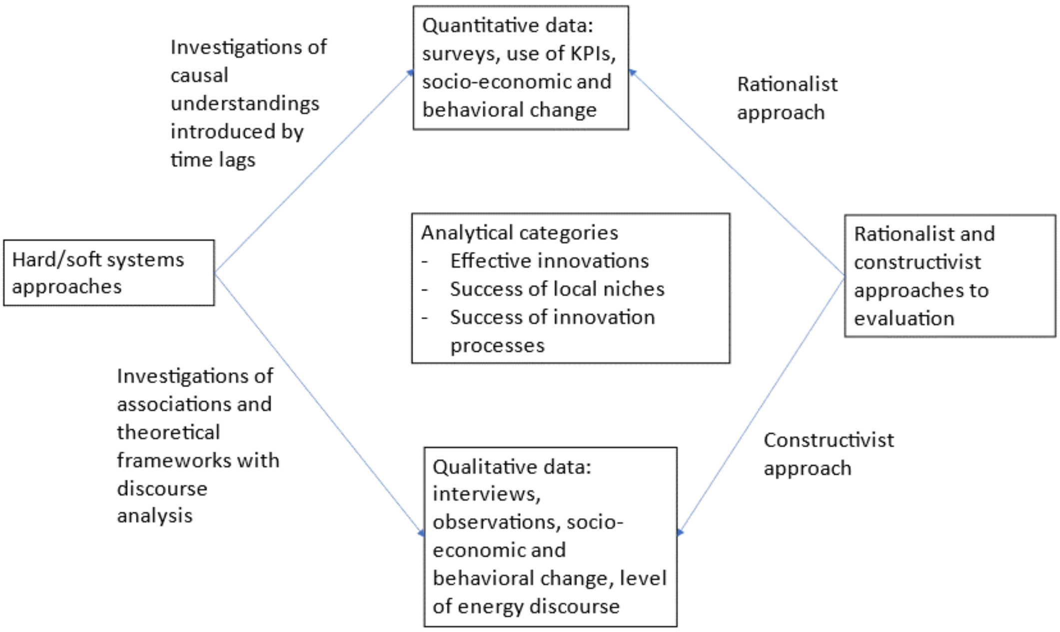


Figure 2 Evaluation framework

This evaluation framework provides an overall framework for the set-up of evaluations and monitoring of the social-economic changes in the demonstrators across the different technical and social innovations which are the interventions in the system. In the previous sections we discussed data sources, methods and intervention processes. For the evaluation of the intervention processes we presented the strategic niche management theory as the overall program theory/logic model and principles to guide the conduct of evaluations.

The analytical categories we study in the demo sites are the effectiveness of the innovations and the success of the innovation processes and of the local niches. The (technical) innovations in the demo sites are about improving or replacing fossil fuel technologies, for example by a new process, a product, or a service. Part of the new processes or new services might be a new social organisational structure. This innovation might be effective or not. By introducing innovations in the demo sites it is also about the success of the innovation process in terms of technical and social readiness level. A niche or niche innovation is more than the innovation as such. The niche is about investigating the experimental introduction within a sociotechnical system of sustainable technologies using societal experiments (e.g. pilot and demonstration projects). In the niches we do not just try to understand if the innovations were effective, but because they are created and nurtured in the demo sites we also try to understand the success of support structure, the interactions among the elements of the socioeconomic system and the barriers for the introduction and the potential for upscaling and creating a wider local energy transition.

Starting point for the difference in evaluation approaches of local energy systems and innovations is the idea of hard and soft systems change rationality. Hard systems thinkers look for concrete problems and solutions for definable systems. While the soft system approach recognizes that people have their own perspectives of a given system, and that it is about understanding unclearly defined problems. The hard system approach matches with a more rationalist ex-post evaluation with as core the explanation of why certain effects do or do not occur, as assumed in the intervention or impact theory. This also presumes that we can work with causal understandings.

The soft system approach matches with a more hermeneutic methodology, which seeks an alternative to the causal explanatory model and focuses on ‘understanding’ rather than ‘explanation’ of factors underlying the occurrence of the effects of the system change activities. This about multiple interventions, associations and discourse analysis instead of constructing causal pathways.

In the SERENE project we use a range of methods and both quantitative and qualitative data to evaluate energy system change. The quantitative data fits more with the hard system, causal understanding part of the (single intervention focus) evaluation. And the qualitative data with the soft system, hermeneutic understanding part of the (multiple factor associated interventions) evaluation.

For every demonstrator site in the SERENE project we need to operationalize the overall framework to the context and particular situation. The technological and social innovations are mentioned in deliverables 3.2 and the technological innovations will be further explained in deliverables 2.1 of the project. Apart from the technological and social innovations as singled out interventions and multiple interventions in the demonstrator sites we are also looking for the overall system change. For every Demonstrator site we will follow these steps (partly in WP3 and for the rest in WP4, 5 and 6);

Step 1 Describe the context of the technical and social expected innovations in the demonstrator site in the base line survey and the actual context in the final survey.

Step 2 Make an inventory of the logic of the innovations and the impact they aim for.

Step 3 Determine goal achievement in the demonstrator site in terms of social-economic effects (KPI’s).

Step 4 Determine socio-economic system changes, including changes in discussions and discourses on energy and climate and changes by individual citizens (energy behavior).

Step 5 Determine the innovation level in the demonstrator site on the basis of qualitative key indicators for innovation activities and replication potential.

Step 6 Analyze in how far the social factors contributed to technical innovations change the local energy system in the demonstrators.

Step 7 Analyze in how far the social innovations contribute to the local energy system changes.

Per demo sites these steps will be more operationalised in workshops with the partners in the demo sites and fitted to the partner expectations.

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# Attachment Serene Base Survey

Start of Block: Block 1

**Introduction**

Title of Research Study: Building a Low Carbon, Climate Resilient Future: Secure, clean and efficient energy.

Investigator Names: Name of the University

What am I being asked to do?
You are being asked to participate in a research project that will survey you about your economic and political attitudes towards local, clean, and security energy. This project is funded by the European Commission under the Horizon 2020. You will first report on your demographic information, then the questions will focus on your energy use and related concerns.

The survey has 70 questions and takes about 60 minutes. To participate in this study, you must

also meet the following criteria:
1. You are 18 years old or older.
2. You have not taken this survey before.
3. You have agreed to participate in this research project.

What are the potential risks and benefits of participation?

There are no risks associated with participation in this study. There are no direct benefits associated with participation in this study.

What about privacy and confidentiality?
Because we do not ask for your name or other information that might uniquely identify you, the responses you provide can never be traced specifically to you. You will be identifiable using an ID number, not your personally identifiable information (also known as PII).

Voluntary participation and withdrawal

Your participation in this study is completely voluntary. If you agree to be in the study, you may stop at any time. You may stop by exiting this web page or by simply closing your web browser. You may also skip any questions you do not want to answer.

Who should I contact if I have questions?
If you have any questions, please feel free to contact the researchers, dr. Dasom Lee (email: d.lee@utwente.nl, phone: +31 53 489 7841). If you have any questions about your rights as a human subject in this research, you may contact the??? . We encourage you to print this consent form out for your records. By signing, at the bottom of this page, you are agreeing to participate in this survey, and you will be taken to the beginning of the survey.

*[block to sign agreement to take part in the survey]*

End of Block: Block 1

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Start of Block: Demographic Questions

**Q1 What is your age?**

- ○ 18-30 (If you are under 18, stop. You should not take the survey)
- ○ 31-40
- ○ 41-50
- ○ 51-60
- ○ 61-70
- ○ Over 70

---

**Q2 What is your gender?**

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

---

**Q3 Which city and country were you born in? Please specify.**

________________________________________________________________

---

**Q4 What is your occupation? Please specify.**

________________________________________________________________

**Q5 How much of your work is done at home?**

- 0%
- 1-20%
- 21-40%
- 41-60%
- 61-80%
- 81-100%

**Q6 How far do you commute to your work when not working at home?**

- 0-5km
- 6-30km
- Longer than 30 km
- I always work at home.

**Q7 What method of transportation do you use to commute? Choose all that apply.**

- ☐ Private vehicle
- ☐ Bus
- ☐ Tram/Subway
- ☐ Train
- ☐ Walk
- ☐ Bicycle
- ☐ More than one or other. Please specify.

________________________________________________

**Q8 If you perform at least some of your work at home, do you have any specific facilities or equipment that you use at home for work?**

- ◯ Yes
- ◯ No
- ◯ I don't know

---

**Q8-1 Is your work equipment in…**

- ◯ Your own private property (own yard, apartment, storage unit, etc.)
- ◯ Your neighborhood's or apartment block's common spaces (roof, entrance, parking, corridor, etc.)
- ◯ In public municipal spaces (street, sidewalk, etc.)
- ◯ I don't have any equipments
- ◯ Other. Please specify. ________________________________________________

**Q8-1 If you said yes to the above question, what facility or equipment do you use at home for work?**

___________________________________________________________________________

**Q9 What is your individual annual gross income?**

- ◯ Less than €10,000
- ◯ €10,000 - €20,000
- ◯ €20,000 - €30,000
- ◯ €30,000 - €40,000
- ◯ €40,000 - €50,000
- ◯ €50,000 - €100,000
- ◯ €100,000 - €200,000
- ◯ €200,000 or more

**Q10 How would you describe your political views?**

- ◯ Christian democrats
- ◯ Social democrat
- ◯ Liberals
- ◯ Greens
- ◯ Conservatives

**Q11 What type of house do you live in?**

- ◯ Apartments
- ◯ Semi Detached houses
- ◯ Detached houses
- ◯ Terraced houses
- ◯ Other. Please specify. ________________________________________________

---

**Q12 How would you characterize the area where you currently live?**

- ◯ Rural
- ◯ Suburbs
- ◯ City (urban)
- ◯ Small town
- ◯ Other. Please specify. ________________________________________________

---

**Q13 Are you a member of any citizen or community organization(s)? (select one or more options)**

- ☐ Local—building
- ☐ Local—neighborhood
- ☐ Municipal
- ☐ Regional
- ☐ National/international
- ☐ Not a member

---

**Q14 What energy matters are discussed commonly with your neighbours? (select one or more options)**

- ☐ Related to my home’s private spaces
- ☐ Related to my neighborhood’s or building’s common spaces
- ☐ Related to public municipal spaces
- ☐ None

---

**Q15 How are energy matters discussed with your neighbours? (select one or more options)**

- ☐ Informally
- ☐ Housing committee
- ☐ Neighborhood association
- ☐ Not discussed

---

**Q17 How would you characterise the natural environment around your immediate neighbourhood?**

- ○ Substantial presence: abundant green and water elements
- ○ Moderate: a few trees or other green and water spaces
- ○ Minimal: mostly non-natural elements

End of Block: Demographic Questions

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Start of Block: Household Questions

**Q18 How many people are earning in your household?**

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6 or more

---

**Q19 What is your household income?**

- ◯ Less than €10,000
- ◯ €10,000 - €20,000
- ◯ €20,000 - €30,000
- ◯ €30,000 - €40,000
- ◯ €40,000 - €50,000
- ◯ €50,000 - €100,000
- ◯ €100,000 - €200,000
- ◯ €200,000 or more

---

**Q20 Do you receive any welfare from the government related to income?**

- ◯ Yes
- ◯ No
- ◯ I don't know

---

**Q20-1 If you answered yes to the above question, how much do you receive per month?**

____________________________________________________________

---

**Q21 How large is your house in square meters? (Excluding outdoor space such as gardens, balconies etc.) If you are more familiar with cubic meters, you can write it in cubic meters too. Make sure you specify the unit.**

____________________________________________________________

**Q22 When was your home constructed?**

- ◯ Before 1900
- ◯ Between 1900 - 1950
- ◯ Between 1951 - 1970
- ◯ 1970s
- ◯ 1980s
- ◯ 1990s
- ◯ 2000-2010
- ◯ After 2010

**Q23 Do you own or rent your house/apartment?**

- ◯ Own
- ◯ Rent
- ◯ Other arrangement. Please specify. ____________________________________________________

**Q24 How many people are residing in your house/apartment (your apartment unit, not the whole building)?**

______________________________________________________________________

**Q25 How many of those people are minors (under the age of 18)?**

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ More than 7

---

**Q26 How many of those are under the age of 5?**

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ More than 7

**Q27 Please list the age of all household members (age in number of years).**

____________________________________________________________

**Q28 Did the number of household members change in the last two years?**

- ◯ Yes, increased with more than two
- ◯ Yes, increased with two
- ◯ Yes, increased with one
- ◯ No
- ◯ Yes, decreased with one
- ◯ Yes, decreased with two
- ◯ Yes, decreased with more than two

**Q29 What is the gender division of the household members?**

- ◯ Male only
- ◯ Not male only, but male majority (e.g., two male, one female)
- ◯ Gender balance (e.g., one male, one female)
- ◯ Not female only, but female majority (e.g., two female, one male)
- ◯ Female only
- ◯ Other. Please specify. ____________________________________________

**Q30 What is your house's energy label?**

- ○ A
- ○ B
- ○ C
- ○ D
- ○ E
- ○ F
- ○ G
- ○ I don't know

**Q31 Click to write the question text**

- ○ Click to write Choice 1
- ○ Click to write Choice 2
- ○ Click to write Choice 3

**Q32 What is the primary energy carrier you use at home?**

○ Electrons (electricity)

○ Natural gas

○ Biomethane (green gas)

○ Oil

○ Solid fuels

○ Coal

○ Lignite

○ Wood

○ Biomass

○ Solar

○ Wind

○ I don't know

○ Other. Please specify. ____________________________________________

**Q33 What is the heating system in your house?**

- ◯ Electrons (Electricity)
- ◯ Natural Gas
- ◯ Biomethane (green gas)
- ◯ Oil
- ◯ Solid Fuels
- ◯ Coal
- ◯ Lignite
- ◯ Wood
- ◯ Biomass
- ◯ Solar
- ◯ Wind
- ◯ I don't know
- ◯ Other. Please specify. ________________________________________________

**Q34 Check all the appliances that you own.**

- ☐ Air conditioner
- ☐ Air fryer (convection oven)
- ☐ Blender
- ☐ Clothes dryer
- ☐ Clothes iron
- ☐ Coffee maker
- ☐ Dehumidifier
- ☐ Deep fryer
- ☐ Dish washer
- ☐ Electric blanket
- ☐ Electric water boiler
- ☐ Electric heater
- ☐ Food processor
- ☐ Kitchen hood
- ☐ Garbage disposer
- ☐ Fan (attic, ceiling, fan heater, window)
- ☐ Freezer (not refrigerator, freezer on its own)
- ☐ Hair dryer

- ☐ Humidifier
- ☐ Juicer
- ☐ Laptops/Desktops
- ☐ Lawn mower
- ☐ Microwave
- ☐ Oven
- ☐ Refrigerator
- ☐ Sewing machine
- ☐ Slow cooker
- ☐ Stove
- ☐ Television set
- ☐ Vacuum cleaner
- ☐ Washing machine

**Q35 Check all the appliances that you use frequently (more than 1-2 times a month).**

- ☐ Air conditioner
- ☐ Air fryer (convection oven)
- ☐ Blender
- ☐ Clothes dryer
- ☐ Clothes iron
- ☐ Coffee maker
- ☐ Dehumidifier
- ☐ Deep fryer
- ☐ Dish washer
- ☐ Electric blanket
- ☐ Electric water boiler
- ☐ Electric heater
- ☐ Food processor
- ☐ Kitchen hood
- ☐ Garbage disposer
- ☐ Fan (attic, ceiling, fan heater, window)
- ☐ Freezer (not refrigerator, freezer on its own)
- ☐ Hair dryer

- ☐ Humidifier
- ☐ Juicer
- ☐ Laptops/Desktops
- ☐ Lawn mower
- ☐ Microwave
- ☐ Oven
- ☐ Refrigerator
- ☐ Sewing machine
- ☐ Slow cooker
- ☐ Stove
- ☐ Television set
- ☐ Vacuum cleaner
- ☐ Washing machine

---

**Q36 How much electricity does your household use per month? (in kWh)**

________________________________________________

---

**Q37 How much do you pay for electricity per month?**

________________________________________________

**Q38 How many vehicles does your family own?**

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more

**Q38-1 Of the vehicles that your family owns, how many of them are electric vehicles (excluding hybrid vehicles)?**

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more

**Q38-2 Of the vehicles that your family owns, how many of them are hybrid vehicles (excluding electric vehicles)?**

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 or more

**Q38-3 Please list the year and brand of all your vehicles. (e.g., 2015; Volkswagen)**

________________________________________________________________

**Q39 Do you have solar panels installed and currently in use in your house?**

- ◯ Yes
- ◯ No
- ◯ I don't know

**Q39-1 If you said yes to owning solar panels, what is the system size of your solar panels? (in kW)**

________________________________________________________________

**Q40 Do you own any renewable energy generators other than solar panels? Please specify.**

________________________________________________________________

**Q40-1 If you said yes to the two previous questions, was it difficult to interact with your municipality to issue a permit and have them installed?**

○ Easy

○ Moderate

○ Difficult

○ Did not have to interact

**Q41 Specify the people's gender and age that are currently living in your house. (This is a validity check question – compare answers with the previous questions on age and gender to check for validity.)**

________________________________________________________________

End of Block: Household Questions

Start of Block: Behavior Questions

**Q42 I view myself capable of realizing intended energy saving targets.**

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly Agree

**Q43 I have the intention to significantly lower my energy consumption.**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

---

**Q44 I have the intention to only use locally produced energy.**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

---

**Q45 I have the intention to improve energy efficiency in my household.**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

---

**Q46 How much more are you willing to pay for locally produced energy from renewable sources compared to conventional energy pricing?**

- ◯ 1 - 5%
- ◯ 5 - 10%
- ◯ 10 - 15%
- ◯ More than 15%
- ◯ No intention to pay more

---

**Q47 Without any financial compensation, I am prepared to slightly adjust my behavior in order to make better use of locally and sustainably produced electricity.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

---

**Q48 If it saves me a few tens of euros per year, I am prepared to slightly adjust my behavior in order to make better use of locally and sustainably produced electricity.**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

End of Block: Behavior Questions

---

Start of Block: Opinions about Energy and Climate

**Q49 Production of renewable energy is important.**

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

---

**Q50 Lower energy price is more important to me than sustainable energy.**

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

---

**Q51 Environmental issues matter to me.**

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

**Q52 I support the use and development of nuclear energy.**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

**Q53 Global climate change is important. It needs to be addressed**

- ○ Strongly disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

**Q54 Local communities can organize themselves best.**

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly Agree

---

**Q55 I do not trust large scale traditional energy companies.**

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly Agree

---

**Q56 National government policy mainly supports traditional (centralized) energy systems.**

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly Agree

**Q57 Saving energy is an important value in my family and friends.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

**Q58 Generating one's own energy locally is an important value in my family and across my friends.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

**Q59 The climate changes in my immediate surroundings (i.e., my home or my neighborhood) is an important factor for me in making energy related decisions.**

- ◯ Yes, heatwaves
- ◯ Yes, cold spells
- ◯ Yes, both heatwaves and cold spells
- ◯ No
- ◯ I don't know

**Q60 My personal health improves if the energy system becomes more sustainable.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

**Q61 If it saves me a few hundreds of euros per year, I am prepared to slightly adjust my behavior in order to make better use of locally and sustainably produced electricity.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

---

**Q62 I like to participate in a common project together with the neighborhood to save electricity.**

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

End of Block: Opinions about Energy and Climate

---

Start of Block: Comments

**Q63 Thank you for completing the survey. If you would like to add any comments or questions regarding the survey or the Serene project, please write here.**

End of Block: Comments