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1 Executive Summary

The deliverable presents the details of the essential conditions for achieving socio-economic development and citizen engagement in more autarkic energy systems, and specifically for establishing new organizational configuration for the demonstrator sites. It's verified based on clearly mapping the necessary socioeconomic, regulatory and governance settings for creating local energy communities (source: SUSTENANCE Grant Agreement). This report accomplishes its objective by adapting and applying a four-step environmental design framework. The framework translates conceptual aims of self-sufficient energy communities (derived from the obstacles and limitations identified in deliverable 3.1) into operationalizable design solutions for each demonstrator site (combining social solutions with the technical interventions described in deliverable 2.1). The organisation of socio-technical design solutions follows the typology of autarkic energy communities that is described in deliverable 3.3.

The report is structured as follows. Chapter two introduces an environmental design framework for moving from obstacles (D3.1) to conditions (this D3.2) and for translating the planned interventions of SUSTENANCE (D2.1) into community design solutions (this D3.2). Chapter three reviews available knowledge about community autarky primarily from a socio-spatial perspective. Chapter four briefly describes the Danish, Dutch, Indian, and Polish demonstrators based on the findings of D2.1 and D3.1 and applies the environmental design framework to delineate community design solutions for the socioeconomic, organisational, and citizen engagement development of the demonstrators. Chapter five attempts a summary and synthesis of the recommendations.

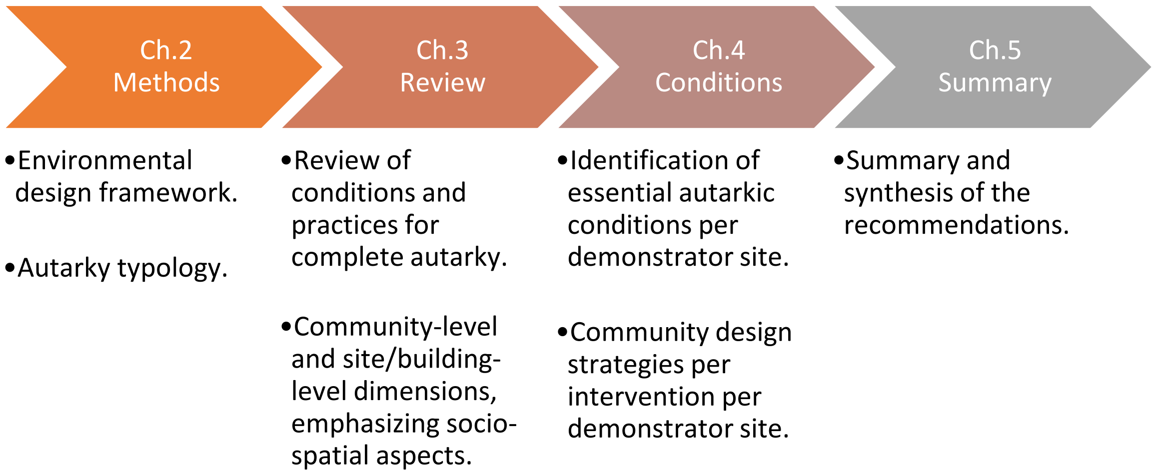

Figure 1.1: Report structure

2 Introduction: Translating obstacles into essential conditions

This section introduces a four-step environmental design framework to move from conceptual solutions into concrete design interventions. The framework aims to combine the obstacles identified in D3.1, interventions described in D2.1, and the literature review in D3.2 and D3.3, in order to discuss what else needs to be in place for socioeconomic and organisational development and citizen engagement in the demo sites. The developed recommendations are organised according to the autarky typology developed in D3.3. This section also summarises the autarky typology while referring to D3.3 for further details.

2.1 The environmental design conceptual framework

Kaplan et al. (2008), drawing from environmental design and social sustainability issues, developed a conceptual framework to translate conceptual social objectives into concrete design solutions. The framework includes four steps and aims to produce a gradual, iterative translation of generic objectives or policy orientations into examples of how specific design interventions accomplish the envisioned concepts in real-world contexts. More specifically, step 1 of the original framework identifies objectives or goals related to aspects and experiences of quality of life. Step 2 expresses those objectives into design concepts and strategies. Step 3 translates the design concepts into physical and organisational interventions. Step 4 aims to further concretise the interventions by providing specific application examples that describe how the objectives are being met through the functioning of the interventions. The work reported in this deliverable has maintained the key elements of the conceptual framework of Kaplan et al. (2008), adapting it specifically to the domain of autarkic energy communities, from a socioeconomic development, community organisation, and citizen engagement perspectives. Table 2.1. overviews the adapted framework.

Table 2.1. Conceptual framework for delineating essential conditions for the socioeconomic and organisational development of autarkic energy communities, after Kaplan et al. (2008).

Autarkic aspects	Design principles	Design concepts	Design applications
Objectives or goals that express a socioeconomic, organisational, or citizen engagement aspect of autarkic energy communities.	Key attributes and characteristics of an aspect of autarkic energy communities. They constitute the basis for design concepts and strategies.	Strategies to achieve design principles, as applied to the physical and organisational environments of an autarkic energy community.	Selected examples that best illustrate the design concepts, including both "success stories" and sometimes "design failures".
Aim(s) of the intended technical intervention in terms of autarky.	*Intended technical or socio-technical intervention.*	*Merging with obstacles and essential conditions.*	*Recommendations in the form of design narratives.*

2.2 Summary of the typology of autarkic energy communities

A typology of autarkic energy communities has been developed within the activities of WP3 of SUSTENANCE in order to guide the implementation of energy autarky elements in the Danish, Indian, Dutch, and Polish pilot sites. The typology is described in detail in deliverable 3.3 of SUSTENANCE. This section provides a brief overview, because it is utilised as a part of developing design solutions for autarkic energy communities in the present deliverable (see section 2.1).

The typology defines nine key physical-technical and social-regulatory dimensions (axes) that capture the various socio-technical configurations that lead to various degrees of energy autarky. We also define four non-energy sectors that have a significant interrelationship with the local renewable energy systems but are not part of the typology per se. Table 2.2 provides a concise description of the nine physical-technical and social-regulatory dimensions of the typology and Figure 2.1 left provides an example illustration of one site's signature in respect to the nine dimensions.

Table 2.2. The nine dimensions of our typology of autarkic energy communities.

Physical-Technical	Social-Regulatory
Technological dependence, pertaining to the degree of grid integration of the community. This ranges from full integration all the way to no integration / island status.	**Social organization**, pertaining to the diversity, density and complexity of informal social networks (such as clubs and organizations) within the autarkic community, ranging from absence of such forms of social organization all the way to an elaborate structure of multiple overlapping networks.
Availability of local renewable energy, pertaining to the mix of local sources of renewable energy (e.g., wind, solar, geothermal, biomass) and the total capacity to provide and store local renewable energy. This dimension, therefore, also introduces the climate conditions factor of the maximum theoretical supply and demand capacity of the local RES.	**Energy and land regulations**, pertaining to legislative and regulatory context in which autarkic communities are realized and developed. This aims to represent the ease or difficulty (or extent) to which it is possible to implement autarkic solutions in the energy and spatial systems of a community, which may be possible or not according to the law.
Settlement characteristics, aiming to capture scale and density as key urban morphological parameters, and therefore communicate one aspect of the complexity of energy demand. This dimension aims to be a window to the dependency of land uses and built-up form.	**Sophistication of formal governance**, which aims to capture the kind, structure, and "weight" of governance system in place, ranging from a sophisticated set of rules to a completely ad-hoc set of practices.
Building characteristics, aiming to capture the architectural and engineering characteristics of individual residential (and commercial, industrial, public) structures, which determine (in combination with the next dimension) the	**Alignment of values and motivations**, with respect to autarkic systems. This dimension pertains to the fact that there is always an underlying motivation and value being generated by a local community approach to sustainability and resilience. This for instance

various demands that the community has for their local autarkic energy system.	can be purely instrumental such as affordability or broader such as environmental preservation or procedural/distributive fairness. We aim here to capture the diversity and synchronization of these.
Energy uses and basic needs, aiming to capture a second key aspect of the complexity of energy demand and to understand whether the community looks at energy autarky for basic needs only or for the full spectrum of uses, including cross-sectoral integration and interaction. This dimension aims to be a window for introducing the key dependencies of food, water, waste, mobility, and economic activity.	

Ultimately, the nine dimensions are reduced to two axes, one physical-technical and one social-regulatory, which helps to arrive at a final taxonomy of autarkic communities in SUSTENANCE as well as the final description and implications of the identified types (Figure 2.1 right).

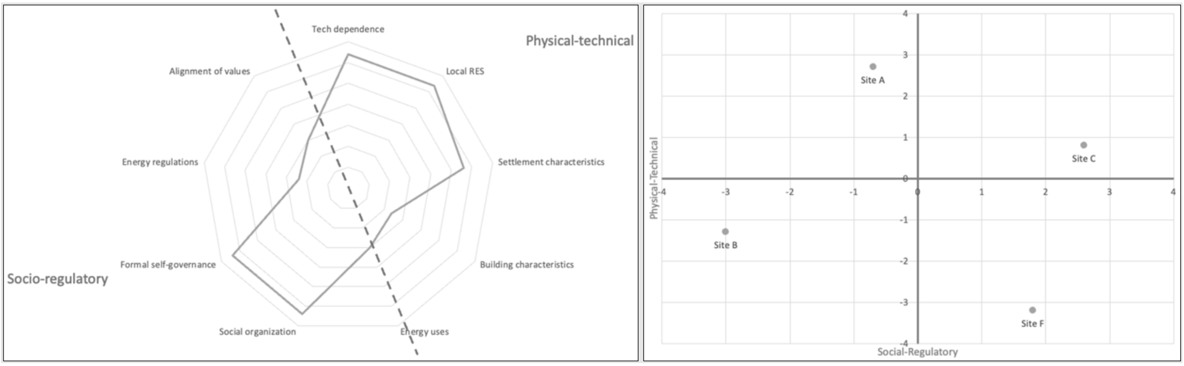

Figure 2.1: **Left*****: Illustration of the typology's nine dimensions.*** **Right*****: Illustration of the final taxonomy, considering their position along the two main axes of physical-technical and social-regulatory type.***

3 Conditions of autarkic energy communities

3.1 Community organisation & complete autarky

Insights to essential socioeconomic and political conditions for completely autarkic communities can be drawn from the anthropological and archaeological analysis of settlements for two reasons. Firstly, a historical perspective can provide indications to the original notion of full autarky, when acquiring and storing essential resources is a precondition to survival, and thus social and spatial organisation has to facilitate this goal. Secondly, an evolutionary perspective becomes important in our context, due to the absence of complete political autonomy. Autarkic communities are subjected to larger political entities, such as municipalities, regions and nations, and therefore their internal socio-spatial organisation will exhibit self-determination elements found in earlier evolutionary stages of spatial situated communities.

Adam-Veleni (2009) notes that settlements approached autarky at the household level. To this end, the availability of storing capacity per household was crucial (Adam-Veleni 2009), although we do have ample evidence of the addition of communal storage as the settlements increase in scale and complexity when moving from the stone to the bronze age (ca. 3000-1100 BCE) (Hitchcock and Preziosi 2000). In the bronze age, an additional key factor emerges, namely the ability of efficiently moving resources within and outside the settlement, beyond just storage (Adam-Veleni 2009). An interesting regional perspective is provided by Smith (2019), who discusses evidence for a regional strategy for autarky, noting that the amalgamation of several small settlement units provided a political entity (the city-state) that was large enough to be self-sufficient, and which not only ensured survival but also sustained a comfortable lifestyle.

In terms of social organisation, Renfrew and Bahn (2020) note, among others, the importance of polity, community scale, and internal organisation of power and benefits. Polity is defined as the scale at which decision-making is done, therefore affecting the ability of a community to self-determination. However, as noted above, sometimes regional aggregation is also an autarky strategy (Smith 2019). For this reason, it is important to understand how much autonomy is retained within the community, when community and polity do not coincide (Renfrew and Bahn 2020). Furthermore, it is important to understand the internal structure of power, which will affect the (re)distribution of benefits but also responsibilities and essential functions. Service’s (1971) evolutionary model of social organisation is still widely used in anthropology and categorises societies in a spectrum that includes loosely organised individuals or small groups (“bands”), segmentary societies (“tribes”), one-leader societies (“chiefdoms”), or one-leader societies with increased authority of the leader (“early states”). The point at which the autarkic community is in Service’s (1971) spectrum of social organisation can move as the community changes or evolves, and determines whether there is stratification in internal decision-making, how essential tasks or functions are distributed among community members, as well as whether and to what extend key benefits are being (re)distributed throughout the community (Renfrew and Bahn 2020). The last point on (re)distribution of benefits relates to the point being made in the next paragraph, the presence of elites has been a source of new knowhow and technological solutions into the community (Adam-Veleni 2009). The question would then be how these new elements and their benefits are being distributed or redistributed depending on Service’s model of social organisation.

At the community scale, autarkic settlements placed importance, firstly, on their political boundaries and, secondly, on the way the community distributes its human capital within and outside its territory. With respect to political boundaries, it has been found that settlements aimed to meet resource autarky by establishing a vital boundary around the settlement, that is drawing the line farther away than merely the settlement’s buildings, which increased as the settlement grew (Adam-Veleni 2009). It is important to clarify that the vital space around the settlement aimed to ensure autarky with the essentials (food and materials); non-essentials were still sourced from outside the settlement through exchange or trade from early on in settlement history. This suggests that settlement autarky, even under the strict definition of autarky in early settlements, was not seen as excluding resource exchange with other communities. Regarding the latter, it was necessary to be able to translate the primary resources sourced from the settlement’s vital space into usable for the community items, including secondary production. The archaeological record indicates that this was accomplished by establishing a distribution of labour that was able to distribute the human resources within and outside the settlement sometimes according to predefined roles and sometimes according to ability or capacity (Adam-Veleni 2009). This can be seen as a subset of the dimension of local-regional social and economic organisation, which is one of the key parameters in settlement evolution in human history (Birch 2013). Lastly, there is solid evidence that settlements were open to cultural inflows, particularly of new technologies, materials, and sociocultural habits, often via the wealthy or ruling social strata (Adam-Veleni 2009). This element further adds to the significance of establishing internal and external mobility of resources, both in material and immaterial senses. An interesting extension into the adaptive capacity of a community, coming from the study of Eastern African settlements, is Foley's model of a community and its vital space being located near external flows of resources, which were outside its territory but still close enough to utilise when needed (Foley 1981).

It therefore appears that fully autarkic communities do not presuppose complete absence of flows to/from the "outside world". However, borrowing from Renfrew and Bahn (2020), it is still important to understand to what extend an autarkic community is/should be approached as an independent political unit or as an instrumental or subordinate element of a larger structure, because this will dictate the possibilities for its "catchment area" so far as resources are concerned. Settlements have their hinterland (Renfrew and Bahn 2020); political or administrative boundaries that can ensure fundamental resources (which remain to be defined) is an essential condition, and these boundaries should be flexible to accommodate growth of the settlement. Politically, this condition is usually a spatial planning task and requires a look into the general and mid-scale plans of the involved region and municipality to ensure feasibility. Non-essential resources can be acquired through exchange without conflicting with autarky, but this must be supported also by the ability to store and move the resources, internally within the community and externally with neighbouring ones. This connects to the second condition of the community having the ability to translate essential resources into usable output by utilising and organising (but also recognising) the community's internal human capital. This implies a change from a "passive consumer" community into an "active exchange" community being in control of its value and resource flows, a transition that has been extensively advocated in urban commons literature. Still in the domain of exchange and human capital, it appears that the more effluent members of the community can act as importers of new technologies and practices due to motivational factors that relate to status but ultimately transforming the entire settlement.

However, in terms of regionalisation and scale, it should be noted that not all future societal trends are consistent with every climate change scenario. Top-down and bottom-up trends and choices about climate adaptation and mitigation are normally positioned in a more fundamental macro-context of societal change. More specifically, the Shared Socioeconomic Pathways (SSPs) are five possible world outlooks towards sustainability, which produce internally consistent scenarios on energy and emissions, adaptation and mitigation, and population and the economy (O'Neil et al. 2016; Riahi et al. 2017). Riahi et al. (2017) describes the following scenarios. SSP1 (sustainability) describes a society with the most sustainable world view that takes the green road and implies low challenges to mitigation and adaptation. SSP2 (middle of the road) describes a society that poses medium challenges to mitigation and adaptation. SSP3 (regional rivalry) entails high challenges to mitigation and adaptation. SSP4: Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation). SSP5 (fossil-fuelled development) describes the opposite of sustainable practices with a society that entails high challenges to mitigation but also low challenges to adaptation. Based on integrated assessment models, SSP1 and SSP4 are the societal contexts in which RES are expected to proliferate (Riahi et al. 2017), which in year 2100 corresponds to low-moderate climate forcing in the range of 2.0 W/m2 (SSP1) and 6.0 W/m2 (SSP4). It should be therefore kept in mind that SSP3, the "fragmentation" of which could be associated to a generalised movement towards local autarky beyond energy, may not be directly compatible with the proliferation of renewable energy of scenarios SSP1 and SSP4.

3.2 Key technical and building-scale considerations

First, it needs to be established that literature about self-supplying energy addresses largely electrical energy (e-autarky), e.g., Brosig & Waffenschmidt (2016) discussing energy autarky of households by sufficiency measures. Also, the focus lies on one source rather than multisystem supply, although the literature recently expanded to include heating (microgrids). Cross-over systems are seldom described or monitored for their potential autarky. Nonetheless, in alternative energy communities, practices of multi-source systems (e.g., regaining warmth from wastewater) can be found and are contributing to a local self-supporting network for all types of energy-demand in households. These can include more complex energy conversions and practices in which the sink can be in a different sector, such as, for instance, electricity to heat or electricity to transport. Furthermore, autarky in technical terms is mostly calculated and designed for regional and national scales, where the main grid acts as distributer and storage.

Troendle et al. (2019) see technical potential as the most important aspect of analysing the possibility for autarky. One example is the available roof surface suitable for PV, although off-building extensive space for PV, such as greenfields, is a related discussion but may not be available for the type of cases in SUSTENANCE and potentially lead to conflicting land-claims. Their study concludes that small systems are more cost-intensive and may be less stable, and areas with high density population, and environmentally protected areas will not be able to become e-autarkic. Finally, for the demand-side it is crucial to calculate a net-zero e-balance (be it on daily or yearly basis): if, for instance, the project/community includes offices or industrial spaces, there will be additional energy-needs, with different types of operation. This should not be seen as a simple enlarging of the system, as it opens opportunities for synergies that optimize the energy balance (Perez Sanchez et al. 2022).

On these premises, two major technical criteria apply for the technical/physical dimensions of the cases, namely building characteristics/energy efficiency and system boundaries/ grid independence, which, in the present report, relate largely to private living and residential or mixed residential-commercial land uses without considering other functions such industrial or municipal buildings.

With respect to building characteristics and energy efficiency, in the EU, buildings need to comply with the Energy Performance of Buildings Directive (2010/31/EU)[1] and become net zero-emission buildings by 2030. Each country has its national energy performance calculation (EPC) model, which is mandatory for building permission and based on the building characteristics as well as estimated (standardized) demand. Without going into detail, it is important for the case-studies to declare in how far they comply

[1] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

with these indicators (comparability of results) and to explicitly identify which components of the project may be different from the calculation model (e.g., the building material of Earthships does not appear in EPC-models).

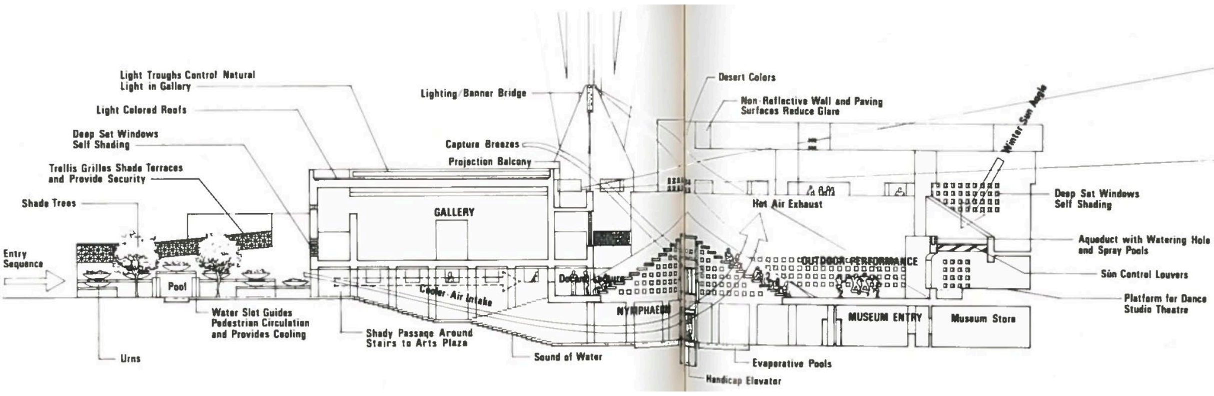

Figure 3.1: Nelson Fine Arts Centre, Arizona State University in Tempe, Arizona. Note the systemic approach to indoor and outdoor natural energy flows of the building/site (source: Ghirardo 1996).

On the demand side, local microclimatic conditions in a neighbourhood can be treated not just as a boundary condition to the performance and theoretical demand and supply limits of its local renewable energy system, but as a plannable factor in energy autarky. Specifically, the microenvironment represents (a) a time-varying and often volatile factor that challenges the scheduling and delivery of demanded energy; (b) concurrently, a regulatable factor through nature-based solutions, ecosystem services, and climate architecture. Green and blue infrastructure and other passive heating and cooling design techniques have been traditionally seen as key elements in the heating and cooling autarky of buildings and sites; originally in challenging climates (for instance, desert settlements) but increasingly in more contexts due to the extent of climatic changes around the world. From a planner's perspective, a recent development is the development of "local climate zones" (LCZs), as a means to connect how neighbourhood's physically look like with their energy balance. Therefore, plannable microclimatic factors can be conceptualized as conditions. Stewart and Oke (2014) describe a universal typology of built environments—according to the height, density, materials, and use of buildings and the type of open public spaces found in a neighbourhood—the types of which have different effects on the neighbourhood's microclimatic behaviour and response to weather extremes, especially temperature extremes. The typology consists of ten "local climate zones" (LCZs) and planning choices surrounding them has consequences on the heating and cooling profile of buildings and neighbourhood, effectively providing a tool to understand how local RES demand and supply can be affected by neighbourhood design choices. From an architect's perspective, climate considerations in the design of buildings and sites can achieve significant autonomy in terms of heating and cooling demand and supply. Givoni (1998) provides an overview of techniques that resolve indoor and outdoor human thermal comfort issues in a variety of architectural and urban design contexts. These cover materials, passive (solar) heating systems, passive cooling of buildings, green solutions at site and neighbourhood scales, as well as how these should be though about in different climate conditions. Often, these systems take on a systemic flavour, treating energy flows between and within exterior and interior spaces in a holistic way, as seen in Ghirardo (1996) and Givoni (1998). Figure 3.1 (Ghirardo 1996) is an illustration of such a (nearly) autonomous building-site system, and also demonstrates that such design solutions can also be made to play a role on contingent features such as the movement of people.

Concerning system boundaries and grid independence, only as of 2021 the EPC enables the inclusion of e-storage (such as e-cars/bikes) acknowledging their contribution to e-efficiency and e-autarky. Shared spaces such as laundries which potentially contribute significantly to energy efficiency (Tummers 2021) are not part of standard EPC models. They bring the autarky unit outside the individual household e-autarky of the commons. The case studies therefore also need to outline not only the m2 of built surface and insulation values, but also be clear about their use/functions and what is included in the final assessment and result. In the same vein, if autarky is considered on household level, it needs to be clear whether this includes only the dwelling and its devices and equipment, or whether their transport (e.g., e-car & charging station) is also included. This would highlight the different conditions connected to the location of buildings, particularly distance to main grids and public transport system.

3.3 *Summary and correspondence to the autarky typology*

Table 3.1 summarises the conditions discussed in sections 3.1 and 3.2 and maps them onto the autarky typology introduced in section 2.2.

Table 3.1. Summary of the essential community conditions indicated by the literature

Autarky dimension(s)	Condition	#	Short description
Social organisation Building characteristics Settlement characteristics	Household and cluster as the elementary autarkic units.	1	From the demand perspective, the elementary unit of autarky is the household, from supply perspective the elemental unit is the cluster.
Sophistication of formal governance	Polity and scale	2	The scale of a self-determining community at which the decision-making is done must be clearly understood. If polity and autarkic community do not coincide, the level of autonomy within the larger political aggregation is important.
Social organisation	Internal social organisation	3	The dispersion and stratification of involvement and leadership determines the specialisation of community members toward a task or essential function. As a consequence, it is key in the way a community (re)distributes benefits (and costs).
Energy and land regulations Settlement characteristics	Catchment area/local sources	4	Able to provide vital space for the local provision of essential resources; flexible to accommodate community growth.

Alignment of values and motivations Settlement characteristics	Mobility and exchange of resources; prosumers	5	In- and out-flows do not conflict with autarky, internal mobility and exchange can enhance autarky. External exchange is referred to for elements beyond a community's autarky scope. Both presuppose an exchange community, rather than passive consumerism. Beyond mere storage, esp. as the settlement grows, the stored resources must be supported be able to move and be exchanged, both internally and externally.
Settlement characteristics	Regional aggregation	6	A strategy of forming a unified political entity among small settlements can ensure (near) self-sufficiency, in terms of both survival and comfortable lifestyle.
Social organisation Sophistication of formal governance Stratification of values and motivations	Utilisation of human capital; access to financial capital.	7	Communities must be able to translate local or exchanged resources into usable output by sufficiently organising the local human capital and operationalising certain levels of technology. The more experiment and risk-prone community members are key to the introduction of new technologies and practices. Access to finance is key to the room for such technologies and practices.
Settlement characteristics Building characteristics	Climate architecture and urban design; minimise use of resources	8	Passive heating and cooling solutions by using green and blue infrastructure and elements such as wind flows can significantly increase the energy autarky of and neighbourhoods. Energy demand of individual buildings needs to be reduced to optimise the options for efficient and flexible supply (envelope insulation etc).
Technological dependence and system boundaries	Distance and utilisation of central grid	9	While storage capacity at the household level is crucial, communal storage becomes a key element as communities grow in scale and complexity.
Availability of local renewable energy	Multi source systems: integrating and cascading	10	Multi-source and cross-over systems contribute to a local self-supporting network for all types of energy demand in households. At the same time, their sufficient description and tracking of performance is crucial.
Building characteristics	Directive 2010/31/EU for new buildings	11	The autarkic practices of new buildings need to be related to and clarified in terms of EU's building performance directive, because the EPC does not yet include all practiced solutions. Still, many existing

			buildings can form local energy communities, which will not be subject to the directive, meaning higher flexibility to include a wider ensemble of the available practiced solutions.
Availability of local renewable energy Building characteristics Settlement characteristics	Size and location of PV production	12	Space for on-building PVs (e.g., roof) is a key condition for energy autarky, whereas small-scale systems are seen as cost-intensive and unstable. At the same time, off-site space (e.g., greenfields) is an alternative but introduces aspects of land resource competition.
Settlement characteristics	Mixed land use	13	Enlargement of the system by introducing non-residential uses introduces possibilities for synergies and optimisation of the energy balance.
Alignment of values and motivations	Convergence between RCP and SSP scenarios	14	Each climate change (RCP) scenario is related to only a subset of socioeconomic pathways (SSP). This implies that the flavour of such conditions as energy use, sustainability support, and social-political organisation depends on global warming parameters.

4 Community design strategies per demonstrator site

The interventions implemented in the Danish, Dutch, Indian, and Polish pilot sites concentrate on local demand response and demand side management. Aspects of local supply and supply side management are also accounted for, including battery storages, solar PV panels and small wind turbines. Sections 3.1 to 3.4 below describe the interventions and design recommendations for each of the sites. The description of the pilot sites, planned interventions, and identified obstacles is based on information in Sustenance deliverables 2.1 and 3.1. The objective of this section is to interpret this information from perspective of the socioeconomic development and citizen engagement in the envisioned autarkic energy communities, in order to delineate community design strategies for each demonstration pilot.

4.1 Denmark

4.1.1 Brief introduction

One pilot is being tested in Denmark. The site includes 20 houses within and in the vicinity of the village of Voerladegård. The village has about 550 inhabitants and is located in the municipality of Skanderborg in the region of Midtylland (Central Denmark).

4.1.2 Planned interventions and obstacles

The main objective of the Voerladegård pilot is the development of a new integrated community energy system with active citizen participation, which can provide possibilities for energy sharing between households. In the long run, after the buildings are completed and the community is in place, the pilot aims to engage the local prosumers, local aggregator, and distribution system operator, as the key stakeholders. The focus will be on heat pumps, phase change material-based thermal storage tanks, solar PV panels, battery storage, and electric vehicles charging.

Within the above context, the demand response interventions that are being designed for the Danish pilot focus on smart control of heat assets and EV charging, while concurrently maximising the utilisation of the community's own solar energy that is produced on-site by solar PV panels. On the behavioural side, the intervention focuses on consumer preferences such as room temperature limits and EV charging preferences, as well as monetary savings. On the technical side, the intervention focuses on electricity and heat storage limits, and on voltage and grid capacity limits.

One set of physical-technical obstacles that have been identified for the Danish pilot site are the insufficient local capacity to produce renewable energy, as well as the limited management capacity to optimise demand and increase efficiency. A second set of social-regulatory obstacles has been identified in the form of regulations that reduce the cost-effectiveness of energy sharing, as well as the potential difficulty of realigning underlying motivations and values away from economic aspects, towards ecological ones.

4.1.3 How to achieve a more autarkic, citizen-centred energy system

Below we provide an identification of the key conditions for establishing a local autarkic community in the Danish pilot site, given its current status and realities, aspirations, and envisioned interventions, which are interpreted through the review of section 3 and the summary Table 3.1. These are key conditions to prioritise for the realisation of the autarkic community based on its existing vision, planned interventions, and its existing social, natural, or technical capacities. These key conditions are as follows for the Danish pilot site:

- **Condition 1: Elementary autarkic units**. The focus on detached and semi-detached single-family houses enables the focus on households as the demand-side elementary unit of autarky, which is a condition historically adopted by autarkic communities. At the same time, the supply-side elementary unit of autarky can be realised at the cluster level, viewing the entire residential development as a self-sufficient RE supplier. Hence, these two pillars can guide community participation and the relation between citizens, markets, and governance—as part of the formation of local energy communities—while still allowing flexibility on redefining the elementary unit at the supply side, moving closer towards the household or dwelling structure if desired.

- **Conditions 2 and 3: Polity, scale, and internal social organisation**: The Danish pilot benefits from the presence of a local residents' association, which on one hand handles internal matters, but on the other hand also serves as a connection to formal top-down governance. This translates to the presence of a significant condition that may accomplish two elements. Firstly, it can be seen as a way to shift to establish an emulated form of local polity, by participating into and influencing regional decision-making. Secondly, it can be seen as establishing some form of social organisation that, ultimately, will facilitate and/or organise how the community members will distribute responsibilities to accomplish commons objectives as well as how the economic benefits and costs of energy autarky will be distributed and translated within the community, an aspect that is further discussed in the following two condition points.

- **Condition 5: Mobility and exchange of resources**. The apparent presence of the underlying goal of economic benefits through energy autarky, although potentially restrictive, can be seen as a positive condition to align values about resource exchange and sharing. More specifically, a clear goal such as seeking economic benefits from energy can be utilised as a facilitator to establish clear definitions and objectives about, firstly, what exactly is being exchanged by the community (outflows) and, secondly, how are the benefits going to be exploited and in what form (inflows).

- **Conditions 2 and 3 in relation to condition 5: Polity, scale, and internal social organisation**. Following from condition 5, a clear economic understanding of the form and distribution of exchanged inflows and outflows by and within the community can also have significant secondary local social and political benefits. More specifically, self-determination in the economic domain can establish a light version of polity inside the community in which some of the important (economic) wellbeing conditions are decided, therefore relating to condition 2. Moreover, clarity in the economic goals and the (re)distribution of costs and benefits can serve as a catalyst for further clarifying the distribution of the incoming benefits and in what form among the community.

- **Condition 8: Climate architecture and urban design**. The Danish pilot site has considerable capacity for minimising energy demand for heating and cooling. Due to its rural setting with ample presence of vegetation on-site and in the wider area, the natural energy flows throughout the year can be exploited with climate architecture (for the buildings) and climate urban design (for the neighbourhood) in order to establish a pronounced passive heating and cooling character. It should be noted that this does not necessarily mean the modification of existing or already approved plans, but energy passivity in terms of heating and cooling can be well enhanced by the way existing landscape plans are realised. This condition can be readily exploited by starting at the site (private gardens and areas, entrances) and neighbourhood level (streets, parks), which offer ample choices due to the single-family detached and semi-detached dwellings. Moving onto more complex architectural design strategies can be a further exploitation of this condition in the future.

4.1.3.1 Suggested community design strategies per intended intervention

The conditions described in the preceding section can be seen as stand-alone, capable of increasing one or more autarkic aspects (consult Table 3.1) by enhancing capacities that are inherent in the pilot. In addition, Table 4.1 below develops a further set of more specific community design strategies. These aims to consider more explicitly the intended technical interventions (D2.1), combine them with the identified obstacles (D3.1) and conditions (present D3.2) from an environmental (i.e., socio-spatial, not ecological) design perspective. The first two interventions of Table 4.1, although expressing different design principles and design concepts, can be achieved by the same design application. In other words, while the technical aims differ, the community design application can be approached as one process. The third intervention is more targeted in scope and therefore treated completely separate from the above. Lastly, the intervention described in the fourth row of Table 4.1 has been the most challenging to convert into a community design strategy due to its very specific technological scope. For this reason, we propose an organisational approach that can combine the intended aim with the wider urban and regional planning process of the locality, assumed to be the best avenue to maximise both social and technical potential. In this manner it also offers synergies with the first three design strategies.

Table 4.1. Suggested community design strategies for the Danish demonstrator.

<table>
<tr><th>Autarkic aspects</th><th>Design principles</th><th>Design concepts</th><th>Design applications</th></tr>
<tr><td>Technological dependence.</td><td>Maximising use of the community's own solar energy.</td><td>The topology and spatial and natural capital of the neighbourhood is utilised towards two aspects. Firstly, utilisation of neighbourhood spaces and their physical design (location, distribution, clustering, shadow management) to maximise the capacity of PV panels to cover EV charging and heating demand. Secondly, to maximise the use of building envelopes and public grounds for solar PV capacity by combining production capacity, climate-dependent efficiency, and passive heating and cooling capacity (see row 2).</td><td rowspan="2">The local residents' association organises a series of co-design workshops, in which the resident households develop a climate architecture plan that utilises the neighbourhood's ample natural and spatial capital to increase passive heating and cooling capacity. The co-designed plan also accounts for the spatial and temporal distribution of thermal comfort and EV charging needs within (buildings) and across (public space) the energy community's households, which feed into the specifics of the climate design. Communication of trade-offs thus becomes a main element of the activities.</td></tr>
<tr><td>Alignment of values and motivations.</td><td>Limits on thermal comfort and EV charging. Limits on voltage, electricity grid capacity, and heat storage.</td><td>Climate architecture and urban design solutions are deployed to decrease maximum demand for heating and cooling. This can serve as a "soft limit" on thermal comfort. Furthermore, a community-led</td></tr>
</table>

		information system is organised where the thermal comfort and EV charging needs of households are systematised and mapped onto the topology of the neighbourhood (see row 1).	
Social organisation.	Inclusion of the local aggregator and distribution system operator into the local prosumer community.	The common motivation of prosumer households and the private sector to maximise both economic utility and social credits will lead to a partnership that identifies economically and socially efficient state-of-the-art refinements.	Establishment of an “advanced solutions” task force between prosumer households and aggregator, operator. Its goal is to identify and deploy advanced solutions that maximise net benefit-to-cost ratio over a short- or mid-term time horizon (cost-benefit analysis), from household, neighbourhood, and system perspectives (distributional cost-benefit analysis).
Sophistication of formal energy governance.	Smart control of heat and EV assets.	The internal (within the residents) and external (with the municipality) reach of the residents’ association serves as the communication avenue between neighbourhood and the urban and regional planning process of the locality. The main aim is to ensure that physical necessities (for instance communal	The processes and the results of the first three strategies are being facilitated by the residents’ association and communicated to key spatial planning contact points. The focus of this activity, beyond ensuring information flow and institutional support, is on implementing physical interventions. First concerning the

		storage and charging facilities) are realised with the technical and institutional support of the spatial planning system. This connects to rows 1-3).	management infrastructure. Secondly, accommodating the storage infrastructure and its physical arrangement within the public spaces of the community.

4.2 India

4.2.1 Brief introduction

Three demonstration sites are being tested in India. The first site at Borakhai village includes 40 houses in two near to each other areas. The village is located near the city of Silchar in Assam state of eastern India. It is partly electrified, with electricity being available for a limited number of hours per day. Water supply for domestic use is unreliable, the primary energy source for cooking is firewood, whereas lighting is provided by kerosene lamps with some houses also having a liquified petroleum gas (LPG) connection. The transport system is very limited and unreliable. The second demo site includes about 57 houses in the village of Barubeda in the state of Jharkand. The village is not connected to a larger energy grid and has limited access to water. Lighting is provided by kerosene lamps and firewood provides the energy for cooking. There is no public transport, and the nearest road is around 3 km from the village. There is seasonal migration of the male workforce to the nearby city. The third demo is located at the IIT Bombay campus in the city of Mumbai. The campus houses around 20000 people and receives 24/7 electricity from the main grid, also having a solar PV system of 1MW capacity.

4.2.2 Planned interventions and obstacles

The main objective of the Borakhai village pilot is to develop a multi-energy cluster based on renewable sources, which will include electricity based on solar and wind power, water supply, e-rickshaw transport, and a facility that converts biowaste to manure. The demand response intervention focuses on the local generation system by controlling the loads of the household, water pump, and e-rickshaw charging through direct load control. Concerning electricity autarky, the electricity vector will comprise clean energy generation sources, such as Solar PV, wind power, biogas-based electricity generation, along with battery energy storage. Due to the geographical location and number of houses (4-8), it is planned to have local PV/wind or other energy resource installations in a “cluster” form with all the clusters in the village connected to each other via a smart localized energy management. The interconnection among the clusters within the village will enable the mutual coordination of power flow. Concerning mobility, electric rickshaw transportation will be provided for the inhabitants to for local clean and sustainable transportation.

The main goal of the Barubeda village pilot is to develop an off-grid local renewable energy system based on solar, wind, and biogas energy, and which includes battery storage. The pilot will also include solar powered water pumping, e-rickshaw mobility, multi-utility heating, cooling and drying, as well as biogas and biomass powered cooking. As with the Borakhai site, the demand response intervention focuses on controlling the loads of the household, water pump, and e-rickshaw charging through direct load control. Concerning electricity autarky, the four planned clusters will be provided with a common solar PV system with a provision of storage for providing power supply to the rural community in the selected area. All the vectors of energy resources are planned to be installed at one location and connected in themselves. Concerning mobility, similar to the previous site, electric rickshaw transportation will be provided for the inhabitants to for local clean and sustainable transportation. Concerning water supply autarky, a solar PV powered water pumping system is planned for reliable domestic water supply to the target community. This will provide easy access for water availability to the villagers, without which, they have to walk around 2-3 kms to get water from the well (source).

A further plan is the provision of power from the establishing solar PV system for improving living standards in terms of reliable water supply for drinking and, if possible, for irrigation. The overall expected outcomes will improve the living standards of the residents in the selected area as they are getting access to electricity and water supply which will support them with easy access to drinking water and for their cultivation. Also, since there is no proper transport facility in the selected area, the e-rickshaw concept incorporated in this site will be a potential for local energy businesses in the area.

The main objective of the IIT Bombay campus pilot is to set up a smart integrated energy system that consists of a smart building with its own micro-grid and EV charging infrastructure, including vehicle to grid services. The demand response intervention focuses on the local management of the loads of lighting, fan, water heating, and air conditioning. Additionally, demand response intervention on EV vehicle-to-grid response is planned. Concerning electricity autarky, local solar PV and some wind generation sources are expected to supply the smart electrical home and also supply EV charging load in the campus. With respect to mobility, smart EV charging based infrastructure is planned to cater EV load in the campus, which is expected to help in smart EV charging solutions and seamless adoption of clean transportation in the campus. Regarding water supply autarky, a solar PV powered water pumping system is planned for reliable domestic water supply to the target community.

The physical-technical obstacle associated with the Borakhai and Barubeda sites is the limited wind speed with an average annual wind velocity of of around 1.6 to 1.9 km/h. At Borakhai site, as the village is connected to the local grid (main), frequent grid outages (due to load shedding from the grid) can potentially affect the excess power transfer (local) above consumer demand with the main grid. From a socioeconomic perspective a main concern is about the growing load demand of the local community to sustain the integration of the newly introduced RES and mobility technologies in the long term, including techno-economic (e.g., feasible maintenance resources) and behavioural (e.g., integration to established essential cultural practices) dimensions.

4.2.3 How to achieve a more autarkic, citizen-centred energy system

4.2.3.1 Core conditions present in the pilot

The Indian demonstrator sites present the following conditions for supporting the aforementioned planned technical interventions in the context of also achieving the community's development from socioeconomic and organisational perspectives.

- **Conditions 8, 10 and 12: location of PV production, minimisation of resource use, and integrated multisource systems**. A key strategic condition possessed by both Borakhai and Barubeda villages is the alignment between, on one hand, the plans for integrated multisource and multiuse systems, and on the other hand, locations that can factually accommodate the planned reliance on solar energy. This alignment can take the two communities a long way towards systemic energy autarky. Borakhai reports "tremendous" solar energy potential, while Barubeda reports sufficient potential for harnessing solar power to accommodate the technical goal of having solar energy as the primary electricity generation source. At the same time, biogas will also be used to generate electricity and small wind turbine electricity generation will supplement the local energy demands for achieving autarky of the energy system. Importantly from a use perspective, there is realistic balance between the different energy sources and correspondence with the intended use. For instance, in Barubeda biogas is planned primarily for cooking applications and particularly for peak power demand hours, whereas wind is positioned correctly as a supplement due to the reported limited wind potential, and in Borakhai the key sustenance aspect of irrigation is included into the energy planning. Similar to the two villages, the IIT Bombay campus site reports satisfactory potential for solar and wind power, with existing 1 MW rooftop PV (in addition to 24X7 power supply from the main grid).

- **Conditions 2 and 4: polity and scale, catchment area**. Given the presence of conditions 8, 10 and 12, which aim for comprehensive multisource energy autarky, the (physical and/or technological) remoteness of Barubeda and Borakhai villages may turn out to be an advantageous condition. The main reason for this is the hypothesis that physical remoteness and *de facto* minimal technological dependence (due to absence of connectivity and low investment levels) are translated to political remoteness—as far as energy is concerned—and is expected to further translate into sufficient local sovereignty and no significant spatial planning constraints are expected for the realisation of the energy autarky plan, including local territorial capacity to scale up.

- **Conditions 3 and 7: internal social organisation, utilisation of and access to human and financial capital**. The presence of a large urban academic community, with the typical diversity in terms of leadership, risk-taking, and investment potential and behaviour, is expected to facilitate further introduction and dispersion of innovation. At the same time, the often-widespread involvement and engagement of human capital within academic communities (following initial top-down investment initiatives) may mean that the costs and benefits of trailblazing initiatives will be distributed in a way that ultimately facilitate the success and scaling up of the technical interventions. This diversity and dynamism are present in the Borakhai and Barubeda villages as well, constrained however by the social, governance, and economic setup of the two villages is fundamentally different from that of the IIT Bombay campus. In both village demo sites, the project's demo activities aim to get residents and the local society involved in the sustainability of the installed systems, including the possibility of a nodal agency participating in governing their operations.

4.2.3.2 Suggested community design strategies per intended intervention

In addition to the conditions described in section 4.2.3.1, we propose a number of more specific community design strategies for the Indian demonstrators.

Table 4.2. Suggested community design strategies for the Indian demonstrators.

Autarkic aspects	Design principles	Design concepts	Design applications
Technological dependence through the availability of local renewable energy.	Introducing solar, wind and biogas energy as a means of independence.	At Barubeda site, solar PV, wind and biogas powered electricity generation will cater the local energy demand including residential load, and common water pumping load and E-rickshaw charging load. At Borakhai site, a multiport bidirectional converter will be used for the coordinated power flow control between the clusters via coordinated power transfer from solar PV, wind energy system and battery for energy support for powering the houses. At IIT Bombay site, smart EV charging infrastructure along with smart electrical building system is planned to facilitate clean and sustainable transportation system and local demand response.	The proposed design facilitates reliable power supply to the selected residents in Barubeda and Borakhai sites. Besides, it will help in establishing local water RE based sustainable water supply system and transportation.
Energy uses and basic needs supported by local renewable energy.	Lighting, cooking, heating, cooling, and drying supported by multiple local renewable energy sources.	Local communities will be provided with RE based electricity to replace cow dung and firewood -based cooking, and kerosene-based lighting.	The planned local energy system is expected to provide the local community with the reliable essential utilities of electricity, water, transportation and biogas-based cooking,

			thus facilitating economic growth of the community, and minimising the need for seasonal migration.
Introduction of new energy uses affecting settlement characteristics.	Introducing e-mobility across the settlement via e-rickshaw. Establishing solar PV powered water pumping system for domestic water supply	The transportation facility being established in the site through the local energy management system facilitates the residents with access to e-mobility at a subsidised rate. Moreover, a solar powered water pumping system will provide for reliable clean water supply for domestic applications	Village energy committee at both Barubeda and Borakhai site will facilitate introduction of new energy technologies and its use within the local community. For IITB site, RE based smart charging system will be established for seamless adoption of sustainable transportation within the campus.
Alignment of values and motivations.	Replacing firewood with sustainable energy, to address basic cooking and heating needs. Establishing reliable local water supply system.	Reliable power supply and reliable water supply to the residents in the selected area. Converting plant waste to income generating manure. Subsidised transportation facility for improving the living standards of the residents of the selected area.	Helps in minimising the CO2 emission and environmental pollution. Creates awareness among the residents regarding the need for renewable power for the sustainable growth and pollution free environment. In order to integrate this with local community governance and ensure equitable distribution of the anticipated economic benefits (cf. strategy in row three), it is suggested that discussion on common values and

			motivations is incorporated in the proposed energy committee described in the strategy of row three.

4.3 The Netherlands

4.3.1 Brief introduction

Two pilots are being tested in the Netherlands. Vriedenerf is a community-led eco-housing project in the village of Olst in the province of Overijssel. It consists of 12 single family houses and a community centre, all constructed between 2016 and 2017. The houses were constructed with zero-energy standards and include solar panels, heat pumps, ground thermal storage, and an electric vehicle (EV) charging station. The second pilot, SlimPark, is a self-sufficient EV charging station located at the campus of the University of Twente in the city of Enschede, Overijssel province. The station is powered by a 27 kWp solar panel rooftop and includes battery storage.

4.3.2 Planned interventions and obstacles

The main objective of the Vriedenerf pilot is to explore energy exchange and flexibility within the community. The main objective of SlimPark is to serve as living lab for the direct interaction between users and the system, for instance through apps or business models.

The Dutch intervention focuses first on collaborative models of demand side management where the involved stakeholders (primarily local energy users and energy retailers) are voluntarily engaged in an equal playing field when sharing energy locally, as opposed to a traditional competitive ecosystem. The USEF framework[2] is utilised for this purpose, which provides a common standard for building all smart energy products and services, with flexibility and efficiency among the key objectives. The most essential for the present context feature of USEF is its market-based coordination mechanism that recognises four operational regimes: green with normal operation and power balancing; yellow with capacity management, peak load reduction and power balancing; orange with graceful degradation and load shedding; and red with power outage and grid protection. This model extends the operation of the free market in smart grids to the green and yellow regimes, as opposed to the green regime in classic grids. Figure 4.1 provides an illustration of the USEF framework's operational regimes, while more information can be found in SUSTENANCE deliverable 2.1.

[2] https://www.usef.energy/app/uploads/2016/12/USEF_TheFrameworkExplained-18nov15.pdf

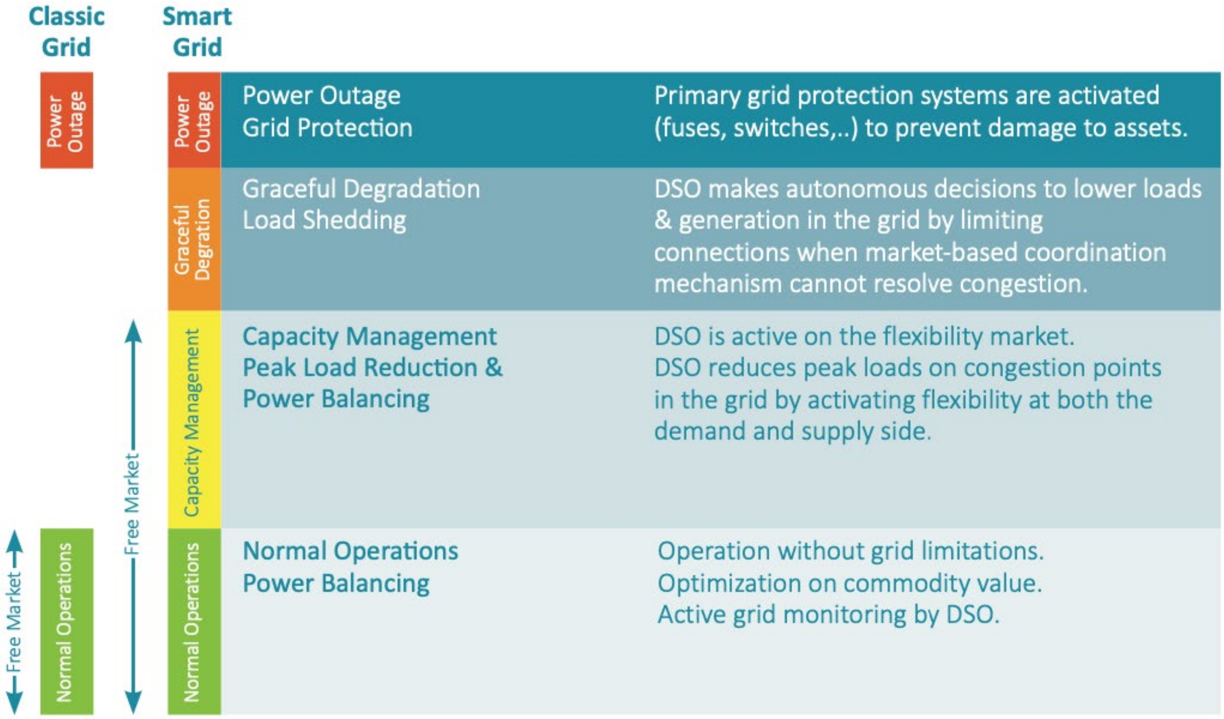

Figure 4.1. Overview of the USEF framework.

With the aforementioned context, intrinsic and extrinsic motivations are part of the collaborative model, and the collaboration is aimed to take place in the green and yellow states of the USEF framework. The second aspect of the intervention refers to a gradual reduction in the quality of offered service to end users at times when the electricity grid is operating in the orange state of the USEF model. The quality of service is aimed to be reduced automatically by an energy management system according to the level of urgency, with notions of fairness and robustness in mind, also given the absence of legal and practical implementation protocols.

The attention of the Vriedenerf pilot is inwards, exploring how an otherwise self-sufficient energy community can increase its internal sharing capacity. However, there is no local micro grid in the community that facilitates direct interaction and peer-to-peer sharing, neither does the community have local storage capacity. Moreover, both micro grid and direct energy sharing are at present not in line with Dutch energy regulations. On the other hand, the SlimPark pilot's major obstacle is lack of information on the internal composition and characteristics of its community of users. Furthermore, limited access possibilities within the target community (university employees and students) are an important limitation when considering the aim of sufficient understanding about user interaction with such a system.

4.3.3 How to achieve a more autarkic, citizen-centred energy system

4.3.3.1 Core conditions present in the pilot

Given its current state and scope, and seen through the prism discussed in section 3 and summarised in Table 3.1, the Dutch pilot site in Vriedenerf exhibits the following conditions:

- **Condition 4: Catchment area / local resources**. The community exhibits an extended availability of common spaces and the nature-based design of those spaces. This signifies the presence of a catchment area for the community that can accommodate to some extent the storage or production of local resources in aspect beyond just energy. Moreover, they can provide the necessary flexibility to accommodate potential growth and change in the scale and complexity of the community.

- **Condition 5: Mobility and exchange of resources**. The envisioned social interaction necessary to establish peer-to-peer energy sharing can be initiated and/or facilitated by the presence of the community building as the locus of social capital. Next to that, the community building can serve as the locus of extending the kinds of autarky achieved by Vriedenerf, notably in the ecosystem services direction, serving as the centre of generating non-energy flows and organising the total inflows and outflows historically seen in traditional autarkic settlements. This condition has multiple connection to others, notable condition 7 below.

- **Condition 7: Utilisation of human capital and access to financial capital**. The pilot is a small cluster of single-family units in a row/attached layout, with a community building. Although the size of community is rather small, its tight context can also be approached as having the necessary socioeconomic capital to introduce new technologies and practices by individual members. These may be initially due to self-interest and due to socioeconomic differentiation dynamics (cf. section 3). However, they will ultimately diffuse to the entire community, either through indirect effects by positive externalities, or directly via social contagion dynamics.

- **Condition 8: Climate architecture and urban design**. Vriedenerf exhibits a rather green profile at a rural setting, with ample vegetation and use of nature-based design elements on-site. The wider vicinity of the neighbourhood is also rather green. As a consequence, application or further extension of climate considerations in the architecture and urban design of the pilot site can reduce energy demand throughout the year if passive heating and cooling solutions are exploited.

- **Condition 12: Size and location of PV production**. The residential structures and the community building means that the building envelopes can provide a significant amount of local space for on-site, on-building PV installations. Although the community is already self-sufficient and is selling excess energy back to the grid, the potential extensibility to vertical surfaces and public spaces means a substantial capacity to overcome the cost-intensive and unreliable nature of small-scale RES. Moreover, exploitation of this condition—in combination with condition 5 and likely also condition 8—can help the community address the (internal) growth in consumption coming from an expected growth of EVs ownership in the community.

On the other hand, the EV charging station at the University of Twente (SlimPark) exhibits the following condition:

- **Condition 2: Polity and scale**. SlimPark is of minimal scale, being a single user in the view of regulation, and integrated in the university’s own micro grid. These aspects establish the presence of a positive condition regarding polity and scale, with the locus of decision-making largely on-site and with reasonable autonomy and self-determination within the larger regulatory context.

- **Condition 3: Internal social organisation**. Although a single user in the view of regulation, fairness among existing and new users inside the community can be addressed by drawing from the characteristics normally found in academic communities. In this respect, the diversity and multiscale nature of the university community can be harnessed in order to establish communication and monitoring essentials that ensure fair distribution of benefits across the user community. This can be achieved by drawing from the multiscale community governance experiences of the university in other resource sharing (e.g., facilities) and communication (e.g., inter/intra student and faculty communication) domains.

4.3.3.2 Suggested community design strategies per intended intervention

Here we focus on the Vriedenerf community. In addition to the essential conditions that were described in the preceding section, and which can be seen as stand-alone directions to exploit existing strengths of the community, we propose below two concrete design strategies. These storylines aim to utilise some of the identified conditions in order to overcome obstacles to the intended interventions. The design concept is identical to both intended interventions, whereas the design applications differ per interventions (Table 4.3). This is because the two interventions are seen to differ in intensity of the aim rather than representing different aims altogether, at least from a community perspective.

Table 4.3. Suggested community design strategies for the Dutch demonstrators.

Autarkic aspects	Design principles	Design concepts	Design applications
Vriedenerf			
Social organisation and alignment of values and motivations that facilitate collaboration.	“Equal-grounds” voluntary energy sharing between energy users and retailers, while in USEF green/yellow.	As it is difficult to achieve smart P2P sharing via supply and distribution, a “demand sharing” community is created. The community organises information and identifies strategies to reduce demand at the household and at the cluster scales.	A dedicated space is created and equipped at Vriedenerf’s community building, hosting the “Vriedenerf energy autarky task force”. The first task is to document and systematise the spatiotemporal distribution of energy needs and habits at household level. The second task is to develop a “climate design plan” that increases the passive heating and cooling capacity at cluster level by deploying

			climate design solutions within the topology of the neighbourhood.
Sophistication of formal energy governance through automation.	Automated gradual quality of service reduction, while in USEF orange.		The “autarky task force” initiates a second phase, the result of which is the actual modification of the natural features of the neighbourhood in order to increase passive heating and cooling capacity in the neighbourhood’s demand hotspots.

4.4 Poland

4.4.1 Brief introduction

One pilot is being tested in Poland. It is a housing cooperative that consists of five residential apartment buildings, one commercial building, and one technical building. The site is located along Mickiewicza street in the city of Sopot.

4.4.2 Planned interventions and obstacles

The main objective of the Sopot pilot is to develop a micro-grid integrated local energy system within the housing community. The three building types (residential, commercial, technical) are seen as part of a “topology”, including solar PV systems, heat pumps, EV charging, and battery storage. In addition, smart control, monitoring and management systems will be utilised for optimising the operation of the system.

The intervention includes domestic hot water heat pumps and rooftop solar PV panels at the residential apartment building, an EV charger with vehicle-to-grid capability at the office building, and energy storage at the technical building. The smart control system is divided into three subsystems that control the three solutions in the residential, commercial, and technical buildings. One overall data-driven controller (utilising, for instance, weather forecasts and DSO data) is aimed at taking local demand-side actions that optimise the energy use of the three-member topology. These actions include peak shaving (involving the solar PVs and battery via forecasting of energy flows), peak shifting (involving the heat pump and solar PVs, maximising self-consumption by referring to forecasted peak PV production), minimisation of energy costs (by storing energy during consumption lows that will be used during high-price periods), partaking in the global DSM (by delivering services such as energy demand reduction), and enabling an “island” mode (enabling off-grid mode in case of additional energy storage installation, being especially sensitive to EV charging and heat demand).

Referring to deliverable 3.1, the Polish demonstrator is confronted with three obstacles: complex energy uses in conjunction with insufficient social organisation, and uncertainty regarding energy regulations. Concerning complex energy uses, it is noted that the current state of infrastructure and low local energy production necessitate careful and smart energy management solutions, where technological innovation can play a role. However, it is also noted that the necessary collaboration and coordination among the users is hindered by the lack of social organisation which will further hinder community building. In terms of energy regulations, a general uncertainty is noted about the local energy transition of all projects in Poland.

4.4.3 How to achieve a more autarkic, citizen-centred energy system

4.4.3.1 Core conditions present in the pilot

The vision of the planned interventions in the Polish pilot, in conjunction with its current state of affairs and characteristics, can be interpreted as follows by applying Table 3.1 (see section 3) on conditions for autarkic communities.

- **Condition 1: Autarkic unit**. The Polish pilot represents an interesting combination of elementary autarkic units at the demand and supply and sides. Demand-wise, the presence of clearly defined households based on apartment structure appears to be a good start for evaluating autarky, whereas the planning of local RES supply in terms of a cluster is an equally good match. While these elementary units can be modified, their co-presence already sets a positive stage.

- **Condition 2: Polity and scale**. Moreover, the aforementioned housing committee is not only present on-site, but is present in a mixed residential-commercial land use setting. This means that its potential composition can encompass members beyond just residents, including the commercial users of the cluster. Although decision independence cannot be completely located at the pilot's context, exploiting this condition can at least shift the locus to the pilot site.

- **Condition 3: Internal social organisation**. While internal social organisation needs more work in the Polish pilot, there exists a housing committee as one of the main governing bodies on site. This sets a solid foundation for the further development of an internal self-governance structure that not only facilitates cooperation, but also ensures allocation of responsibilities and (re)distribution of benefits and costs among the pilot site's community members.

- **Condition 4: Catchment area / local sources**. The pilot is a cluster of buildings spread along a small area. From an urban design perspective, this firstly means that the community is endowed with a non-trivial number of public spaces in between. Secondly, it signifies the presence of a catchment area for the community, even if it is ultimately a small one. Combined together, these imply that the community can accommodate to some extent the storage or production of local resources and additional social capital. These conditions can increase its autarky and diversify its profile to include aspects beyond just energy. Moreover, they can provide the necessary flexibility to accommodate eventual growth and change in the scale and complexity of the community.

- **Condition 7: Utilisation of human capital and access to financial capital**. The scale of the pilot, being a cluster of apartment and commercial buildings, increases the chances of prosumers on-site. This in turn, in combination with the presence of condition 3, increases the likelihood of new technologies and new solutions being introduced to the community. At first due to self-interests, but ultimately benefiting the entire community.

- **Condition 8: Climate architecture and urban design**. The pilot site exhibits a notably green profile with ample vegetation both on-site in the vicinity of the buildings and in the extended area beyond the site. As a consequence, application of climate considerations in the architecture and urban design of the pilot site can potentially reduce energy demand throughout the year if passive heating and cooling solutions are exploited.

- **Condition 12: Size and location of PV production**. As the pilot site comprises several buildings, their envelopes—starting from but not limited to rooftops—can provide a significant amount of local space for on-site, on-building PV installations. Although sometimes seen as more cost-intensive and unreliable, this condition will relieve the site of the legal and political contestations surrounding the use of of-site land for PV infrastructure.

- **Condition 13: Mixed land use**. The presence of residential and commercial functions in the pilot site, as well as the envisioning of dedicated technical functions is an essential condition already present at the site. Although it can initially take some time to configure integration and cooperation between them, this diversity is expected to introduce increased potential for synergies and optimisation of the energy balance.

4.4.3.2 Suggested community design strategies per intended intervention

Some of the essential conditions described in section 4.4.3.1 can also be combined with the envisioned technical interventions. Based on the information of sections 4.4.3.1 and 4.4.3.2, and considering the essential conditions identified for the site in section 4.4.3.1, the following (Table 4.4) community design strategies can be recommended per intended intervention. These aim to exploit the existing essential conditions present in the pilot site and help the intended technical interventions (as described in D2.1) to support also the socioeconomic and organisational development of the autarkic energy community.

Table 4.4. Suggested community design strategies for the Polish demonstrator.

Autarkic aspects	Design principles	Design concepts	Design applications
Sophistication of formal energy governance through automation.	An automated data-driven management system that optimises demand peaks and costs, also serving as the link to the general grid.	A clearly delineated spatial, temporal, and social locus, where users (representing the site's households and businesses) review system performance, exchange information on refinements and own practices, and	A dedicated "control room" where households and businesses can monitor key performance indicators of the system. The room has also tools to input user information and hosts regular "energy meetings".

		communicate with the housing committee.	
Adaptive technological dependence.	Ability to automatically activate an “island” mode upon additional storage capacity.	The households and businesses of the community document and synthesise their demand needs in order to align social and technical aims and capacities. At the same time, they explore how their neighbourhood topology, and its physical and natural capital, may be co-utilised to expand local production and storage capacity.	A co-created inclusive spatiotemporal systemisation of the energy use needs and habits of households and businesses, product of the “control room” (see row 1). It is accompanied by a community design of storage and vegetation distribution across the site that reduces internal and external demand (see row 3).
Distributed building characteristics as part of settlement characteristics.	Management and realisation of energy production, storage, and consumption forms a mutually dependent topology.	Organisation of community co-design events, where the residential and commercial members of the community explore climate design solutions that reduce heating and cooling needs.	Placement of vegetation on the building envelopes and in public grounds, co-created by the community.

5 Conclusions and Outlook

This report set out to translate the characteristics, aims, and obstacles of the pilot sites of SUSTENANCE into essential autarky conditions that can facilitate the socioeconomic and organisational development of their communities. The report first identified and systematised a set of essential conditions for thriving autarkic communities, pasted on a diversity of historical and current examples. Subsequently, combining these essential conditions with information drawn from the description of the pilot sites and obstacles (based on deliverable 3.1), a developed autarky typology (based on deliverable 3.3), and the planned technical interventions (deliverable 2.1), this report developed an environmental design framework that translates the above elements into design strategies. This report therefore produced two sets of guidelines from a community design perspective.

Firstly, this report identifies and discusses **a set of essential conditions** for each pilot site, that draw from their current strengths and capacities and, if exploited, can achieve aspects of autarky known from past examples in the literature. While the four sets of conditions are different per SUSTENANCE country and also take on different flavours depending on local characteristics, a few commonalities have been identified. The Danish and Polish pilot sites can both exploit conditions surrounding households and the demand-side elementary autarkic unit and cluster (the neighbourhood) as the supply-side elementary autarkic unit, which ensure synergies, on one hand of scale and arrangement of supply resources, and, on the other hand effective and clear social organisation. Furthermore, both the Danish and Polish pilots have some commonalities in their decision-making and internal social organisation conditions, exploitation of which can achieve (some) internal locus of decision power as well as enhance the cooperative and co-creation capacity of the community internally. A condition that appears present across the Danish, Dutch, Indian, and Polish municipalities is that of physical and spatial planning capacity for climate design solutions, exploitation of which can decrease demand by increasing passive heating and cooling capacity. This is an often-overlooked condition that can significantly increase the manoeuvring space of supply-side objectives; more storage and more capacity can be helped with reduced demand after all, which has been traditionally an important element of autarkic communities. Local human capital is common in the Danish, Indian, and Dutch pilots, which can exploit the motivational structures of parts of the community to introduce and implement state-of-the-art solutions that will ultimately benefit the entire community. Moreover, the Polish pilot site is remarkable in the sense of the diversity of its capacities, whereas the Danish demonstrator has the benefit of being an ongoing spatial planning process. In the former case, mixed land uses and the implied internal flexibility is the keyword. In the latter case, co-design among multiple private and public actors is the keyword. Lastly, the Indian demonstrators in Borakhai and Barubeda villages, are remarkable in the fact that, due to their physical and infrastructural remoteness, represent cases closer to the original understanding of systemic autarky beyond just energy. This renders them as prime cases of incorporating a wider spectrum of political, sustenance, and energy use dimensions than normally found in European contexts, where this type of sustenance remoteness is not feasible or desirable, but might become relevant in certain RCP-SSP scenario combinations. As noted throughout the sections, such conditions have been found to be essential elements of autarkic communities throughout very different settings, including in historical times when autarky was a necessity rather than choice. They can be seen as stand-alone "recommendations" to exploit already existing capacity towards increased (energy) autarky.

Secondly, this report develops **a set of design strategies** for each pilot site that translate obstacles and conditions into targeted environmental design workflows, aimed to assist specifically the intended (technical) interventions od each pilot site. These are aimed as more targeted recommendations, serving as complementary to the abovementioned essential conditions. The community design strategies translate the aim(s) of the intended technical interventions (identified in D2.1) in autarky terms, and merge these aims with obstacles (identified in D3.1) and essential conditions (identified in the present D3.2). Based on this, recommendations are developed in the form of design narratives that aim to achieve part of the technical aims in a way that also strengthens the socioeconomic and organisational development of the communities in each pilot site. The design recommendations differ per site, but a few common elements are present. Firstly, it is evident that existing communities can be better organised by specifying much more concrete loci of their activities, in terms of space, time, and community objectives. Dedicated spaces, structured and regular interaction, and clear scope— in a co-creation context—should not be underestimated, because it can transition social capital from mere "wishers" into designers and implementers of their own spatial and organisational solutions. Secondly, it is notable how much climate considerations in architecture and urban design can bring about practical social and technical synergies. As noted earlier, the natural capital of most of the demonstrators is significant and can help optimise both demand and supply aspects while achieving a wider set of synergies.

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