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# Towards a Theory of Local Energy Transition

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**Abstract:** The intended transition to a low-carbon energy system presents a systemic challenge for every country. The focus of this article is on local energy transition, a decentralized approach in which local municipalities will play a key role. The main question in this article is which determinants support the process towards local energy transition. Therefore, an analytic framework is presented. The three-levels-model is a holistic approach which focuses on determinants considering local context, a macro, and a micro framework. It highlights the dependency of the process from the local context and a sound national transition policy. The model summarizes the complex interrelationships of local energy transition and will enable local communities, networks, and citizens to successfully engage in an energy transition process.

**Keywords:** environmental governance; energy transition; renewable energy; transition policy; climate change; sustainable development; civic engagement; citizen participation

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## 1. Introduction

The Swedish scientist Svante Arrhenius predicted in the 19th century that the industrial release of carbon dioxide would lead to a rise in temperature in the atmosphere [1,2]. In the meantime, the average global temperature has risen by 1.1 °C, according to the Intergovernmental Panel on Climate Change [3]. The Paris Agreement was first signed on 22 April 2016. The signing countries pursue efforts to limit the rise of global temperature to well below 2 °C compared to pre-industrial levels. This means that a goal of zero net anthropogenic greenhouse gas emissions should be reached during the second half of the 21st century [4]. The agreement was a real breakthrough, as 193 states as well as the European Union are now subject to this international law [5]. At the time this article was written, 28 years remained to achieve the goals of the Paris Agreement. It is becoming clear that a drastic and rapid effort is needed, especially by the countries that are mainly responsible for $CO_2$ emissions.

Many studies show that a secure supply of exclusively renewable energy to societies in Europe is possible. Diesendorf and Elliston [6] point out that scenarios based on 100 percent renewable energy potential have been calculated for several countries, such as Denmark, Croatia, Portugal, New Zealand, and the USA. In 2021, researchers from the German Institute for Economic Research (DIW) and the Technical University of Berlin analyzed whether such an approach with renewables is feasible for Europe and Germany [7]. The simulation undertaken with the AnyMOD model is based on the assumption of a decentralized distribution of battery storage, electrolyzers, and hydrogen turbines, as well as a constant exchange of energy surpluses and deficits with the countries of the EU. The researchers concluded that a secure supply to Germany can be achieved in a system based 100 percent on renewable energy.

The intended transition to a low-carbon energy system presents first and foremost a "systemic" challenge for every country [8]. The energy transition is nothing less than a revolutionary restructuring of the entire energy supply in the sectors of electricity, heat, and transportation. Some scientists argue that this comprehensive reorganization is a task for generations [9,10]. Time is, however, running short to realize the aforementioned transition goals.

Local energy transition (LET) can be a core strategy to reach a carbon-free energy system in Europe. LET in this article is defined following Leonhardt et al. (2022) as the transition from centralized fossil and nuclear energy generation to renewable energy generation and consumption at the local level. This local transition process is characterized by a high degree of private ownership and control, as well as collective benefits. It is driven by small-scale energy projects with local participation and local energy initiatives (Da Soares Silva und Horlings 2020). The goal of the process is to achieve zero greenhouse gas emission due to energy generation and savings.

In such a decentralized transition approach, municipalities will play a key role. To put it simply: if all municipalities in a country become self-sufficient in generating energy based on renewables, the whole country will meet the climate target of zero $CO_2$ gas emissions.

Engelken et al. [11] highlight the importance and the need of an integrated LET approach that takes determinants for suitable policy interventions into consideration. Such an integrated holistic approach for LET has been missing until now. Therefore, the objective of this article is to build a theoretical framework for the implementation of LET. The main question is which determinants support the process towards the self-sufficient production of renewable energy at a local level. An analytic framework will be developed. The content presented in this article is based on findings of the ERASMUS+ Strategic Partnership for Higher Education LOTUS (locally organized transition of urban sustainable spaces; https://lotus-transition.eu, accessed on 22 July 2022). The case studies developed in the project show that the process of LET is subject to certain conditions that should be considered. The article aims to contribute to expand and accelerate LET and make it attractive to all municipalities in Europe.

The paper is organized as follows: the next section (Section 2) provides the theoretical background; Section 3 describes the three-levels-model of determinants for the LET process; in Section 4 this model is applied for the analysis of two LOTUS case studies; and the final section (Section 5) provides some concluding remarks.

## 2. Theoretical Background

The main objective of the article is the development of an analytical framework for LET. Thus, it refers to the theory of national and regional competitiveness developed by Michael Porter. The paper is an attempt to transfer and adapt this approach to the field of LET.

In 1990, in *'The Competitive Advantage of Nations'*, Porter developed a new theory of the competitiveness of nations, states, and other geographic areas [12]. For Porter, the competitiveness of a location is a complex outcome of the forces described as factor conditions, context and rivalry conditions, demand conditions, and supporting industries. This so-called diamond model provides a holistic and very flexible concept that can be used as a tool for analysis to consider competitiveness of a location in its complexity and to discuss improving the environment for raising competitiveness [13]. Over time, Porter realized that many of the factors influencing microeconomic competitiveness were not generic or distributed evenly across nations, but "clustered" within regions [14]. In clusters, local companies and organizations are linked closely by complementarities, trustworthy relationships and by competitive and cooperative interactions. Learning effects, knowledge spillovers, and innovation due to spatial agglomeration provide a dynamic competitiveness allowing adaptation and resilience to continuously changing markets and technology [15]. Therefore, Porter's model of regional competitiveness is built on three levels of determinants:

- Endowments describe the regional context and include natural resources, geographical and population characteristics, climate conditions, land area, and historical legacy which create a foundation for prosperity. In Porter's view, true competitiveness arises from productivity of the use of these endowments.

- Macroeconomic competitiveness includes sound monetary and fiscal policy, effective public institutions, and human and social development with a good education and health care system. It is important to underline that, following Porter, macroeconomic competitiveness provides the economy-wide context in which local competitiveness can emerge, but is not sufficient to ensure it.
- Microeconomic competitiveness ultimately depends on improving the microeconomic capability of the economy and the sophistication of local competition. The important determinants for local competitiveness are the quality of the business environment, the sophistication of company operations and strategy, and the state of cluster development.

Some obvious similarities exist between this regional innovation system approach and the LET approach [16]. In both cases, the approaches focus on regional or local phenomena. Scholars point out the uneven geographical distribution of renewable energy technologies and sustainable transitions [17] which is the same for the regional competitiveness approach. The ability to build a local innovative environment is necessary to foster regional competitiveness and to ensure the success of LET [16]. Successful LET initiatives are characterized by strong local actor networks [18], comparable to economic clusters. Therefore, a theory transfer from regional competitiveness theory to LET is appropriate. This transfer will be carried out in the following Section 3.

## 3. Determinants of Local Energy Transition—The Three-Levels-Model of LET

In this chapter, a model describing determinants of successful LET is proposed. This model, analogous to the theory of regional competitiveness, encompasses three different levels: the local context (endowments), the macro framework, and the micro framework (Figure 1).

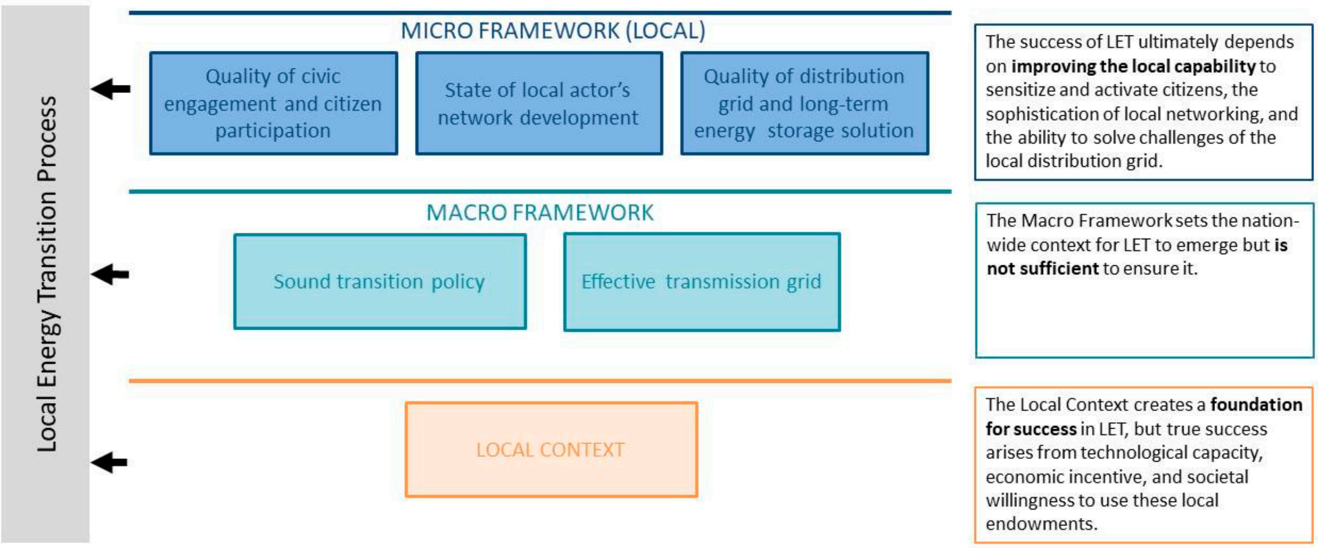


**Figure 1.** Determinants of LET. Source: author's diagram; Design: Nina Kulawik.

This theoretical approach provides a holistic view of the determinants of the LET process. It is intended to enable a discussion on how these insights can help to most effectively realize LET. All three levels have an influence on the process of LET. It will be shown, however, that the local level is especially crucial for the success of LET.

### *3.1. Local Context*

The local context includes all regional, location-specific factors that influence the process of regional energy transition. There are geographical, geological, and meteorological conditions that influence the production of renewable energies. Even within individual countries, these natural conditions can differ considerably between regions. Proximity to coasts and locations within mountain ranges usually facilitates the use of wind as a source of renewable energy. The geographical proximity to rivers enables the installation of water turbines. In coastal regions, tidal power plants may be installed. The use of solar energy is favored by a long average annual sunshine duration and by a low variation in the length of daylight over the year. Geologically stable areas may allow the use of geothermal energy. Sufficient land is also required for all these types of energy. Local demographics are another important influential factor. Big-city neighborhoods with their high population density require different, possibly more large-scale approaches to energy supply than rural areas. Energy saving plays a more important role in urban areas. Another category of endowments are economic structures of locations. In agricultural regions, there is usually potential for the use of biogas. In industrial regions, waste heat from industrial processes can possibly be fed into a local heating network.

The local context varies, sometimes significantly, from region to region [19]. For example, the city of Valetta in Malta averages 2.5 times more hours of sunshine per year (2957 h) [20] than the city of Glasgow in Scotland (1203 h) [21]. There is a tendency for the number of average sunny days per year in Europe to increase the further south the region is located [19]. Similar variabilities apply to wind conditions in Europe [22].

Some energy sources can be excluded against the background of local conditions. It is obvious that water turbines are not an option in regions without rivers. The successful use of geothermal energy has been historically based on a learning process. It has been shown that sufficient knowledge of geological constraints is necessary for the implementation of this kind of renewable energy production, because certain regions are not suitable for this purpose. For example, in 2007 in southwestern Germany, seven geothermal wellbores were drilled in the medieval town of Staufen in southern Baden. The resulting uplift of the ground severely damaged many historically listed buildings in the town [23].

The case studies of the LOTUS project show that a mix of different renewable energy sources is generally used in the municipalities. Photovoltaics and wind energy play a central role. Regional characteristics influence energy production. For example, in the municipality of Freiamt in the Black Forest, additional energy is produced from hydropower, biogas, wood pallet and wood chip combustion, and wood stoves on many private properties. In Hamburg's district of Wilhelmsburg, energy is generated from photovoltaics, wind power, gas emissions from a disused landfill, and industrial waste heat. In addition, energy consumption is reduced through energy-efficient refurbishment of buildings.

The different local conditions must be considered when restructuring the energy supply. The local characteristics serve to differentiate one region from another. They require different approaches to the LET. According to Horlings, the ability to adapt effectively to the current environmental vulnerabilities presumes a local approach and interdisciplinary solutions, building on the specific resources, assets, capacities, and distinctiveness of each location [24]. Therefore, it can be stated that residents, due to their knowledge of local characteristics, may be best suited to decide how LET can be implemented in their own region.

### *3.2. The Macro Framework*

The macro level relates to the national and supranational policies which influence the transition process. This so-called energy transition policy gives a framework for transition initiatives on the local level. Most probably, there is no "panacea" for transition governance towards a post-carbon society. Cultures, structures, and practices in this regard are context dependent. Therefore, transition policies will have to be tailored to national circumstances [25]. A second important technical component of the macro framework is the electricity transmission network. It is another key element for energy transition.

#### 3.2.1. Sound Transition Policy

Transition policy encompasses a whole range of different policy areas. Overlaps in content between these policies are possible. It is important to be aware of this diversity of political influence. Ultimately, whether an LET process can be implemented in a promising way depends on these policies.

*Energy policy* is maybe the most decisive policy area. Politicians must decide whether the transition process will be implemented in a centralized or decentralized way. In contemporary energy governance, political decision making evolved together with centralized generation models [26,27]. Energy generated from fossil or nuclear sources is usually produced large-scale at centralized locations. Renewable energy generators, characterized by small entities of renewable energy generation such as photovoltaics on roofs, single wind turbines, or biogas generation, are producing on small scales at decentralized locations. However, large-scale renewables, typically wind offshore and large onshore wind farms or large photovoltaic open area parks, produce equally well in a centralized manner.

Since 2016 at the latest, all EU countries have committed to pursuing a low-carbon strategy [28]. To date, it is neither clear what exactly will be the sustainable energy system structure of the future and how the transition process to this sustainable structure will be managed and governed [29], nor have national governments or EU funding policies yet indicated whether the energy transition process should be a centralized or decentralized one [30–32].

The implementation of energy policy is to take place very differently. On the one hand, various countries are seeking to expand their nuclear energy capacities. The main arguments for this are energy security and energy independence [33]. These countries include, above all, the Eastern European EU states and France. On the other hand, some countries are phasing out nuclear power generation or deciding not to introduce it at all. An important driver was the Fukushima disaster, which significantly strengthened the rejection of nuclear energy in countries such as Italy, Portugal and Germany [34]. Energy policy that favors the expansion of nuclear power does not need to consider changing the central generation model. The same is true for energy policies that favor renewable energy but rely particularly on large offshore and onshore wind farms and solar farms for power generation. Nevertheless, energy policy can also pursue the goal of generating renewable energy in smaller units and in a geographically decentralized manner. This approach is compatible with the local energy transition.

In the context of transition policy, *fiscal policy* can be considered as the policy instrument tool box which engenders desired change through financial incentives [35]. The government attempts to increase the construction and use of renewables and to reduce energy consumption. On the supply side, this can be achieved through instruments such as renewable energy production subsidies, carbon taxes, investment tax credits, and research subsidies. On the demand side instruments such as consumption taxes, rebates for energy-efficient goods, and tax credits for investing in more efficient technologies can be applied.

Financial supports such as funding programs, loans, and grants are the most frequently discussed instrument in the literature on community energy [36]. So-called carbon pricing tries to standardize the marginal cost of abatement across diverse sources, technologies, and consumers. It is widely seen as the least-cost economy-wide policy to reduce $CO_2$ emissions [37]. The carbon tax will allow emitters to choose abatement strategies [38]. Feed-in tariffs that offer fixed payments for renewable energy generation over an established period are another important driver for local energy development [39,40].

With that said, these fiscal policy instruments are not perfect. They require a great deal of information to ensure that levels are optimally set. For example, when carbon taxes are set too low, objectives of the tax are not archived. When they are too high, social welfare can suffer [41].

*Regulatory policy* is about achieving the government's objectives using regulations, laws, and other instruments to deliver better economic and social outcomes. Regulatory policy is used, for example, to regulate or deregulate monopolies to reduce the welfare losses resulting from the market failure of the monopoly. Network economies such as electricity or heat networks are characterized by the phenomenon of natural monopoly because of network externalities and economies of scale. The electricity sector can be split into four subsectors: generation, transmission, distribution, and retailing (Transmission refers to long-distance transport at very high voltages, while distribution is done at lower voltage for local delivery to customer locations). In European countries competition is more or less introduced to energy generation and retailing. Transmission and distribution remain monopolies [42]. Incumbent companies in the energy market favor centralized strategies and policies [43]. We can assume that incumbent firms will at least not support and may even hinder the local energy transition process [30]. The reason is simply that they risk losing market share and money. Regulatory policy is the instrument to overcome this problem, e.g., with legal regulation making feed into the grid possible and economically attractive for other companies and prosumers. Furthermore, renewable energy producers often are hindered by other market hurdles. Ameli and Brand [44] analyze which barriers hinder households from investing in efficient and renewable energy. They mention, for example, principal-agent problems and asymmetric information. Principal-agent problems may arise when the people responsible for investment decisions are not the same as those who benefit from the energy savings. A commonly cited example is the relationship between landlord and tenant. Since the tenant typically benefits from the savings from energetic renovation on the energy bill, there is little incentive for the owner to invest. Asymmetric information may discourage lenders from offering loans for energy efficiency investments to individual households because financial institutions often lack the know-how to measure and verify energy savings. Possible investments in energy renovation of buildings and in the production of energy with renewables do not take place. Policies are needed to try to mitigate and remove these barriers.

According to Edquist, *innovation policy* in the energy transition context may be defined broadly as all policies that have an impact on innovation, or more narrowly as policies (or policy instruments) created with the intent to affect innovation [45]. There is a general belief that science and politics are key to solving global and complex issues of sustainable development, relying on the strength and innovativeness of citizens, local communities and initiatives, entrepreneurs, and their networks [46–48]. National governments in Europe and the European Commission try to foster innovation in the energy transition process via funding programs [49,50].

In the context of the energy transition, *social policy* has to deal with energy or fuel poverty, a phenomenon that actually occurs in social housing [51,52] and development aid [53]. According to Boardman [54] energy poverty exists when a household is unable to afford adequate energy services in the home on their current income. It includes all uses of energy—not just heating—and the standards to be obtained are what is needed, not what is being achieved. The United Nations define poverty in a much more complex way: Poverty entails more than the lack of income and productive resources to ensure sustainable livelihoods. Its manifestations include hunger and malnutrition, limited access to education and other basic services, social discrimination and exclusion, as well as the lack of participation in decision-making [55]. Energy poverty is therefore only a small part of the moral and social problem that results from poverty. It is, however, relevant to energy transition because those affected may have the impression that transition policy instruments are the cause of their poverty. The resistance to these instruments will therefore be considerable. This can be well observed in the movement to date of the "gilets jaunes" (yellow vests) protesters in France [56]. The movement was initially motivated by rising crude oil and fuel prices, triggered by a new carbon tax. Due to the weekly protests the new tax was cancelled by the French government. The protests continued. Of course, the problem of a general high cost of living and economic inequality was not solved with the withdrawal of the carbon tax. This episode from the French energy transition policy shows that social impacts of measures must always be considered.

It can be stated that a sound transition policy is a prerequisite to make successful local energy transition possible. Therefore, a balanced, well-coordinated policy mix on the macro level is needed. This will not, however, automatically lead to a successful process on the local level, as there are further important success factors (see Section 3.3). On the other hand, a misleading and inadequate transition policy may prevent any success of a local energy transition process. For example, subsidies can result in such low energy prices that investment in renewable energy facilities becomes unattractive. Feed-in tariffs that are too low lead to the same result. A lack of decentralization policy may enable incumbent companies to successfully oppose the LET process.

#### 3.2.2. Effective Transmission Grid

The expansion and modification of transmission infrastructure constitutes a key element of the successful implementation of energy transition in Europe. Researchers discuss a lot of many different approaches to deal with the expected further increase in renewable energy generation in Europe under the perspective of a fundamental upgrade of the transmission system. A major challenge linked to energy transition is the variability of the most promising resources. Weather conditions determine the output of wind and solar energy generation. These variabilities must be balanced in the electricity grid in order to guarantee liability. Different options to balance supply and demand in the renewable electricity market are discussed in the literature, such as, for example, large scale energy storage, expansion of interconnection capacity, flexible power plants, market integration, and system operation closer to real time [57,58].

Today, electricity systems in Europe are mainly coined by centralized structures of generation and distribution [29]. As energy generation by renewables will be more decentralized than energy generated by fossil and nuclear power plants, Lienert et al. [59] expect that new power lines will need to be built. This kind of conventional grid expansion has been compared to grid optimization measures such as “overhead line monitoring”, “power-to-heat”, and “demand response in the industry” [60]. Another option are upgrades at a higher voltage by constructing a new overlay grid or supergrid [61].

All these expansion measures are likely to involve very high investment costs. The investment costs for a conventional expansion of the transmission infrastructure in Germany alone are estimated at 52 billion euros until 2030 [62]. The implementation of these infrastructure changes will probably lead to major challenges for infrastructure policy. Authors mention the lack of public acceptance, financing, and protection of environment and landscape [59,63]. A recent study from the Technical University Berlin (TU Berlin) and the German Institute for Economic Research (DIW) shows, however, that a transition based on local and decentralized energy generation leads to a significant lower need for grid infrastructure expansion [7]. This seems reasonable because larger amounts of the electricity consumed locally are also generated locally.

A very important aspect is the improved interconnection of the European transmission grid. The expert group on electricity interconnection targets set up by the European Commission envisages five clusters of benefits that electricity interconnectors bring to the European Union [64]:

- Deeper integration of European electricity markets, which allow for a better use of the complementarities that exist between the differing generation mixes across Europe and which contribute to generation adequacy by lowering the needs for operational security margins and reducing grid losses.
- A higher level of interconnection in combination with the increase in generation from renewables reduces the extent of power shutdowns.
- Increased security of supply across Europe.
- Strengthened regional cooperation between Member States.
- Cooperation on interconnectors, which offers opportunities for uptake of European technologies and thus strengthens employment and industrial competitiveness.

Furthermore, Kies et al. [65] showed that unlimited transmission in Europe would reduce storage energy needs in a 100 percent renewables scenario by approximately 45 percent.

### *3.3. The Micro Framework*

The transition to locally produced energies and the capability to reach local energy autarky depends ultimately on the local level. This means it depends on the capacity of local actors and administration as well as citizens to initialize and implement projects, to innovate and to create acceptance and support. Local energy autarky, the target of this process, is conceptualized in the literature as a situation in which the energy services used for sustaining local consumption, local production, and transport are derived from locally renewable energy resources [66]. Schmidt et al. distinguish between absolute and relative autonomy [67]. Absolute energy autarky does not allow any balancing, thus implying that energy resources are not imported at all. In this article, the concept of relative local energy autarky is applied. It describes a situation in which, on a renewable basis, a municipality produces at least as much energy as is consumed over the course of one year. This does not mean that a municipality is energy self-sufficient at any time during the year. Energy surpluses and deficits can occur at certain times of the year or on a particular day.

#### 3.3.1. The Implementation of LET

Schaffrin and Fohr [16] divide the LET process at the local level in four different phases which is, for the theory of LET, extended by a first phase of planning:

1. Planning phase: the examination of local renewable energy potential; analysis of potential local actor networks; sensitization and mobilization of local citizens; and the search for external knowledge sources.
2. Pioneer phase: strong entrepreneurial activity and knowledge development, which can be supported by publicly available presentations of energy-benchmark and pilot-projects.
3. Pivotal network phase: diffusion of knowledge and mobilization (sensitization) of resources within the community; building strategic networks—including external, more experienced actors—by establishing platforms of dialog and common routines with the aim to reach a high level of trust and close relationships between local individual actors.
4. Extended network phase: key actors formulate their expectations and initiate the process; and the municipality supports local capacities by implementing and practicing participative elements in the early process of planning and decision making.
5. Market formation: energy projects are realized, resources mobilized, and counteraction of local resistance takes place if necessary; long-term investments in critical infrastructures such as the electricity grid or hydrogen infrastructure are realized; and opportunities for local and external actors to cooperate on innovative projects emerge.

Through the analysis of the case studies of the LOTUS project, three areas of determinants at the local level were identified. To enable successful LET process, these determinants should be considered at all stages of implementation. The three areas of determinants are:

- Networking of local actors;
- Citizen participation;
- Expanding local distribution grids into smart grids and developing a long-term energy storage solution.

These three areas are analyzed in more detail below.

#### 3.3.2. Networking of Local Actors

Understanding the networking mechanisms in communities is important for improving the management and success of the LET process. Research suggests that collaboration is critical for LET project implementation [68,69]. Participatory models of governance have a particular stimulating effect in solving local challenges. They lead to greater acceptance and a stronger incentive for the commitment of the stakeholders [70]. This governance approach is also known as collaborative governance. It brings multiple stakeholders together in common forums with public agencies to engage in consensus-oriented decision making [71].

In the LOTUS case studies, we identified several local stakeholders playing a crucial role in the LET process. A detailed description of these actors can be found in Table 1.

**Table 1.** Main LET stakeholders. Source: author's table.

| Stakeholders | Role of Actors |
|---|---|
| **Municipality** | The municipality can play an important role in the LET process as initiator, network manager, idea provider, exemplary model, and financial supporter. Municipalities should develop strategies with principles of good governance, such as negotiation, transparency, communication, trust, and cooperation between stakeholders [72]. In most cases of LET, the municipality will take on at least some of these roles. Sometimes these roles can, however, also be taken by other actors, such as private individuals and companies. In this case, it is sufficient for the municipality to actively support the LET process by aligning its administrative planning procedures and its own communication, and by processing approval procedures quickly and as straightforwardly as possible. |
| **Citizen's associations** | These associations serve as a platform for the citizens to discuss renewable energy projects. Through these associations, persuasive efforts are carried out. They are the link between the other actors and the citizens. Citizen's associations can even take up an active leadership in the production of renewable energy [70]. In two rural LOTUS case studies, we observed that the associations contribute to the organization of guided tours for interested groups and answer questions from the press and other organizations. |
| **Private companies** | The presence of private companies in the local network is an important indicator of the project's potential for success. They will only be engaged if there is an opportunity to make profits. Companies also contribute the necessary technical and economic know-how to the network. Citizen-owned energy companies or cooperatives should be highlighted as important in order to involve citizens economically in the use of sustainable energy. These companies may invest in wind turbines or photovoltaic panels. Capital can be mobilized from private households. |
| **Local energy manager** | The tasks of the energy manager are the expansion of the local distribution grid and the development of a local long-term energy storage solution. In many municipalities there are already local distribution grid managers (e.g., public utility companies). These could also take on the task of building a local hydrogen economy (see also Section 3.3.4). |
| **Farmers** | Farmers are key actors especially in rural areas. They are the owners of the land where wind turbines and biogas plants are built. Furthermore, they have large roof areas which are used for photovoltaic systems. Many local farmers themselves invest in renewable energies. They become energy producers, not only for their own consumption but also as entrepreneurs. |
| **Financing institutions** | In many LOTUS cases renewable energy projects were co-financed through loans by a bank. At the very beginning of the LET process, such projects were still "uncharted territory" for the local banks. Since then, local banks have taken up the financing of such projects too. |
| **Universities, research institutes** | The heterogeneity of the places and the different local context make every LET process also a journey of discovery. Universities and research institutions are the ideal partners to assess such unique local situations and to generate innovations. They can, for example, help to build a smart distribution network that is tailored to local requirements [73] or analyze special local storage and production possibilities, such as the conversion of a World War II flack bunker into a heat storage facility [74]. |
| **LET manager** | The LET manager initiates, coordinates, manages, and monitors projects in the LET process. If necessary, he also implements them. The position will usually be located in the municipality or in a local public company but can also be filled in smaller communities by civic engagement or a civic enterprise. The connectivity of a specific actor, working as 'place leader', helps to span boundaries between local stakeholders. This corresponds with studies on the role of leading individuals or place leaders in bridging scales, crossing rural–urban boundaries, and spatial networking [24]. Because the LET manager needs to coordinate the external network of local actors and the internal network of local administration, the job description is similar to that of a cluster manager [75]. Their tasks are also found in the relatively new professional profile of the climate protection manager in the local government in Germany [76]. |

A supporting network of local stakeholders may improve the local capacity to develop, implement, and manage the LET process with their specific knowledge and expertise [77]. There is a general belief in science and politics that the key for solving global and complex issues of sustainable development lies in the strength and innovativeness of local communities and initiatives, entrepreneurs, and their networks [47]. Local actors are seen as experts of their living environment. They are the most qualified to find effective and creative solutions to specific local challenges of the LET. We must consider as well that a high level of innovation is not limited to agglomerations, as the regional competitive approach might suggest. Shearmur [78] and others point out evidence for innovation, even in rural and peripheral locations, triggered by social and network proximity, local knowledge that is difficult to communicate, or close connection of local actors with local resources [79,80].

Nevertheless, there is a risk of failure of local networking. Strong social networks and predefined and consistent institutions on the local level might lead to gated communities. They might limit the ability to adapt and integrate new external information [46,81]. These closed networks might reproduce unbalanced power structures and social conflicts within the community. Therefore, collective actions might become impossible. To avoid such difficulties in the networking process, a trained and well experienced LET manager might be very helpful.

#### 3.3.3. Citizen Participation

Since the 1960s, participatory processes in governance are discussed in the literature. Arnstein described the degrees of citizen empowerment corresponding to levels of involvement [82]. She argued that greater levels of citizen involvement increase effectiveness of public projects more than top-down decision making.

This seems to be particularly true for sustainability projects in local communities [69,83]. An intense interconnection of citizens within the LET process is made possible by common interests and values. Collaboration in local governance is considered to be a fundamental element for sustainable development [84]. Conti et al. found that a city can only be sustainable if the governance process allows citizen participation [85].

The benefits of citizen participation are uncontested. Collaboration and citizen-driven mechanisms provide opportunities to resolve conflicts among stakeholders [86]. Participation processes support sound planning and policy implementation [87]. Furthermore, they facilitate learning and build trust in government, if successful [70]. In many places, protests and resistance against the expansion of renewables takes place. Citizens feel affected by potential noises, shadowing, or more generally negative impact on the environment. The local tourism industry may fear the consequences of high visibility of wind turbines, but there is evidence that public ownership of and participation in energy infrastructures increases citizens' acceptance and support [88,89]. Citizen ownership may be realized by energy cooperatives [90] or other types of business ownership such as we observed in the LOTUS case studies. In a participatory LET process, one can also expect that innovation takes place [16,91,92]. Krause found that cities with a larger number of participating citizens in the US Mayors' Climate Protection Agreement are themselves more likely to commit to climate protection by joining the program [93].

Collaborative governance systems also carry risks. Participation processes might, for example, be merely pro forma or serve interest groups with more influence [70]. They then create an imbalance of power and lead to political apathy.

Conti et al. [85] provide a detailed overview of risks and benefits resulting from the participatory approach of LET (Table 2).

**Table 2.** Benefits and Risk of LET according to Conti et al. (2019).

| Benefits | Risks |
| --- | --- |
| • Participation of citizens and civil society.<br>• Integration of different views and options into the discussion.<br>• Identification of specific challenges according to the location.<br>• Shared actions and responsibilities will increase support and commitment.<br>• Local ownership creates incomes.<br>• Long-term plans can be established.<br>• Transparency.<br>• Breaking private lobbies.<br>• Credibility in decisions.<br>• Improve locations livability. | • Frustrations and unfulfilled expectations due to lack of management or excessive expectations.<br>• Participants recurrence in discussions—lack of overall representation of the citizens.<br>• The domain of the public agenda by organized groups.<br>• Conflicts and tensions between different stakeholders.<br>• A long-term requirement for decision-making.<br>• Exclusion of citizens and organizations that do not have time to participate in governance processes.<br>• Lack of clarity or feedback in the communication process.<br>• Emphasis on participation and low achievement.<br>• Artificial queries and manipulation.<br>• Deformity in public policy development.<br>• Extremisms in the negotiation process. |

Schaffrin and Fohr [16] point out that citizen participation in the LET process can only provide sustainable results if it ensures long-term capacity building within the whole transition process. This concerns not only the provision of electricity and heat by renewable resources. Furthermore, a long list of sustainability issues such as energy security, nature protection, environmental and social justice, regional value added, support of local businesses, and the provision of public services must be taken into account.

#### 3.3.4. Enhancement of the Distribution Grid and Development of a Local Long-Term Energy Storage Solution

The task of the distribution grid is to distribute electrical energy from the substations to the grid stations that supply the low-voltage grid and the consumers connected to it [94]. With the increasing share of renewable energies, the management of the distribution grid faces new challenges. Photovoltaic and wind power plants are highly dependent on the weather. Within one day, strong fluctuations in energy production can occur, which might put the security of supply in question. Possible bottlenecks caused by too much simultaneous consumption or feed-in are a danger to the operation of distribution grids and must be prevented.

To avoid such overload phenomena in the grid, different approaches can be adopted. Local energy producers, such as wind farms and solar plants, can be combined in a virtual power plant. Through an interconnection of many plants, the security of supply is increased. The dependence on location and weather is reduced and the predictability of the grid situation is improved [95,96]. Local self-consumption of locally generated electricity is another important component in relieving distribution grids. In a simulation, McKenna et al. [97] found a 24 percent reduction in average annual electricity demand from the grid from households with PV generation. In the simulation, it was assumed that households consume 45 percent of their own electricity production. Collective prosumer business models and regulations for self-generation and self-consumption appear [98]. New forms of local energy markets are on the rise with the intention to consume locally produced energy, e.g., the peer-to-peer approach [99]. The integration of digital technologies in grids, so-called "smart grids", enables many new applications [100]. The inclusion of wind, solar, and load forecasts, and the installation of smart meters in households opens up great optimization potential [100,101]. Another important element in the local energy supply in a smart grid is energy storage, which can be used when overcapacities or shortages occur in the grid. Storage facilities can compensate for imbalances between supply and demand [94]. Research highlights the need for energy policy to develop market mechanisms which facilitate the deployment of community storage [102].

The local electricity grids must be expanded according to local conditions and equipped with "intelligent" technology, e.g., demand-side response (DSR), frequency response, storage, vehicle-to-grid, and electrification of heat [103]. In recent years experimentation in different countries shows that an intelligent management of demand, generation, and storage can alleviate system stress. Numerous experiments have recently been undertaken throughout Europe to analyze how distribution network operators can manage the network effectively, e.g., via an online platform [30,104].

To store energy over a longer period of time, e.g., from summer to winter, the development of local long-term energy storage solutions is discussed. The generation of hydrogen from electricity is also referred to as power-to-gas (PtG). PtG generates CO2-neutral substitutes for gas and fuels in the form of hydrogen or methane for use in other consumption sectors [105,106]. PtG offers the ability to store energy from renewables when electricity production is high but demand is low, and to shift energy into periods with low electricity supply. It can also be used to prevent local overloading of the power grid [107]. Multiple recent studies mention the reconversion of hydrogen into electricity as a central element and a key energy carrier in a renewable energy system. Nevertheless, using Germany as an example, many business models may not be viable under current market conditions. Jarosch et al. [108] found that the price of hydrogen needs to be sufficiently high and changes in electricity price components, such as more flexible grid-usage fees, must be realized. Other forms of long-term energy storage may be taken into consideration, depending on their location. Pumped hydro-electric storage uses surplus power to pump water from a lower reservoir to a higher-level reservoir. When energy demand exceeds supply, water is released from the higher reservoir to turn the turbine and to produce electricity. Another mechanical solution is compressed air energy storage. Surplus power is used to compress air at high pressure into an underground reservoir or a surface vessel. During times of energy demand surplus, the compressed air is combined with a fuel to drive a turbine generator set [109].

It is important that the choice of the long-term energy storage system is not introduced by the national government in a top-down manner. A region's local conditions should be taken into account first. In a mountainous location, pumped hydro-electric storage may be the best solution. In other regions PtG technology may be the best. Secondly, a top-down decision as to which technology has to be used may prevent local innovation.

## 4. Application of the Three-Levels-Model of LET on Two Case Regions

This chapter of the paper is devoted to the application of the three-levels-model for the analysis of LET in two case regions in Germany. The first is the rural community of Freiamt in the Black Forest and the second is an urban one, i.e., Wilhelmsburg, the largest district of the city of Hamburg. The Municipality of Freiamt is located on a plateau in the Black Forest at an altitude of 250 to 750 m. The 4222 inhabitants (in 2020) are distributed over five small villages. The settlement area makes up only 4 percent of the municipality. The landscape is characterized by forest and agriculture. Tourism is an important economic factor. The LET process in Freiamt started at the end of the 1990s. The community has undergone an amazing development from carbon-based energy consumer to renewable energy producer. Today, renewable energy is generated in Freiamt by 6 wind turbines, 2 biogas plants, 4 small hydropower plants, about 300 photovoltaic and 150 solar plants, many woodchip and pellet heating systems, and heat pumps in many private households [110]. Energy production exceeds consumption by at least a factor of two.

Hamburg is the largest harbor of Germany, although the city is located around 100 km from the Northern Sea, connected to the sea via the river Elbe. A total of 1.8 million people live in Hamburg. Not surprisingly, the harbor is still the most important economic resource for the whole region. With 53,064 inhabitants in 2020 Wilhelmsburg is the biggest district of the city, situated in the south between two wide arms of the river Elbe and in the direct neighborhood of the harbor.

In 2013 a study proved that relative energy autarky for the Wilhelmsburg district through renewable energies is achievable [111]. Since then, the city-owned International Bauausstellung Hamburg GmbH (IBA) initiated more than 60 projects for the production of renewable energy in the Wilhelmsburg district, e.g., construction of wind turbines, solar panels on roofs, a local district heating grid, including heat storage in a World War II flag bunker, integration of industrial waste heat into the grid, and energy refurbishment of old buildings. Data of energy production and consumption in the district are not available because the public company Hamburg Energie, which holds a monopoly position in the local distribution grid, does not publish data.

Table 3 shows how these two cases fit into the described framework of the local context and the macro and microenvironment. As both cases are from Germany, the macro framework is similar for both cases. The micro framework, however, is very different.

**Table 3.** The three-levels-model of LET applied to the two case studies considered. Source: author's table.

<table>
<tr><th>Level</th><th>Freiamt</th><th>Hamburg-Wilhelmsburg</th></tr>
<tr><td>Local context</td><td>Located on a mountain plateau.<br>Rural, agriculture and tourism.<br>Low density of population.<br>Small rivers.<br>Residents have long been sensitive to environmental protection, sustainability, and renewable energies.</td><td>Proximity to coasts.<br>Urban and industrialized.<br>High density of population.<br>River Elbe.<br>Residents face social problems and integration.</td></tr>
<tr><td>Macro framework</td><td colspan="2">Energy policy in Germany is influenced by large popular resistance against nuclear power, at least since the Chernobyl nuclear disaster in 1986. After the Fukushima core meltdown accident in 2011, the German government, supported by a large majority of the people, decided on a nuclear phase-out by 2022.<br>The notion that a low-$CO_2$ energy supply could soon be necessary and that renewables therefore would play a key role in future energy systems already emerged in the 1980s. The awareness of global warming continued to grow in the 1990s and was picked out as a central theme by the Green party in every election campaign. For the first time in German history, in 1998, the Greens, a party which focused on ecology became part of the federal government. The Act on Granting Priority to Renewable Energy (Renewable Energy Act, EEG), came into force in March 2000. The Renewable Energies Act made it a requirement for grid operators to feed all energy from such sources into the grid, even in the event of oversupply, and to pay for it according to fixed feed-in-tariffs. In case of doubt, conventional power plants must be shut down to compensate. Various shortcomings of the law, such as very high costs to taxpayers due to high feed-in tariffs and insufficient incentives for self-use of locally produced energy, have been remedied over time.<br>As a consequence, the German market price for electricity became one of the highest in Europe. This burden on German-based industry simultaneously makes investments in renewables more attractive.<br>The federal system of Germany allows municipalities to own the local distribution grids and to organize energy production locally.</td></tr>
</table>

**Table 3.** *Cont.*

| Level | Freiamt | Hamburg-Wilhelmsburg |
| --- | --- | --- |
| **Micro framework** | | |
| Citizen's participation | The Freiamt LET initiative is a genuine bottom-up project organized by some citizens of the community. Participation of the people is guaranteed in the communication and decision making, as well as in the profits. The citizens founded several commonly owned energy companies which executed the construction of wind turbines and solar panels. The large civic engagement is certainly a reason why opposition to wind turbines is more or less inexistent. Furthermore, the common citizens' will to promote energy transition in Freiamt overcomes obstacles created by state policy, e.g., in the form of excessive bureaucracy. | The Wilhelmsburg LET initiative is a top-down project, organized by the city-owned IBA. Civil society has been involved in several actions in different ways but plays a minor role. Citizens or civic movements do not take the initiative. They provide information and make suggestions in workshops but otherwise play a rather passive role. |
| Actors network | A citizen's organization taking the role of a transition manager, farmers, private companies, the municipality, financing institutions, universities; the participants in the network share the same similar values which build trust among the stakeholders allowing common and intensive engagement in the LET process. | IBA Hamburg GmbH, which successfully takes the role of the transition manager, the city of Hamburg, municipal and private companies, and universities; The strong cooperation enables innovative projects, such as the reuse of a WWII flag bunker, which has been converted into an electricity and heat plant and storage. The facility supplies 3000 households with renewable heat and 1000 with renewable electricity [74]. |
| Distribution grid/hydrogen economy | Since 2018, studies have been undertaken to make the grid smart, introduce storage and organize a higher degree of self-consumption. A hydrogen economy or other long-term storage solutions are inexistent. | The electricity distribution grid as well as the local district heating grid is owned and managed by Hamburg Energy, a public company of the city. It is the main energy producer in town. The company cooperates with research institutes to make the grid smart. A hydrogen economy or other long-term storage solutions are inexistent. |

To sum up, Table 3 shows how the three-levels-model can be implemented as an analytical tool for exploring and comparing different locations. The much more developed process of citizen participation in Freiamt explains, for example, the stronger mobilization of private capital. In Wilhelmsburg, citizens were able to get involved primarily in workshops. Participation was limited. This may explain why attempts by the municipality to persuade private homeowners to carry out energy-efficient renovations were largely unsuccessful. However, the close cooperation between stakeholders involved in the local LET network in Wilhelmsburg, managed successfully by the IBA Hamburg, enabled the integration of a large mix of renewables as well as interesting innovation such as the reuse of the bunker facility as an energy plant and storage.

The model provides a holistic view of LET initiatives and shows how determinants at different levels affect LET projects. The influence of the macro level on the local level in Germany is highly visible. The EEG of 2000 laid a foundation for LET processes. The law, however, had and still has weaknesses. For example, there were initially no incentives to consume locally generated energy locally. In Freiamt, all wind energy is fed into the grid. Local consumption of this energy is not technically envisaged. So far, no special promotion of LET in the form described in this article is evident at the German macro level.

## 5. Conclusions

Many studies show that a secure supply of societies in Europe with exclusively renewable energy is possible. LET is an approach that is already being implemented in communities across Europe. LET projects can be realized in about 20 years. This still leaves time to achieve the targeted climate protection goals by 2050.

The three-levels-model developed in this article is a holistic approach which focuses on determinants for success of LET. The model summarizes the complex interrelationships of LET in a decentralized approach that has already proven itself in the analysis of regional competitiveness. It allows some important insights into the process of LET. A promising local context is necessary but not sufficient to attain local energy autarky. Efficient implementation of renewables arises from technological capacity, economic incentive, and societal willingness to use local potential. National transition policies set the nation-wide framework for the LET but they are not sufficient to ensure its success. Inappropriate policies may rather prevent LET from being successful. The capability to reach local energy autarky depends ultimately on the local capability to sensitize and activate citizens, on the sophistication of local networking, and on the capacity to adapt the local transmission grid and to implement a long-term storage economy (based on hydrogen, methane, biofuels, or similar alternatives).

The framework is very helpful in supporting the planning of a local LET initiative and to analyze existing projects. It highlights which determinants must be taken into consideration when planning a new LET initiative, such as local potential for renewable energy generation, the local actor's network or the participation of local citizens. The application of the model on two case regions shows that the model can also be used as an analytical tool. Validation using further case studies is, however, necessary to verify this conclusion.

Due to the time pressure created by the Paris Agreement and, not least, by the increasingly apparent consequences of climate change in Europe, municipalities must be provided with the necessary knowledge and expertise to initiate LET themselves. Local LET managers need to be trained to create the necessary expertise for these processes in local communities. The Erasmus+ LOTUS project has provided the prerequisites for further training and academic qualification.

Another possibility to accelerate the LET would be to establish the process as a mandatory task for municipalities. This question is already the subject of controversial debate in Germany [112,113].

Finally, one must recognize that the discussion about LET has a geo-political dimension too. Until 24 February 2022, the day of the beginning of Russian aggression in Ukraine, LET was mainly seen as tool to fight climate change. Now it becomes an important geostrategic tool to gain energy independence from Russia and other dictatorships in the world and weaken these dictatorial regimes by decreasing demand for conventional energy, such as crude oil, gas, or uranium. Lee [114] analyzes the risk of terrorist attacks on energy facilities, which become easier to execute because of the use of drones. Although terrorist attack on the energy industry account for only 3.8 percent of the total terrorist attacks, their financial impact is large [114]. Attacks on decentralized production of renewable energy are less likely, as the main goals of terrorists cannot be achieved: to disrupt the global energy supply, to increase global energy prices, to damage a country's economic foundations, or to cause panic, as could be the case with an attack on a nuclear reactor [115]. The same aspects apply to the military defense of a country that wants to secure its energy supply in the case of conflict.

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