INTERACT - Integration of Innovative Technologies of PEDs into a Holistic Architecture

Helmut BRUCKNER[a,*], **Markéta ADAMCOVÁ**[b], **Albana ILO**[c], **Andrea WERNER**[d]

[a]Sonnenplatz Großschönau GmbH, Sonnenplatz 1, 3922 Großschönau, Austria
[b]LEEF Technologies s.r.o., Forum Karlín, Pernerova 676/51, 186 00 Prague 8, Czech Republic
[c]TU Wien, Institute of Energy Systems and Electrical Drives, Gußhausstraße 25/370-1, 1040 Vienna, Austria
[d]University of Applied Science Technikum Wien, Research Area Renewable Energy Systems, Giefinggasse 6, 1210 Vienna, Austria

*h.bruckner@ped-interact.eu

Abstract: INTERACT is an international research and innovation project which boosts the emergence of Energy Communities as one crucial building block to achieve Positive Energy Districts. It is designing an optimal organization and structure for Energy Communities based on success-factors of existing PED/PEN approaches, stakeholder needs and motivation, the available technologies, and a holistic LINK-based architecture. Technological and market-related solutions are delivered that maximize the benefit for the environment and society, considering the current legal framework and available business models. The project will develop a roadmap for the Energy Community's secure and reliable embedding into the power system structure, focusing on two pilot regions, a green-field project in Sweden and an existing municipality in Austria. The holistic architecture is used to ensure the integrity of the solution by harmonizing all interactions within the Energy Community itself, between it and the market, and the European power system. Its standardized and flexible structure allows the straightforward application of the roadmap to perfectly meet the diverse necessities of local communities, thus supporting the large-scale roll-out of the new control paradigms.

Keywords: Positive Energy Districts, Energy Communities, *LINK* Solution, Stakeholder Involvement, Distributed Energy Resources

1. Introduction

The SET-Plan, adopted by the European Union in 2008 and revised in 2015, is a first step to establish an energy technology policy for Europe.[1] The SET Plan focuses on 10 key actions fields, of which action 3.2 on "Smart Cities and Communities" aims to support the planning, deployment and replication of 100 Positive Energy Districts (PEDs) by 2025 for sustainable urbanization.[2] The reference framework of **Positive Energy Districts** (PED) / Positive Energy Neighbourhoods (PEN) is defined in the „White Paper on PED Reference Framework"[3] as "energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability."[3]

Climatic conditions worldwide force the comprehensive integration of renewable and distributed energy resources into the power system, as well as the effective use of energy and of the existing infrastructure. Business models in the energy sector are changing and becoming more customer-centric:

The customers play an active role in energy supply.[4] The way in which the power grid should be managed is changing, as also the rate of change in the electric power industry accelerates annually.[5] Driven by reduced costs of solar PV and storage Energy Communities are on the rise and disrupte the energy value chain, pushing energy retailers and DSOs towards deep transformation.[6]

Energy Communities have been currently formally acknowledged and defined within Europe as "renewable energy communities" and "citizen energy communities". At the same time a further revision of the Renewable energy directive was brought forward in July 2021, proposing to raise the target of renewables to 40% by 2030, further fostering the transformation of the energy system.[7] The European Commission is describing Energy Communities as follows: „Energy communities organise collective and citizen-driven energy actions that will help pave the way for a clean energy transition, while moving citizens to the fore. … By supporting citizen participation, energy communities can moreover help in providing flexibility to the electricity system through demand-response and storage."[8] With the increase of renewables in the energy system as stated above, and the planned increase of electrification of energy (direct use of low-emissions electricity) as one of the most important drivers of emissions reductions[9], the pressure and demands on electricity grids are increasing. The implementation of Energy Communities is bringing a new actor into the electricity markets, driven by investments in sustainable infrastructure, production of green electricity and heat, social and environmental sustainability or self-sufficiency, bringing positive impacts on the energy transition.[10] All of these positive effects are clearly supporting the build-up of PEDs/PENs.

Furthermore, and in line with the **INTERACT** approach,[11] holistically structured energy communities can also support the operation of distribution networks, helping to increase the usable capacity of the grid and to avoid congestion by improving the overall performance of reactive power control.[12] The necessary ICT structure for a reliable operation of the electricity grid might therefore be one of the ICT systems to be integrated in a PED, enabling direct and indirect electricity services needed for an optimized operation of local resources. A holistically designed energy community following the INTERACT project and the *LINK*-architecture[13] increases the installed capacity of distributed energy resources (DER) in the given power grid, offering energy services like flexibility trading, and therefore supporting the ambitions of specific districts of the neighbourhood in becoming PED/PENs.

Not surprisingly there as, the goal of the INTERACT project is the emergence of Energy Communities as one crucial building block to achieve PEDs. The project will design an optimal organization and structure for Energy Communities based on success-factors from a competence-network of existing PED/PEN approaches, stakeholder needs and motivation, the available technologies, and a holistic architecture.[11] The project will conclude with the development of a roadmap for the secure and reliable embedding of the Energy Community into the structure of the power system, focusing on two pilot regions in Sweden and Austria.

2. Methodology

Energy communities are in the early stages of consolidation within the PEDs. Therefore, INTERACT has developed a comprehensive methodology to consider the results of different projects. It creates a solid foundation for the development of energy communities in all their complexity. The objectives of the project will be achieved by combining the results of four investigation steps as follows:

1. Assessing and Evaluation of existing successful PED-approaches - This step aims to assess the state of the art of current PED approaches and to establish a network of international PED communities to foster the knowledge exchange and learning opportunities. It is focusing on assessment criteria for success of PED projects, based on existing project experience.
2. Characterization of current & expected future state of the specific energy communities - A common methodology for the inventory of the current stock of renewable energy resources, the documentation of the automation used, and the existing ICT infrastructure are being defined.

Based on this methodology and the project data management plan, all new technologies already existing and installed are recorded.

3. Design of the *LINK*-based Energy-Community with respect to Stakeholder Needs - The INTERACT Energy Community according to the holistic *LINK*-solution will be designed by defining workflows (use cases), as well as technical and market related interfaces.
4. Contracting Models and Regulatory Framework - Based on the relevant European Directives, the legal framework for the future design of the electricity market and grid is defined and the implementation of energy communities is being prepared. Regional differences among these national regulatory frameworks will be analysed regarding main barriers for establishing local and regional energy communities.
5. Design of the roadmap for the implementation of the INTERACT energy communities - Define a set of instructions or suggestions needed for the implementation of the INTERACT energy communities all over Europe.

3. First Results, Outlook, and Discussion

The project is still at an early stage of development, but there are already results and initial successes to report. During CESB conference in July 2022 the current status of INTERACT will be presented.

3.1. Assessing and Evaluation of existing successful PED-approaches.

We identified about 60 European PED approaches via desk research pilots with the aim of adding new PED approaches to already existing repositories like the PED-booklet by JPI Urban Europe.[14] Based on criteria showing relevance to Energy Communities (local energy markets, Peer-to-Peer trading, flexibility management, etc.), and/or implementation stage (in implementation or already implemented), 16 PED-approaches from the project partner countries have been identified for deeper analyses and personal interviews.

3.1.1. Competence Mapping

Part of the deeper analysis of existing selected PED-approaches was competence mapping, where a coding system was created, which is categorized in project function, competence level, competences, project and country. Project function defines different roles of PED project partners. Competence level is categorized by 3 levels: formal, informal and institutional level. Formal competences are qualifications employees learned in their academical education. Informal competences comprise non educated competences, e.g., social competences, communication. Institutional competences can be understood as every competence which brings institutions themselves. Coding, analysis, and visualization was conducted with the qualitative data analysis software MaxQDA, especially using the code relations models. The frequencies of connections of selected codes were compared. Hence the line width of all figures is relative to the number of relations, not the importance, of the extracted competences. Figure

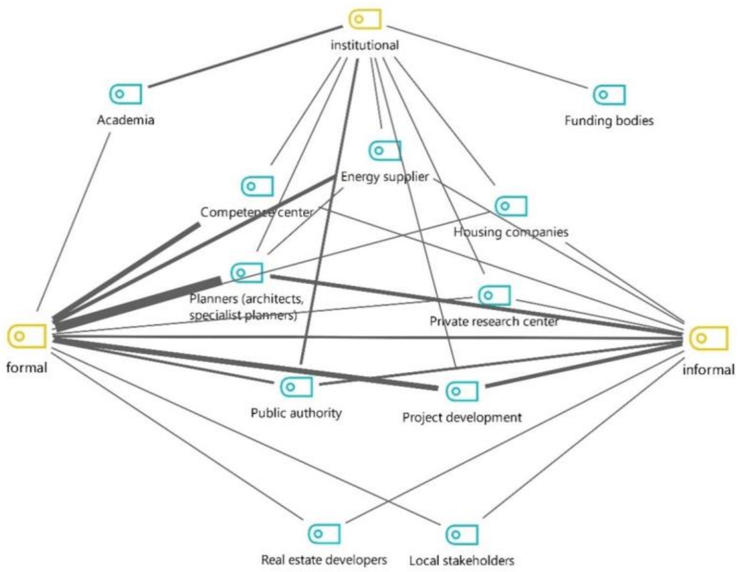

Figure 1: Code - Relations - Modell on Competence Level vs. Project Function

1 shows the code-relations-model derived for the competence level on project functions. Seven out of eleven project functions are related to each competence level. “Planners” and “Project development” can be highlighted in high connection with both formal and informal competence level. “Competence centre” and “Energy supplier” tend more towards the formal competence level. Taking a closer look at the competences of the analysed PED-approaches, the below within figure 2 shown competence network was visualized:

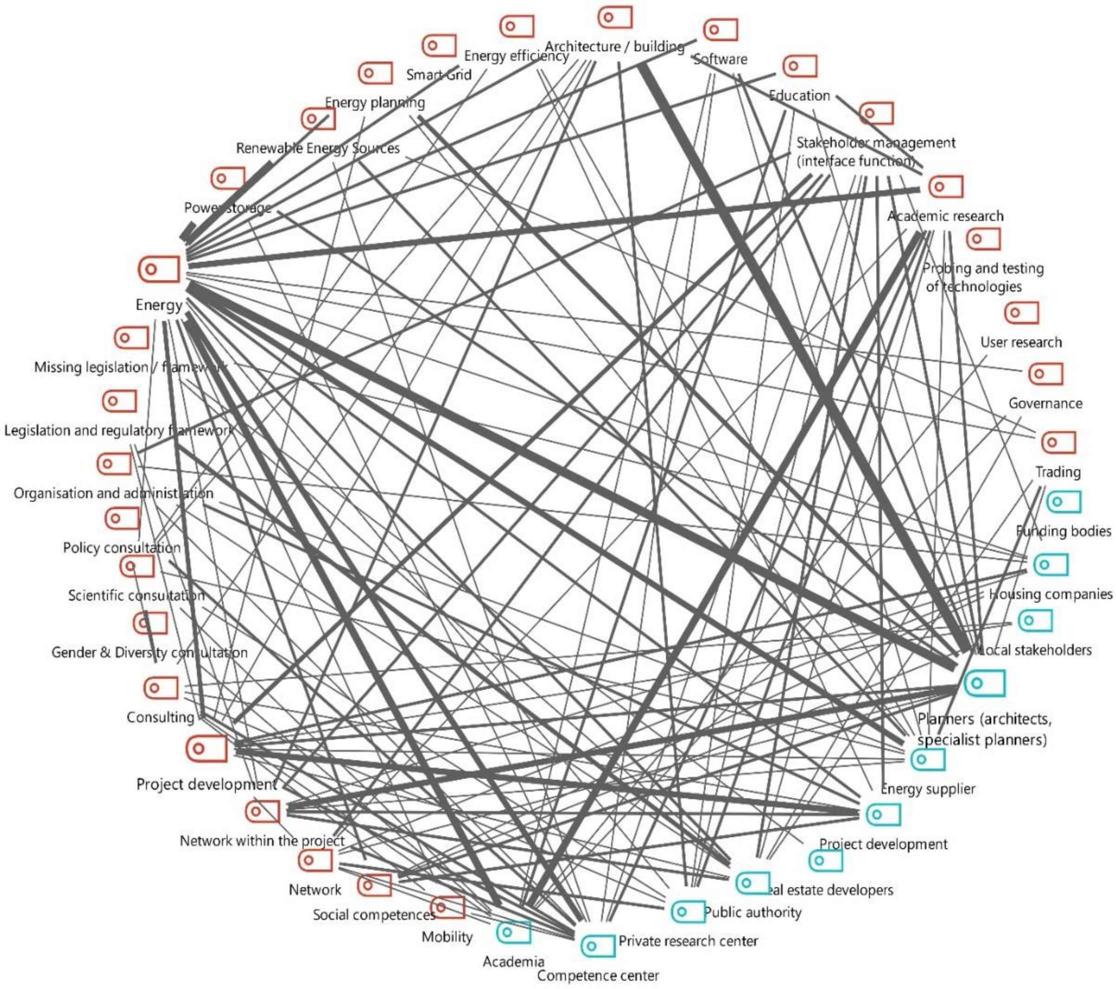

Figure 2: Code - Relation - Model on Competences vs. Project Function

It is noticeable that many thick lines start from “Energy” and “Planners”. The competence “Energy” is well connected with the project functions “Academia”, “Competence centre”, “Energy supplier” and especially with “Planners”. Many connections to other competences are “Academic research”, “Project development” and to energy subcodes such as “Power storage” and “Renewable energy”. Based on more in-depth information on success-factors a normative level associated with the identified competences can strengthen the mapping process substantially and support the establishment of good-practice in PED/PEN initiatives.

3.1.2. Stakeholder Analysis

In parallel, all relevant stakeholders within the two focus regions have been identified and a stakeholder mapping approach has been applied: 15 stakeholders of the municipality in Austria have been selected for interviews, as well as 3 stakeholders of the green-field project in Sweden. The goal was to identify stakeholders’ roles and their perspective on other stakeholders’ roles regarding e.g., knowledge, benefits, burdens as well as potential impact on the success of an energy community, see below table 1.

Criteria for active stakeholder participation, identification of relevant subgroups and strategies for information and implementation are now being derived from the empirical assessments within the focus regions.

Table 1: Stakeholders - Assessment of Motivation by others

Stakeholder	Assessment of Motivation by others
Municipality	Increase Renewables; Climate protection; Energy autonomy; Financial benefits; Security of supply
Communal organizations	Increase Renewables; Climate protection; Financial benefits, savings; Pioneer, Role model; Security of supply
Infrastructure	Grid stability, relieve
Associations	Pioneer; Climate protection; Electricity from renewables; Financial benefits
Private Sector	Pioneer; Financial benefits; Security of supply
Multipliers	Pioneer; Regionality and added value; Financial benefit; Continuation of work, projects; Security of supply
Citizens	Pioneer; "Green" thinking; Community Spirit; Financial benefits; Security of supply; Role model

Main motivation is attributed to the role of being a pioneer, and to financial benefits. This is followed by climate protection. The findings show similar drivers for participation in an ECs as found by Caramizaru and Uihlein, only missing the goal of a common investment in infrastructure.[10]

3.2. *Characterization of current & expected future state of the specific energy communities*

We established a common inventory methodology for recording available technologies. Described are data categories, data sources, data types, data purpose in the project, data management, and the inventory workflow itself based on the project type. It enables the project to record the existing technologies at the focus community in Austria and allows future green-field projects to base on the same standard. Based on the recorded data the necessary requirements to upgrade to the primary control as well as to the secondary control will be defined and described. Furthermore, the communication protocols between market, grid, EC, and customer plant will be described, together creating the *LINK*-ICT-structure.

3.3. Design of the LINK-based Energy-Community with respect to Stakeholder Needs

The Energy Community must work in harmony with the power grid and needs flexible interaction with the market, which should enable transparent and non-discriminatory energy trading between different interest groups. Figure 3 illustrates the harmonization and coordination of the market structure with the Grid-Links arrangement.

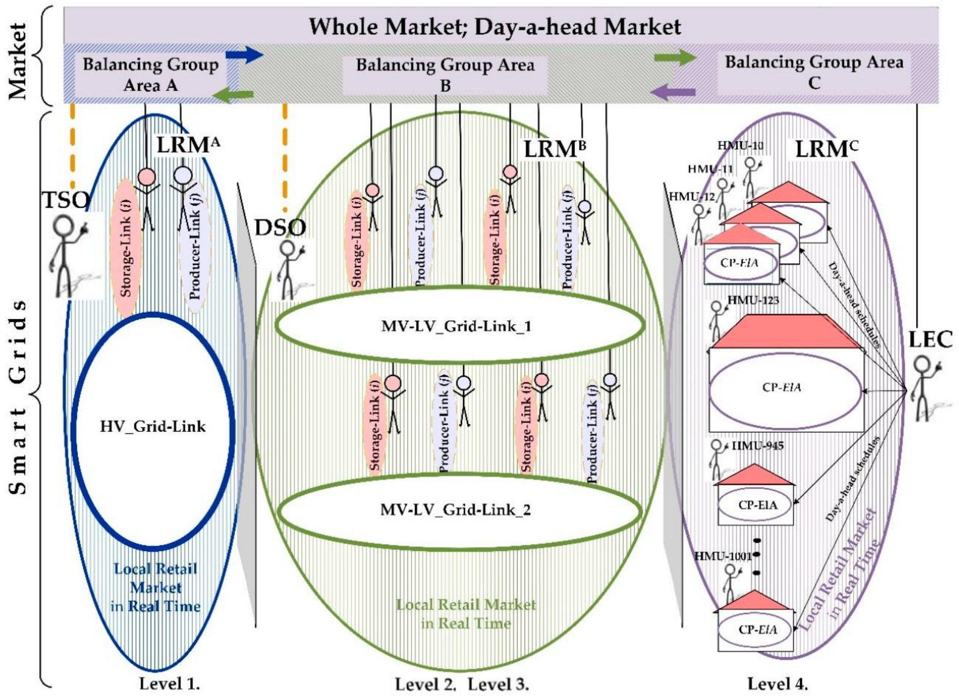

Figure 3: Harmonization of the market structure with a Local Energy Community on Level 4 in the grid link arrangement [13]

The market structure that incentivizes grid operators, Energy Communities, and customers to contribute to energy services shall be specified by employing a review of the existing competitive electricity markets. Further development of the general lines of the *LINK*-Market structure[13] that motivates customers to contribute to the energy services (local market) will be specified based on the Electricity Market Design of the "Clean energy for all Europeans package".[15] The market-based control must take into account the technical behaviour of the smart grids and support their safe, reliable, and resilient operation while at the same time attracting the demand response bids. The necessary information exchange will be determined, and the use cases will be described. This organizational structure and the resulting management of the EC can be done by using an existing organization or establishing a new organization. The chosen organizational structure depends on the national possibilities and should be in line with the aims and size of the Energy Community operated by the organization, including its mid-term strategic goals regarding growth, size, and responsibilities.

3.4. Contracting Models and Regulatory Framework

The member states of the European Union are implementing the formal legal framework for the establishment of Energy Communities based on the European Electricity Market Directive and the Renewable Energy Directive. This is one cornerstone of the regulatory framework which Energy Communities are based. INTERACT will analyse the regional differences in terms of main barriers for establishing local and regional energy communities in Austria, Belgium, Czech Republic, and Sweden. Furthermore, possible business cases based on the INTERACT energy community will be specified. The defined technological solution will be analysed from the point of its economic feasibility with regards to its implementation by all relevant stakeholders. Based on the actual energy behaviour of the INTERACT focus regions, scenario planning for the development of energy demand, energy production and energy storage will be done. This enables us to estimate and evaluate the market potential of the designed ideal energy community, and the implications of it on the various stakeholders involved.

3.5. *Roadmap for the implementation of the INTERACT energy communities*

Under the vision of prosperous Energy Communities with the strategy of the holistic approach of the LINK-solution, the roadmap will include a set of instructions or suggestions needed for the implementation of the INTERACT energy communities. Five large, different areas that are needed to implement an energy community in practice are being addressed. Technique; Market; Regulation; Legislation and Organization

There are foreseen three cases: a common case, an upgrade case on the example of Großschönau, Austria, and a green-field case on the example of Fyllinge, Sweden. The roadmap will support the planning, deployment, and replication of the targeted 100 Positive Energy Districts (PEDs) by 2025 for sustainable urbanization, shall foster the creation of Energy Communities operating in harmony with the grid, and increase the potential for installing DER at a given grid-infrastructure.

The technical problems are the most persistent barriers to making energy communities a reality. The establishment of energy communities should not only not disturb the reliable operation of the grid but should bring new benefits to them. There is a vacuum in the literature about the details of the technical barriers that lead to the resignation of the energy communities. Therefore, suggestions for overcoming the technical barriers are being given a special place on the roadmap.

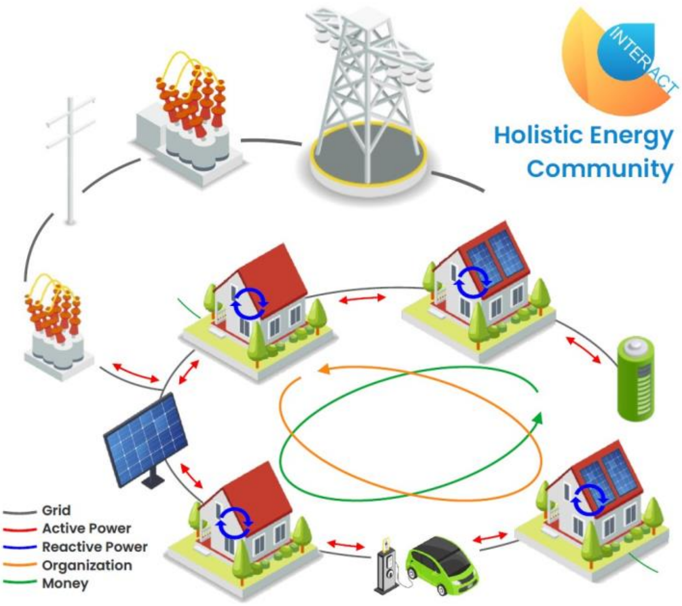

Figure 4: Schematic presentation of the harmonized operation of the INTERACT holistic energy community with the grid

LINK-solution Figure 4 shows a schematic presentation of the harmonized operation of the INTERACT holistic energy community with the grid. There are included the high-, medium- and low voltage grid as well as prosumers, batteries and e-mobility. The last ones are organised and operated under the umbrella of the INTERACT energy community. The possible voltage challenges appearing in radial structures of distribution grid by too high PV penetration are solved using the LINK-solution for the Volt/var control process. The voltage will be kept within the limits by using the control ensemble L(U) local control at the low voltage level and Q-Autarky at the customer plant level[16], Figure 5.

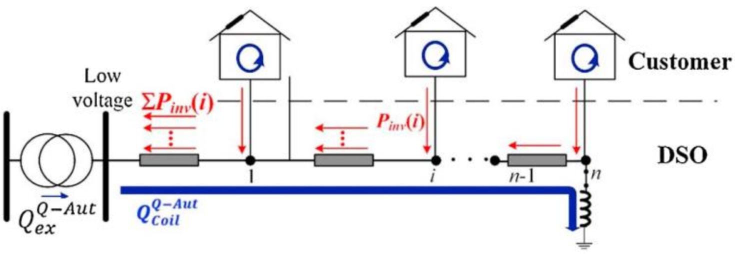

Figure 5: Active and reactive power flow in a low-voltage feeder with PV penetration that injects with cos(ϕ) = 1, the L(U) control strategy is employed, and Q-autarky is applied

4. Conclusions

INTERACT stands for Integration of Innovative Technologies of Positive Energy Districts into a Holistic Architecture. Based on the analysis of competences of 60 existing PED-approaches with the help of 16 personal interviews, the needs, and requirements of around 20 different interviewed stakeholders, recorded existing (and missing) technologies and the LINK-based holistic architecture, an optimal organization and structure of Energy Communities is being designed. The technical approach is based on LINK technical solution. Market, regulation, legislation, and organization are being analysed, current barriers identified, and improved solutions suggested. At the end of the project (January 2023) a roadmap for the implementation of the designed INTERACT energy community in general and for the specific local perspectives will be available, fostering the creation of Energy Communities operating in harmony with the grid all over Europe. All current results and related scientific work can be found at www.ped-interact.eu.

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