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# Implementation Framework for Energy Flexibility Technologies in Alkmaar and Évora

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**Abstract:** As energy generation based on renewable resources does not always match energy consumption profiles, Positive Energy Districts (PEDs) should embody energy flexibility technologies to decrease possible negative impacts on existing grids due to, e.g., reverse power flows. As part of the EU H2020 Smart Cities and Communities project POCITYF, the cities Alkmaar (NL) and Évora (PT) aim to support the deployment and market uptake of such districts and in doing so demonstrate innovative and integrated technologies to enable flexibility in the energy system. This paper addresses implementation conditions for energy flexibility technologies that help cities to engender the expected impact and ensure replication of these technologies to other sites. It aims to guide both urban planners and technology solution providers through pitfalls and opportunities that can appear during the design and implementation of PEDs. Taking this into consideration, the RUGGEDISED innovation and implementation framework for smart city technology was taken as a starting point to describe and analyze the experiences in Alkmaar and Évora.

**Keywords:** governance; energy flexibility; positive energy districts; sustainable energy; smart city deployment

## 1. Introduction

The need for cities to become more sustainable is high and several definitions of smart cities refer to this need. A definition of a smart city is "a sustainable and efficient City with high Quality of life that aims to address Urban challenges (improve mobility, optimize use of resources, improve Health and safety, improve social development, support economic growth and participatory governance) by application of ICT in its infrastructure and services, collaboration between its key stakeholders (Citizens, Universities, Government, Industry), integration of its main domains (environment, mobility, governance, community, industry, and services), and investment in Social capital" [1]. However, retrofitting existing environments remains challenging [2]. Positive Energy Districts (PEDs) play an important role in more liveable and sustainable future cities. PEDs are districts producing energy from local and distributed renewable energy sources, presenting generation surplus over a specific balance period (typically one year) that may be transferred to areas outside a PED's boundaries [3]. One definition of PEDs by JPI Urban Europe (2019) refers explicitly to the active management of energy flows: "PEDs are 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" [4].

The large deployment of distributed generation based on renewable energy (RE) can increase the complexity of grid management and operation due to several factors (see, for instance, the impact of reverse power flows on distribution transformer aging [5]. Increased energy flexibility in the existing energy systems is therefore a crucial mechanism to delay costly and overdesigned adaptation of the grid infrastructure itself [6]. In this context, technology can be of great help in linking resource efficiency and flexibility in energy supply and demand with innovative, inclusive and more cost-effective services for citizens and businesses. Such technologies can integrate infrastructures like smart grids that have been piloted in several cities in FP7 and H2020 projects [7].

In Alkmaar (Netherlands) and Évora (Portugal), innovative and integrated technical solutions are being implemented in order to support the deployment and market uptake of PEDs. This research and the pilots in Alkmaar and Évora are being conducted within the EU H2020 Smart Cities and Communities project POCITYF [8]. The project started in October 2019 and includes the demonstration of solutions of a high technology readiness level (TRL ≥ 6) [9] for achieving flexible and efficient use of electricity in contexts with different climatic conditions and regional characteristics (technical, financial, social and legal). Alkmaar and Évora are proving grounds for innovative and integrated technical solutions for buildings and districts in which energy management systems are implemented to increase flexibility. Starting points are lessons learnt from pre-pilots at other sites, i.e., locations and buildings where individual technologies have been implemented before. The second step, which is dedicated to demonstration activities, combines technologies toward integrated systems at the building, block and district levels in the areas of Alkmaar and Évora. The third step refers to replication of these integrated systems in other selected areas of Alkmaar and Évora and in the six fellow cities: Granada (Spain), Bari (Italy), Celje (Slovenia), Újpest in Budapest (Hungary), Ioannina (Greece) and Hvidovre (Denmark).

Starting from the RUGGEDISED innovation and implementation framework developed in the EU H2020 RUGGEDISED project [10], this paper addresses implementation conditions for energy flexibility technologies in Alkmaar and Évora in order to support the achievement of expected impacts and ensure replication of these technologies within and beyond POCITYF. The technologies under consideration are ReFlex [11] for Alkmaar and flexibility control algorithms for Évora. Both aim at exploiting the energy flexibility provided by the available controllable devices (e.g., batteries or electric water heaters) at the building, block and district levels in order to achieve specific objectives (e.g., improve matching between renewable generation and energy demand or decrease peak loads).

The RUGGEDISED innovation and implementation framework is an analytical tool that helps city planners to assess important success factors in the implementation process of smart technologies well in advance. This framework focusses on smart city technologies in a broader sense without concentrating necessarily on energy flexibility technologies alone. Therefore, this paper aims to guide both urban planners and technology solution providers through pitfalls and opportunities that can appear during the design and implementation of a PED. It describes practical examples of implementation conditions seen or experienced in Alkmaar and Évora (or that were missing). This can be used to describe valuable lessons for the implementation of energy flexibility in future PEDs. This framework identifies both the implementation conditions that were of relevance and influence in either case of the two cities, and those conditions that did not play a role. In doing so, it provides insights in improving and adjusting projects and shifts the focus on conditions that matter. This paper discusses the application of the framework by presenting how it is being used in practice for the analysis of the implementation of PEDs in Alkmaar and Évora.

## 2. Materials and Methods

The RUGGEDISED framework [10] can be used to assess the implementation process of smart city projects and therefore "advises" what should be in place for successful implementation. In POCITYF, records of progress on pre-pilots and foreseen demonstration activities in Alkmaar and Évora have been taken, using questionnaires. These questionnaires focused on key technical components and specifications of the innovative solutions, on the demonstration sites (considering specific challenges related to the context), on problems and restrictions experienced and on lessons learnt (e.g., technical improvements, energy savings or socioeconomic benefits). The project partners involved with each innovative solution took care of the respective questionnaires. These project partners work for different organizations, e.g., research institutes, governments, utilities and technology providers.

Despite common challenges, the cities of Alkmaar and Évora face city- and district-specific challenges due to divergent geography, geology, demography, climate and socio-economic and cultural characteristics. These characteristics mean that urban energy transition challenges are embarked upon from different starting points and perspectives, thus enhancing the complementarity of the POCITYF solutions. Évora represents South European cities, which generally show lower investments on reducing the footprint of their households and business sector but can enjoy an abundant solar potential. Alkmaar represents West European cities that are strongly dependent on gas for electricity and heating.

In more detail, the RUGGEDISED framework provides a useful base for analyzing success factors and hindering factors for the implementation of smart technologies. In POCITYF, innovative smart city solutions are implemented in order to achieve PEDs. This framework (see Table 1) was consolidated in the EU H2020 RUGGEDISED project and allows the analysis of suppressing and enhancing factors in implementation processes of smart solutions. Such an analysis is beneficial in designing successful implementation processes, in assessing the potential project impact and in selecting aspects that need further consideration for successful implementation.

**Table 1.** RUGGEDISED innovation and implementation framework: enhancing and suppressing factors [10].

| Hardware | Software | Orgware |
|---|---|---|
| | Level of impact 1: Realization and output of smart solutions | |
| Pre-deployment assessment<br>Technology assessment<br>Impact on energy grid | Software<br>Privacy<br>Security<br>Smart Grid ICT<br>User Interfaces | Business models<br>Data and data ownership |
| | Level of impact 2: Embedded outcomes of multiple smart solutions | |
| Communicating infrastructure<br>Robustness of the system | Interoperability Dashboards | Integrated vision on the smart city<br>Smart governance<br>Windows of opportunity<br>Stakeholder management<br>Ownership<br>Business models and split incentives |
| | Level of impact 3: Upscaling and replication | |
| | | Integrated planning<br>Innovation platforms<br>Conditions for upscaling: finance, regulation (including standardization), access to information and social aspects |

The framework distinguishes three levels of impact that are needed in order to think beyond implementation of single solutions and consider the real impact of implementation, namely:

- Impact Level 1 (Realization and output of smart solutions): the first level of impact considers a single smart solution that is successfully implemented and delivers its output (it is an isolated realization of a smart solution).
- Impact Level 2 (Embedded outcomes of multiple smart solutions): A smart solution produces real output if it is well-embedded in the existing context. At the second level of impact, multiple smart solutions interact and produce outcomes because they are well-connected and efficiently work together.
- Impact Level 3 (Upscaling and replication): The third impact level is city-level outcomes. This occurs when smart solutions are taken beyond single projects and are successfully scaled-up to create smart urban structures. Real impact is made when smart solutions are replicated to other areas and projects with different contexts.

The implementation factors influencing the development of smart solutions are described per impact level. A division is made between hardware, software and orgware implementation factors. Hardware focuses on physical infrastructure topics such as energy storage, conversion and savings. Software refers to ICT, data-related factors and applications. Hardware and software must be supplemented with orgware, which refers to organizational and governance aspects such as stakeholder management, institutional and organizational arrangements and innovation platforms. Dividing impact levels and implementation factors in three categories allows for structuring the different factors that influence projects in different stages. Some factors help or hinder the realization and output of smart solutions, whilst others specifically impact the working together of multiple solutions to realize embedded outcomes. The framework shows that the importance of orgware implementation factors increases as the impact level rises. These orgware implementation factors, in turn, affect the upscaling and replication of smart solutions.

## 3. Results

One of the objectives of the POCITYF project is to deploy and validate smart energy management and storage solutions to optimize energy flows with the goal of maximizing self-consumption, reducing grid stress and valorizing flexibility services. To that end, innovative solutions to be demonstrated and replicated include several individual elements: e.g., low-temperature waste heat, innovative short- and long-term storage solutions, such as hydrogen fuel cells or electrical vehicles (EVs) coupled with stationary batteries, smart ICT solutions to interconnect the energy management system at the household, building and district levels, the virtual power plant (VPP) concept, thermal grid controllers or market-oriented building flexibility services.

Figure 1 illustrates how the individual elements corresponding to the various layers, from concrete, device-specific to abstract, domain-specific, are stacked on top of each other and interact to bring about the full implementation and impact of an integrated innovative solution. On the left side, the data and control flow is bidirectional for the full stacked solution to perform as per design, while on the right side, there is only sharing of information to gain insight into the system, evaluate different options and decide for further optimization and improvement steps. The loop is closed by feeding these insights back to the operational system in place.

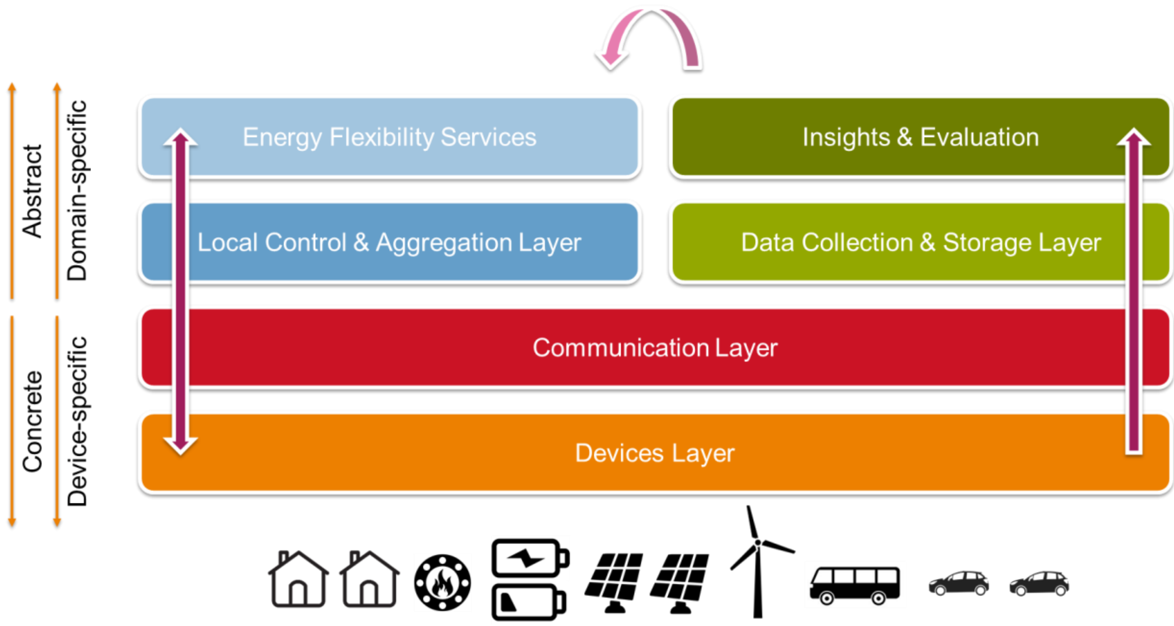


**Figure 1.** From the concrete, device-specific layer to the abstract, domain-specific one.

Taking this into consideration, Tables 2 and 3 map the information associated with the technologies under analysis (i.e., ReFlex for Alkmaar and flexibility control algorithms for Évora) based on the impact levels and implementation factors that comprise the RUGGEDISED framework described in Section 2.

**Table 2.** Mapping Alkmaar.

| Implementation Factor | Explanation |
| --- | --- |
| Level 1 realization and output | |
| **Hardware** | |
| Pre-deployment assessment | • Availability of multiple assets that may be a source of flexibility.<br>• Consideration of the objective to apply solutions that expose and valorize flexibility and potential alternatives.<br>• Feasibility study of physical implementation (all components) as modeled in silico. |
| Technology assessment | • The battery systems placed in residences are by default connected to a different phase of the 3-phase grid than both the solar panels and household energy usage. This originates from standards used in the installation sector. This means that the battery system cannot be used effectively to balance energy within the residence.<br>• Technical readiness level of components must be improved in order to use small-scale storage solutions (through VPP or vehicle-to-grid (V2G)) in a reliable way to control vital infrastructure, especially in brown field situations. Improvements in the European and international standards can ensure compatibility of the components in all situations. |
| Impact on energy grid | • Potential network constraints due to excessive flexibility operation within the system have been identified. Analysis of the implemented scenarios was carried out in which each flexibility source was individually considered; it became clear that they can be used for network congestion management up to a certain limitation. It was concluded that operation of flexibility and the different forecasting systems can also cause a congestion in the network which changes the network operation. Next to this, aggregator strategies further impact the network operation.<br>• Considering each flexibility source in relation to network limitations, especially taking into account balancing concerns and guarantee of supply.<br>• Good understanding of the layout of the low-voltage (LV) grid is a prerequisite for implementing smartification efficiently. Without these accurate data, one cannot determine where to place the measurement equipment in the grid. State estimation is needed in order to be able to draw conclusions about the current situation of the grid.<br>• VPP in trade mode at times might have a negative effect on grid balance given the current pricing mechanism. There are instances where energy is sold, and thus delivered to the grid, during moments of local energy generation. This can increase the peak load on the low-voltage grid in the districts.<br>• By using the VPP for energy trading, based on forecasts of energy consumption, PV generation, the energy prices on the trading market and the availability of the battery, overall energy costs can be decreased. A low density of VPP contributors in the LV grid (less than 5% of residences were equipped with battery systems) showed little impact on the grid. The density of the VPP contributors should be increased to notice the effect on the grid and to have accurate predictability of average household behavior.<br>• The distribution system operator (DSO) can alleviate peak loads on the grid by using small storage (battery) systems. These batteries need to be operated in an inherently grid-supporting mode, and peak load shaving requires fast and reliable control mechanisms. From a business perspective, adequate financial stimuli are needed. The DSO should have a mandate to overrule the settings of the VPP to ensure grid stability and prevent a power outage. |

**Table 2.** *Cont.*

| Implementation Factor | Explanation |
|---|---|
| Level 1 realization and output | |
| **Software** | |
| Privacy | • Including privacy by design in order to meet both national and European standards and adhere to GDPR guidelines. In doing so, privacy concerns will not pose obstacles to implementation. |
| Security | • Taking cyber security issues into account as they may arise. Including privacy and security by design so that they will not become an obstacle for implementation and the implementation will meet the required national and European regulations and standards. It can be helpful to follow the eight principles of privacy by design [12]. |
| Smart grid ICT | • Internet of things software from ICT.eu links all electricity consumers per platform. The data are made accessible via the cloud, giving the energy supplier remote control. Via this platform, everything can be connected per household that uses or generates energy. |
| User interfaces | • Using future-proof standards (even with low maturity) to implement new use cases and future business models. |
| **Orgware** | |
| Business models | • Cost reduction of grid operations as a result of unlocking and exploiting flexibility.<br>• New revenue streams potential from valorizing flexibility.<br>• Analysis of pricing mechanisms and market liquidity has been carried out as well as a usability analysis.<br>• Bundling multiple smaller devices to increase accessibility to the trade market. |
| Data and data ownership | • Handled according to the principle "as open as possible, as closed as necessary". |
| Level 2 embedded outcomes of multiple smart solutions | |
| **Hardware** | |
| Communicating infrastructure | • Continuous internet connection in order to communicate in real time between assets, the network and the energy market. |
| Robustness of the system | • Fast response to disconnection.<br>• Backup facility.<br>• Risk management: what goes wrong if the system is down or unavailable? Taking measures appropriate to the risks (system overload or just some missing data).<br>• The placement of bidirectional charging stations is currently not a standard job. They are still far more expensive than standard charging stations, they need a reliable internet connection to function and during the City-zen project, problems with the hardware were encountered frequently.<br>• The reliability of OT/IT connections through 4G and Wi-Fi communication networks used for VPP and V2G applications is lower than that of the grid itself. The reliability needs to increase to match the reliability of the grid before a VPP or V2G can be used as part of the vital infrastructure balancing loads on the LV grid. |

**Table 2.** *Cont.*

| Implementation Factor | Explanation |
| --- | --- |
| **Software** | |
| Interoperability | • ReFlex is compatible with several open smart grid standards such as EFI/S2, USEF and OCPI and is easy to implement in an aggregator's existing architecture. Still, bidirectional translation of asset protocols to EFI is a necessary configuration step to enable reliable communication.<br>• Reliance on standards instead of proprietary protocols to allow interoperability is paramount.<br>• The maturity of standards for interoperability is low; as such, in every single project, protocols and interfaces need to be (re)determined between different suppliers of technology. |
| Dashboards | • Management and administration dashboards are included in ReFlex. |
| **Orgware** | |
| Integrated vision on the smart city | • A local needs assessment showed that good accessibility with a balanced mobility system and a healthy, clean, safe, economic future-resilient, green and climate-adaptive city where everyone can happily live, work and recreate were important.<br>• Flexibility solutions can help the DSO in operating the network and prevent investments in grid infrastructure. |
| Smart governance | • Insights gained regarding both the flexibility potential and its value within the selected pilot areas can further support decision making and planning. |
| Windows of opportunity | • Implementation of ReFlex instead of investments in grid reinforcement: awareness of DSO that avoiding grid reinforcements is in their own interests and that ReFlex is valuable for network operation so that different problems and interests of stakeholders are aligned.<br>• The higher the number of flexible assets, including EVs, the more value can be extracted through ReFlex deployment.<br>• Local communities can become sustainable by being as self-proficient as possible while monitoring energy use at the individual and district levels and using this information for behavior change. The business district of Boekelemeer could initiate a Citizen Energy Community (CEC) or a Renewable Energy Community (REC). According to the EU directive [13], this could improve their position in the local energy market. They can use this institutional framework to represent interest of the local community in the park management. |
| Stakeholder management | • A guiding role for the municipality in building the relationship between stakeholders.<br>• Involvement of and willingness to engage from residents is crucial in relation to user acceptance. Support of homeowners is needed but they lack information and knowledge on energy flexibility as well as on practical consequences and potential benefits.<br>• Different reward mechanisms for VPP participants should be tested to determine the financial and general economic value of these systems. |
| Ownership | • Multiple aggregators in order to guarantee freedom of choice for citizens (selling energy flexibility) and the DSO (congestion management).<br>• Citizen (local) communities, municipality and housing corporations can have ownership of the applications and should be determined per case. |
| Business models and split incentives | • Analysis of market liquidity and pricing mechanisms. |

**Table 2.** *Cont.*

| **Implementation Factor** | **Explanation** |
|---|---|
| Level 3 upscaling and replication | |
| **Orgware** | |
| Integrated planning | • It is important that processes continue to be managed and it is essential that the involved key figures remain available at crucial positions.<br>• There was no technical supplier as a consortium partner or as official project partner. It is recommended to seek active collaboration with a supplier of technical components. |
| Innovation platforms | Important element to create a successful local innovation ecosystem is a problem-solving environment providing structure and practices of innovation management, training and tools as well as financial resources for innovation.<br>In Alkmaar, this has been initiated but from an external perspective not well anchored in the city organization. |
| Conditions for upscaling: finance, regulation (including standardization), access to information and social aspects | Market development:<br>• Aggregator strategies can potentially greatly impact upon the energy system since their objective of pursuing economic maximization of their assets may not always align with optimization of operations for said assets; for example, stationery batteries or EV operation may be masked by the aggregator whose portfolio includes such assets by revealing only the worst case of the day instead of their real-time state. Nonetheless, it also opens the door for other aggregators to dive in with their flexibilities. This might result in a game theory problem where in reality the aggregators would self-regulate themselves. Since there is no flexibility market, the single aggregator in one network can act as a monopolist.<br>• Certain capabilities of both the VPP and V2G system cannot be utilized due to regulatory barriers, sector standards or both. *See also below*.<br>Regulation and standardization:<br>• Similarly, regulation must be adapted to enable better use of the current and future electricity system possibilities such as use of flexibility and congestion management. Due to current regulations and sector standards, certain capabilities of both the VPP and V2G system cannot be utilized. Examples are the use of the V2G system for emergency power and the self-consumption of energy using the VPP by connecting the battery and solar panels of a household to the same phase.<br>• Implementation of a variable tariff system in the NL in which energy taxes are coupled to the energy price and network tariff. Changing the Dutch taxation tariff system can pave the way for using (local) flexibility and prevent more grid reinvestments than necessary. This can be accomplished with, e.g., variable network tariffs. Coupling the energy tax not to the energy amount but the price of energy and network tariffs can have positive effects. Further research is needed in order to determine which tariff system is best applicable.<br>Social aspects:<br>• Finding and retaining participants for VPP and V2G projects is a time-consuming task. Active participation and a substantial time investment are required which is not always possible or desired. In addition, participants sometimes move or retract from the project due to life events. The promoted definitions of CEC and REC from the EU Green Energy Package can provide a much-needed boost on this area. |

**Table 3.** Mapping Évora.

| Implementation Factor | Explanation |
| --- | --- |
| Level 1 realization and output | |
| **Hardware** | |
| Pre-deployment assessment | • Definition of objectives for the flexibility control algorithms.<br>• Characterization of controllable devices providing energy flexibility.<br>• Preliminary tests using software tools. |
| Technology assessment | • Flexibility control algorithms were developed based on knowledge collected during the participation on the working group "Annex 67" of the Energy in Buildings and Communities (EBC) program from the International Energy Agency (IEA).<br>• The deployment of flexibility control algorithms has been considered to (i) improve PV self-consumption and buildings' self- sufficiency; (ii) explore the existing energy flexibility available in water heaters to decrease electricity costs; or (iii) characterize and use of the energy flexibility provided by water pumping and storage systems to reduce electricity costs and support power systems. |
| Impact on energy grid | • The impact related to the deployment of flexibility control algorithms on existing grids should be considered before the respective real-world implementations.<br>• This impact assessment should consider different scenarios (e.g., seasons of the year) and can be conducted using simulation tools and specific information about the grids under consideration.<br>• The acquisition of information about the grids under consideration can be challenging if the operator is not included in the process. |
| **Software** | |
| Privacy | • Data privacy issues in relation to the framework for data exchange and related roles and responsibilities were not considered in the pre-pilots of flexibility control algorithms, however technical issues supporting the exchange of data in a secure and interoperable manner are easy to integrate, respecting Portuguese law. |
| Security | • Data security in relation to the framework for data exchange and related roles and responsibilities were not considered in the pre-pilots, however technical issues supporting the exchange of data in a secure and interoperable manner are easy to integrate. |
| Smart grid ICT | • All flexibility-related data are available on the cloud and can be shared with authorized third parties. |
| User interfaces | • User interfaces were developed for the pre-pilot installations and they can be easily integrated with high-level SCADA (or similar) solutions. |
| **Orgware** | |
| Business models | • Depending on the objectives of the considered DSM measures, the flexibility control algorithms have resulted in PV self-consumption improvements up to 30% or in peak load reduction up to 10%.<br>• Flexibility control algorithms have also been used to take advantage of time-of-use tariffs in order to shift energy consumption to less expensive periods, resulting in savings up to 40%.<br>• New revenue schemes based on flexibility usage provide grid operation cost reduction. |
| Data and data ownership | • In the pre-pilot, data are private but available for authorized third parties during the assessment phase. |

**Table 3.** *Cont.*

| Implementation Factor | Explanation |
|---|---|
| Level 2 embedded outcomes of multiple smart solutions | |
| **Hardware** | |
| Communicating infrastructure | • As a software solution, flexibility control algorithms will not have a physical presence in the Positive Energy Blocks (PEBs). This solution will run in servers located at partners' facilities, communicating with the devices installed at the demonstration sites. |
| Robustness of the system | • Servers will have a backup, in case of hardware failure.<br>• On-site devices will have a distributed software solution in order to increase the robustness of the overall solution.<br>• Backup procedures will be considered. |
| **Software** | |
| Interoperability | • Besides the building level control of the available energy flexibility, flexibility control algorithms can be used at district level to support the coordinated operation of other technologies providing energy flexibility to achieve building-level objectives while targeting improvements at the district level (e.g., peak load reduction).<br>• The deployment of the flexibility control algorithms requires the interaction with existing controllable devices to perform the required monitoring and control activities. In POCITYF, this interaction will be supported by APIs made available by the controllable device itself (e.g., direct interaction with energy routers [14] or by other intermediate systems (e.g., indirect interaction with 2nd life batteries through energy management systems).<br>• Usage of standard protocols. |
| Dashboards | • Dashboards will be provided by outside solutions that offer a graphical interface for the users. Foreseen devices include: energy routers, 2nd life batteries, electrical water heaters or freezing storage systems. |
| **Orgware** | |
| Integrated vision on the smart city | • An assessment at district level should be carried out to define higher-level objectives to be considered by the flexibility control algorithms in order to support the achievement of a specific smart city vision. |
| Smart governance | • Smart governance would increase the usage of flexibility control algorithms at the municipality scale (and citizen engagement would be enlarged) in order to increase sustainability and climate change mitigation. |
| Windows of opportunity | • Deployment of flexibility control algorithms (considering the energy flexibility provided by, e.g., existing residential batteries and other controllable devices such as electric water heaters) instead of investments in grid reinforcement. |
| Stakeholder management | • Local communities' engagement will be a key element in the deployment and proper operation of flexibility control algorithms. |
| Ownership | • Residents and municipality will have access to the systems on their premises. |
| Business models and split incentives | • Specific business models and incentives should be developed to accommodate potential conflicts between building- and district-level objectives. |

**Table 3.** *Cont.*

| Implementation Factor | Explanation |
| --- | --- |
| Level 3 upscaling and replication | |
| **Orgware** | |
| Integrated planning | • High-level analysis will be needed in order to choose the best locations for upscaling the installation of controllable devices, combined with global flexibility control algorithms. |
| Innovation platforms | • Demonstration partners will have preferential access to all developments/features of the innovative elements and the opportunity to shape them according to their needs. |
| Conditions for upscaling: finance, regulation (including standardization), access to information and social aspects | • Mobilization of (and networking with) key stakeholders to create strong links and foster engagement of the different target groups at the local, national and international levels, which also represent the enablers for further upscaling and replication of the POCITYF solutions.<br>• Adapt regulations and market conditions in order to fully use the potential of flexibility, providing market-oriented building flexibility services.<br>• Find attractive ways of engaging citizens. |

## 4. Analysis

The RUGGEDISED framework allows for conducting an analysis of important implementation conditions in the cities of Alkmaar and Évora. This section presents the respective main observations.

- Energy flexibility management relies on both energy flexibility characterization and its respective use. This means that the energy flexibility system is based on two main steps. First, it is necessary to get insights (mainly related to flexibility characterization) on the flexibility usage potential and application. Secondly, this flexibility potential will be applied while managing and controlling the energy system.
- Complex energy services like peer-to-peer (P2P) energy trading and VPP, management aggregation services and an energy flexibility marketplace are built upon different individual components. These lower layer(s) components must be functioning and deliver their output in order to provide, possibly stacked, smart (energy) services. As such, Level 1 functioning of such individual components is a prerequisite for smart energy services to exist and be deployed.
- P2P platforms are deemed important from the abstract scenario perspective. However, development mostly starts from a technical solution perspective, while end-user and other stakeholder requirements are paramount in development. Citizen perspectives are often overlooked. Citizens mostly experienced P2P as a burden or a complex, technical solution. According to Alkmaar's experience, relevant stakeholders were not interested, and they lacked knowledge and information, while developers assumed citizens were eager for these technologies. Therefore, engaging all stakeholders and especially end-users already from the conceptualization phase of energy flexibility systems will benefit end-user satisfaction. To achieve this, it is important to bring developers and end-users together so that requirements and needs of the local community are considered and in the long term to ensure widespread and sustainable uptake. Most devices cannot provide flexibility without the involvement of users. Therefore, they are crucial in generating flexibility in energy systems. It is undeniable that the perspective of end-users is important in every phase from conceptualization to development, deployment and operations.
- Transition from Level 1 to Level 2 is normally funded by subsidies. However, subsidized projects in which energy flexibility technologies are piloted have different timeframes that do not always match with the daily business of industrial and business partners. Next to this, the research or development objectives of subsidized energy projects do not per se align with business goals

(in time, budget and purpose). This results in the delivery of flexibility technologies that function (Level 1) but will not necessarily graduate to achieve Level 2 and Level 3 impact; as such, upscaling and replication are not induced. Single flexibility technologies are delivered but this does not result in energy flexibility as a whole or flexibility in smart city systems. At the community or neighbourhood level, subsidies are effective in reaching goals, but in order to achieve large-scale impact (Level 2 and Level 3), combined strategies and widespread collaboration are needed.

- Energy flexibility usage at higher levels should take into consideration the control objectives of previous levels. This is the case when the energy flexibility of a specific device is being used at Level 1 to, e.g., reduce electricity costs and then it is used to, e.g., reduce electricity consumption $CO_2$-related emissions at Level 2. Therefore, the considered business models should properly address the transition to upper limits in terms of objectives of energy flexibility use. Following the previous comment, one can infer that each level may have different objectives which may not only be disconnected from each other but also in some cases directly conflicting. Business models need to be designed in order to address the different strategies that can be applied to the same individual devices at different levels.
- User engagement is key in exploiting the energy flexibility provided by several types of controllable devices as the comfort needs should always be respected. Additionally, the characterization of the energy flexibility provided by some devices (e.g., white appliances) might require the direct user interaction to define the respective operation boundaries. This constitutes a constraint to be considered at all levels.
- It is of upmost importance to regard investments in flexibility usage as win–win situations. For effective upscaling to take place, all involved stakeholders (e.g., DSO, municipalities, end-users) must have a clear idea about the advantages of investing in flexibility.
- There is no possibility to have accurate modeling without data, and data cannot be used if privacy and security issues are not considered. Agile data management should be considered in order to take the best profit from the considered technologies. A good example is the smart metering data, where often end-users do not take advantage of their full potential.

## 5. Conclusions

In this paper, the RUGGEDISED framework was applied as the starting point to evaluate the implementation conditions of energy flexibility solutions within the POCITYF project. Indeed, the selected framework can be leveraged to provide a first analysis of both the success and hindering factors for the implementation of smart technologies while taking a holistic approach that includes not only technological perspectives but also organizational and systemic ones.

The main recommendations and findings for implementing energy flexibility-related technologies at the PED level are summarized below.

- Advanced innovative services and new business models, such as P2P trading and VPP, are quite complex technologies and procedures. They can only be implemented at Level 1 if the individual necessary components such as storage devices (for example, batteries) have passed Level 1.
- Services like P2P can only be introduced when user needs have been considered and user requirements are met. Therefore, involving end-users in the development of the services is key to reach goals and ensure continuous uptake from a bigger group of clients. It is the developer's responsibility to consult end-users and the entire stakeholder value chain.
- The two main functions of the energy flexibility system must be connected. Data insights will have to feed back into the management and control process. The results of the control process will have to be monitored and provide insight on the impact of the introduced control mechanism. Without this feedback loop, the installed energy flexibility system will not be able to deliver the potential optimal flexibility. Ergo, if there is impact, it is by coincidence and therefore it cannot be sustained in the long term. Feedback can change the characterization and the use. A feedback

loop enables deeper understanding of the sources of error, that can either be found in the control (use) or in the characterization function. For acceptance of energy flexibility, it is important to close this loop. Insights delivered via tracking key performance indicators (KPIs) are needed both on rational arguments (economic and energy metrics) and on perception arguments (e.g., satisfaction of citizens).

- A legal framework will have to be updated to realize the full-scale potential of flexibility, because the current legal framework does not allow for using and implementing flexibility. We may apply it as a local, pilot-based tool. However, if one wishes to exploit its potential in full, a consistent and encompassing legal framework is necessary.
- In order to implement energy flexibility systems in the built environment and to eventually scale up at district and city levels, gaps between daily practice and subsidized projects should be closed. Goals of all partners must coincide with the aims of pilot projects. This is crucial for realizing Level 3 outcomes but also for Level 2.
- The absence of an adequate legal framework is a very important issue and not only for specific energy flexibility technologies. Systemic hiccups introduced by a lack of appropriate or mature legal instruments should be overcome beyond pilot project boundaries which in any case are funded by subsidies whose power to influence directly relevant legislation is limited (both in scope and time).

The experiences of Alkmaar and Évora result in an easy-to-use methodology for cities to deal with energy flexibility technologies and create optimal conditions for their successful implementation and integration. In the coming period, demonstration of the related energy flexibility technologies is being carried out in both cities at the block and district levels. Starting from the analysis, progress is to be tracked especially focused on achieving Level 1 and moving forward to higher impact levels. This effort will also support the replication process not only in other areas within Alkmaar and Évora but also the so-called "fellow" cities participating in the POCITYF project.

## 6. Practitioners Review by Roel Massink MSc

The authors of this paper asked me to provide my view on the methods and results of this research paper in my capacity as Project Coordinator for the H2020 Smart City Lighthouse project IRIS and innovation manager for the Municipality of Utrecht. I am happy to fulfil this task and I thank the authors for the carefully presented research results based on actual demonstration. This review is based on the experiences collected in the IRIS Smart Cities project, a similar project to RUGGEDISED and POCITYF. In IRIS, an integrated project approach is demonstrated: in the Kanaleneiland district (Utrecht, The Netherlands), near zero-energy-efficient building retrofitting is connected to the development of a smart energy and mobility system integrating PV panels with stationary and V2G storage. The smart solutions in IRIS Smart Cities Utrecht mostly all fall within Level 2 of the RUGGEDISED implementation framework. Below, some general reflections based on these experiences toward the RUGGEDISED implementation framework and the conclusions of the paper can be found.

The structure of the RUGGEDISED framework is very much in line with what is happening in practice in the IRIS Smart Cities project and further development of the framework in practice is appreciated. Within the IRIS Smart Cities project, the smart solutions are implemented along transition tracks and structured through a maturity assessment in the following categories: (1) pre-pilots: solutions that have been tested on a small scale in a pilot project; (2) integrated solutions: multiple smart solutions that are demonstrated as integrated solutions at a larger scale at the demonstration site of the project; and (3) replicated solutions: through either the copying of a successful integrated solution to other sites or by upscaling of the integrated solution in the same city or region. This categorization provides the IRIS partners and stakeholders a framework and a roadmap for all smart solutions to be developed, demonstrated and scaled-up. The RUGGEDISED framework is valuable and will offer practitioners at public authorities, grid operators, solution providers and knowledge institutes a coherent overview of what is important for implementation. However, below I have some suggestions in view of the practical applicability of the RUGGEDISED framework. First, smart solutions are integrated solutions by nature. To ensure that the smart solutions (that are realized in isolation; Impact Level 1) meet the requirements of an embedded outcome of multiple smart solutions (Impact Level 2), it is suggested that an integrated approach with all implementation factors is taken into account. To ensure such an integrated (and systemic) assessment throughout the development of smart solutions, an iterative execution of the implementation framework could be proposed. This means that at Level 1, the implementation factors of Level 2 and Level 3 are also considered. Assessment of implementation factors in Level 2 and Level 3 includes more detailed and specific information once the development of smart solutions progresses.

The following three reflections are supportive of including higher-level implementation factors at the start of the pilot projects.

The paper highlights the importance of aligning partner goals with pilot project aims. This should be seen as a conditional factor for achieving progress at the different impact levels. An example from IRIS Smart Cities Utrecht is the development of a bidirectional charging ecosystem for grid flexibility and mobility services. Currently, this integrated solution consists of multiple smart solutions (bidirectional charging infrastructure, bidirectional enabled electric vehicles, stationary battery storage, energy management system) that are being connected to provide embedded outcomes (Level 2). The current state of development is a result of careful stakeholder management from the start of the pilot projects (already pre-IRIS). Companies, knowledge institutes, grid operators and public authorities aligned their roadmaps and activities in pilot projects under the lead of an ambitious SME (Level 1) and now this is leading to embedded outcomes in the IRIS demonstration project (Level 2). Furthermore, scaled adoption in public procurement documents of electric charging infrastructure now paves the way for city-wide flexibility services of electric vehicles (Level 3). An important success factor was/is stakeholder alignment from the start of the pilot projects. Based on this experience, it is argued that stakeholder management (or rather stakeholder alignment) should take position already at Level 1 to ensure that partner roadmaps are aligned to move the smart solution to Level 2 and 3.

The paper also points towards the requirement of end-user involvement (or co-creation) in the development of smart solutions and could argue for the inclusion of a new implementation factor in the RUGGEDISED framework. This could be "end-user satisfaction" or similar. This is a valid point; often smart solutions are hampered because end-user needs were not considered well enough in the original approach. A design-thinking (or another systemic) approach could offer smart solution developers tools to better involve end-users. A practical notion that requires attention here is the use of grant subsidies in this innovation framework (as the authors also refer to in moving from Level 1 to Level 2). It is recommended that subsidy programs, grant applicants and consortia put more attention into making end-user involvement more explicit in call texts and subsequently also allow more flexibility in the implementation of the grant project based on changes offered by end-users.

Next to this, the paper explains the requirement of a legal framework that supports the transition from pilot projects to scaled solutions. This is true as well for the IRIS Smart Cities project. Especially within the field of smart energy projects or services like peer-to-peer, a supportive legal framework is needed for scaled adoption. The exploitation of grid flexibility services is hampered by legal constraints. Research from the IRIS project shows that bidirectional charging services are discouraged because of double energy taxation (for each charging and discharging cycle, energy tax needs to be paid on either the stored or consumed kWh). This significantly hampers the realization of profitable business models and commercial scaling of these integrated smart solutions. Therefore, it could be argued that regulation/the legal framework is already introduced as an implementation factor in Level 2 of the framework to ensure that, in time, legal constraints are targeted in a concerted action by smart cities.

Finally, what the paper does not explain but what is highly valuable for practitioners is guidance on how the implementation framework leads into an implementation process. The presented implementation framework provides an assessment of implementation factors related to smart solutions but does not directly translate the assessment into implementation guidelines. Further guidance on the implementation pathway resulting from the assessment could support practitioners in applying this framework more easily.

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