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Positive Energy Districts European Network

Deliverable 3.1

Review of existing urban laboratories (Review existing concept, projects and facilities that are relevant to PED Labs)

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1. EXECUTIVE SUMMARY

59 WG3 members, representing 26 countries, worked around the concept of PED-LAB with the specific objective to review existing concepts, projects and facilities that are relevant to PED Labs.
D3.1 contributes as input to T3.3 - Consolidate the concepts of PED Labs and derive guidance on their design and implementation from technological, social, financial and regulatory perspectives.
The positioning of the PED-LAB concept in the context of the international debate on sustainable city development led to the conclusion that the PED-LAB concept is placed in an intermediate context between the concepts "Smart City", "PED", "NED", etc. and the concepts "Urban living lab", "testing grounds", “sand boxes” etc. In practice, the PED-LAB is a test-bed for the validation of innovative concepts (technological, spatial, regulatory, financial, legal and socio-economic) in risk-controlled development frameworks.
Specific questions that D3.1 helped to answer are:

- What are currently the barriers to the implementation of PED-LABS? → **chapter 4**
- What are the drivers but also the incentive factors (unlocking) that determine the "fertility of the soil" for PED-LAB initiatives? → **chapter 5**
- What are the processes and the actors involved that define the steps, power relationships and subsidiarity in the responsibilities and decisions in PED LAB initiatives? → **chapter 6**
- Based on the PED-LAB experiences to date, what, in summary, have been the strengths, weaknesses, opportunities and risks encountered in the implementation of PED-LABs? How can these experiences ultimately inform future experiments in this direction? → **chapter 7**
- What are the facilities (tangible and intangible "assets") that are needed in the implementation of PED-LABs? → **chapter 8**
- And finally, what information still needs to be systematically collected from ongoing PED-LABs experiences and thus how to appropriately inform the collection of information through the questionnaire prepared by WG1-WG3[1]? → **chapter 9**

The methodologies used were mainly qualitative: questionnaires and focus groups.
In summary, the following were identified and discussed:

- 49 barriers to PED-LAB implementation divided into 8 categories
- 21 drivers and unlocking factors

Subsequently, the key stakeholders (7 categories) and the PED-LAB implementation processes (6 main phases) were identified and discussed.
A SWOT analysis then identified the strengths, weaknesses, opportunities, and risks associated with the PED-LAB concept.
Finally, a list of facilities necessary for the implementation of the PED-LAB concept was drawn up.
In the last chapter, the structure of the questionnaire that will be launched in October 2021 to collect detailed information on the current PED-LAB case studies is presented.

[1] The contents of this questionnaire have been developed between WG3 and WG1. This collaborative work has been carried out through several meetings in which three sections have been defined: 2 common sections and 1 specific section for each group. The technical department of CIEMAT has developed the current version of the online questionnaire.

2. INTRODUCTION

Deliverable 3.1 is titled - Report on existing urban living laboratories - and is part of the work of WG3 of COST-PED-EU-NET titled PED Laboratories, Monitoring and Replication and in particular of Task 3.1 - Review existing concept, projects and facilities that are relevant to PED Labs.

Explore the success factors of PED Labs and provide recommendations on their implementation. Define methods for the monitoring, evaluation and replication of PEDs and PED Labs.

Within this macro-objective, T3.1 set itself the specific objective of positioning the PED-LAB concept within the international debate and answering some research questions related to the development of the PED-LAB concept.

T3.1, with its D3.1, contributes a substantial input to T3.3 entitled - Consolidate the concepts of PED Labs and derive guidance on their design and implementation from technological, social, financial and regulatory perspectives.

WG3 is composed, at the date of publication of this deliverable, of 59 members who have contributed in various ways and in alternation to the consultation activities and focus groups covered by this report. The participating members represent 26 EU and associated countries. Below is the list of countries represented in WG3.

AT – Austria	HU - Hungary
BA - Bosnia and Herzegovina	IE - Ireland
BE – Belgium	IL - Israel
BG - Bulgaria	IT - Italy
BG - Bulgaria	LU - Luxembourg
CH - Switzerland	MD - Moldova
CY – Cyprus	NO - Norway
CZ - Czech Republic	PL - Poland
DE - Germany	PT - Portugal
DK - Denmark	RO - Romania
EL – Greece	RS - Serbia
ES – Spain	SE - Sweden
FR – France	TR - Turkey

3. REVIEW OF CONCEPTS RELATED TO PED LABS

POSITIONING OF THE POSITIVE ENERGY DISTRICT LABORATORY (PED-LAB) CONCEPT
We started from the following assumptions:

a) that it is necessary to define more precisely the concept of PED-LAB, introduced for the first time by SET PLAN Action 3.2 (European Commission 2018), also and above all in comparison with the definition of PED.

> The SET PLAN Action 3.2 introduces the PED LAB as follows:
>
> *<< PED Labs, as **seeding ground for new ideas**, **solutions and services,** will be developed according to placebased needs and local context baselines. PED Labs will follow an integrative approach including technology, spatial, regulatory, financial, legal, social and economic perspectives.>>*
>
> *<< PED Labs will be pilot actions of cities towards PEDs. PED Labs are designed for cities' needs and support concrete next steps in the planning and deployment phase, which includes a range of activities and steps towards PEDs (e.g. test new technologies, test new forms of stakeholder engagement, test new regulations, test new funding mechanisms). PED Labs should **support cities in the development of innovative solutions** (that can then be used and replicated in all PEDs). A systematic analysis of experiences and lessons learnt from already existing PEBs and PEDs should inform the set-up and specificities of PED Labs. The goal is to create, collect, qualify, compare and analyze data from the 100 European PEDs, which then contribute to the PED Lab. The identification of how each system innovation evolves in specific settings helps to plan and manage the spatial diffusion of such PED innovations and to strategically feed into the value chains.>>*

b) the fact that the attempt to establish a definition of PED, contained and described in the article of COST PED-EU WG1 (Albert-Seifried et al., n.d.) and IEA EBC Annex 83 (Hedman et al. 2021), has not led to a final definition but to a comparison of the various interpretations and definitions that different bodies and authors have given in the course of the last months/years, setting the definition of PED in more or less operational and project contexts.

> From (Albert-Seifried et al., n.d.):
>
> *<< The main challenges include the definition of PED boundaries, the method for calculating energy balance, the scope of non-energy matters and the assessment of qualitative requirements. As the PED definitions are to be applied to locations with considerably different local contexts, it would be sensible to develop PED definitions in the form of an adaptive framework.>>*
>
> *<< Positive Energy Districts (PEDs) are recognised as one of the central pillars for driving the urban energy transition in Europe. The concept of PEDs can be traced back to the concept of net-zero energy districts (NZEDs) that corresponds to the transformation at the neighbourhood level triggered by the energy and climate targets. The concept marked a shift from individual buildings to the neighbourhood level as a way to scale up the efforts and speed up the pace of the global energy transformation. Building on NZED, the Energy Efficient Building Committee of the European Construction, Built Environment and Energy Efficient Building Technology Platform (ECTP)*

designed the concept of Positive Energy Blocks (PEB) to stimulate the citywide energy transition in Europe. The concept was strongly promoted by the European Innovation Partnership on Smart Cities and Communities (EIP-SCC), which established an initiative on PEBs in 2016. The main goal of the initiative was to facilitate the deployment of 100 PEBs throughout EU and neighbouring countries by 2020. A step up from PEBs came the concept of Positive Energy Districts (PEDs). The European Commission (EC) endorsed the SET Plan Action 3.2 "Smart Cities and Communities" in June 2018. The main objective of Action 3.2 is to develop integrated and innovative solutions for the planning, deployment, and replication of PEDs. According to the Action, 100 PEDs are expected to be in concrete planning, construction or operation, synergistically connected to the energy system in Europe by 2025 . >>

From (Hedman et al. 2021):
<< A common shared definition, as well as technological approaches or methodological issues related to PEDs are still unclear in this development and a global scientific discussion is needed.>>
<< The main topics of discussion in the PED context are the role and importance of definitions of PEDs, virtual and geographical boundaries in PEDs, the role of different stakeholders, evaluation approaches, and the learnings of realized PED projects>>
<< The PED concept introduces an opportunity to develop a framework that introduces energy positivity on a district level, with clear guidelines for grid interaction, energy storage and renewable integration for both buildings and Electric Vehicles (EVs). The main principle of a PED is to create a district within the city that is capable of producing higher energy than it consumes, it is flexible to respond to the energy market situation and in addition to this, it contributes by improving the quality of life and wellbeing of the residents>>

<< The transition towards carbon neutral districts require multisector and multidimensional solutions. It embraces a synchronized and parallel development of instrumental technologies, public perceptions of building energy technologies, new economic paradigms, assessment approaches, and tailored business models. In this case cities can provide and act as a living lab to facilitate and incubate new technologies and solutions. This is needed in order to co-design all-inclusive packages of citizen's centric carbon-free energy solutions>>

c) the debate around the concept of Positive Energy District and therefore also of PED-LAB stems from a series of experiments that began almost 20 years ago under the name of Smart (energy) Cities (Mosannenzadeh and Vettorato 2014a), (Mosannenzadeh, Bisello, Vaccaro, et al. 2017) and were then integrated and evolved into the various concepts of Nearly Zero Energy Building, Zero Energy Building, Zero Energy Districts, Positive Energy Building (Lindholm, Rehman, and Reda 2021), (Albert-Seifried et al., n.d.), From (Mosannenzadeh and Vettorato 2014a);

<< The first step towards creation of Smart City is to understand its concept. A brief review of literature on Smart City definition shows there are still many open questions that refer to following issues: − The necessity of creation of Smart Cities (Why?) − The main aspects of Smart City (What?) − The key actors in Smart City (Who?) − The ways to create Smart City (How?) − The right place and time to create Smart City (Where? and When?)>>

<< There are various definitions of Smart Cities in literature and the phrase "Smart Cities" has been used in many different situations and by different stakeholders>>

<< A difference of viewpoints exists between the three domains (Academic, Industrial, and Governmental). It derives from the different interests of each domain, as well as diverse interpretation of the word "Smart". In academic literature, with an interest in knowledge and information development, the meaning of "Smart" covers a range of technological characteristics, such as self-configuring, self-healing, self-protection, and self-optimizing (Nam & Pardo, 2011). In industrial literature with a tendency in business and industrial instruments, "smart" refers to intelligent-acting products and services, artificial intelligence, and thinking machines (Nam & Pardo, 2011). Finally, governmental documents, which aim to manage urban development, interpret "smart" with regard to an urban planning theory, "Smart Growth", which was emerged in the US in early 90s to avoid urban sprawl (Herrschel, 2013). "Smart Growth" supports compact, mixed-use and walkable cities and aims to make development decisions predictable, fair and cost effective. It encourages community and stakeholder collaboration in development decisions (EPA, 2014).>>

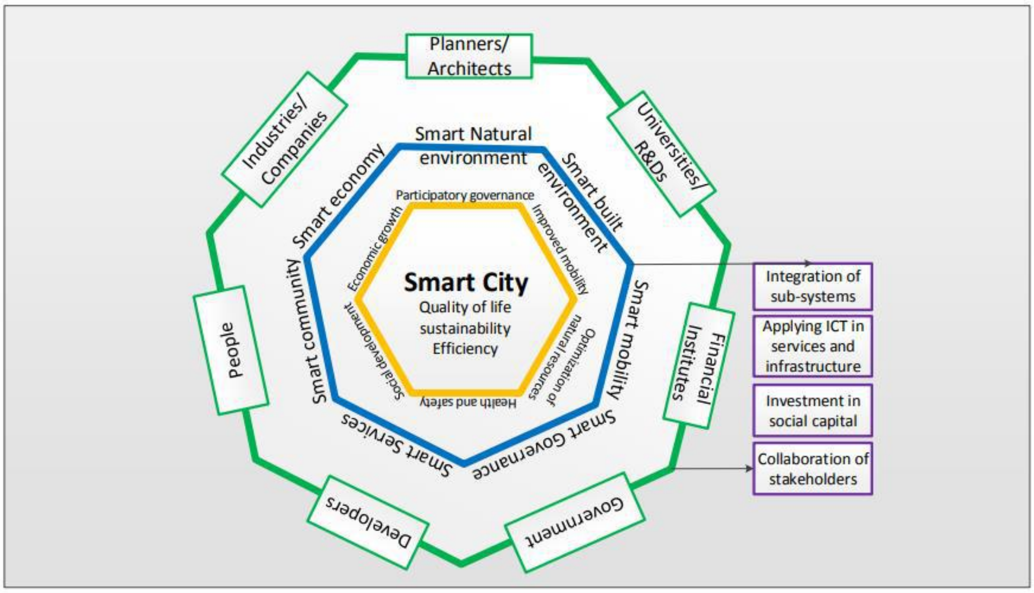

Figure 1: A conceptual framework to define Smart City - from: (Mosannenzadeh and Vettorato 2014)

<< Smart City is a holistic approach that aims to address recent urban challenges and exploit recent opportunities provided by advancements in ICT

and Urbanization. The first step to create Smart Cities is to understand the nature of the concept.>>

<< Since each city has its unique economic, social and administrative situation, as well as different priorities, we suggest that authorities keep the main structure as the basis of the conceptualization, and then regenerate their own concept with respect to their priorities and context.>>

From (Lindholm, Rehman, and Reda 2021):

<< There are many concepts for buildings with integrated renewable energy systems that have received increased attention during the last few years. However, these concepts only strive to streamline building-level renewable energy solutions. In order to improve the flexibility of decentralized energy generation, individual buildings and energy systems should be able to interact with each other. The positive energy district (PED) concept highlights the importance of active interaction between energy generation systems, energy consumers and energy storage within a district. >>

<<The renewable energy environment varies between different EU regions, in terms of the available renewable energy sources, energy storage potential, population, energy consumption behaviour, costs and regulations, which affect the design and operation of PEDs, and hence, no PED is like the other.>>

<<Various zero energy building (ZEB) concepts have been applied and used in the building sector all over the world. The overall ZEB definition states that "the building can be considered as ZEB after it shows through actual measurements that the energy delivered to the building is less than or equal to the onsite renewable exported energy">>

<<The USA established the Energy Independence and Security Act of 2007 to support the building sector to create zero energy commercial buildings by the year 2030. It also mentions converting 50% of American commercial buildings to ZEBs by 2040 and converting all commercial buildings into ZEBs by 2050. […] According to the US Department of Energy (DOE), a ZEB is an "energy efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy">>

<<In Europe, the European Union (EU) has developed a framework that aims to reduce the emissions from buildings by improving the energy efficiency at the building level. The Directive on Energy Performance of Buildings (EPBD) initiated in May 2010 states that a nearly ZEB is a building with a high efficiency in terms of energy utilization and an energy demand that is mostly covered by on-site renewable energy generation>>

<<The International Energy Agency (IEA) has proposed a concept called autonomous ZEB, which is an extension of the ZEB . These buildings are self-sustaining buildings with no connection to the grid and are able to produce enough on-site energy to satisfy their own energy demand. In order to satisfy

the energy demand day and night, summer and winter, energy must be stored. This differs from the net ZEB concept, as the net ZEBs are able to interact with the external grid as long as the annual energy export is equal to the annual energy import. The IEA does also bring up energy plus buildings (+ZEB), which export more energy than they import>>

From: (Mosannenzadeh et al. 2017):

<<Smart energy city development is a component of smart city development aiming at a site-specific continuous transition towards sustainability, self-sufficiency, and resilience of energy systems, while ensuring accessibility, affordability, and adequacy of energy services, through optimized integration of energy conservation, energy efficiency, and local renewable energy sources. It is characterized by a combination of technologies with information and communication technologies that enables integration of multiple domains and enforces collaboration of multiple stakeholders, while ensuring sustainability of its measures.>>

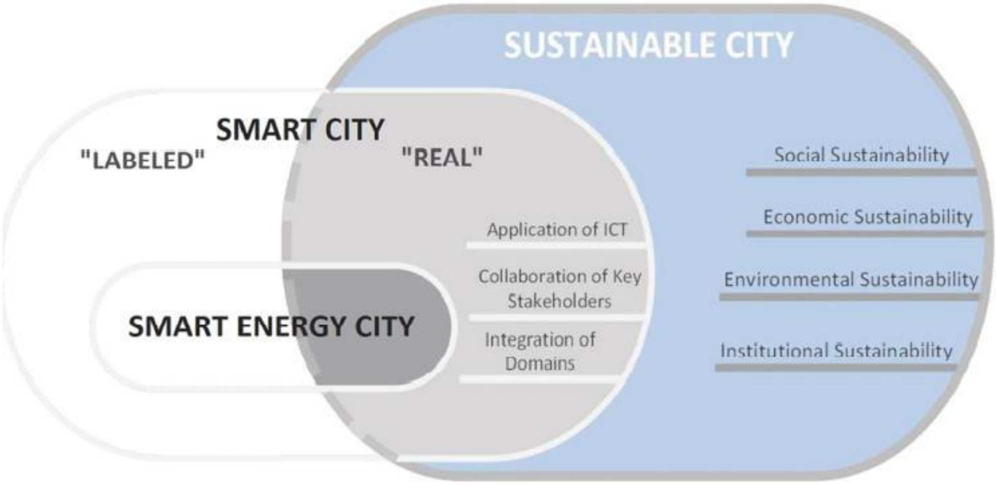

Figure 2: Relationship between the three urban development concepts of sustainable city, smart city, and smart energy city – from: (Mosannenzadeh, et al. 2017)

a) that the experience of the "urban living lab" in the broad sense has a discrete tradition both in literature and in practice, although it is not yet possible to find a stable concept of the term itself, but that in any case, it is necessary to include this tradition within the debate on what a PED-LAB is.

According to (Steen and van Bueren 2017):

> << *The term "urban living lab" is to refer to a variety of local experimental projects of a participatory nature. It is often used interchangeably with the terms "testing ground", "hatchery", "incubator", "making space", "testbed", "hub", "city laboratory", "urban lab", or "field lab"* >>.
>
> In addition, possible connected concepts in the framework of PED-LABs and Urban Living Labs are: *incubators, testing facilities, prototypes, pilot actions.*

Again, according to (Steen and van Bueren 2017)

> << *although urban living labs could […] help cities to speed up the sustainable transition, urban living lab experts agree that, in order to truly succeed in these ambitious tasks, the way urban living labs are being shaped and steered needs further research. Yet, they also confirm the existing variation and opaqueness in the definition of the concept".* >> The same article concludes: << *in this context, it would be valuable to extract the details of the methods recommended in the living lab literature and how they compare to the methods being used in practice, what the* ***drivers and barriers*** *are for the emergence and implementation of sustainable urban innovations, and which other* ***methodological lessons*** *can be learned from previous experiences with urban living labs. Reformulating these findings in the form of recommendations regarding the methodology, design, and* ***governance of urban living labs*** *would enhance the ability of urban living labs to achieve successful* ***development, adoption, and replication of sustainable urban innovations***. >>

b) that the European Commission has recently launched some Missions and new concepts related to sustainable urban development such as the Climate Neutral City Contract [2]and the New European Bauhaus[3], and that it is, therefore, necessary to place the concept of PED-LAB also in relation to these new initiatives that are still being developed.

Considering these assumptions, and the preliminary consultation on "Testing Platforms as Drivers for Positive-Energy Living Laboratories" already carried out within the Joint Program on Smart Cities of the European Energy Research Alliance and published here (Soutullo et al. 2020) we can therefore hypothesize not so much a definition of PED-LAB as its positioning in the international debate, thus beginning to better understand what the role of PED-LABs is and what interactions this new concept may have with other past, present or future concepts. Below is a diagram of the positioning of PED-LABs. In particular, their origin is highlighted, which draws its foundations from the debate on Smart Energy Cities, NZEB, ZEB, ZED, etc, and from the experience gained in urban labs, urban living labs, city laboratories, incubators, etc... to then inform the creation of Positive Energy Districts. The whole of this debate, which is still ongoing, should be seen as a subset of the broader debate on the sustainability of urban development, which has currently led, in Europe, to the two new concepts of Climate Neutral City and New European Bauhaus.

[2] Mission area: Climate-neutral and smart cities | European Commission (europa.eu)

[3] New European Bauhaus : beautiful, sustainable, together. (europa.eu)

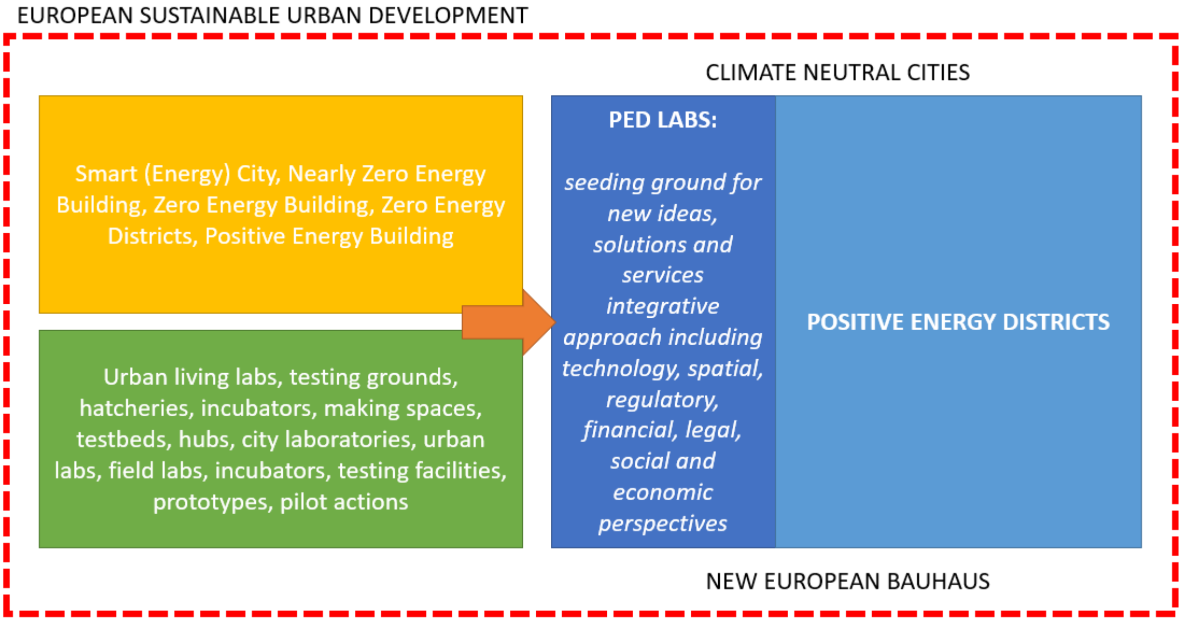

Figure 3: Positioning of PED-LAB concept in the current European debate on sustainable urban development

Also in accordance with the above considerations, the working group has therefore prepared some analytical and experts consultation steps, through the use of focus group methodology, to contribute to the debate and to help answer, at least in part, the research questions that are still open:

- What are currently the barriers to the implementation of PED-LABS? → **chapter 4**
- What are the drivers but also the incentive factors (unlocking) that determine the "fertility of the soil" for PED-LAB initiatives? → **chapter 5**
- What are the processes and the actors involved that define the steps, power relationships and subsidiarity in the responsibilities and decisions in PED LAB initiatives? → **chapter 6**
- Based on the PED-LAB experiences to date, what, in summary, have been the strengths, weaknesses, opportunities and risks encountered in the implementation of PED-LABs? How can these experiences ultimately inform future experiments in this direction? → **chapter 7**
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- And finally, what information still needs to be systematically collected from ongoing PED-LABs experiences and thus how to appropriately inform the collection of information through the questionnaire prepared by WG1-WG3[4]? → **chapter 9**

[4] The contents of this questionnaire have been developed between WG3 and WG1. This collaborative work has been carried out through several meetings in which three sections have been defined: 2 common sections and 1 specific section for each group. The technical department of CIEMAT has developed the current version of the online questionnaire.

The Focus group methodology used

Following (Dawson, Manderson, and Tallo 1993) and (Silverman 2004) manuals, the "Focus Group" methodology was selected to allow for an expeditious exploration of a topic on which little has yet been published, namely the PED-LAB experience.
The focus group methodology was coupled with another qualitative research tool: questionnaires.
The focus group experience of T3.1 was based on several group discussions with participants belonging to WG3, who alternated according to their willingness to participate in the online meetings. Each focus group had an average participation of about 20 experts, who have in common their technical background related to PED development.
The focus groups' management phases saw in particular two moments: the first one that reported on the results of the questionnaires, the second one that, through online working tools (i.e. MURAL) opened the discussion to the working group in order to refine the results of the questionnaires and reach a shared result.
The focus groups were all held in English and were led mainly by Daniele Vettorato and Viktor Bukovszki.

4. BARRIERS

Based on the following articles (Mosannenzadeh, Di Nucci, and Vettorato 2017), (Mosannenzadeh, Bisello, Diamantini, et al. 2017), (Mosannenzadeh et al. 2016), which analyzed the barriers to the implementation of SMART (ENERGY) CITIES projects funded by the European Commission during Framework Programme 7 and the beginning of Framework Programme 8, and on (Razmjoo et al. 2021) and (Bukovszki et al. 2020), a list of barriers grouped by subgroups was prepared. Subsequently, this list was updated, adapted, and ranked through a consultation/workshop (focus group methodology) among WG3 experts in order to make it suitable for the description of the PED-LAB concept. The starting point for this activity is clearly based on the conviction that the barriers to the implementation of the SMART (ENERGY) CITY concept are similar and scalable to the PED-LAB concept.

18 experts belonging to COST-PED-EU, mainly WG3, participated in the Focus Group and were asked to:

a) Approve the proposed list of barriers and groupings or propose changes;
b) Weigh the importance of the listed barriers scoring each element according to a Linkert scale from 1 to 5 where 1 is not very relevant, 5 is very relevant;
c) Discuss together the results of the questionnaires to extract some learnings.

Below is a radar chart of the results of the consultation/focus group on barriers.

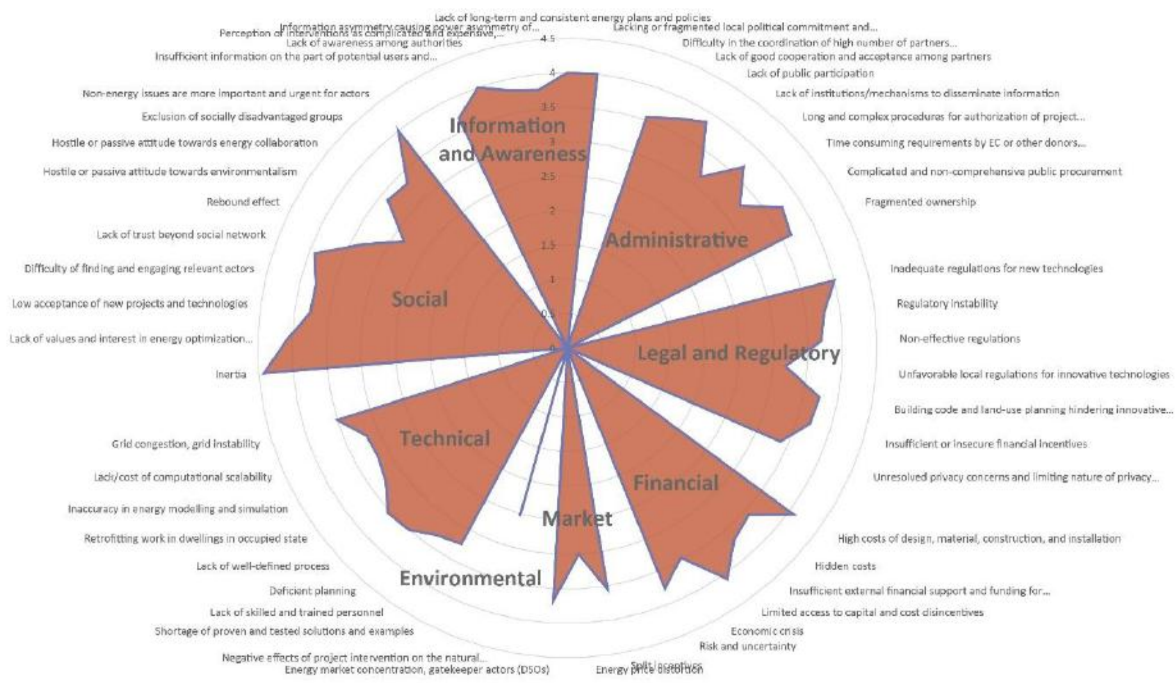


Figure 4: Weighted barriers to PED-LAB development

Below is the complete list of barriers listed and grouped into clusters, along with their paraphrase and the annotated result of the consultation to allocate a weight to each barrier. In addition, the different elements were classified into endogenous and exogenous according to their relevance to the internal context of the PED-LAB projects, i.e. the possibility of the PED-LAB project to influence the conditions of the factor itself, or external to the PED-LAB projects, i.e. the dependence of these factors on decision-making processes and actors outside the PED-LAB project.

Policy

	EXOGENOUS	ENDOGENOUS
Lack of long-term and consistent energy plans and policies	■	■
The lack of a long-term vision of governance bodies, as well as the lack of culture and tradition of investments related to sustainability, energy conservation and the production of energy from local renewable sources that are integrated into the territory, can determine a barrier especially related to the support of these PED-LAB initiatives in their integration into the urban territory, legislative and governance context and, therefore, in their adoption and replicability towards the PED concept.		
Lacking or fragmented local political commitment and support on the long term		■
The traditional time frames of urban transformation and the traditional time frames of administrative and political turnover can come into conflict with the implementation of PED-LABs where there is no guarantee of temporal continuity and commitment, and thus a temporal fragmentation of political commitment.		

Administrative

Difficulty in the coordination of a high number of partners and authorities		■
The complexity of PED-LAB initiatives requires a very important coordination effort due to the large number and diversity of actors involved in the process of urban transformation.		
Lack of good cooperation and acceptance among partners		■
Similarly to the previous point, the lack of cooperation and, in general, the lack of good relations between key actors in urban transformation processes becomes a barrier to the implementation of PED-LABs.		
Lack of public participation		■
In relation to the Quadruple Helix concept, public participation is crucial to ensure the adoption and replicability of solutions by citizens and public administrations that represent the public interests of citizens.		
Lack of institutions/mechanisms to disseminate information		■
The transparency of the process of urban transformation, linked to the high level of introduction of innovations, both from the point of view of technology and from the point of view of economic, relational and social aspects, is of paramount		

importance to adequately communicate the benefits that PED-LAB can bring to the urban living environment.		
Long and complex procedures for authorization of project activities		
The current (urban) authorization procedures do not seem to be compatible with the complexity of urban transformations PED-LAB and with the energy transition times necessary to reduce the effect of climate change and in general the dependence on fossil or nuclear energy sources.		
Time-consuming requirements by EC or other donors concerning reporting and accountancy		
Especially in relation to European funding, but also in relation to other donors, reporting and accountancy procedures absorb many resources that could be dedicated to the management of urban transformation operations. These management operations, especially at the local level, are often underestimated both in terms of the human resources and time required and the budget allocated.		
Complicated and non-comprehensive public procurement		
Public procurement procedures often become barriers to the adoption of prototypical solutions, typical of the PED-LAB concept, because they limit the ability of public agencies to request specific solutions and specific performance often provided by a single supplier. Therefore, not compatible with the concept of the "free market" and the guarantee of free competition, which is mandatory in public administrations.		
Fragmented ownership		
Especially in relation to the residential sector, but not only, fragmentation of ownership (i.e., apartments in condominiums - then scaled up over an entire neighborhood) drastically reduces the speed of decision-making but also the search for agreement among all private owners with respect to a scenario of the overall transformation of the building stock and the urban fabric of the district.		

Legal and Regulatory

Inadequate regulations for new technologies		
The adaptation of regulations often does not keep pace with the speed of the introduction of technological innovation. In particular, with respect to the concept of PED-LAB and the transformation of existing urban areas, the regulatory framework greatly limits the possibility of testing new technologies and solutions on a large scale. A very clear example comes from the concrete implementation of the concept of energy communities on a neighborhood scale.		
Regulatory instability		
The legislator's priority is not to build a stable regulatory framework that allows for the development of long-term scenarios. Consider, for example, incentives for renewable energies that change from year to year.		
Non-effective regulations		
The testing of regulatory frameworks also demonstrated that in a number of cases the regulatory schemes implemented (i.e., incentive schemes, permits, etc.) were not adequate and therefore not fully effective in meeting the needs of implementing new technologies.		
Unfavorable local regulations for innovative technologies		

At the local level, especially with respect to local building codes, there are additional barriers to the massive redevelopment of entire districts.		
Building code and land-use planning hindering innovative technologies		
Here we refer specifically to building codes and urban planning tools that do not incorporate and integrate, for example, performance indicators related to energy consumption or energy production from renewable sources.		
Insufficient or insecure financial incentives		
Also in relation to the previous point, "regulatory instability", an obvious barrier is related to the insecurity but also the inadequacy of financial incentives that are not stable over time. Often, in fact, incentive schemes last only a few months and/or are renewed from year to year. With respect to the timing of planning and implementation of urban transformation, this insecurity determines more conservative and less ambitious choices in PED-LABs business models.		
Unresolved privacy concerns and limiting nature of privacy protection regulation		
Especially in relation to the GDPR, the concept of privacy of personal information, although designed to ensure the security of EU citizens, has introduced very strong limitations on the ability to access and use data relating to energy behavior. In particular, the profiling of energy behavior is "borderline" with respect to legal possibilities and left to the respective national privacy guarantors. The possibility of requesting access to data from individual citizens through informed consent has undoubtedly lengthened and complicated the procedures for adopting PED-LAB solutions, while also increasing the legal risk for the implementers of these solutions.		

Financial

High costs of design, material, construction and installation		
Compared to a Business As Usual approach, PED-LAB solutions cost more in terms of design, materials - especially in relation to their preparation and integration into non-main stream technological solutions - as well as for the construction and installation phases which require specialised workers. These increased costs, which are usually absorbed by incentive schemes or research project funds, become a barrier when putting solutions on the market where the supply chain capable of reducing costs through economies of scale has not been created first. Therefore, the additional costs passed on to end-users tend to lead to the adoption of traditional solutions that cost less in terms of investment in the short term.		
Hidden costs		
Hidden costs have emerged as a barrier in particular in relation to the difficulty of planning in advance for all possible contingencies that may arise during the transformation of whole neighbourhoods.		
Insufficient external financial support and funding for project activities		
The calculation of financial risk becomes particularly complex in the case of prototype tests that may hide unforeseen events. In these situations, the financial support provided by the funding of innovation projects does not always cover these additional costs.		
Limited access to capital and cost disincentives		
On the side of financial instruments and banking instruments, there is also a barrier where there are no financial and/or banking instruments created		

specifically for testing innovative solutions. Here, the barrier is clearly related to the financial risk calculation tools that still fail to include innovation projects.		
Economic crisis	■	
The economic crisis also leads to a reduction in the investment capacity, especially of private individuals, and therefore the adoption of less expensive solutions in the short term.		
Risk and uncertainty	■	
Finally, in general, the risk and uncertainty, even psychological, with respect to a prototype solution, where there are no demonstrations of correct operation or data on the performance of the systems, reduces the attitude to investing in innovative solutions.		

Market

Split incentives	■	
In cases where energy bills are paid by parties other than the building owners, we face might this barrier. In particular, owners are not encouraged to invest in the renovation of buildings because they would not benefit directly.		
Energy price distortion	■	
Market incentives may bring an immediate benefit in relation to the adoption of specific energy technologies, but they may also create market bubbles, after which the adopted technologies may become uncompetitive and more expensive. Similarly, incentives for certain energy sources (e.g. oil, nuclear, etc.) can reduce the market competitiveness of efficiency and renewable energy solutions.		
Energy market concentration, gatekeeper actors (DSOs)	■	
DSOs prove to be barriers to the adoption of horizontal solutions based for example on the concept of energy communities, where they compete directly for the management of the local energy market.		

Environmental

Negative effects of project intervention on the natural environment	■	
The lack of precise information especially on the Life Cycle Assessment of "smart" solutions for PED-LABs creates uncertainty about the potentially negative environmental effects that these solutions may produce. In particular: use of rare materials, embodied energy, etc.		

Technical

Shortage of proven and tested solutions and examples	■	
The lack of tested solutions increases the need for prototyping and requires a greater commitment from the engineering and industrial sector than the adoption of already tested solutions.		
Lack of skilled and trained personnel		■
Innovation in solutions requires qualified personnel for both design and implementation.		
Deficient planning		■
Planning innovative solutions is particularly complex due to the large number of elements, processes, actors to be integrated, and the high risk of failure.		
Lack of well-defined processes	■	■

In particular, the definition of clear and effective processes seems to be one of the most important technical barriers in the implementation of PED-LABs.		
Retrofitting work in dwellings in an occupied state		
The adoption of PED-LAB concepts often requires the involvement of residential buildings, most of the time inhabited. The occupation of the dwellings limits free access and the application of certain important technical solutions that are too invasive.		
Inaccuracy in energy modelling and simulation		
The lack of accuracy of energy models and simulations leads to an increased risk of failure and unforeseen events.		
Lack/cost of computational scalability		
From the point of view of simulation and energy models, moving from a building scale to a city-scale requires a significant scalability of calculation systems that is often not present.		
Grid congestion, grid instability		
From the point of view of energy networks, in relation to bidirectional smart grid models (production-consumption), there is still congestion and instability often resulting from a one-way network architecture that is not ready/suitable to host prosumers and energy communities models.		

Social

Inertia		
Inertia to change mainly due to reduced acceptance of solutions that also affect people's habits and behaviour.		
Lack of values and interest in energy optimization measurements		
Lack of culture and therefore of values and interest in environmental issues and in particular in energy efficiency and production from renewable sources, as well as in the concepts of the energy community.		
Low acceptance of new projects and technologies		
Low general acceptance of innovation in relation to the implementation of new projects and the adoption of new technologies.		
Difficulty of finding and engaging relevant actors		
Difficulties in involving key actors, who should promote both top-down and bottom-up change.		
Lack of trust beyond the social network		
Lack of trust in people who do not belong to one's social network, particularly in relation to the adoption of new solutions. There is a tendency to trust word of mouth within one's own network rather than even well-structured information from outside.		
Rebound effect		
The reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioral or other systemic responses. These responses diminish the beneficial effects of the new technology or other measures taken.		
Hostile or passive attitude towards environmentalism		
The attitude of not considering the environment as a priority, especially if environmentalism is faced with higher costs in the short term - linked to the propensity to invest.		

Hostile or passive attitude towards energy collaboration		
A low level of collaboration limits the possibility of activating models such as energy communities.		
Exclusion of socially disadvantaged groups		
Excessively expensive technologies and solutions that require an initial private investment can exclude disadvantaged groups.		
Non-energy issues are more important and urgent for actors		
Energy sustainability is not the only priority of governments and stakeholders and therefore competes with other dimensions.		

Information and Awareness

Insufficient information on the part of potential users and consumers		
Innovation brings with it the need to adequately inform stakeholders at all levels. Lack of adequate information or information asymmetry can lead to partial adoption of solutions.		
Lack of awareness among authorities		
From the point of view of awareness within the public authorities themselves, if this is lacking, the authorities are unable to promote the benefits that PED-LABs can bring to the city.		
Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts		
PED-LAB innovation can be perceived as very complicated and expensive. If this happens, it can have negative effects on the perception of the effects that these projects can bring to the city.		
Information asymmetry causing power asymmetry of established actors		
Finally, information asymmetry can produce competitive advantages for some actors who can take advantage of knowledge about certain interventions or benefits expected from certain PED-LAB innovations, thus exacerbating the negative socio-economic effects on the most vulnerable groups of citizens.		

5. DRIVERS and UNLOCKING FACTORS

Starting from the analysis of available literature relative to the drivers that support smart cities initiatives (Pezzutto, Fazeli, and De Felice 2016), (Veselitskaya, Karasev, and Beloshitskiy 2019), (Mosannenzadeh, et al. 2017), (Bukovszki et al. 2020) a preliminary list of drivers and unlocking factors was elaborated following the definitions:
Driver: a factor that drives the adoption of a development initiative following the PED-LAB concept.
Unlocking factor: a factor that determines a favourable starting condition without which it is difficult to implement the PED-LAB concept.
Furthermore, as with the BARRIES, the various elements were classified as Endogenous and Exogenous according to their relevance to the internal context of the PED-LAB projects, i.e. the possibility of the PED-LAB project to influence the conditions of the factor itself, or external to the PED-LAB projects, i.e. the dependence of these factors on decision-making processes and actors outside the PED-LAB project.
23 experts belonging to COST-PED-EU, mainly WG3, reviewed the first proposal of Drivers and Unlocking factors and refined it scoring each element according to a Linkert scale from 1 to 5 where 1 is not very relevant, 5 is very relevant.

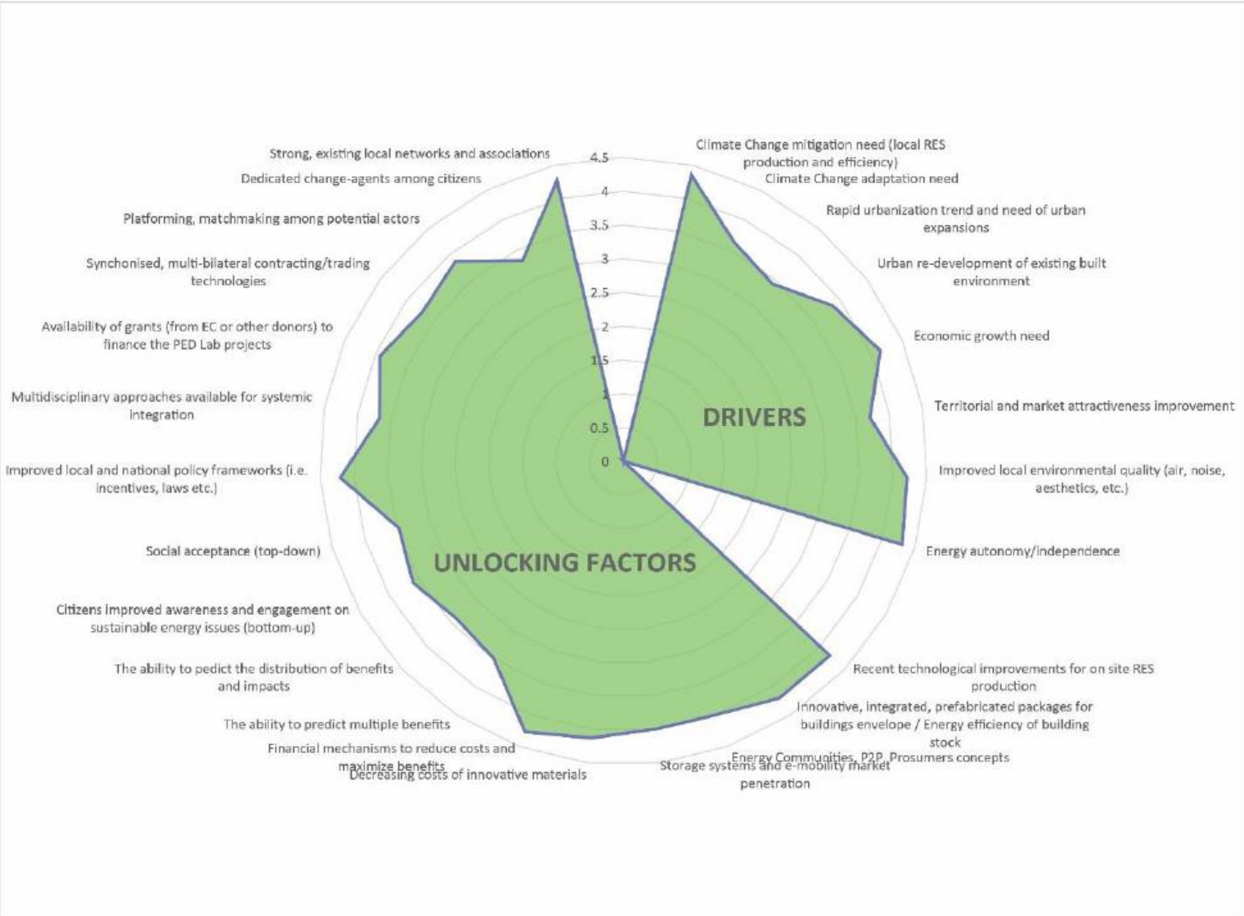


Figure 5: Weighted Drivers and Unlocking factors to PED-LAB development

UNLOCKING FACTORS

	EXOGENOUS	ENDOGENOUS
Recent technological improvements for on-site RES production	■	
The capacity and technologies to efficiently produce energy using local resources and land, including the ability to integrate energy production facilities into the architecture of buildings and urban spaces and to store energy on a daily or seasonal basis.		
Innovative, integrated, prefabricated packages for buildings envelope / Energy efficiency of building stock	■	
The ability to make buildings efficient through retrofitting or new construction using principles of standardisation, prefabrication, modularity and technological integration in the envelopes.		
Energy Communities, P2P, Prosumers concepts maturity	■	
The ability to create 'energy islands' capable of exchanging energy within them, implemented both technologically and socially.		
Storage systems and E-mobility market penetration	■	
The ability to introduce and integrate energy storage technologies, including through the systematic integration of storage in e-mobility vehicles.		
Decreasing costs of innovative materials	■	
The ability of the market to implement economies of scale in order to reduce the costs of innovative and "smart" materials		
Financial mechanisms to reduce costs and maximize benefits	■	■
The ability to design financial instruments to support innovation that reduces investment costs but also maximise benefits for investors.		
The ability to predict Multiple Benefits		■
The ability to consider the potential opportunities created by PED-LAB projects and turn them into indirect benefits beyond the direct benefits of the energy sector.		
The ability to predict the distribution of benefits and impacts	■	■
The ability to consider direct and indirect benefits, as well as positive impacts, as a spin-off to be redistributed throughout the territory to support the local economy.		
Citizens improved awareness and engagement on sustainable energy issues (bottom-up)		■
The ability to adequately involve citizens in the PED-LAB transformation so that they properly understand the benefits and issues involved in implementing PED-LAB projects.		
Social acceptance		■
The ability to accept change also from a social point of view, including changes in habits and cultural paradigms.		
Improved local and national policy frameworks (i.e. incentives, laws etc.)	■	■
The ability to improve local and national policies to make them compatible with the implementation of PED-LAB concepts.		

Multidisciplinary approaches available for systemic integration	■	■
The ability to combine multidisciplinary approaches (economics, sociology, anthropology, psychology, engineering, environmental sciences, etc.) in order to achieve effective systemic integration of PED-LAB projects within the socio-economic and urban fabric of cities.		
Availability of grants (from EC or other donors) to finance the PED Lab projects	■	
The availability of external funding and donors to support the reduction of investment risk related to the prototyping and testing of solutions not yet on the market.		

DRIVERS

Climate Change mitigation need (local RES production and efficiency)	■	
The need to mitigate climate change by reducing direct and indirect CO2 emissions		
Climate Change adaptation need	■	
The need for adaptation to climate change, systemic increase in the resilience of urban systems		
Rapid urbanization trend and need for urban expansions	■	■
The trend of rapid urbanisation that requires large expansions of cities but also increases in building density (i.e. elevations).		
Urban redevelopment of the existing built environment		■
The need to review the development paradigms of urban systems		
Economic growth need	■	■
Need for economic growth and opportunity to use the transition to PED-LAB to grow the economy		
Territorial and market attractiveness		■
Need to improve territorial and market attractiveness		
Improved local environmental quality (air, noise, aesthetics, etc.)		■
Improvement of urban environmental quality through the adoption of the PED-LAB concept		
Energy autonomy/independence		■
Need to achieve energy autonomy and independence from fossil fuels.		

6. STAKEHOLDERS and PROCESSES

Based on the experience gained and described in the Smart City Guidance Package (Borsboom-van Beurden et al. 2019) another Focus Group took place, composed by 20 experts from the COST ACTION PED-EU, mainly WG3, to discuss:
a) The structure of the PED-LAB implementation process.
b) The importance of different types of stakeholders in the various process steps identified.
The graph below represents the results of the focus group and in particular shows the relevance of the different stakeholders in contributing to the various phases of the implementation of PED-LABs.
As can be seen from the graph:
VISION phase: the participation of University and R&D sector is determinant as well as that of Government and Planners. Consultation of citizens is also a high priority.
DECISION phase: the Government is the main actor, supported by citizens.
PLAN phase: here the Planners manage this phase in support of the Government assisted by Industry, Universities and Developers.
DO Phase: Industry and Developers are the main actors in this phase within a framework promoted by the Government, which also sees the growth of financial institutions in their role as investors.
Check/Act Phase: All stakeholders have to be involved in this phase in various ways.
Upscale/replicate phase: This phase links to the DO phase and sees a similar distribution of roles. The lack of presence of citizens in this phase is surprising. Aspect to be further investigated.

In general, one can notice the marginal role attributed to financial institutions that should be able to promote innovative business models. This aspect is also supported by the other Focus Groups which highlight the lack of financial institutions able to assess and support innovation as one of the main barriers to the implementation of PED-LABs.

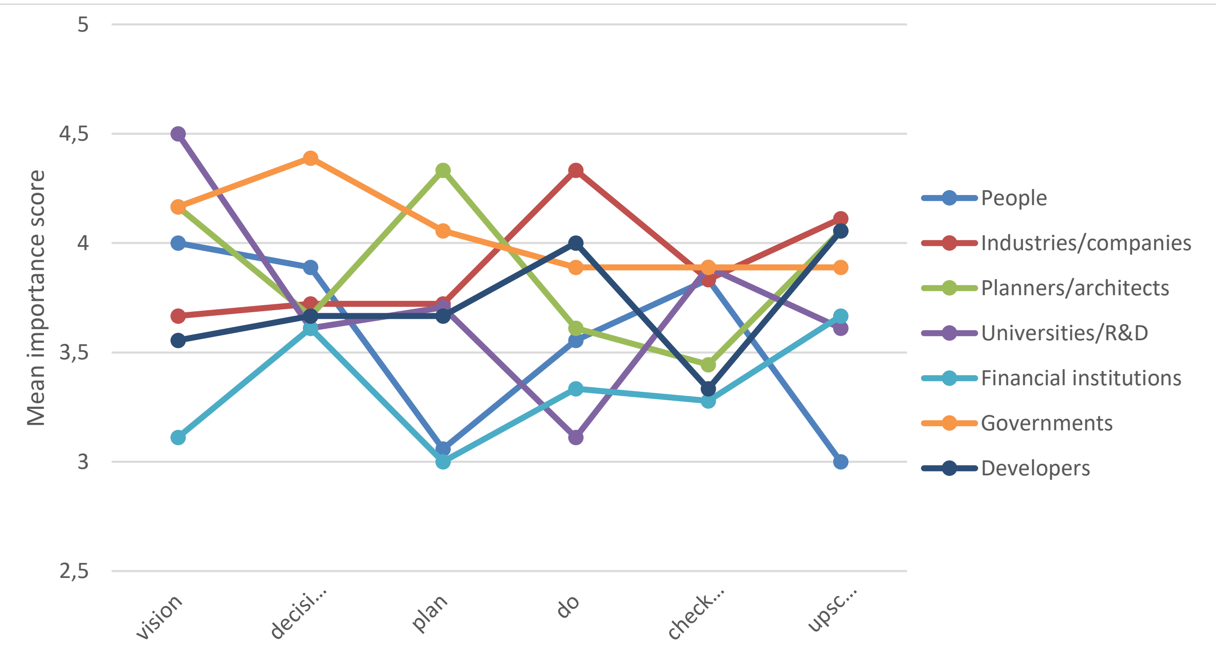


Figure 6: Stakeholders and process steps of the PED-LAB development

7. SWOT ANALYSIS

Building on the work already published in (Soutullo et al. 2020) carried out within the Joint Program on Smart Cities of the European Energy Research Alliance, a further Focus Group was set up to update the list and discuss it with 15 COST PED EU WG3 experts.
In particular, the focus group compiled a SWOT table answering the question: What are the elements (STRENGTHS, WEAKNESSES, OPPORTUNITIES and THREATS) that contribute to the realization of PED-LAB. The results of the two consultations are reported and compared below. As is evident, the results of the two consultations are only partially overlapping, but rather complementary.
STRENGTHS

From (Soutullo et al. 2020): *Testing platforms STRENGTHS* • *High climatic representativeness of Europe.* • *Availability of different scales of action for the studied laboratories, allowing the assessment of several urban flows.* • *Availability of measurements in real conditions of use and in virtual conditions.* • *Availability of different technologies for the use of laboratories: Energy, social, e-mobility, ...* • *Possibility of evaluating urban configurations that integrate various types of uses.* • *Availability of different types of buildings, energy systems, and storage systems.* • *High representativeness of renewable technologies.* • *High generation potential of renewable technologies.* • *Availability of other types of technologies such as cogeneration or Stirling engines.* • *Diversification of energy generation and consumption due to the competitiveness of generation technologies and energy efficiency measures.*
From the COST PED WG3 Focus group: • Experience in sustainability and smart grid • Predict the behaviors of the urban environment • Have an opportunity to test actions before taking action • Experience on results of tested solutions • Co-design for onboarding, and capturing stakeholder specific objectives • Shared learning within and between PEDs

WEAKNESSES

From (Soutullo et al. 2020): *Testing platforms WEAKNESSES* • *Few laboratories available for the analysis sample. To raise the representativeness of the study, more cases should be added.* • *Absence of extreme weather conditions: Tropical (climate zone A) and polar (climate zone E).* • *Necessity to expand the climate applicability of this study. More dry (B zones) and continental (D zones) regions should be included.* • *More virtual laboratories are needed.* • *Low availability of laboratories that include social aspects, water, and waste flows.* • *More cases of some renewable technologies should be included into the sample: Solar thermal technologies, wind turbines or biomass boilers.* • *Gap between theoretical models and real situations of certain systems due to the lack of validation based on real data.* • *Technical aspects in order to optimize the management of a combined configuration.* • *Administrative, regulatory, and normative barriers can be found for the optimal operation of the laboratory.* • *Absence of experimental analysis protocols for high scales of action.*
From the COST PED WG3 Focus group: • Lack of common understanding • Lack of stakeholders' commitment • Lack of alliance of (RES) plans with spatial planning • Lack of specific regulation • inertia of participants • Lack of immediate value perceived • Not enough time for polished implementations (refinement of solutions) • Competence vacuum on this scale - no overseeing institution (neighborhood scale no self-government institutions) • Lack of governance commitment • Lack of standard communication protocols among the (large group of) key stakeholders Lack of space for renewable systems • Lack of definition (with/without mobility, with/without plug load) • Siloes and decoupling of Monitoring & Evaluation by discipline (social vs technical)

OPPORTUNITIES

From (Soutullo et al. 2020): • *Testing platforms OPPORTUNITIES* • *Quantification of several urban flows thanks to the availability of different scales of action laboratories.* • *Evaluation of the energy balance for combined urban solutions.* • *Integrated management optimization for the resources and services of a district.* • *Development of virtual PED labs to assess configurations that integrate different urban aspects.* • *Helping tools to increase the decarbonization of the districts through sustainable models with a favorable impact on the quality of life of citizens.* • *Optimization of solutions that promote the efficient renovation of the building stock and the optimization of public infrastructures.* • *Improvement in the comfort perception and the environmental conditions in urban districts.* • *Evaluate, under controlled conditions, the joint participation of different stakeholders for the development of positive-energy districts.* • *Creation of qualified jobs.*
From the COST PED WG3 Focus group: • Distributed technologies: DLT, DHT for databases • Distributed technologies: edge comp., federated learning for analytics • SDGs related activities • Monitoring of energy flexibility • Citizens' awareness • Develop strategies and roadmap to increase PED numbers/benefits

THREATS

From (Soutullo et al. 2020): *Testing platforms THREATS* • *Deviation in the obtained results due to the absence of measure protocols for PED labs.* • *More regulatory barriers for urban large-scale laboratories.* • *Need for flexible and efficient networks connected to the living labs.* • *Administrative problems for urban large-scale laboratories due to data protection laws.* • *Necessary investment for the implementation of some technologies and infrastructures.* • *Legal barriers to constructing an urban large-scale laboratory.* • *Difficulty of defining a large-scale laboratory due to the existing urban layout in cities.* • *Social lack of knowledge for the benefits produced by urban large-scale laboratories.*
From the COST PED WG3 Focus group: • Loose motivation after hard initiation processes • Lack of information due to uncooperative project partners or data protection • Lack of proper information regarding the life cycle of materials and assemblies • Difficulty of comparability: contextual factors • Difficulty of comparability: non-normative KPIs • Lack of financial resources • Lack of follow-up

8. FACILITIES

(Soutullo et al. 2020) addressed the issue of the facilities required for the successful development of PED-LABs by analysing the factsheets of 16 PED projects. In particular “once the possible applications of the testing infrastructures have been defined in a general way”, the work identified ”the most common ones at each scale of action, specifying the technologies that are involved in the experimental processes”.

Starting from that work, a Focus Group composed by 15 experts from the WG3 of the COST Action PED -EU NET, further worked to answer the following research question:
What are the facilities (tangible and intangible "assets") that are needed in the implementation of PED-LABs?
In particular, the Working Group worked on these three points:
a) the definition of "facilities", identifying their specific role in the development of PED-LABs.
b) dividing facilities into tangible and intangible assets, where tangible means a hardware asset and intangible a software asset.
c) Creating a list of facilities.

The list of facilities identified by (Soutullo et al. 2020) is given below for completeness.

- *Social aspects. The interactions between humans and their environment can be analyzed as an urban issue in the existing facilities.*
- *ICT/control. These laboratories assess the performance of control systems and technologies of information and communication.*
- *Outdoor climate conditions. The ambient climate conditions of the district can be evaluated through experimental devices.*
- *Indoor climate conditions. The ambient conditions inside the buildings can be monitored through the integration of experimental devices.*
- *Energy loads. The building performance can be quantified through the energy loads calculation. Two types can be evaluated: Thermal and electrical loads.*
- *Electrical vehicle. The interactions between electrical vehicles, buildings, and grids can be assessed through electrical mobility facilities.*
- *Lighting systems. The operation of artificial lighting systems produced in the district can be analyzed and regulated through different equipment.*
- *Energy networks. The energy interaction between the generation sources, distribution networks, and consumption points can be evaluated through the use of different devices. Two district types can be evaluated: Thermal (heating and cooling) and electrical networks.*
- *Storage elements. The fluctuations produced between the energy production and the demand side can be evaluated through the energy performance of the storage systems. Two types can be evaluated: Thermal and electrical storage.*
- *Water systems. The performance of water recovery systems or treatment of water can be assessed by means of different devices in the existing facilities.*
- *Waste treatments. These laboratories evaluate different solutions to minimize urban waste and increase environmental conditions.*

The conclusions reached in the identification of the facilities by the WG3 Focus Group of the COST Action PED-EU NET are shown below.
First, the need to group facilities into "tangible" and "intangible" was discussed. "Tangible" facilities: facilities that refer to the part of hardware or facilities that allow a physical transformation of the district (ie, the structures and infrastructures). "Intangible" facilities: facilities that concern soft aspects or facilities that transform districts into their non-physical components (ie society, economy, knowledge, skills, behavior, attitude, etc.).

Finally, an additional classification of the facilities was made with reference to the process discussed in Chapter 6 of this report in order to identify when and where these facilities are relevant in the PED-LAB implementation process.

	Vision	Decision	Plan	Do	Check/act	Upscale/replica
Tangible assets						
Grid			X	X	X	X
Energy Storage			X	X	X	X
Measurement systems				X	X	X
ICT infrastructures			X	X	X	X
Physical space/land to host RES		X	X	X	X	X
Natural resources	X	X	X	X	X	X
Smart Insfrastructures				X	X	X
Intangible assets						
Human resources	X	X	X	X	X	X
Participation and contribution	X	X	X			X
Awareness		X				X
Legislative frameworks	X	X	X			X
Communication and outreach			X	X	X	
Culture	X	X				X
Heritage	X	X				X
Community		X	X	X		X
Identity	X	X	X	X		
Pre-existing org./associations in the neighborhood		X	X			
Education	X	X				
Incentives				X	X	X
Partnerships in larger knowledge networks	X	X				
Land use planning	X	X				
Citizens science			X	X		
Incentives			X	X		X

9. ONLINE QUESTIONNAIRE FOR PED LABS

PED Lab Database

One of the objectives of working group T3.1 is the development of a PED Lab database within the framework of Cost Action CA19126. This objective requires the development of a methodology that allows the compilation of all the available information on these urban laboratories among the participants of the Cost Action. With this aim, the working group T3.1 has formulated general, technical and non-technical questions to collect all the information that each participant wants to share related to its laboratory.

This online questionnaire has been developed by the IT department of CIEMAT and has been carried out through collaborative work between the WG1 and WG3 groups. The final objective of this online survey is to collect information from PED Labs as well as PED / PED cases, but this questionnaire can be extended to other working groups of the Cost Action. The information resulting from this online survey will allow the creation of the PED database.

To facilitate the development of the online survey, a glossary has been included that explains, in some cases, the meaning or objective of the question.

In September 2021, the online questionnaire is already available (http://encuestas.ciemat.es/index.php/862321) and its implementation is being validated with the introduction of some examples. Once this process is finished, it will be distributed among the members of the Cost Action in different phases. In each of them, the information necessary for the creation of the PED Labs database will be compiled.

Online Questionnaire

To collect the information from the existing PED Labs among the Cost Action participants, an online platform has been created within the scope of Working Group 3. This platform is being developed by CIEMAT Information Technology Department (See Figure 7) and is fed by the templates developed collaboratively between the working groups WG3 and WG1.

The website of this online questionnaire: http://encuestas.ciemat.es/index.php/862321

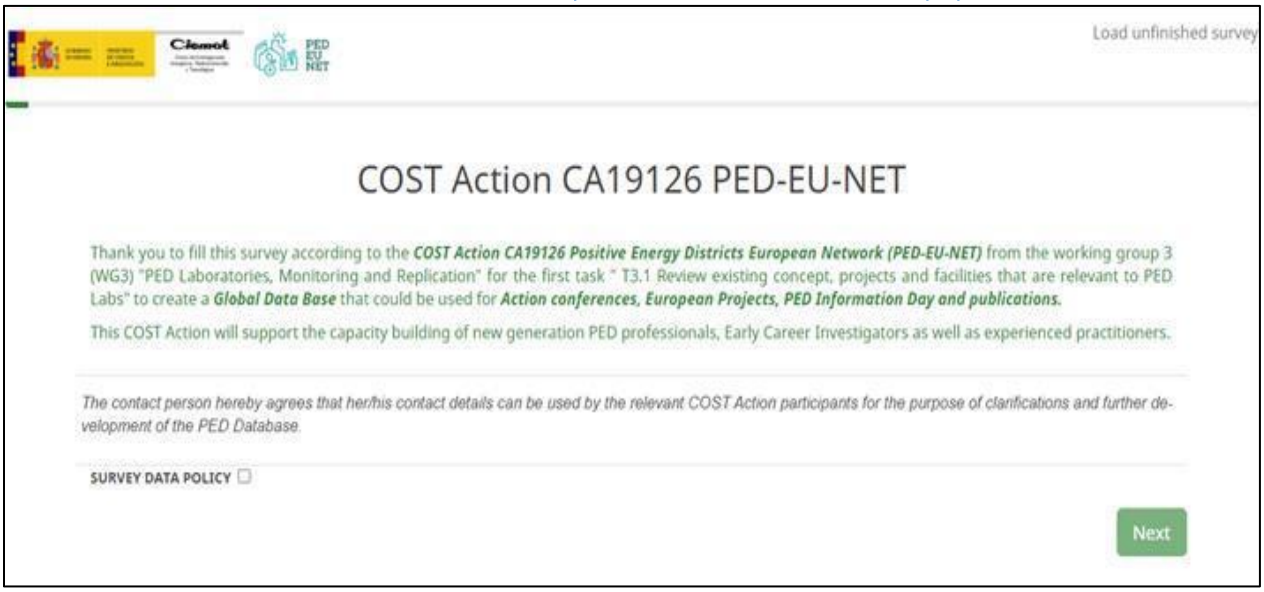


Figure 7: Screenshot of the CIEMAT platform

This platform is expected to work for upscaling the data as well as for future collections of information from other COST Action working groups. For this, it will be necessary to continue with the collaborative and multifunctional work that has been carried out.

PED Database Sheets

The online questionnaire has been created to collect the information related to PED infrastructures: PED cases and PED Labs. With this objective, three sheets have been defined in this online platform: two common and one specific to each infrastructure (PED or PED Labs). Sheet A is common for PED and PED Labs, and it identifies the general characteristics of the case studied, such as location, plant size, facilities or boundary conditions. Sheet B is specific to PED or PED Labs and it identifies the characteristics of each case. Finally, sheet C is common and collects information about drivers and barriers.

Glossary

To facilitate the understanding of the questions formulated in the survey to the participants, a glossary has been developed. This help is being implemented in the online version of the questionnaire. This glossary has been created through the collaboration between WG1 and WG3.

The structure of the part of the online questionnaire related to PED-LAB is attached to this report in Annex 3.

10. CONCLUSIONS

This report describes the results of a process of analysis focused on the concept of PED-LAB, proposed within the SET PLAN Action 3.2, starting from the scarce literature available and enriching the debate through a series of qualitative research tools such as questionnaires and focus groups.

First of all, an effort was made to position the PED-Lab concept within the international debate on sustainable urban development (including Climate Neutral Cities and New European Bauhaus concepts). The result of this exercise suggests a positioning of the PED-LAB concept which derives from the tradition, theory and practice of Smart Energy City and Near Zero Energy Buildings and Urban Living Labs to focus on the district scale and combine the opportunities provided by the experimentation - the lab - with the targets of sustainability and energy positivity. In other words, the PED-LAB is simultaneously:

- A concept referring to a small or medium-scale experimentation, in a risk-controlled environment - especially because it deals with experiments on real urban environments, which allows validating innovative solutions to be replicated later on a larger scale involving entire cities.
- A concept referring to the whole of the PED-prototypal experiments, which, by sharing good and bad practices, positive and negative results, constitute an extended laboratory in which integrated solutions are tested and validated in similar or different urban contexts.

The work carried out also contributed to answering the following research questions:

- What are currently the barriers to the implementation of PED-LABS?

The results of the consultation, based on previous research related to the Smart Energy City concept, suggest 49 barriers to the implementation of the PED-LAB concept divided into 8 categories. These barriers were weighted in relation to their perceived importance by experts and will inform WG1 and in particular Task 1.4 - Identify the challenges and barriers for the uptake of PEDs, capture lessons learned and provide recommendations on socio-technical measures for successful implementation.

- What are the drivers but also the incentive factors (unlocking) that determine the "fertility of the soil" for PED-LAB initiatives?

The results of this consultation identified 8 DRIVERS that move stakeholders and cities towards the PED concept and 13 UNLOCKING FACTORS that determine the "fertility of the soil" and the favorable conditions for the development of PED-LABS. We can assume that these factors are in any case similar to those needed to activate the PED development process as well.

- What are the process and the actors involved that define the steps, power relationships and subsidiarity in the responsibilities and decisions in PED LAB initiatives?

Based on the previous experience in Smart Energy City project development, the composition of the key stakeholders necessary for the development of PED-LABS was validated and the development steps in which these actors have to intervene and contribute were identified.

- Based on the PED-LAB experiences to date, what, in summary, have been the strengths, weaknesses, opportunities and risks encountered in the implementation of PED-LABs? How can these experiences ultimately inform future experiments in this direction?

The SWOT analysis tool also enabled us to enrich a previously published work on the strengths, weaknesses, opportunities and risks of the PED prototype concept by adding some additional elements to the ongoing debate.

- What are the facilities (tangible and intangible "assets") that are needed in the implementation of PED-LABs?

Similarly, the list of facilities needed to implement the PED-LAB concept was enriched with additional elements, starting from a list already published in the literature.

- What information still needs to be systematically collected from ongoing PED-LABs experiences and thus how to appropriately inform the collection of information through the questionnaire prepared by WG1-WG3?

Finally, the list of information that will be collected by means of an online questionnaire from October onwards and thus how to appropriately inform the collection of information through the questionnaire prepared by WG1-WG3 was presented.

11. REFERENCES

Albert-Seifried, Vicky, Lina Murauskaite, Gilda Massa, Laura Aelenei, Savis Gohari Krangsås, Beril Alpagut, Anna Mutule, and Nikola Pokorny. n.d. "Definitions of Positive Energy Districts: A Review of the Status Quo and Challenges," 12.

Borsboom-van Beurden, Judith, B. Gindroz, J. Kallaos, S. Costa, and J. Riegler. 2019. "Smart City Guidance Package." NTNU.

Bukovszki, Viktor, Ábel Magyari, Marina Kristina Braun, Kitti Párdi, and András Reith. 2020. "Energy Modelling as a Trigger for Energy Communities: A Joint Socio-Technical Perspective." *Energies* 13 (9): 2274. https://doi.org/10.3390/en13092274.

Dawson, Susan, Lenore Manderson, and Veronica L. Tallo. 1993. *A Manual for the Use of Focus Groups*. International Nutrition Foundation for Developing Countries.

European Commission. 2018. "Setplan Smartcities Implementationplan." 2018. https://setis.ec.europa.eu/system/files/2021-04/setplan_smartcities_implementationplan.pdf.

Hedman, Åsa, Hassam Ur Rehman, Andrea Gabaldón, Adriano Bisello, Vicky Albert-Seifried, Xingxing Zhang, Francesco Guarino, et al. 2021. "IEA EBC Annex83 Positive Energy Districts." *Buildings* 11 (3): 130. https://doi.org/10.3390/buildings11030130.

Lindholm, Oscar, Hassam ur Rehman, and Francesco Reda. 2021. "Positioning Positive Energy Districts in European Cities." *Buildings* 11 (1): 19. https://doi.org/10.3390/buildings11010019.

Mosannenzadeh, Farnaz, Adriano Bisello, Corrado Diamantini, Giuseppe Stellin, and Daniele Vettorato. 2017. "A Case-Based Learning Methodology to Predict Barriers to Implementation of Smart and Sustainable Urban Energy Projects." *Cities* 60: 28–36.

Mosannenzadeh, Farnaz, Adriano Bisello, Roberto Vaccaro, Valentina D'Alonzo, Garfield Wayne Hunter, and Daniele Vettorato. 2017. "Smart Energy City Development: A Story Told by Urban Planners." *Cities* 64: 54–65.

Mosannenzadeh, Farnaz, Maria Rosaria Di Nucci, and Daniele Vettorato. 2017. "Identifying and Prioritizing Barriers to Implementation of Smart Energy City Projects in Europe: An Empirical Approach." *Energy Policy* 105: 191–201.

Mosannenzadeh, Farnaz, and Daniele Vettorato. 2014. "Defining Smart City. A Conceptual Framework Based on Keyword Analysis." *TeMA-Journal of Land Use, Mobility and Environment*.

Mosannenzadeh, Farnaz, Daniele Vettorato, Simon Pezzutto, and MR Di Nucci. 2016. "A Taxonomy of Barriers to Implementation of Smart Energy City Projects in Europe: An Empirical Approach." In *52nd ISOCARP Congress 2016*. -.

Pezzutto, Simon, Reza Fazeli, and Matteo De Felice. 2016. "Smart City Projects Implementation in Europe: Assessment of Barriers and Drivers." *International Journal of Contemporary ENERGY*, no. Vol. 2, No. 2 (November): 56–65. https://doi.org/10.14621/ce.20160207.

Razmjoo, Armin, Poul Alberg Østergaard, Mouloud Denaï, Meysam Majidi Nezhad, and Seyedali Mirjalili. 2021. "Effective Policies to Overcome Barriers in the Development of Smart Cities." *Energy Research & Social Science* 79 (September): 102175. https://doi.org/10.1016/j.erss.2021.102175.

Silverman, David. 2004. *Qualitative Research: Theory, Method and Practice*. SAGE.

Soutullo, Silvia, Laura Aelenei, Per Sieverts Nielsen, Jose Antonio Ferrer, and Helder Gonçalves. 2020. "Testing Platforms as Drivers for Positive-Energy Living Laboratories." *Energies* 13 (21): 5621. https://doi.org/10.3390/en13215621.

Steen, Kris, and Ellen van Bueren. 2017. "The Defining Characteristics of Urban Living Labs." *Technology Innovation Management Review* 7 (7): 21–33.

Veselitskaya, Natalia, Oleg Karasev, and Alexey Beloshitskiy. 2019. "DRIVERS AND BARRIERS FOR SMART CITIES DEVELOPMENT." *N t* 14 (1): 26.

12. LIST OF ANNEXES

ANNEX 1 – Questionnaire on Barriers to the development of PED-LAB

ANNEX 2 – Questionnaire on the Drivers and Unlocking factors of PED-LAB

ANNEX 3 – Database of existing urban living laboratories - Online questionnaire related to PED Labs

PED EU NET

COST Action 19126

Positive Energy Districts European Network

Deliverable 3.1

Review of existing urban laboratories (Review existing concept, projects and facilities that are relevant to PED Labs)

Annex 1 - Questionnaire on Barriers to the development of PED-LAB

Deliverable version: v.1.0 - Final
Dissemination level: Public
Main Authors: Daniele Vettorato, Bukovszki Viktor, Silvia Soutullo Castro.
Main Contributors and reviewers: Ghazal Etminan, Maria Beatrice Andreucci, Gloria Pignatta, Lima Ricardo, Touraj Ashrafian, Giovanni Semprini, M. Nuria Sánchez, Fabio Maria Montagnino, Oscar Seco Calvo.

Due date: 30th of September 2021
Final delivery date: 30th of September 2021

PED Labs implementation BARRIERS

According to your experience with PED implementation, please rate the following barriers to PED Labs implementation from 1 (low importance) to 5 (high importance).

Section 1

Participant details

please share with us few details

1

name, surname, affiliation

2

PED project(s) you are referring to, if any in particular: NAME(s) of the project(s), LOCATION(s).

Section 2

Policy

3

Lack of long-term and consistent energy plans and policies

☆ ☆ ☆ ☆ ☆

4

Lacking or fragmented local political commitment and support on the long term

☆ ☆ ☆ ☆ ☆

Section 3

Administrative

5

Difficulty in the coordination of a high number of partners and authorities

☆ ☆ ☆ ☆ ☆

6

Lack of good cooperation and acceptance among partners

☆ ☆ ☆ ☆ ☆

7

Lack of public participation

☆ ☆ ☆ ☆ ☆

8

Lack of institutions/mechanisms to disseminate information

☆ ☆ ☆ ☆ ☆

9

Long and complex procedures for authorization of project activities

☆ ☆ ☆ ☆ ☆

10

Time-consuming requirements by EC or other donors concerning reporting and accountancy

☆ ☆ ☆ ☆ ☆

11

Complicated and non-comprehensive public procurement

☆ ☆ ☆ ☆ ☆

12

Fragmented ownership

☆ ☆ ☆ ☆ ☆

Section 4

Legal and Regulatory

13

Inadequate regulations for new technologies

☆ ☆ ☆ ☆ ☆

14

Regulatory instability

☆ ☆ ☆ ☆ ☆

15

Non-effective regulations

☆ ☆ ☆ ☆ ☆

16

Unfavorable local regulations for innovative technologies

☆ ☆ ☆ ☆ ☆

17

Building code and land-use planning hindering innovative technologies

☆ ☆ ☆ ☆ ☆

18

Insufficient or insecure financial incentives

☆ ☆ ☆ ☆ ☆

19

Unresolved privacy concerns and limiting nature of privacy protection regulation

☆ ☆ ☆ ☆ ☆

Section 5

Financial

20

High costs of design, material, construction, and installation

☆ ☆ ☆ ☆ ☆

21

Hidden costs

☆ ☆ ☆ ☆ ☆

22

Insufficient external financial support and funding for project activities

☆ ☆ ☆ ☆ ☆

23

Limited access to capital and cost disincentives

☆ ☆ ☆ ☆ ☆

24

Economic crisis

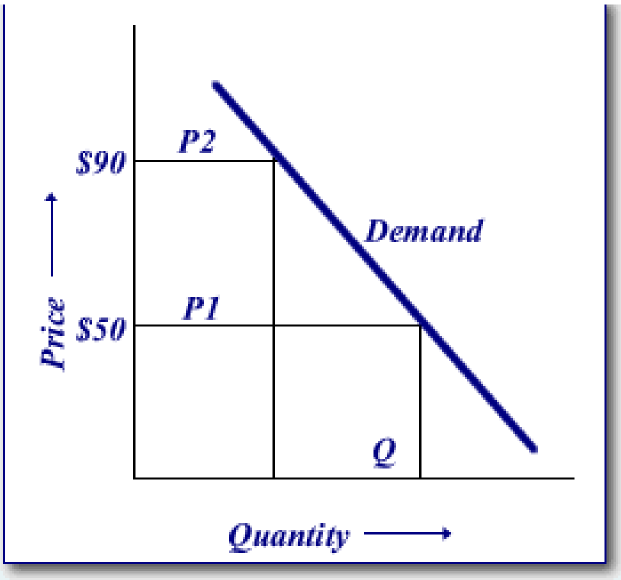
☆ ☆ ☆ ☆ ☆

25

Risk and uncertainty

☆ ☆ ☆ ☆ ☆

Section 6



Market

26

Split incentives

☆ ☆ ☆ ☆ ☆

27

Energy price distortion

☆ ☆ ☆ ☆ ☆

28

Energy market concentration, gatekeeper actors (DSOs)

☆ ☆ ☆ ☆ ☆

Section 7

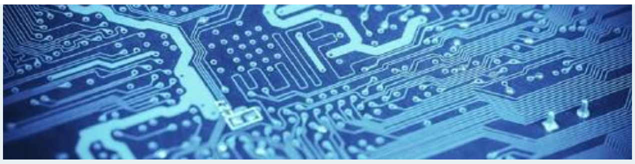
Environmental

29

Negative effects of project intervention on the natural environment

☆ ☆ ☆ ☆ ☆

Section 8



Technical

30

Shortage of proven and tested solutions and examples

31

Lack of skilled and trained personnel

32

Deficient planning

33

Lack of well-defined process

34

Retrofitting work in dwellings in an occupied state

35

Inaccuracy in energy modelling and simulation

36

Lack/cost of computational scalability

37

Grid congestion, grid instability

Section 9

Social

38

Inertia

☆ ☆ ☆ ☆ ☆

39

Lack of values and interest in energy optimization measurements

☆ ☆ ☆ ☆ ☆

40

Low acceptance of new projects and technologies

☆ ☆ ☆ ☆ ☆

41

Difficulty of finding and engaging relevant actors

☆ ☆ ☆ ☆ ☆

42

Lack of trust beyond the social network

☆ ☆ ☆ ☆ ☆

43

Rebound effect

☆ ☆ ☆ ☆ ☆

44

Hostile or passive attitude towards environmentalism

☆ ☆ ☆ ☆ ☆

45

Hostile or passive attitude towards energy collaboration

☆ ☆ ☆ ☆ ☆

46

Exclusion of socially disadvantaged groups

☆ ☆ ☆ ☆ ☆

47

Non-energy issues are more important and urgent for actors

☆ ☆ ☆ ☆ ☆

Section 10

Information and Awareness

48

Insufficient information on the part of potential users and consumers

☆ ☆ ☆ ☆ ☆

49

Lack of awareness among authorities

☆ ☆ ☆ ☆ ☆

50

Perception of interventions as complicated and expensive, with negative socio-economic or environmental impacts

☆ ☆ ☆ ☆ ☆

51

Information asymmetry causing power asymmetry of established actors

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Deliverable 3.1

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Annex 2 - Questionnaire on the Drivers and Unlocking factors of PED-LAB

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Due date: 30th of September 2021
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PED Labs implementation DRIVERS

According to your experience with PED implementation, please rate the following DRIVERS to PED Labs implementation from 1 (low relevance) to 5 (high relevance). They are divided in 2 sections: A) Driving key motivations; B) Driving key unlocking elements.

Section 1

Participant details

please share with us few details

1

Name, Surname, Affiliation

2

PED project(s) you are referring to, if any in particular: NAME(s) of the project(s), LOCATION(s).

Section 2 - A

Driving key motivations

Please rate the relevance of the following global drivers in motivating the PED Labs implementation.

3

Climate Change mitigation need (local RES production and efficiency)

☆ ☆ ☆ ☆ ☆

4

Climate Change adaptation need

☆ ☆ ☆ ☆ ☆

5

Rapid urbanization trend and need for urban expansions

☆ ☆ ☆ ☆ ☆

6

Urban redevelopment of the existing built environment

☆ ☆ ☆ ☆ ☆

7

Economic growth need

☆ ☆ ☆ ☆ ☆

8

Territorial and market attractiveness improvement

☆ ☆ ☆ ☆ ☆

9

Improved local environmental quality (air, noise, aesthetics, etc.)

☆ ☆ ☆ ☆ ☆

10

Energy autonomy/independence

☆ ☆ ☆ ☆ ☆

Section 3 - B

Driving key unlocking elements

Please rate the relevance of the following elements in unlocking/allowing the implementation of PED Labs

11

Recent technological improvements for on-site RES production

☆ ☆ ☆ ☆ ☆

12

Innovative, integrated, prefabricated packages for buildings envelope / Energy efficiency of building stock

☆ ☆ ☆ ☆ ☆

13

Energy Communities, P2P, Prosumers concepts

☆ ☆ ☆ ☆ ☆

14

Storage systems and e-mobility market penetration

☆ ☆ ☆ ☆ ☆

15

Decreasing costs of innovative materials

☆ ☆ ☆ ☆ ☆

16

Financial mechanisms to reduce costs and maximize benefits

☆ ☆ ☆ ☆ ☆

17

The ability to predict multiple benefits

☆ ☆ ☆ ☆ ☆

18

The ability to predict the distribution of benefits and impacts

☆ ☆ ☆ ☆ ☆

19

Citizens improved awareness and engagement on sustainable energy issues (bottom-up)

☆ ☆ ☆ ☆ ☆

20

Social acceptance (top-down)

☆ ☆ ☆ ☆ ☆

21

Improved local and national policy frameworks (i.e. incentives, laws etc.)

22
Multidisciplinary approaches available for systemic integration

23
Availability of grants (from EC or other donors) to finance the PED Lab projects

24
Synchronized, multi-bilateral contracting/trading technologies

25
Platforming, matchmaking among potential actors

26
Dedicated change-agents among citizens

27
Strong, existing local networks and associations

COST Action 19126

Positive Energy Districts European Network

Deliverable 3.1

Review of existing urban laboratories (Review existing concept, projects and facilities that are relevant to PED Labs)

Annex 3 - Database of existing urban living laboratories

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Dissemination level: Public
Main Authors: Daniele Vettorato, Bukovszki Viktor, Silvia Soutullo Castro, Oscar Seco Calvo, Almudena Bailador, María Nuria Sánchez,Ghazal Etminal.
Main Contributors and reviewers: Maria Beatrice Andreucci, Gloria Pignatta, Lima Ricardo, Touraj Ashrafian, Giovanni Semprini, Fabio Maria Montagnino.

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1.1.1. PED Database Sheets

The online questionnaire has been created to collect the information related to PED infrastructures: PED cases and PED Labs. With this objective, three sheets have been defined in this online platform: two common and one specific to each infrastructure (PED or PED Labs). Sheet A is common for PED and PED Labs, and it identifies the general characteristics of the case studied, such as location, plant size, facilities, or boundary conditions. Sheet B is specific to PED or PED Labs and it identifies the characteristics of each case. Finally, sheet C is common and collects information about drivers and barriers.

Sheet A: Main Aspects.

This Sheet is divided in three sections: main information, technological aspects and non-technological aspects. The first section identifies the case study: PED and/or PED Labs, the contact person and describes the main aspects of the case study; location, plant size, activity and global aspects. The second section describes the technological aspects of the case study such as infrastructures, fields of application, energy balance, energy generation, energy flexibility, energy efficiency and monitoring, standardization and tools. The third section describes the non-technological aspects of the case study through the policy frameworks, the economic models, the social models and the environmental measures.

COMMON SECTION A: PED/PED LABS

A.1. GLOBAL CHARACTERISTICS

Question 1 – Main information

A1Q1A: Name of your case study: Enter Text

A1Q1B: Photo (s): (*Upload files):*

A1Q1C: What is the definition of your PED site?

☐ PED/PED relevant case study. ☐ PED Lab.

A1Q1D: Project Phase of your case study/PED Lab

☐ Planning Phase. ☐ Implementation Phase. ☐ Operation Phase /Already built.

A1Q1E: Reference Project: Enter Text

A1Q1F: Sources (publication, link to website, deliverable): Enter Text

Question 2 – Location

A1Q2A: Geographic coordinates (You can take the coordinates by clicking Link to Google Maps)

- X Coordinate (longitude): Enter Text
- Y Coordinate (latitude): Enter Text

A1Q *2B:* Place (geo-referenced position): URL link

A1Q*2C:* Climate Zone (Köppen Geiger classification). Choose one of the following answers:

☐BWh ☐BWk ☐BSh ☐BSk ☐Csa ☐Csb ☐Csc ☐Cfa ☐Cfb ☐Dsa ☐Dsb ☐Dsc ☐Dfa ☐Dfb ☐Dfc ☐ET

Question 3 – Plant Size

A1Q3A: Total land area occupied by your case study/PED Lab (sq. m^2) Numerical v

A1Q3B: District boundary (Choose one of the following answers):

◉ Virtual. ○ Geographic. ○ Functional. ○ Off-grid.

Question 4 –Fields of activity

A1Q4A: Project targets of the PED case study/PED Lab (check all that apply)

☐ Climate neutrality. ☐ Energy neutrality. ☐ Energy community.

☐ Circularity. ☐ Air quality and urban comfort. ☐ Electrification.

☐ Self-sufficiency. ☐ Net-zero energy cost. ☐ Positive Energy.

☐ Other: [Enter Text]

A1Q4B: Ownership of the case study/PED Lab: ☐ Public. ☐ Private.

More comments: [Enter Text]

Question 5 – Contact Person (this question is mandatory)

Name: [Enter text]

E-mail: [email@a.co]

A1Q5A: Do you agree to have this information published within the framework of the Cost Action?

☐ Yes. ☐ No.

D.1 8 Questions: GENERAL PROJECTS/INITIATIVES

D.2 Under construction

A.2. TECHNOLOGICAL ASPECTS

Question 6 – Description of the existing and planned infrastructure

A2Q6A: Fields of application (Check all that apply)

☐ Energy efficiency. ☐ Energy flexibility. ☐ Energy production.

☐ Urban management. ☐ E-mobility. ☐ Urban comfort and air quality.

☐ Digital technologies. ☐ Other: [Enter Text]

A2Q6B: Energy balance:

Renewable resources (GWh/an): Nunmerical

Non-renewable resources (GWh/an): Numerical v

Building Energy Demand / Consumption (GWh/an): Numerical v

Other urban Energy Demand / Consumption (GWh/an): Numerical v

Other: Enter Text

A2Q6B1: Do you have any databases or metrics related to the PED case study/PED Lab?

☐ Yes. ☐ No.

A2Q6B2: If the data is available:

Projection energy balance (GWh/an): Numerical v

Measure energy balance (GWh/an): Numerical v

A2Q6C: Energy generation (Check all that apply):

☐ Photovoltaics. ☐ Wind turbines. ☐ Solar Thermal Collectors.

☐ Geothermal Energy System. ☐ Waste Heat Recovery. ☐ Waste to Energy

☐ Polygeneration. ☐ Co-generation. ☐ Heat Pump. ☐ Hydrogen.

☐ Hydropower plant. ☐ Other: Enter Text

A2Q6D: Energy flexibility (Check all that apply):

☐ Information and Communication Technologies (ICT).

☐ Energy management system. ☐ Demand-side management.

☐ District Heating/Cooling. ☐ Smart electricity grid.

☐ Thermal Storage. ☐ Electric Storage ☐ E-mobility.

☐ Smart metering. ☐ Demand-responsive control systems. ☐ Other: Enter Text

A2Q6E: Energy efficiency (Check all that apply):

☐ Deep Retrofitting. ☐ High-performance new buildings.

☐ Smart Public infrastructure (e.g. smart lighting). ☐ Urban data platforms.

☐ Electric, hybrid and clean vehicles ☐ Mobile applications for citizens.

☐ Other: Enter Text

A2Q6F: Energy balance regarding energy demand, energy use and energy delivered:

Which method do you use to calculate the global balance? Enter Text

A2Q6F1: Do you use or apply ISO 52000? ○ Yes. ○ No

A2Q6F2: Are appliances included in the calculation of the energy balance? ○ Yes. ○ No

A2Q6F3: Is mobility included in the calculation of the energy balance? ○ Yes. ○ No

A2Q6F4: How is mobility included (or not included) in the calculation? Enter Text

A2Q6G: Monitoring, standardization and tools applied

Are any experimental measures implemented to evaluate the performance of the installation? Enter Text

Do you have any Standardization process? Enter Text

D. 3 Under Construction

A.3. NON-TECHNOLOGICAL ASPECTS

Question 7 – Policy framework, Economic models, Social models, Planning models and Environmental measures

A3Q7A: Municipal policy /strategy. Enter Text

National and regional policy/strategy Enter Text

A3Q7B: Identification needs and priorities. Enter Text

A3Q7C: Economic models (Check all that apply):

☐ Open data business models. ☐ Innovative business models. ☐ PPP models.

☐ Life Cycle Cost. ☐ Circular economy models. ☐ Blockchain

☐ Demand management Living Lab ☐ Other. Enter Text

A3Q7D: Social models (Check all that apply):

☐ Energy Communities. ☐ Co-creation strategies. ☐ Citizen social research.

☐ Behavioural Change /End-user engagement. ☐ Policy forums.

☐ Social incentives. ☐ Other: Enter Text

A3Q7E: Planning models (Check all that apply):

☐ Strategic urban planning. ☐ City Vision 2050. ☐ Updated SECAP.

☐ Building /district Certification. ☐ Ddigital twins and visual 3D models.

☐ District Energy plans. ☐ Other: Enter Text

A3Q7F: Climate change mitigation and adaptation measures: Enter Text

D.4 Under Construction

Sheet B2: PED Labs.

This Sheet is divided in two sections: global and operation characteristics of the PED Labs. The first section describes the main characteristics of the laboratory, identifying the motivation, partners and incentives. The second section describes the operational characteristics and the availability of the installations identifying the main infrastructures (facilities, capacities and synergies), monitoring and control devices (measures, Key Performance Indicators or energy balance), governance of the operations and the available tools.

PED LAB. B.2. SECTION

A.1. GLOBAL CHARACTERISTICS

Question 1 – Main description of the laboratory

B2Q1A: Installation life time: months, year, permanent [Enter Text]

B2Q1B: Scale (Choose one of the following answers):

○ Building. ○ Campus. ○ District. ○ Virtual

B2Q1C*:* Boundary conditions for the operation of your laboratory (c*hoose one of the following answers):*

○ Autonomous PED. ○ Dynamic PED. ○ Virtual PED

B2Q1D: Operator of the installation [Enter Text]

B2Q1E: Do you have any replication framework? [Enter Text]

B2Q1F: Lifecycle process.

B2Q1F1: Do you apply any strategy to reuse and recycling the materials? ○ Yes. ○ No

B2Q1F2: What strategy do you apply to reuse and recycling the materials? [Enter Text]

B2Q1G: Select the policy framework apply to your laboratory (Check all that apply):

☐ National. ☐ Regional. ☐ Municipal

Question 2 – Motivation and partners

B2Q2A: Motivation for developing the PED Lab:

○ Strategic (driven by government or large commercial actor)

○ Private (driven by private companies or industries)

○ Civic (co-driven by local urban actors like universities)

○ Grassroots (citizen-based, self-governing micro-projects).

○ Other. [Enter Text]

B2Q2B: Do you have any Incentive for the definition, implementation or operation of this PED lab?: [Enter Text]

B2Q2C: Who is the lead partner (Managing the PED Lab):

○ Research Center/University. ○ Municipality. ○ Industry/Company.

◉ Other. [Enter Text]

B2Q2D: Who are the collaborative partner (Participants in the PED Lab):

○ Academia. ○ Private. ○ Public. ○ Industrial.

○ Citizens, public, NGO. ○ Other. [Enter Text]

A.2. **OPERATIONAL CHARACTERISTICS**
Question 3 – Description of the existing infrastructure **B2Q3A:** Select the fields of application of the laboratory (Check all that apply) ☐ Energy efficiency. ☐ Energy flexibility. ☐ Energy production. ☐ Social solutions. ☐ Economical models. ☐ Governance models. ☐ Urban management. ☐ Mobility. ☐ Integrative solutions ☐ Self-sufficiency. ☐ Urban comfort and air quality. ☐ Climate change/mitigation measures. ☐ Digital technologies. ☐ Circular economy. ☐ Decision making. ☐ Other. **B2Q3B:** There any synergies between the activities?: Enter Text **B2Q3C**: Define the available facilities to test urban configurations in your laboratory: Buildings (residential, offices, schools, industrial…): Enter Text Demand-side management: Enter Text Prosumers: Enter Text Renewable generation (PV, wind, thermal collectors, biomass, geothermal...): Enter Text Non-renewable generation (fuel...): Enter Text Energy storage (thermal and electrical): Enter Text Energy networks (heating, cooling and grid networks): Enter Text Efficiency measures: Enter Text Waste management: Enter Text

Water treatment: Enter Text

Lighting: Enter Text

E-mobility: Enter Text

Green areas: Enter Text

User interaction/participation: Enter Text

Information and Communication Technologies (ICT): Enter Text

Ambient measures (thermal, urban heat island, air quality, noise,...): Enter Text

Social interactions: Enter Text

Sustainability processes: Enter Text

Blockchain: Enter Text

Business models: Enter Text

Financial models (demand side management, market prices...): Enter Text

Circular economy models: Enter Text

Other: Enter Text

B2Q3D: Define the incubation capacities of your laboratory:

☐ Monitoring and evaluation infrastructure

☐ Pivoting and risk-mitigating measures

☐ Tools for prototyping and modelling

☐ Tools, spaces, events for testing and validation

B2Q3E: Availability to the facilities for external people [Enter Text]

Question 4 – Description of the monitoring /control devices

B2Q4A: Specify the monitoring measures:

Execution plan of monitoring: [Enter Text]

Available data: measured, simulated or statistics: [Enter Text]

Type of measured data: variables, periodicity … [Enter Text]

Equipment used: [Enter Text]

Level of access: [Enter Text]

Life Cycle Analysis: [Enter Text]

B2Q4B: Define the Key Performance indicators measured:

Energy: [Enter Text]

Environmental: [Enter Text]

Sustainability … [Enter Text]

Social: [Enter Text]

Economical / Financial: [Enter Text]

Other: [Enter Text]

B2Q4C: Energy balance regarding energy demand, energy use and energy delivered:

Primary Energy Imported: Numerical Tex

Primary Energy Exported: Numerical Tex

Which method do you use to calculate the energy balance? Which method

Calculation for Energy Positivity? Enter Text

Which urban flows have been considered in the energy positivity? Enter Text

Question 5: Governance of the Operations

Execution of operations Enter Text

Capacities needed Enter Text

Relations with stakeholders Enter Text

B2Q5A: Do you have any Standardization or certification process for the Lab? ○ Yes. ○ No

Question 6 – Tool for assessing the performance of the laboratory

B2Q6A: Specify the tools available in the laboratory:

Energy modelling Enter Text

Social models Enter Text

Business and financial models Enter Text

Sustainable models Enter Text

Decision making models Enter Text

Fundraising and accessing resources Enter Text

Matching actors Enter Text

Other tools Enter Text

B2Q6B: External accessibility: Enter Text

Sheet C: Drivers and Barriers.

This Sheet is common for PED and PED Labs and identifies the main drivers and barriers found in the development of the whole installation.

COMMON SECTION C: PED/PED LABS

C. DRIVERS AND BARRIERS

Question 1 – Select the main Drivers (Check all that apply)

- ☐ Legal and policy: policy frameworks, incentives, platforms to matchmaking actors…
- ☐ Technical: energy autonomy, RES generation, advantages of innovative solutions…
- ☐ Environmental: climate change mitigation, improvement of urban comfort and well being…
- ☐ Economic and financial: economic growth, market attractiveness, financial mechanisms, multiple benefits, mortality and morbidity reductions
- ☐ Social and cultural: citizens well being, local networks, use of local resources…

Other: [Enter Text]

Question 2 – Select the main Barriers (Check all that apply)

- ☐ Administrative and policy: cooperation and coordination between partners, complex procedures, ownership, inconsistent energy policies,…
- ☐ Legal and Regulatory: inadequate regulations, national/regional/local codes, inappropriate financial incentives…
- ☐ Technical: more tested solutions, lack of trained personnel, computational factors, scalability, grid instability…
- ☐ Environmental: effects of project intervention, absence of ambient and urban experimental variables, retrofitting works…

☐ Social and Cultural: inertia, lack of interest, low acceptance, actors involved, lack of social networks…

☐ Information and Awareness: low information about users and consumers, perception of cost and benefits, information asymmetry,…

☐ Economical and Financial: high costs, insufficient financial support, economic crisis, risk and uncertainty…

☐ Market: incentives, prices distortion, actors involved…

Other: Enter Text

Question 3 – Other comments: Enter Text

1.1.2. Database Glossary

In order to help the understanding of the concepts and definitions formulated in the PED Database a Glossary has been developed. This glossary has been divided in two sections; the first one related with the common parts while the second one is specific for PED or PED Labs. The definitions and bibliography referenced have been obtained through the collaboration between WG1 and WG3. All the information collected for PED Labs by this Glossary has been included in the online version of the questionnaire.

QUESTIONNAIRE 1 _ PART A+C (Common sections of the questionnaire)

CASE STUDY	ID Parameter	Definition (up to 100 words per definition)	Unit	References for the definition
PART A				
A.1 GLOBAL CHARACTERISTICS				
Question 1 – Main information				
Case Study Title	CS001	Name the city/neighborhood/district where the case study is located	Text	
Photos		Map / Aerial View / Photos / Graphic Details	Image	
PED Site Definition				
PED/PED relevant case study	CS002	District- level project with high level of aspiration in terms of energy efficiency, energy flexibilityand energy production. The pro ject does not necessarily have to meet annual energy positi ve balance, if it meets at least several other aspects of the J PI UE PED Framework Definition ("Positive Energy Districts are energy - efficient and energyflexible urban areas or groups of conne cted buildings which produce net zero greenhouse gas emis sions and actively manage an annual local or regional surplu s production of renewable energy.They require integration of different systems and infrastructures and interaction bet ween buildings, the users and the regional energy, mobility	Text	JPI Urban definition together with WG1 group

		and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environm ental sustainability.”)		
PED LAB		PED Labs will be pilot actions that provide opportunities to experiment with planning and deployment of PEDs, as well as provide seeding ground for new ideas, solutions and services to develop. PED Labs will follow an integrative approach including technology, spatial, regulatory, financial, legal, social and economic perspectives.	Text	SET Plan Acton 3.2
PED/PED Lab Phase				
Planning	CS006		Text	
Implementation			Text	
Operation /Already built.			Text	
References and sources				
Reference Project		Reference of the PED/PED Lab project	Text	
Sources		Any publication, link to website, deliverable referring to the PED/PED Lab	Text	
Question 2 – Location				
Coordinates	CS009	Geographic coordinate system, latitude and longitude	Numerical	
Address	CS010	Open address of the case study/LAB to identify its exact location on the map	Text	
Climate				

Köppen climate classification	CS011	BWh = hot desert or arid climate, BWk = Cold desert climate, BSh = Hot semi-arid climate, BSk = Cold semi-arid climate, Csa = Hot-summer Mediterranean climate, Csb = Warm-summer Mediterranean climate, Csc = Cold-summer Mediterranean climate, Cfa = Humid subtropical climate, Cfb = Temperate oceanic climate, Dsa = Mediterranean-influenced hot-summer humid continental climate, Dsb = Mediterranean-influenced warm-summer humid continental climate; Dsc = Dry-summer subarctic climate; Dfa = Hot-summer humid continental climate; Dfb = Warm-summer humid continental climate, Dfc = Subarctic climate; ET = Tundra climate	Text	https://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification http://koeppen-geiger.vu-wien.ac.at/
Question 3 – Plant Size				
Total Land Area (open space)		Total land holdings or open space under common ownership that are contiguous.	m^2	
District Boundary				
Functional	CS015	when buildings are not close to each other, but they are interconnected, thanks to a gas, electric, or heating network.	Text	**H2020 Making-City** - How to Achieve Positive Energy Districts for Sustainable Cities: A Proposed Calculation Methodology. https://www.mdpi.com/2071-1050/13/2/710/htm
Geographic		When the boundaries are delimited by spatial–physical limits, including delineated buildings, sites, and infrastructures.	Text	**H2020 Making-City** - How to Achieve Positive Energy Districts for Sustainable Cities: A Proposed Calculation Methodology. https://www.mdpi.com/2071-1050/13/2/710/htm
Virtual		when energy demand is covered by a generation unit, which is shared with other consumption points (e.g., a windmill) and located outside the geographical boundaries of the PED, then it could be considered a virtual boundary	Text	**H2020 Making-City** - How to Achieve Positive Energy Districts for Sustainable Cities: A Proposed Calculation Methodology. https://www.mdpi.com/2071-1050/13/2/710/htm
Off-Grid		when a district is self-sufficient, that means it is not connected to the electrical grid, but also to other utilities like water, gas, and sewer systems. This is advantageous in isolated locations where normal utilities cannot reach and is attractive to those who want to reduce environmental impact and cost of living.	Text	https://en.wikipedia.org/wiki/Off-the-grid
Question 4 –Fields of activity				
Project Target				

Circularity	CS014	Circular systems employ reuse, sharing, repair, refurbishment, remanufacturing and recycling to create a closed-loop system, minimising the use of resource inputs and the creation of waste, pollution and carbon emissions. In the case of PED, the revalorization of waste (such as residues from the different sectors) for the energy production is prioritized, but many other pathways could be taken, considering the cycle of water, food, etc.	Text	Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm?. Journal of cleaner production, 143, 757-768.
Self -sufficiency		Self-sufficiency means that within a year, the district will never import energy from outside the boundaries (e.g. consume electricity or gas from the grids)	Text	
Air Quality and urban comfort		The objective of improving air quality is aimed in reducing the concentration of the 5 main pollutants: O3, NO2, SO2, PM2.5 and PM10. The objective of improving urban comfort is aimed in increasing outdoor thermal sensation adapting the thermal-physiology variables to the comfort levels	Text	
Climate neutrality		Climate neutrality means that on a period basis the carbon dioxide emissions within the limits of the district are compensated with the exported energy or by carbon capture	Text	
Electrification		Electrification is the process in which the supply of any energy needs of a district and/or city, such as the heating needs or the mobility sector, are supplied by electricity-driven technologies.	Text	
Energy Community		Community energy refers to a wide range of collective energy actions that involve citizens' participation in the energy system. Energy communities can be understood as a way to 'organise' collective energy actions around open, democratic participation and governance and the provision of benefits for the members or the local community.	Text	https://publications.jrc.ec.europa.eu/repository/handle/JRC119433#:~:text=Energy%20communities%20can%20be%20understood,members%20or%20the%20local%20community.
Energy neutrality			Text	
Net zero energy cost			Text	

Positive Energy			Text	
Other				
Ownership of the case study/PED Lab				
Public			Text	
Private			Text	
A.2 TECHNOLOGICAL ASPECTS				
Question 6 – Description of the existing infrastructure				
Fields of Application				
Energy efficiency				
Energy flexibility				
Energy production				
Urban management				
E-mobility				
Urban comfort and air quality				
Digital technologies				
Energy Balance				
Energy Demand / Consumption	CS026	National standards, national statistical data (with estimated energy demand per square meter dependent on the climate zone of the area, etc.), measured data (if available), or bills can be used to calculate the demand. Furthermore, when	GWh / annum	D4.2 Guidelines to calculate the annual energy balance of a PED www.making-city.eu

		structural data of the building and data from the existing system are available, an energy modelling tool can be useful to estimate the demand.		
Renewable Generation on-site	CS027	After identifying which solutions will be considered for a certain district, energy systems can be listed and the connections between each other (schematics) and the energy source that is supplied to it (biogas, natural gas, solar, wind, electricity from the grid, etc.) can be identified.	GWh / annum	D4.2 Guidelines to calculate the annual energy balance of a PED www.making-city.eu
Technological Solutions / Innovations – Energy Generation				
Photovoltaics	CS029	**Solution Booklet Building Integrated PV** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-building-integrated-pv		
Wind turbine		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Thermal collectors		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Geothermal energy		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Waste heat recovery		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Waste-to-energy		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Polygeneration				?
Co-generation (CHP)				?
Heat Pumps		**PED Solution Booklet (p.18)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		

Hydrogen		
Hydropower plant		
Biomass Production		
Technological Solutions / Innovations – Energy Flexibility		
Thermal Storage	CS030	**PED Solution Booklet (p.19)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts
Electrical Energy Storage		**PED Solution Booklet (p.19)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts
District Heating and Cooling		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/district-heating-cooling-systems.html **Solution Booklet District Heating and Cooling** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-district-heating-and-cooling
Energy management system		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/building-energy-management-system.html **PED Solution Booklet (p.25)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts
Smart metering, Demand-responsive control systems		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/smart-home-system.html **BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/smart-microgrids.html
Smart electricity grid		
Technological Solutions / Innovations – Energy Efficiency		
Deep Retrofitting	CS031	**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/energy-efficient-retrofitting-of-buildings.html

High-performance new buildings				
Building services (HVAC & Lighting)				SCIS
Urban data platforms		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/urban-data-platform.html **PED Solution Booklet (p.25)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Smart Public infrastructure (e.g. smart lighting)		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/smart-lighting.html		
Electric, hybrid and clean vehicles		**Solution Booklet Electric Vehicles & the Grid** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-electric-vehicles-grid **PED Solution Booklet (p.41)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Car sharing		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/vehicle-sharing-system.html **PED Solution Booklet (p.21)** https://smart-cities-marketplace.ec.europa.eu/insights/solutions/solution-booklet-positive-energy-districts		
Traffic control system				?
Smart irrigation				?

Digital tracking for waste disposal		**BABLE solutions** https://www.bable-smartcities.eu/explore/solutions/solution/solution/waste-separation-at-source.html https://www.bable-smartcities.eu/explore/solutions/solution/solution/intelligent-waste-logistics.html		
Smart surveillance				
NON-TECHNOLOGICAL SOLUTIONS/INNOVATIONS				
Governance	CS032		Text	
Economic				
Open data business models	CS033			
Innovative business models				
PPP models				
Life Cycle Cost				
Circular economy models				
Blockchain				
Demand management Living Lab				
Social				
Energy Communities	CS034			
Co-creation strategies				

Citizen social research				
Behavioural Change /End-user engagement				
Policy forums				
Social incentives				
Planning				
Strategic urban planning				
City Vision 2050				
Updated SECAP				
Building /district Certification				
District Energy plans				
digital twins and visual 3D models				
Environmental	CS035		Text	
Spatial	CS036		Text	

Legal/Regulatory	CS037		Text	
PART C				
ENABLING FACTORS & DRIVERS				
Legal and policy		Policy frameworks, incentives, platforms to matchmaking actors	Text	
Technical		Energy autonomy, RES generation, advantages of innovative solutions	Text	
Environmental		Climate change mitigation, improvement of urban comfort and well-being…	Text	
Economic and financial:		Economic growth, market attractiveness, financial mechanisms, multiple benefits, mortality and morbidity reductions	Text	
Social and cultural		Citizens well-being, local networks, use of local resources	Text	
BARRIERS / CHALLENGES				
Administrative and policy		Cooperation and coordination between partners, complex procedures, ownership, inconsistent energy policies,…	Text	
Legal and Regulatory		Inadequate regulations, national/regional/local codes, inappropriate financial incentives	Text	
Technical:		More tested solutions, lack of trained personnel, computational factors, scalability, grid instability…	Text	
Environmental		Effects of project intervention, absence of ambient and urban experimental variables, retrofitting works…	Text	
Social and Cultural		Inertia, lack of interest, low acceptance, actors involved, lack of social networks…	Text	

Information and Awareness		Low information about users and consumers, perception of cost and benefits, information asymmetry,…	Text	
Economical and Financial		High costs, insufficient financial support, economic crisis, risk and uncertainty…	Text	
Market		Incentives, prices distortion, actors involved…	Text	

QUESTIONNAIRE 1 _ PART B (Specific section for PED Labs of the questionnaire)

B.1 GLOBAL CHARACTERISTICS				
Question 1 – Main description of the laboratory				
Main characteristics.				
Existing laboratory		Brief description of the main features of the existing PED Lab	Text	
Life time		Expected life time of the installation: month, year, permanent installation	Text	
Scale of action		The scale of action defined for the PED Lab determines the type of experiments than can be done. Four options are available: building, campus, district and virtual. The differences between them are based on the dimensions, boundary conditions and the energy fluxes that can be evaluated by these facilities.		https://doi.org/10.3390/en13215621
Boundary conditions for the operation of the laboratory				
Autonomous		Autonomous PED Lab: the geographical boundaries are well defined and the laboratory must be self-sufficient.		Wyckmans, A., Karatzoudi, K., Brigg, D., Ahlers, D. 2019. D9.5: Report on attendance at events held by other SCC-01 co-ordinators 2, +CityxChange Work Package 9 Task 9.2.

Dynamic		Dynamic PED Lab: geographic boundaries are well defined, energy import is allowed, and generation can be located off-limits in a lower degree.		
Virtual		Virtual PED Lab: geographic boundaries can be freely located outside the laboratory and the system can import and export energy.		
Operator				
		Identification of the operator that manages the laboratory	Text	
Replication framework				
		Identification, if there is any, of the replication framework defined for the laboratory	Text	
Lifecycle process				
		There is any strategy to reuse and recycle the materials used in the construction, operation and demolition of the laboratory?		
		Description of the strategies used to reuse and recycle the materials		
Policy framework of the laboratory.				
National		National policy framework.		
Regional		Regional policy framework.		
Municipal		Municipal policy framework.		
Question 2 - Motivation and partners				
Motivation for developing the PED Lab.				

Strategic		Strategic motivation driven by governments or large commercial actors. Host by multiple projects.		http://lup.lub.lu.se/search/ws/files/27224276/Urban_Living_Labs_Handbook.pdf
Private		Private motivation driven by private companies or industries. Host by private initiatives.		
Civic		Civic motivation driven by local urban actors such as universities, cities or urban developers. Host by stand-alone projects or city-districts.		
Grassroots		Grassroots motivation driven by urban actors in civic society or not for profit actors. Host by micro-projects or single projects.		
Other		Other motivation	Text	
Incentives				
		Description of the incentive for the definition, implementation or operation of this laboratory.	Text	
Lead partner managing the laboratory.				
Research Center or University				Living Lab Handbook for urban living labs developing natured-based solutions. UNaLAB http://lup.lub.lu.se/search/ws/files/27224276/Urban_Living_Labs_Handbook.pdf
Municipality				
Industry/Company				
Other				
Collaborative partners participating in the laboratory				
Academia.				Living Lab Handbook for urban living labs developing natured-based solutions. UNaLAB http://lup.lub.lu.se/search/ws/files/27224276/Urban_Living_Labs_Handbook.pdf
Private				
Public				
Industrial				

Citizens, public, NGO				
Other				
B.2 OPERATIONAL CHARACTERISTICS				
Question 3 –Description of the existing infrastructure				
Fields of application carried out in the laboratory				
Energy efficiency.				https://digital-strategy.ec.europa.eu/en/policies/blockchain-strategy https://ec.europa.eu/environment/topics/circular-economy/first-circular-economy-action-plan_es https://doi.org/10.3390/en13215621 EIT Urban Mobility Knowledge base of innovative solutions in urban mobility and living labs: Final Report. EIT Urban Mobility. Towards a definition of socially oriented Urban Living Labs. SoHoLab. https://doi.org/10.1016/j.energy.2018.08.206
Energy flexibility.				
Energy production.				
Social solutions.				
Economical models.				
Governance models.				
Urban management.				
Mobility.				
Integrative solutions.				
Self-sufficiency.				

Urban comfort and air quality.				
Climate change/mitigation measures.				
Digital technologies.				
Circular economy.				
Decision making.				
Other.			Text	
Synergies				
		Identification of synergies between the different fields of activities in the laboratory.	Text	The Twin Pillars of Sustainable Energy: Synergies between Energy Efficiency and Renewable Energy Technology and Policy. ACEEE Report Number E074
Available facilities in the laboratory				
Buildings		Buildings with different profiles: residential, offices, school industrial…	Text	
Demand-side management.		Combination of permanent and non-permanent techniques through Demand-side management.	Text	
Prosumers		Prosumers or customers that can produces and supplies electricity and thermal energy	Text	
Renewable generation		Renewable generation such as PV, wind, solar thermal collectors (low, medium and high temperature), biomass, geothermal…	Text	

Non-renewable generatio		Non-renewable generation such as fuel, gas…	Text	
Energy storage		Energy storage: thermal and/ electrical storage systems	Text	
Energy networks		Energy networks: heating, cooling and grid networks	Text	
Efficiency measures		Integration n of efficient measures in the fields of buildings generation and distribution systems or storage systems.	Text	
Waste management		Management of the waste treatments	Text	
Water treatment		Management of the water treatments	Text	
Lighting		Efficient lighting technologies	Text	
E-mobility		Sustainable transport and e-mobility	Text	
Green areas		Integration of innovative actions by using nature solutions	Text	
User interaction/participation		Integration of different models that consider the user involvement in the laboratory such us the influence of the behavior...	Text	
Information and Communication Technologies (ICT)		Implementation of technical innovation for technologies of communication in the fields of energy, buildings, lighting o mobility.	Text	
Ambient measures		Ambient measures such as thermal monitoring, urban heat island, air quality, noise, lighting measures…	Text	

Social interactions		Interactions between users, Stakeholder involvement…	Text	
Sustainability processes		Sustainable Process that consider smart capabilities such as prioritization algorithms, sensitivity analysis or decisions making process.	Text	
Blockchain		Blockchain technology based on: environmental sustainability, data protection, digital Identity, cybersecurity and interoperability:	Text	
Business models		Viable business models implemented in the laboratory	Text	
Financial models		Financial models such as demand side management, market prices...	Text	
Circular economy models		Measures covering the whole life cycle: from production and consumption to waste management and the market for secondary raw materials.	Text	
Other:			Text	
Incubation capacities of the laboratory				
Monitoring and evaluation infrastructure				Steen, K., Van Bueren, E. Urban Living Labs A living lab way of working
Pivoting and risk-mitigating measures				
Tools for prototyping and modelling				
Tools, spaces, events for testing and validation				
Availability				

		Availability to the facilities for external people	Text	
Question 4 –Description of the monitoring / control devices				
Monitoring measures implemented				
Execution plan		Execution plan for the monitoring process	Text	
Available data		Information about the available data: measured, simulated or statistics.	Text	
Type of measured data		Information about the type of measured data: variables measured, periodicity, storage of data…	Text	
Equipment.		Information about the equipment used in the laboratory.	Text	
Level of access		Level of access of the available data	Text	
Life Cycle Analysis.		Information about the life Cycle Analysis.	Text	
Key Performance Indicators (KPI)				
Energy		KPIs related to energy issues such as: primary energy balance, self-consumption or on-site energy ratio.	Text	ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES Definition, key performance indicators and assessment criteria. ZEN REPORT No.32 – 2021 https://doi.org/10.1016/j.enbuild.2017.09.003 https://doi.org/10.1016/j.scs.2021.103013
Environmental		KPIs related to environmental issues such as: total GHG emissions, air quality or thermal comfort quantification	Text	
Sustainability		KPIs related to sustainability issues such as: life cycle assessment or social life cycle assessment	Text	
Social		KPIs related to social issues such as: users' participation, reduction healthy risks or vulnerability areas…	Text	
Economical / Financial		KPIs related to economical or financial issues such as: cost-benefit analysis or reduction of energy import	Text	
Other		Other KPIs	Text	
Energy balance considering energy demand, energy use and energy delivered				

Primary Energy Imported		Numerical estimation for primary energy imported	Numerical	https://doi.org/10.3390/su13020710 https://doi.org/10.1016/j.enconman.2016.05.052
Primary Energy Exported		Estimation for primary energy exported	Numerical	
Energy Balance		Estimation for Energy balance	Text	
Energy Positivity		Estimation for Energy Positivity	Text	
Urban flows		Identification of the urban flows considered in the energy positivity: energy, mobility, social…	Text	
Question 5 – Governance of the Operations				
Execution of operations		Description of the execution of the operations in the laboratory	Text	https://enoll.org/ Living Lab Handbook for urban living labs developing natured-based solutions. UNaLAB https://doi.org/10.1016/j.scs.2021.102776
Capacities		Description of the capacities needed in the laboratory	Text	
Stakeholders		Description the relations with the stakeholders	Text	
Standardization or certification		Identification of any standardization or certification process in the laboratory		
Question 6 – Tools for assessing the performance of the laboratory				
Available tools				
Energy modelling		Description of the available tools used to model the energy performance of the studied solutions	Text	https://doi.org/10.1016/j.scs.2019.101872 https://doi.org/10.1016/j.energy.2018.06.101
Social models		Description of the available tools used to model social processes	Text	
Business and financial models		Description of the available tools to test business and financial models.	Text	
Sustainable models		Description of the available tools used to model sustainable solutions	Text	

Decision making models		Description of the available tools to test decision making models	Text	
Fundraising and accessing resources		Description of the tools available to raise funds and access resources for the implementation and improvement of the laboratory	Text	
Matching actors		Description of the available tools for matching actors	Text	
Other tools		Description of other tools used in the laboratory	Text	
External accessibility				
		Description of the external accessibility to the laboratory	Text	