D8.1: Report on Market and Stakeholder analysis

+CityxChange | Work Package 8, Task 8.3

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List of Acronyms

+CxC	+CityxChange
CaaS	Charging as a Service
CSO	Community System Operator
DER	Distributed Energy Resources
DHC	District Heating and Cooling
DR	Demand Response
DSO	Distribution System Operator
DT	Digital Twin
EE	Energy Efficiency
eMaaS	electro-Mobility as a Service
ER	Exploitable Result
EV	Electric Vehicle
FC	Follower City
KPI	Key Performance Indicator
LEM	Local Energy Market
LFM	Local Flexibility Market
LHC	Lighthouse City
OASC	Open & Agile Smart Cities
PEB	Positive Energy Block
PED	Positive Energy District
PPP	Public Private Partnership
TRL	Technology Readiness Level
TSO	Transmission System Operator
UDT	Urban Digital Twin
V2B	Vehicle to Building
V2G	Vehicle to Grid

Executive Summary

This report presents the market and stakeholder analysis for specific solutions developed in the +CityxChange project. This work has been conducted as part of the Replication package within Task 8.3: Market and stakeholder analysis to understand exploitation potential of +CityxChange solutions. The report is structured in four main thematic sections:

- Market segmentation as addressed by the key results of the +CityxChange project
- Market analysis of the Lighthouse Countries
- Feasibility assessment of the Follower Countries
- Stakeholder analysis

The objective of the work presented in this report is to identify the attractiveness and dynamics of the different particular markets of the +CityxChange solutions. The data gathered support the identification of market size and trends, drivers, regulations, incentives and legal aspects. Additionally, with regards to the stakeholders, their expectations and benefits are mapped to understand how to leverage and engage them. This market analysis focuses on the particular characteristics of the Positive Energy Districts/Blocks (PED/PEB) market, as well as a series of specific markets linked with the exploitable results identified so far in the project (i.e. Urban planning and design software, Local Energy Systems, E-Mobility and Innovative Renewable energy sources). The information collected and analysed will support the consortium to determine business plan strategies, providing information to the consortium partners to best define exploitation strategy for each commercially exploitable result based on their relevant market.

The report forms part of Work Package 8 "Scaling-up, Replication and Exploitation", dedicated to the replication of +CityxChange solutions in the Lighthouse cities, Follower cities and further EU cities, and the commercialisation of +CityxChange exploitable results. This Work Package will define the business case and replication scenarios for the +CityxChange solutions, ensuring maximum economic, societal and environmental impact of the +CityxChange project.

The activities created within Work Package 8 will draw upon the experiences of all partners across all Work Packages. The technologies and methodologies developed in Work Packages 1, 2 and 3 form the basis for the +CityxChange solutions. These solutions are demonstrated and validated in the Lighthouse Cities and replicated in the Follower Cities as part of Work Packages 4, 5 and 6. The results of these demonstration activities help to identify which solutions have maximal impact in their local context and provide valuable input for the accompanying business cases and replication scenarios. Through activities in Work Packages 9 and 10, Work Package 8 can engage with relevant stakeholders to disseminate the validated +CityxChange solutions and gain market traction.

1 Introduction

This report presents the results of the market and stakeholder analysis as conducted within Task 8.3 "Market and stakeholder analysis to understand exploitation potential of +CityxChange solutions". As such, this report will provide guidance to the project partners with the preparation of exploitation plans for the +CityxChange solutions related to the establishment of a number of Positive Energy Blocks (PEBs) or districts (PEDs) as part of Task 8.4 and Task 8.5 and the preparation of commercialisation plans as part of Task 8.6. Furthermore, this report aids Task 8.2 "Replication across EU cities" with the selection of most favourable cities for replication of the +CityxChange solutions and Work Package 6 "+Followers" with the preparation of replication plans for the Follower Cities.

Starting from the work carried out in Task 2.7 and Deliverable 2.4 "Report on bankability of the demonstrated innovations" - where initial business concepts and models as well as investment models have been defined for the +CityxChange solutions, this task has further analysed the market characteristics of the target markets, being the Lighthouse- and Follower-Countries.

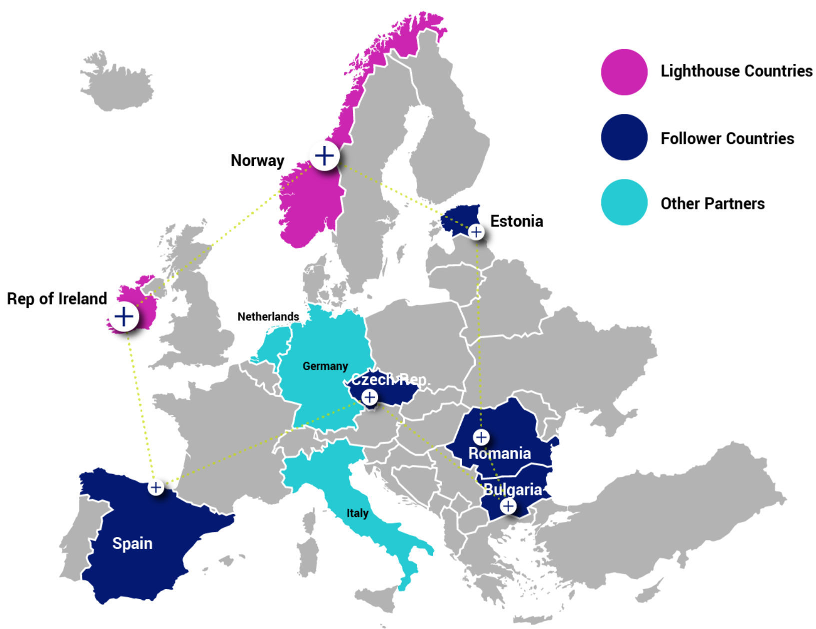

Figure 1: +CityxChange Lighthouse and Follower Countries

In Chapter 2, the market analysis focuses on four specific sectors associated with the exploitable results identified so far in the project which are listed in the General Project Review Consolidated Report for Reporting Period 2. These four sectors are: Urban Digital Twin, Local Energy Systems, E-Mobility and Innovative Renewable Energy Sources. Together, these sectors cover the PED domain. Industry partners have provided input on market trends in their home industries. The intent of this chapter is to provide a general segmentation that gives an overall qualitative snapshot of the four sectors. Each section (2.1 - 2.4) includes an estimation of the size of the market along with a brief, non-exhaustive, description of key factors related to positive energy blocks and districts including but not limited to drivers and barriers, technologies, key bodies, regulation and policy framework, etc.

For the Lighthouse Cities in Norway and Ireland, a state of the art analysis has been performed in the form of a literature review using the PESTEL (political, economic, social, technological, environmental, and legal) methodology, Chapter 3. This comprehensive literature review identifies key external market factors pertaining to both positive energy blocks and districts on either a national or municipal scale. Upscaling and replication of the +CxC solutions is considered most favourable in cities that fall under the same national and regional regulatory framework, share a similar culture and have some of the involved key industry players active on the market nationwide so that's why these markets are considered the primary target markets for +CityxChange solutions.

For each of the Follower Countries, Bulgaria, Czech Republic, Estonia, Romania and Spain, a feasibility study has been conducted, analysing how favourable the market conditions are for each of the four aforementioned markets composing the PED domain, Chapter 4. For each market segment (keeping with the 4 aforementioned sectors), the assessment criteria are based on key performance indicators (KPIs) and the assigned weighting factors have been defined, reflecting the importance of the KPIs regarding PED development. The quantification methodology was chosen based on data availability as summarised in the "Datasets" Annex. The results achieved through the feasibility study show that Spain has the most favourable conditions for three out of the four market segments, namely Local Energy Markets, E-Mobility, and Renewable Energy Sources. Meanwhile, Estonia has the most favourable conditions for the Digital Twin market. Further results are described accordingly.

The stakeholder analysis presented in this work, Chapter 5, builds upon the four basic roles within an operational local power market, as operated together with the PED as defined in D2.1 "Report on Enabling Regulatory Mechanism to Trial Innovation in Cities". Five additional basic roles have been identified that together are involved in the implementation and set-up of a PED. These five roles have been derived from the actors involved in the set-up of the PED in the Follower Cities as described in D6.4 ``Technical feasibility study of the potential PEB replications in each FC for +CityxChange project". By making explicit which roles are involved in each of the development phases of a PED, it becomes more visible how interests, responsibilities and influence from the involved stakeholders shifts when a PED moves from the design and implementation phase to the operational phase. The stakeholder matrix methodology utilized for this chapter is the "power/influence" tool to show the roles, interest, and decision-making importance of each stakeholder segment regarding this subject matter.

2 +CityxChange market segmentation

This chapter presents the results of the analysis of four industry sectors addressed by +CityxChange. The following methodology has been used for the definition and analysis of the market segments:

1. Identification of the +CityxChange exploitable results for which commercial exploitation is foreseen by the responsible project partner. The list of exploitable results is taken from the General Project Review Consolidated Report for Reporting Period 2. An overview of the +CityxChange exploitable results (ERs) is listed in Table 1. Note that three ERs are already featured on the EU Innovation Radar platform[1], being "Integrated Planning and Decision Support Tool", "Energy Trading Platform" and "Bold City Vision Framework".
2. The ERs have been clustered according to the industry sector they are part of. This resulted in five sectors which combined cover the market segments involved in developing and operating a PED. The five sectors are listed in Table 1.

Table 1. Mapping of the +CxC exploitable results (ERs) on industry sectors

Exploitable result (ER)	*ER owner*	*Sector*
Integrated Planning and Decision Support Tool	IES	Digital twin urban planning
Enterprise Architecture Framework	NTNU	
Monitoring and Evaluation Reporting Tool	FAC	
Grid Optimisation and Balancing Technologies	Volue	Local energy systems
Community Grid Technology	MPower	
Energy Trading Platform	Volue	
Energy Community Utility Franchise Model	MPower	
Enabled P2P energy marketplace	IOTA	
Data integrity and trade verification service	IOTA	
eMobility as a Service platform	FourC	Electric mobility
Vehicle to Grid/Vehicle to Building technologies	ABB	
Optimisation of Existing Charger Use	GoCar	
e-MaaS multi-modal Payment Solution	IOTA	
Tidal Turbine for Shallow Rivers	GKinetic Energy	Renewable energy sources
High temperature heat pumps	SV, NTNU	
Regulatory mechanisms for delivering DPEBs	TK	Public engagement Non-commercial
Citizen participatory platform	COL	
Learning Framework	UL	
Positive Energy Champions Framework	UL	
Innovation Labs towards DPEB solution	UL	
Innovation Playground for DPEBs	SE	
Bold City Vision Framework	TK	

[1] https://www.innoradar.eu/resultbykeyword/+CityxChange

3. For each of the five sectors the post-project exploitation vision as being developed in Task 8.4 "Competence analysis, identification and management of exploitable results" has been checked. Commercial exploitation is envisioned for the ERs in the sectors "Digital Twin Urban Planning", "Local Energy Systems", "E-Mobility" and "Renewable Energy Sources" which together shape a commercial energy trading model. The tools developed in the sector "Public Engagement" enable active involvement of citizens but at this stage no commercial exploitation is foreseen by the responsible project partners. Since the goal of this report is to support commercialisation and replication of +CityxChange solutions, the scope of this market analysis has been narrowed down to the sectors where commercial exploitation of the results by the project partners is foreseen.
4. Through desk research, the size and share of the four remaining market sectors has been determined and described, together with its characteristics and trends. The resulting analysis should guide the project partners with the development of replication and exploitation plans for the +CityxChange solutions.

Sections 2.1-2.4 present a brief overview of the market characteristics for the four sectors that classify the commercial ERs of +CityxChange.

2.1 Digital twin urban planning

The digital twin urban planning +CxC sector comprises "Integrated Planning and Decision support tool (IES), "Enterprise Architecture Framework" (NTNU) and "Monitoring and Evaluation Reporting Tool" (FAC).

The complexity of positive energy districts (PEDs) requires spatial urban planning [1], which is important considering the development of PEDs are crucial for the transition towards climate-neutral European cities [2] and Action 3.2 of the SET Plan's aim to have at least 100 successful PEDs in Europe by 2025 [3]. The concept of PEDs is emerging and the knowledge and skills needed for the planning and designing, implementation and monitoring, as well as replication and mainstreaming of PEDs are yet to be advanced [4]. Despite the presence of more than 7800 studies about smart cities published between 1990 and 2019, there are still decision-making uncertainty challenges, which urban planning and design software using digital twins (DTs) can reduce [5]. A DT is "a physics-based dynamic computer representation of a physical object that exploits distributed information management and virtual-to-augmented reality technologies to monitor objects and update discrete data dynamically between virtual and real products" [6]. DTs have the potential to evolve into autonomous systems with less human intervention, through AI-enabled design and control. Through data and feedback, both simulated and real, a DT can develop capacities for autonomy and to learn from and reason about its environment [7].

Creating positive energy blocks (PEBs) and districts show how DTs are an enabler to decarbonising the built environment. By improving the performance of buildings, it's possible to see that decarbonisation is readily achievable through DT technology [8]. One future branch of research is the development of DT platforms for PEBs. It is well-known that DT platforms work by considering the level of information and level of detail associated with a project's components. A dedicated DT platform for PEBs may be practical to make evident the level of information and detail associated with the criteria. For example, qualitative indicators such as a comfort criterion could be evaluated quantitatively or integrated with statistical analysis [9]. While platforms for information sharing through web-based GIS are being consolidated, DTs for PEBs is a new direction that promotes further integration among stakeholders of architecture, engineering, construction (AEC) and planning sectors. In the future, this type of process-oriented platform could be integrated by remote sensing, promoting additional inputs from the construction industry for the application of sensors to accurately measure local environmental conditions (e.g., wind velocity and pressure) [10].

A DT is regarded as a potential solution to optimize PEDs. There are four key components of digital PED twins: a virtual model, sensor network integration, data analytics, and a stakeholder layer. DT refers to the creation of digital models or platforms by monitoring, modelling, and optimizing the PEDs as a complex multi-physics system based on real-time big data sets. DT of PEDs enables a revolutionary way to accelerate sustainability of the society regarding energy transition, circular economic, and climate change. In a DT platform, sensors will be set up to collect all kinds of information, creating the "brain of PEDs. The DT environment will facilitate interaction and collaboration between all stakeholders involved in a PED's life cycle, by enabling integrated data, information, knowledge, and decision sharing capabilities. A PED-centred DT aggregates data through the life cycle of a PED from design and construction (renovation) to operational and demolishment, hence improving the sustainability by more resource-efficient, economic, and environmental decision making [11].

Urban DTs (UDTs) are a virtual representation of a city's physical assets, using data, data analytics and machine learning to help stimulation models that can be updated and changed (real-time) as their physical equivalents change. Some may consider a DT only describing reality (and the history of it), while it is the additional applications that bring the real intelligence and help create the common picture of reality that is the value-added of a UDT. In terms of rationale, they can bring cost efficiencies, operational efficiencies, better crisis management, more openness and better-informed decision-making, more participatory governance, or better urban planning [12]. UDTs can also help cities and property owners reduce energy consumption [13], and measure the structural integrity of buildings over time which can prevent substantial costly mistakes and measure aspects in relation to energy consumption and carbon emissions [14].

UDTs are already transforming how cities are being planned, built, and managed, with examples appearing in cities across the world, including Helsinki, Dublin, Singapore, Sydney, Wellington, and more. From a technical standpoint, open standards play a critical role in UDTs to not only improve accessibility and functionality, but also reduce costs and increase value. Further, like any digital concept, Standards are required before UDTs can mature. Successful UDTs require ongoing collaboration between multiple tiers of government, the private sector, public utilities, building owners, community groups, citizens, and more. Just like standards, UDTs will only work if they are designed to accommodate diverse - and often unforeseen - viewpoints and use-cases since they require ongoing collaboration between multiple tiers of government, the private sector, public utilities, building owners, community groups, citizens, and more. Three overarching priorities that will provide a foundation for successful urban digital twins are: research and development, on topics such as integration of disparate data from heterogeneous sources, data model linkages, or social use cases; open standards development; and community involvement. [15].

The cost of a DT may be secondary considering all that it can offer. As it is digitised, the cost stems from its constant updates to keep the system up to date. If a project is undertaken, a building is demolished or a tree is planted, this must be reflected. These expenses are paid by the respective construction companies, mobility agents or the different local governments, among others. Very often there are municipal regulations that require this form of digital documentation to be submitted for each procedure. The financial return is guaranteed thanks to the use of digital twins as urban planning systems. There is a city-state that has been using DTs for its smart city since 2018. That city is Singapore and its 'Virtual Singapore' model. This digital city has been helping people with reduced mobility for some time now. The city council uses simulation to eliminate architectural barriers. DTS are the perfect environment for planning changes or anticipating problems that may arise in the city and thus improve the life of citizens [16].

Creating an accurate DT of the world around us is challenging. The technology of acquiring 3D data is costly and time consuming. To make future oriented decisions at city scale, it is important for stakeholders to have a digital representation of their respective city and the ability to interact with it. At the same time, there has never been as much city-scale data as today. From traffic, pedestrian information to consumption patterns, data that is spatially relevant is everywhere. However, bringing the data together in a way that makes sense is still complex and a lot of insight is lost by the inability to seamlessly integrate different data sources within a consistent context [17].

The use of DTs is expected to grow extensively in the coming years. A recent study predicts the global DT market will grow from €3.6 billion in 2020 to €56 billion in 2026. The global DT market size was valued at €4.4 billion in 2020, and is expected to reach €31.6 billion by 2025, €43.7 billion by 2026, and €44.1 billion by 2027 [18] [19] [20]. Cities can expect to save €254 billion by 2030 with the deployment and use of DTs [21], and more than 500 UDTs are expected to be deployed by 2025, up from just a handful in 2019 [22]. The Asian Pacific DT market is expected to reach €9.7 billion by 2026 [23], while the DT market in Europe was valued at €0.9 billion in 2019 and may reach €8.4 billion by 2026 [24] with a compound annual growth rate (CAGR) of over 30% between 2020 and 2026 [25]. From 2015-2026, Germany and the United Kingdom (UK) will likely be the DT leaders of the European market [23].

2.2 Local Energy Systems

The local energy systems +CxC sector comprises "Grid forecasting" (Volue), "Community Grid Technology" (MPower), "Digital Marketplace" (Volue), "Energy Community Utility Franchise Model" (MPower), "Enabled P2P energy marketplace" (IOTA), and "Data integrity and trade verification service" (IOTA).

Local energy systems facilitate PEBs that can provide value such as: 1) smoothing and balancing local solar PV surplus, deferring distribution grid investments, and utilising local energy products. Additionally, asset load levels within buildings in PEBs can be adjusted through participation in a local energy market. Buildings within the PEB can actively manage their energy consumption and the energy flow between them and the wider energy system. Eventually, the goal is that interaction between PEBs and the neighbouring district will lead to a PED, where PEBs are smaller components of the PED. Incentivizing trading and active interaction between PEBs will deliver smart grid services that can: 1) provide local supply-demand balance needs, 2) optimise the use of flexibility assets within the PEB, 3) provide flexibility services to the local system operator. But more importantly, it will accelerate the adoption of RES in buildings, improve energy efficiency (EE) and operations of distribution grids, and explore new dimensions and ideas for local electricity market designs [26]. A distinction can be made between Local Flexibility Markets (LFM) and Local Energy Markets (LEM). Since LFMs and LEMs potentially draw on the same local resources and may be implemented on the same trading platforms it is expected that these markets may be closely integrated in practice. A detailed analysis of the components of a LFM and LEM is presented in D2.3 "Report on the flexibility market".

Within a local energy trading market or community grid, a first step towards a PEB is to upgrade buildings, reduce energy demand, and increase self-consumption, before balancing between buildings and energy sources and between different temporal load profiles. With increased local production, higher performing buildings can support lower performing ones, which may only be moderately upgraded. At one point, the yearly balance will turn positive, and the block is on average making energy available to the larger grid. This can also be a trigger to expand the PEB. By integrating mobility aspects into the energy considerations, the energy surplus can also power local mobility needs. A PEB achieves an average annual positive energy balance through the use, optimization, and integration of advanced materials, energy reduction, local renewable energy production and storage, smart energy grids, demand response (DR), energy management of electricity, heating, and cooling, user involvement, and information and communication technologies (ICT) [27].

In PEBs/PEDs, annual local energy consumption is less than locally produced energy from renewables. PEDs also promote charging capabilities for electric vehicles (EVs) and make use of advanced materials, local renewable energy sources, local storage, smart energy grids, DR, energy management, user interaction and involvement, and ICT. At the same time, affordability for the inhabitants is highlighted in the implementation plan. Reaching the goal of a PED requires firstly improving EE, secondly cascading local energy flows by making use of any surpluses, and thirdly using low-carbon energy production to cover the remaining energy use. Smart control and energy flexibility are needed to match demand with production locally as far as practical, and to minimise the burdens and maximise the usefulness of PEDs on the grid at large [28].

Peer-to-peer (P2P) energy trading is a business model, based on an interconnected platform, that serves as an online marketplace where consumers and producers 'meet' to trade energy directly, without the need for an intermediary [29]. P2P energy trading is gaining attention to effectively handle distributed energy resources (DER) [30] in microgrids or local energy systems or encouraging consumers to purchase green energy certificates–which ensure they consume only green energy–if they are incapable of investing in RES [31]. With proper design, P2P energy trading creates a triple win situation for customers, microgrids/local energy systems and wider bulker energy systems [32]. P2P trading also contributes to effective management of energy supply and demand by direct exchange of energy in defined local or virtual communities based on dynamic energy prices. In times of high demand, the dynamic electricity prices are likely to exceed the predefined feed-in tariff (FiT) remunerations, which are decreasing in many countries [33]. Just as it happens in traditional energy markets, in P2P energy markets it is also necessary that supply and demand are in balance all the time, due to physical constraints. Hence, these differences between supply and demand must be corrected at the balancing market in real time [34].

Local energy systems introduced the concept of flexibility as a system operator asset. DR would support the distribution system operator (DSO) with voltage control and congestion management, and balancing power and frequency control for the TSO. As the idea of P2P trading has emerged, the focus has shifted towards the market and end-user perspective rather than the implications for the grid operators. Two P2P pilots are the Brooklyn Microgrid in the USA and the sonnenCommunity in Germany. Both projects are constituted to help the DSO by completely decoupling or controlling the electricity supply in case of natural emergencies and use mechanisms to balance supply and demand [35]. A successful P2P electricity trading within a microgrid requires a P2P electricity trading price and strategy that enable both energy prosumers and consumers to obtain profits [36].

There are three main setups to engage in P2P energy trading: (i) Over the grid trading: in this set-up a consumer remains connected to the central grid and manages price and volume risk independently by purchasing or selling electricity to other counterparts directly. (ii) Partly independent microgrid: in this set-up participants build a microgrid designed to manage a portion of the aggregate energy requirements, but still connected to the central grid for a residual portion of the required capacity. (iii) Fully independent microgrid: in this set-up several participants create a private electricity network that is fully self-sufficient, not connected to the central electricity network and parties transact through a P2P platform. In this case the investments for participants in the initiative, as well as the associated savings, are higher than the other two setups. An example of a P2P energy trading platform that can enable all three setups is ENTRNCE, launched in 2017, and currently handles transactions for over 10.000 peers daily between producers and consumers, regardless of their location [37].

The existence of millions of EU energy prosumers reveals a new category of investors and producers of electricity which should be better involved in the system. Similarly, several local and regional organisations, including cities, are also becoming players to consider with the fast-growing development of decentralised generation. Energy systems are more decentralised, with new actors being empowered at local level, bringing new approaches, which eases the increasing challenge of public acceptance. Shared networks, information society tools, and smart grids will further empower the consumers in the system [38].

The global smart grid market size was valued at €27 billion in 2020 but it's projected to be worth around €142 billion by 2030 [39]. Between 2017 and 2023, the global smart grid technology market is expected to triple in size reaching some €53 billion [40]. The global market for smart grid technology is estimated to grow from €32 billion in 2021 to €49 billion by 2026, at a CAGR of 8.7% during the forecast period of 2021-2026. The North American market for smart grid technology is estimated to grow from €10.6 billion in 2021 to €14.1 billion by 2026, at a CAGR of 5.8% during the forecast period of 2021-2026. The Asia-Pacific market for smart grid technology is estimated to grow from €8.3 billion in 2021 to €14.7 billion by 2026, at a CAGR of 12.0% during the forecast period of 2021-2026 [41] [42].

2.3 Electric mobility

The electric mobility (e-mobility) +CxC sector comprises "eMobility as a Service platform" (FourC), "Vehicle to Grid and Vehicle to Building technologies" (ABB), "Optimisation of Existing Charger Use" (GoCar), "e-MaaS multi-modal Payment Solution" (IOTA), "EV sharing" (ABG). A functional proof-of-concept eMaaS system that integrates the aforementioned solutions has been developed by +CityxChange and is described in Deliverable 2.5 "Seamless e-mobility system including user interface". This seamless e-mobility solution, including an eMaaS scheme, has been implemented and demonstrated in Lighthouse city Trondheim and is described in detail in Deliverable 5.13 "+Trondheim eMaas Demonstration".

PEDs require interlinkage of mobility and ICT systems [43]. Because of PEDs, energy surplus can be used to meet mobility demands of residents or passing EVs [44]. However, even though a PED considers the mobility system with its own share of energy needs, it does not set criteria for how much of its users' mobility energy shall be produced by the PED [45].

The eMobility ecosystem consists of four interactive segments, namely: (i) EVs which were worth €301 billion in 2020, equivalent to 10-15% of the global automotive market, (ii) infrastructure which was worth €26 billion in 2020, (iii) providers which accounted for €20 billion in 2020, and (iv) regulations and subsidies which in 2020 raised roughly €27 to €35 billion worldwide, with direct and indirect buyers' premiums accounting for around 85% and 15% from industry subsidies [46].

The global e-mobility market size was €111 million in 2018 [47] **and €134 billion in 2020**, and it's projected to reach €418 billion by 2025 [48] and surpass around €631 billion by 2030, growing at a CAGR of 22% from 2021 to 2030 [49] [50]. Sales of battery electric vehicles (BEVs) rose by 40% worldwide in 2020, and plug-in hybrid vehicles (PHEVs) by 74%. While China remains the largest BEV market in absolute terms, the main impetus for the growth of the overall EV market comes from Europe. BEV sales in Europe more than doubled in 2020, while PHEV sales grew more than threefold [51]. The global PHEV and BEV market is projected to grow by 37.3% and 44% CAGR from 2020-2026. The global converter market for EVs will be worth more than €25 billion in 2026 with a CAGR from 2020-2026 of 27.7%. The global market value for semiconductor power electronic devices for EVs will reach €4.9 billion in 2026 with a CAGR from 2020-2026 of 25.7%. There are basically three converter types in an electric car: the main inverter, DC/DC, and on-board charging systems. The main inverter is the largest market among the different converters due to the higher power levels, leading also to the highest content of power semiconductors. Thus, the global main inverter market is expected to reach €17 billion by 2026, representing 67% of the total EV/Hybrid EV converter market, with a CAGR of 26.9% [52]. Strict CO2 targets will push EV/HEV share to 38% of all passenger vehicles in 2026, representing a €4.9 billion market opportunity for various semiconductor technologies and power devices [53].

Europe will remain the global leader in electrification in terms of EV market share. In addition to the European Commission target, which requires around 60 percent EV sales by 2030, several countries have already announced an end to internal combustion engine sales by 2030. In line with this, seven original equipment manufacturers (OEM) brands have committed to 100% EV sales by 2030 within the European Union. In the most likely accelerated scenario, consumer adoption will exceed regulatory targets and Europe will reach around 75% EV market share by 2030. The European Union announced a zero-emissions target for new cars by 2035. Industry players are accelerating the speed of automotive technology innovation as they develop new concepts of electric, connected, autonomous, and shared mobility. The industry has attracted more than €354 billion in investments over the last decade—with about €88.5 billion of that coming since 2020 [54].

Europe has enjoyed strong EV market growth, led by Germany and Italy. Both markets saw sales growth of more than 200%. In Germany, now at the top of the market indicator rankings, sales of EVs rocketed from 112,000 to more than 400,000 vehicles, making Germany now the second-biggest market for EVs. This was accompanied by a drop in total automotive sales, giving EVs a market share of more than 12.6%. Next in the E-Mobility Index 2021 ranking comes France, which remains in second place thanks to a strong increase in the market share of EVs, from 2.5% in 2019 to 9.5% today. Italy also saw sales of EVs grow by 160%, resulting in a market share of 4.1% compared to 0.9% in 2019. Italy thus demonstrates the best progress in terms of EV market share, up 376%; it now ranks fourth in terms of market. Other key takeaways from the E-Mobility Index 2021 include increased sales volumes in Europe are to a large extent due to the purchase incentives contained in stimulus packages, the EU Commission is considering tightening emission limits for new vehicles by 2030, and finally automotive OEMs and suppliers must prepare themselves for additional regulation in real consumption data and emissions across the entire vehicle lifecycle [55].

Plug-in hybrid EVs became the most popular type of passenger EVs in the EU in 2020. To provide appropriate charging infrastructure, the number of charging stations available across Europe is increasing at a rapid pace. By 2030, electric vehicle-related energy demand is anticipated to be between 130 and 195 terawatt hours in the EU. Globally, the number of publicly available fast electric vehicle chargers came to around 264,000 units in 2019. Germany is the leading European market for plug-in electric car sales, while Norway has the largest share of EV registrations among European countries. Norway has a population of roughly 5.4 million people, and every second new car registered in Norway is a battery electric vehicle. Globally, plug-in light vehicle sales are tipped to reach a new record in 2020, with Europe being the largest driver of growth. Renault's Zoe and Tesla's Model 3 are among Europe's best-selling electric vehicle models, both in terms of vehicles in operation and new car registrations. In the latter category, Volkswagen's new ID.3 model climbed through the ranks and topped the charts in December 2020 [56].

Mainland China, Germany, and the U.S. were the biggest markets for EVs in 2020 and accounted for more than 60% of all electrical vehicle sales globally in 2020. Most of the European countries witnessed robust sales in 2020 as compared to 2019. In Japan, EVs sales declined in 2020 continuing the downward trend of 2018. In terms of charging infrastructure, Mainland China again leads the pack with more than 800,000 publicly accessible charging points, followed by the U.S. (98,981), the Netherlands (ca. 65,633), and Korea (64,188). The total number of electric buses in the world is expected to increase by 300% from 386,000 in 2017 to about 1.2 million in 2025, with Mainland China accounting for 99% [57].

2.4 Renewable energy sources

The renewable electricity sources +CxC sector comprises "Tidal Turbine for Shallow Rivers" (GKinetic Energy) and "High temperature heat pumps" (NTNU). These are specifically developed generation options; other sources and technologies are used as they are available on the market and integrated and connected into the PEB, where the integration is the main innovation.

PEBs support the uptake of on-site renewable energy production [58]. When considering the PEB concept, a series of elements naturally come into place: the need for a smart grid; local renewable energy production; advanced materials, digital design; energy storage and connection to electromobility solutions [59]. CNR, the technical partner of LE PRÊCHEUR and MARIE-GALANTE PEB projects, is the first exclusively renewable energy producer in France (hydropower, wind, and solar PV power, certified by the independent organisation TÜV SÜD). CNR is the second largest electricity producer in France and is committed to promoting renewable electricity and electric mobility for sustainable transport [60].

PEDs are embedded in urban and regional energy systems driven by renewable energy aiming to provide security and flexibility of energy supply [61]. The energy balance in PEDs needs to devise effective energy strategies, including power, gas, and thermal energy networks. The technology and knowledge required to achieve PEDs already exists—put simply, the use of renewable sources for building energy use needs to double and gas usage needs to be halved [62]. A neighbourhood can be designed as an eligible candidate for PED transition, if energy production is higher than the overall demand [63]. PEDs work towards a surplus production of renewable energy with annual net zero energy import and net zero CO_2 emissions [64]. A high level of EE and renewable energy production are pillars of PED design, along with energy flexibility and e-mobility [65].

Prosumers cooperating for the energy needs of communities facilitate PEDs, which are composed of several buildings connected to each other at the neighbourhood level to contribute to the energy support of the whole through a "smart" distribution of energy networks. Prosumers (PRO-ducers + conSUMERS of energy, simultaneously), can indicate buildings that not only use the energy produced on site from renewable energy sources for self-consumption, but which also share the excess of energy produced with their neighbours through the connection to a smart grid. This concept is one solution to the increase in energy demand from buildings, due to the introduction of energy-efficient electronic equipment, introduced by users to improve their lifestyle. To maximise the share of energy destined for self-consumption, a prosumer must be equipped with a mix of efficient technologies, such as photovoltaic (PV), heat pump (HP), energy and thermal storage systems, and EVs [66].

The global HP market has increased more than 25% in 2021 and a total sales volume exceeding 2 million units is expected by the end of 2022. 130,000 HPs were installed last year, and investments in them amounted to €800 million. The largest group of investors was the owners of single-family houses and residential buildings. In addition to single-family houses, GSHPs were increasingly installed in large units such as apartment buildings and service buildings, and to produce the district and block heating and cooling [67].

In 2020, primary energy consumption in the EU dropped sharply to 1 236 million tonnes of oil equivalent (Mtoe), which is 5.8% better than the efficiency target for 2020, thus clearly outperforming it. This is still 9.6% away from the 2030 target, so efforts to improve efficiency need to be maintained in the years to come. Final energy consumption reached 907 Mtoe: 5.4% better than the efficiency target for 2020 and 7.2% away from the 2030 target [68].

Nuclear accounted for almost 25% of the EU's total electricity production in 2020. The largest producer of nuclear power in the EU was France (52% of the EU total nuclear energy production; 353 833 GWh), followed by Germany (9%; 64 382 GWh), Spain (9%; 58 299 GWh) and Sweden (7%; 49 198 GWh). These 4 countries together accounted for more than three quarters of the total amount of electricity generated in nuclear facilities in the EU. France remained the EU Member State most reliant on nuclear electricity, which represented 67% of all electricity generated in the country in 2020. The only other EU country with more than half of its electricity generated in nuclear power plants was Slovakia (54%) [69].

The global renewable energy market was valued at €780 billion in 2020 with total revenues of €613 billion. In 2021 it was valued at €803 billion, by 2027 it's expected to be valued at €1.3 trillion, and €1.9 trillion by 2030 [70] [71] [72] [73] [74] [75] [76]. Solar PV and wind account for 86% of global renewable capacity additions in 2020, but their annual expansion declined by 17% and 12% respectively compared to 2019 [77]. Exceptionally high-capacity additions became the "new normal" in 2021 and 2022, with renewables accounting for 90% of new power capacity expansion globally [78]. Five trends will drive 2022 growth, opening new avenues in the renewable energy market: new technologies, new business models, infrastructure development, Supply chain ecosystem, and sustainable growth [79].

3 Market analysis of Lighthouse Countries

Limerick, Republic of Ireland and Trondheim, Norway are the two Lighthouse Cities in the +CityxChange project. Together with Follower Cities: Alba Iulia, Pisek, Võru, Smolyan and Sestao, their ambition is to achieve sustainable urban ecosystems with zero emissions and to establish 100% renewable energy city-regions by 2050 [80] [81]. The following methodology has been used.

1. The scope of the analysis has been determined based on the primary target markets for short-term replication of the +CityxChange solutions. Replication is expected to be most efficient in cities in the two Lighthouse Countries since they fall under the same national regulatory frameworks and have the same climate conditions and culture as the Lighthouse Cities.
2. For both Lighthouse Countries, a state of the art analysis has been performed in the form of a literature review using the PESTEL (political, economic, social, technological, environmental, and legal) methodology. This comprehensive literature review identifies key external market factors pertaining to both positive energy blocks and districts on either a national or municipal scale.

This chapter presents the results of this PESTEL analysis.

3.1 Limerick, Republic of Ireland

3.1.1 Political

Key governmental institutions in Ireland governing the energy sector include the Department of Communications, Climate Action, and Environment (DCCAE), the lead government department with responsibility for setting Ireland's overall energy, climate, and environment policies. The Sustainable Energy Authority of Ireland (SEAI) advises the government on policies related to the reduction of GHG emissions in the energy sector [82].

Ireland's energy policy framework was set out in the 2007 Government White Paper, 'Delivering a Sustainable Energy Future for Ireland', designed to steer Ireland to a new and sustainable energy future, placing sustainability at the heart of the Government's policies on energy and environment. The decision to move towards energy sustainability implies accelerating the growth of renewable energy supply and maximising EE [017].

In Ireland there are policies in place that promote the installation and use of RES, mainly in the domestic sector. RES for heating purposes is promoted through subsidies and a tax return, and the incentive for renewable energy use in transport is a quota system [83]. The government in Ireland is responsible for creating policy relating to the regulation of electricity markets. It is the government's goal to reduce Ireland's CO2 emissions, and the government designs policy and supports schemes to achieve this, which promote RES and support Ireland in its goal to reach national and EU renewable energy targets. The government also creates policy and legislation allowing for the liberalisation and regulation of the gas market in Ireland [84]. The Green Party announced a red line for entering government is a commitment to reduce GHG emissions by at least 7% each year to 2030 [85].

Energy efficiency underpins the three pillars of Ireland's energy policy: sustainability, security of supply, and competitiveness. Improving Ireland's EE is an essential part of its sustainable energy policy. EE is internationally recognised as the most cost-effective means of reducing dependence on fossil fuels. The National Development Plan 2007 – 2013 contained sustainable energy policy objectives in two Priority areas: Economic Infrastructure Priority and Enterprise, Science, and Innovation Priority [86].

Ireland's Climate Action Plan 2021 aimed at a 51% reduction in GHG emissions by 2030 and towards a path to reach net-zero emissions by 2050, as committed to in the Programme for Government and set out in the Climate Act 2021. This Plan makes Ireland one of the most ambitious countries in the world on climate and will put Ireland on a more sustainable path; cut emissions; create a cleaner, greener economy and society; and protect from devastating climate change consequences. It's an opportunity to create jobs and grow businesses in areas such as building retrofitting, therefore making homes warmer and safer. The Plan lists the actions needed to deliver on climate targets and sets indicative ranges of emissions reductions for each sector of the economy. It will be updated annually to ensure alignment with legally binding economy-wide carbon budgets and sectoral ceilings [87].

To meet Ireland's 2050 net-zero emissions targets, the Climate Action, and Low Carbon Development (Amendment) Bill 2020 proposed a new path via a set of five-year economy-wide carbon budgets. The bill is indicative of Ireland's recent efforts to create a clear and reliable framework for decarbonization that provides strong signals for investment in renewables. Restating Ireland's pledge that 70% of its electricity will come from renewable sources by 2030, the plan aligned a state-led auction scheme – the Renewable Electricity Support Scheme – with a target for 15% of Ireland's renewable electricity demand to come from corporate power purchase agreements by 2030. It also highlighted the need to address planning, consenting and grid-connection issues for offshore wind development. The Coalition's Programme for Government (PfG), ratified in 2020, supports the 2019 plan. It stated the intent to reach net-zero emissions by 2050 and upped the offshore wind development target from 3.5GW to 5GW by the end of the decade [88].

A new retrofit plan in Ireland will cater for up to 500,000 homes, with the Government promising that large groups of houses will be retrofitted by the same contractor to reduce costs. These costs can then be paid off by the homeowner through smart finance and easy pay-back methods. Another retrofitting programme will install 400,000 cleaner heat pumps in homes and businesses to replace older, less energy-efficient ones. Ireland's retrofit grant programmes are targeted at buildings of modern construction and are not suited to traditionally built buildings due to the retrofit technologies and performance standards specified. By 2030, a ban will be placed on the sale of all new petrol and diesel cars, with plans to introduce a scrappage scheme to boost the number of EVs in Ireland. The Government committed to have 950,000 EVs on Irish roads by 2030, up from an estimated 8,000 that were registered by 2020 [89].

Decarbonisation of heating is a priority area for Ireland [90]. The Irish government set a target for 16% renewables in final energy consumption by 2020 and revises their National EE Action Plan (NEEAP) every three years in line with the EU EE Directive (EED) [91]. Policy instruments to help reduce carbon emissions including the deep retrofitting of buildings will be kept open and funded up to 2030 [92], one example launched in 2020 was the "Better Energy Financing" pilot, a Pay-As-You-Save scheme for retrofitting existing buildings [93].

A policy instrument called the « Deep retrofit pilot scheme » (2017-2019) offered grants of up to 50% of costs for deep retrofits towards an 'A' energy rating [94]. There is a mounting pressure on facilitating energy retrofits and addressing by-effects of the energy transition in a more equitable way [95]. Exemptions for micro renewable projects were introduced by the Department of the Environment, Heritage, and Local Government in 2007 and 2008. These measures reduced the regulatory burden to promote RES as GSHPs and for alignment with key national policy objectives including addressing climate change through the national renewable energy action plan (NREAP) [96]. Additional active grants include: "Home Energy Grants" [97] which is the most common and straightforward; "Better Energy Warmer Homes" [98] This for low-income households (very restrictive and means assessed); "Better energy communities" [99]; and "Warmth and Wellbeing" for people with respiratory disease [100].

In Ireland the most significant contribution towards the target of 12% RES-H (Renewable energy source – Heat) has come from the industrial sector, with more modest contributions from the household and services sectors. Deployment of RES-H such as biomass boilers and solar thermal systems has been supported by grants for renewable heating sources (e.g., ReHeat Scheme 2009–2011 targeted at commercial and industrial applications and the Greener Homes Schemes 2008–2011 for the residential sector). The Building Regulations (2011) included a minimum threshold requirement for renewable energy supply for new residential buildings that can be met via renewable heat technologies. The gap to the RES-H target could be closed by the installation of renewable technologies in 300,000 homes or 3,000 service sector buildings or 200 large industrial sites [101].

3.2.2 Economic

Since 2007, the Single Electricity Market (SEM) is the electricity market for Ireland and Northern Ireland. The SEM includes a centralised all-island gross mandatory pool market, and all electricity is traded through a market clearing mechanism. Generators receive the System Marginal Price, payments through a capacity mechanism and constraint payments. Most gas for Ireland is sourced from Great Britain's National Balancing Point (NBP) which is characterised by high levels of liquidity. Trades in Ireland can take place at a NBP called the Irish Balancing Point (IBP), which is also very liquid [102].

Ireland has recovered remarkably from the economic crisis which started in 2008 and has the fastest growing economy among all IEA countries since 2014, when GDP exceeded pre-crisis levels. Energy use has increased with GDP growth but remains under the 2006 peak, partly reflecting the structural shift in the economy toward dominance by the services sector. However, the government's strategy to establish Ireland as a preferred location for the global digital and data hosting industry, could result in strongly growing electricity demand. This makes fast decarbonisation of the electricity system a necessity [103].

Ireland is grappling with ongoing turmoil in financial markets (like other Member States) and the need to stabilise the economy before moving back towards growth and expansion. We have set out a Framework for Sustainable Economic Renewal: Building Ireland's Smart Economy, which places energy policy at the heart of our programme for recovery and identifies the twin imperatives of securing the supply of reliable and affordable energy and achieving the transformation to a low-carbon, high efficiency, sustainable and smart energy system. Ireland has witnessed a great many changes over the past two decades, including rapid and sustained economic growth, substantive investment in road and rail infrastructure and the widespread availability of broadband. In parallel, the energy sector has expanded to meet the rising energy demand from a growing economy [86].

One revolutionary change to Ireland's energy economy is set to be one of the biggest projects undertaken in the history of the State, spanning approximately 500km between Ireland and France. The €1bn Celtic Interconnector is a giant subsea electricity cable linking the Irish grid with the rest of Europe. Its 700 MW capacity is expected to power 450,000 households. Such efforts are important stepping stones to achieving Ireland's 2030 renewables target [104]. The project is being jointly developed by EirGrid and its French counterpart Réseau de Transport d'Électricité. EirGrid CEO Mark Foley said that this grant will help construction start in 2022, with the goal of having it completed by 2026 [105].

The 2018 National Development Plan complementing the National EE action plan (NEEAP 4) from 2018 to 2027 prioritised the decarbonisation of heat generation, with one proposed measure being the replacement of oil-fired boilers with HPs in at least 170 000 homes by 2027, for which €700 million has been allocated [106], along with SEAI grants of €3 500 for GSHPs are also planned [107]. Economic growth in Ireland is projected to increase by 3.0% in 2020, and 2.8% in 2021 [108]. Renovation of the housing stock in the main urban centres of Ireland received a boost in Budget 2014 with the introduction of a Home Renovation Tax Incentive scheme. The Traditional Skills and Buildings at Risk Jobs Leverage Scheme in Ireland leverages private capital for investment in labour-intensive, small-scale renovation projects directed at structures protected under Planning Law [109]. In 2018, greater levels of institutional investment entered Ireland from the United States and Europe [79]. The electrification of residential heating is an economic priority for Ireland [110].

€1.3 billion was extracted from carbon taxes to support the national retrofit ambition out to 2025, with additional funds to be announced through the budgetary process each year. This unprecedented funding for EE will support the government's target of retrofitting 500,000 homes to a Building Energy Rating of B2 and the installation of 600,000 heat pumps, of which 400,000 which will be in existing homes by 2030 [111].

Budget 2022 commits €202 million in carbon tax revenue to fund the SEAI residential and community retrofit schemes and a further €10 million from the Exchequer for the Solar PV scheme. This investment will support over 22,000 home energy upgrades, including over 6,000 homes to a Building Energy Rating of B2. It will deliver warmer, healthier, and more comfortable homes with lower energy bills. It will also reduce emissions from the residential sector and improve air quality. €109 million of this €202 million allocation will be used to provide free EE upgrades to households that are in, or at risk of, energy poverty. Over 4,500 upgrades will be carried out under these SEAI schemes. The Minister for Housing, Local Government and Heritage will invest a further €85 million as part of the Local Authority Retrofit Programme in 2022. A new low-cost loan scheme for residential retrofitting will be introduced. This part-Exchequer and part-EU funded scheme will enable credit institutions to offer loans at reduced interest rates, making energy upgrades more affordable [112].

3.1.3 Social

In Limerick, Ireland, it is about behavioural change where a PED program is wrestling with an old building stock," said Mihai Bilauca, head of digital strategy and EU programs at the city and county council [113]. +CityxChange will develop a single integrated modelling platform for buildings, transport, and energy services. The model will identify energy consumption in city blocks, renewable energy generation, energy storage capacity, energy grid infrastructure, e-mobility network & services, and environmental indicators, with citizen engagement on transport mobility, energy use, wellbeing, satisfaction, etc. This data will be displayed at block / city level for Limerick citizens to view and comment upon. Limerick will be Ireland's first positive energy city, aiming to ensure its sustainable future [114].

Electric Ireland is Ireland's largest electricity supplier in terms of customers across all segments and in terms of energy supplied in the domestic (residential) and Large Energy User (LEU) markets. Irish consumers assess the performance of their retail electricity and gas markets above the EU average with the difference being very small for the latter (75.1 points compared to 72.0 and 74.6 compared to 74.1), which in 2014 corresponded to 13th and 14th place in the EU ranking. The Energy Customers Team of the Commission for Energy Regulation (CER) acts as a single contact point providing consumers with information on electricity and gas. They also provide a free dispute resolution service [102].

In 2016, there were a total of 2,003.645 houses and apartments in Ireland according to the Census carried out by the Central Statistics Office. Of these, 1,697.665 were occupied by persons usually resident in the State, while 9,788 were occupied by guests or visitors. Vacant holiday homes accounted for 62,148 housing units. The remaining 183,312 were vacant houses and apartments. The overall vacancy rate in 2016, including holiday homes, was 12.3%. If holiday homes are excluded from the housing stock the vacancy rate drops to 9.4 %. The European Housing Review of 2007 found that Ireland has the youngest dwelling stock in the EU. However, a significant proportion remains dated. Nearly one third of the current housing stock was completed before 1970 and only approximately a quarter date from 2001 onwards [115].

SuperNode is the brainchild of Mainstream Renewable Power, an Irish company developing wind and solar projects from Chile to the Philippines alongside its new Norwegian owner, Aker Horizons. Such global collaboration is a feature of Ireland's exceptionally open economy, with more than 1,600 multinationals based there. With dozens of offshore floating wind projects in the development pipeline due for completion in 2030, SuperNode aims to have its cabling technology commercially ready by 2029. The scientific and engineering challenge is to design much thinner cables capable of carrying electricity at ten times existing limits and at vastly greater distances than is possible with today's copper-based cables [116].

Onshore wind deployment has had a consistently positive impact on net employment and the Irish economy in 2020. The additional direct employment was driven by investment in new wind turbines. These new jobs drove increases in average income per capita and real disposable income in 2020 (where electricity cost savings were made). Future changes in the price of electricity because of supporting investment in onshore wind, via the renewable energy FiT, impact on the net jobs created, however the macroeconomic and employment impact is always positive (net new jobs were estimated at around 2,880 in 2020) [117].

Housing stock typologies in Ireland traditionally fall into three categories: bungalows/detached (40% of national stock) semi-detached/terraced (40%) and flats/apartments (20%). There were just over 2 million residential buildings in Ireland as of 2016, of which over 97% were single-family dwellings, and nearly half of them were constructed before the introduction of building regulations. The renovation of Ireland's existing building stock is a source of considerable, yet almost untapped potential for energy saving, due to the existing amount of poorly insulated building stock in the state. In 2017, only 6.8 % of the heat demand in Ireland was met by renewables and for 2020 the target is 12%. Ireland has a highly dispersed population reliant on individual oil-fired boilers for heating, accounting for 41% of home heating [90] [91]. Retrofitting for EE in civic offices, public sports facilities, community centres, and social housing aims to cut GHG in Dublin by 40% by 2025 [118]. By 2014, there were 517,365 residential and approximately 28,205 non-residential EPCs published, representing cumulative coverage of more than 30% and 23% of the housing and non-residential buildings sectors, respectively [119].

The Better Energy Communities (BEC) programme in Ireland makes EE improvements available to those in energy poverty not captured by the Warmer Homes Programme (such as tenants) and to test the economies of scale by targeting clusters of homes in energy poverty. Furthermore, under the Residential Deep Retrofit programme, energy-poor households can receive grants of up to 95% of the capital costs of renovations. About 28% of households in Ireland in 2015 were estimated to be living in energy poverty. A household is classed as energy poor when it spends more than 10% of its income on fuel. Energy poverty of households living in social housing was over 70% and they spent an average of 17% of their income on energy. Social housing made up 6.6% of the Irish buildings stock. However, homeowners accounted for most energy-poor households at over 250 000 [82].

3.1.4 Technological

In 2018, final energy consumption in Ireland was 11.2 Mtoe, 10% higher than in 2000. The transport sector was responsible for the largest increase in energy demand. It increased by 17% over the period, and in 2018 accounted for 37% of all final energy use, up from 34% in 2000. The next largest sector was households, accounting for 25% of final energy use. In households, the space heating energy consumption per m2 (normal climate) improved by 42% between 2005 and 2015. This was due to a combination of factors including improved building regulations for new dwellings and retrofitting of existing dwellings. Overall transport energy demand in Ireland has seen periods of dramatic growth and contraction between 2000 and 2018, as transport activity remains highly sensitive to economic growth. Despite these activity changes the split of transport energy consumption by mode remained almost the same in 2018 as in 2000. Private car transport remains the dominant mode of passenger transport, reflecting Ireland dispersed settlement patterns [120].

ICT was identified as a significant growth sector both worldwide and in Ireland. The IEA has indicated that energy use in the ICT sector grew at approximately 7% per annum between 1990 and 2008 and now represents a major cause of electricity growth internationally. It is projected that without further policy intervention, total electricity consumption of the sector could increase by a further 250% by 2030. The SERVE Project (Sustainable Energy for the Rural Village Environment) in North Tipperary aims to demonstrate sustainable energy use in rural communities. The project encompasses retrofit and new build development work and, together with strong local community support, will raise awareness of rational use of energy and renewable energy services [86].

The ESBN plans to roll out 2.25 million smart meters by 2025, in three phases as part of the National Smart Metering Programme (NSMP). This is a multi-year investment project including the roll-out of new digital electricity (and gas) meters, a communications network to support them and investment in new information technology systems. At the DSO level, the ESBN is also working on smart grid technologies. It launched a pilot project on the Dingle peninsula in April 2018, in which the ESBN deployed a range of technologies to understand how evolving technologies will interact with the electricity network of the future. A key component of the

Dingle pilot project is the work with the local community in discovering what opportunities the future of energy can unlock for end customers. Under the project, smart devices on the network will help in monitoring and predicting the network events better, to ensure less outages and more resilience on the distribution network [82].

3.1.5 Environmental

In 2018, Ireland's GHG emissions were 60.9 million tonnes of CO2 equivalent. This was 9.9% higher than the 1990 figure of 55.5 million tonnes. In 2018, Ireland ranked seventh worst out of 28 EU Member States in terms of its total greenhouse gas emissions at 89.0 relative to the base year of 2005=100. In 2018, Ireland had the third worst emissions of greenhouse gases per capita in the EU at 12.6 tonnes of carbon dioxide equivalent per capita. Ireland's emissions were 53% higher than the EU28 average of 8.2 tonnes. The transport share of greenhouse gas emissions increased from 9.3% in 1990 to 20.1% in 2018. The energy sector's share of greenhouse gas emissions in 2018 was the third largest sectoral contributor to emissions with 17.4% of the total [121].

Energy use for heat in homes and businesses in Ireland decreased by 0.7% in 2019 when the impact of a warmer year is considered. Collectively these sectors account for over one third of our national energy use and CO2 emissions from fossil fuel use. The work required to upgrade our homes and business is good for the economy. It creates jobs, enables householders to save on energy costs now and in the future, and it makes business more efficient – leading to competitiveness gains. The environmental benefits are clear. By burning fewer fossil fuels, Ireland contributes to global emissions reductions, and experiences better air quality in homes, benefiting everyone. Deploying EE to reduce fossil fuel use and generating more energy from Ireland's vast national renewable sources will also improve their security of energy supply [122].

Ireland releases about 60 million tonnes of GHG each year, crudely broken down into 40 million tonnes from energy (electricity, heat, and transport) and 20 million tonnes from agriculture. Ireland's climate policy ambition, encapsulated in the 2019 Climate Action Plan, is to reduce total greenhouse-gas emissions to about 45 million tonnes in 2030 (equivalent to an annual average reduction of 3%) by 2030, with average annual emissions reductions of 4% and 1% from energy and agriculture respectively. These emissions reductions would be met, according to the climate plan, with targets for EE (including retrofitting half a million homes), EVs (nearly one million EVs), electric heating (more than 600,000 HPs), and renewable electricity (70% from renewable sources) by 2030 [123].

In Ireland, total renewable energy increased by 10% in 2018. Wind is the largest source of renewable energy, accounting for 55% of all RES in 2018. It grew by 15% in that year. Renewable energy accounted for 10.0% of primary energy in 2018, up from 9.3% in 2017. Looking at final energy split by sector, transport has by far the largest share, accounting for 42%. The next largest sources of energy demand after electricity are households and industry, accounting for 23% and 21% of final energy use respectively in 2018. Heat final energy use had greater year to year fluctuations than transport or electricity [115].

Ireland’s climate is classified as western maritime. Temperature is almost uniform over the entire island [124]. Ireland's Climate Action Plan of 2019 has set targets to meet the required level of emission reduction by 2030 with EE upgrades, including the deep retrofit of more than 500,000 existing properties. These retrofit projects will span the entire country, encompassing urban and rural housing, private and local, commercial premises, and facilities such as Gaelic Athletic Association clubs and community centres [125]. The share of renewables in Ireland was 2.8% in 2005 and reached an impressive 10.66% in 2017 [126]. Renewable energy contributes to 7.8% of gross final energy consumption in Ireland [93].

The Moneypoint plant is Ireland’s single largest power station, with a total capacity of 915 MW. It accounted for almost 12% of the total generation in 2017. The plant underwent a EUR 500 million environmental retrofit in 2016 to reduce emissions of particulate matter of nitrogen and sulphur oxides. The Moneypoint plant is essential for ensuring security of supply, providing stability to an electricity system that is increasingly integrating intermittent generation. It is also critical for supplying electricity to the greater Dublin area, as it connects to the starting point of a 400 kV transmission line serving the metropolitan area [82].

3.1.6 Legal

Since the first mandatory Building Regulations in Ireland that explicitly addressed conservation of fuel and energy in buildings were issued in 1992 and some 58% of residential dwellings date from before this time, the data indicates that there is likely to be significant potential in the residential sector for major renovation works. The EPBD also requires that any existing building undergoing major renovation is required to be brought up to cost optimal level for energy performance. Irish building regulations for non-domestic building are in force since 2017 with EPBD compliance effective from January 2019. For domestic regulation these are in place since 2019 and effective from November 2019 [115].

EE obligations placed on suppliers or distributors of energy represent a very efficient and cost-effective option to achieve Demand Side Management by final customers. They are established through a legal obligation on suppliers or distributors, to achieve energy savings and peak load reduction from their customers through a range of approved measures. The Energy Services Directive (ESD) is the overarching framework within which EE policy is formulated. The Directive seeks to promote cost-effective end-use EE in EU Member States through various promotional, awareness and support measures, as well as the removal of institutional, financial, and legal barriers [86].

Since 2007, any person in Ireland who commissions the construction of a new building with a floor area exceeding 1,000m2 is obliged by law to ensure, before work commences on its construction, that due consideration has been given to the technical, environmental, and economic feasibility of installing alternative energy systems in the proposed building. Options for consideration include the use of renewable energy systems and combined heat and power (CHP). From 2008, in line with the requirements of the Energy Performance of Buildings Directive (Directive 2002/91/EC), the owner of any air conditioning system with a rated output of more than 12kW is required by law to have the system inspected by a trained inspector to ensure efficient energy usage by the system [86].

Primary legislation governs environmental requirements for building works in Ireland. Secondary legislation exists governing the energy performance of buildings in accordance with the EC Energy Performance of Buildings Regulation 2006. The European Communities (Energy Performance of Buildings) Regulations 2008 require that a 'Building Energy Rating Certificate' is provided in the sale or letting of all buildings, new and old. The certificate is effectively an energy label which is issued on foot of a report which sets out recommendations for cost-effective methods of improving the energy rating of the building. However, the recommendations are not binding [127]. In 2014, Ireland was referred to the European Court of Justice for failing to fully transpose the EU's RED [102].

Energy regulation in Ireland is derived from the transposition into Irish National Law of EU Regulation and Directives, as it is with other EU member states. The first building regulations in Ireland came into force in 1992. These were then superseded in 1997, along with numerous updates since then. Until the 1990s building regulation mainly consisted of local authority building codes and planning and development bylaws. Building regulations apply to new buildings, extensions, and material alterations to existing buildings [128].

Ireland has set up a legal framework for gas security based on the following act and regulations: (i) Gas (Interim) (Regulation) Act 2002 and amendments made by Statutory Instrument 697/2007 specify that the Natural Gas Emergency Plan (NGEP) should set out procedures for the declaration and handling of an emergency. The NGEP also defines roles of the various bodies involved in an emergency event and provides measures to ensure that supplies to vulnerable customers, as determined by the CRU, are protected. (ii) Statutory Instrument 336/2013 gave legal effect to EU Regulation 994/2010. EU Gas Security of Supply (SoS) Regulation 2017/1938, repealing Regulation 994/2010, came into force in November 2017 to ensure all necessary measures are taken to safeguard an uninterrupted supply of gas throughout the European Union. Solidarity and enhanced regional co-operation among EU member states are the guiding principles of this new regulation [82].

There are several construction licences that a contractor may be required to obtain before carrying out works, for example: Planning permission where applicable, must be in place before works commence; Fire certification and Disability Access Certificate (where relevant); 7 Day Notice; Commencement Notice; Certificate of Compliance (Design); Notice of Assignment of Person to Inspect and Certify Works ("Assigned Certifier"); Certificate of Compliance (Undertaking by Assigned Certifier); Notice of Assignment of Builder; Certificate of Compliance (Undertaking by Builder); Any work carried out that involves asbestos requires that a health and safety plan is submitted to and approved by the Health & Safety Authority. Further, a licence from the Environmental Protection Agency may be required for the works; An air/water pollution licence may be required from the Environmental Protection Agency, depending on the works; and Contractors wishing to put a skip or erect scaffolding on a public highway must obtain a hoarding licence from the relevant local authority [129].

Part L of the Irish Building Regulations has been subject to considerable review, with the Building Regulations (Part L Amendment) 2017 signed into law to set higher building energy performance standards. Furthermore, the current 2019 regulations provide for the requirements of Articles 2-9 of the EU's EPBD (recast) (2010/31/EU of 19 May 2010). The changes in the Irish Building Regulations apply to any relevant works from 2019 onwards. Buildings must achieve cost-optimal performance when in excess of 25% of the building surface area undergoes major renovation works. This cost-optimal performance level is 125 kWh/m2/year, as calculated in the Dwelling Energy Assessment Procedure (DEAP) [130].

3.2 Trondheim, Norway

3.2.1 Political

Trondheim Municipality has adopted the Climate and Energy Action Plan to 2030, which sets an ambitious climate goal of 80% reduction of GHG emissions by 2030 (from a 1991 baseline). The city is aiming for a per capita 20% decrease in stationary energy consumption 2030 based on a 2013 baseline. Trondheim Municipality has recently also initiated programmes for EE measures and renewable energy for cultural heritage buildings and areas. A bold city vision, public incentive schemes, and open innovation with industry partners and the national Research Centres on Environment-Friendly Energy within Zero Emission Neighbourhoods in Smart Cities, Smart Grids, EE in Industry and Sustainable Energy in Society will be important instruments to reach these goals [131].

The PED concept fits with Norway's high-level energy strategies and national policies, thereby positioning Norway in a prominent role towards decarbonization of the electricity system with focus on local energy generation. Norway aligns with the Nordic approach to sustainable development, which includes a common strategy for implementing Agenda 2030 and the Sustainable Development Goals (SDGs). In 2008, the Norwegian Parliament decided that Norway should become carbon neutral by 2050, and Norway enhanced its nationally determined contribution under the Paris Agreement to reduce emissions by 50% [132].

Enova SF is a Norwegian government enterprise responsible for sustainable energy production and consumption. Its stated purpose is to explore new sources of clean energy, reduce overall energy consumption, and to provide educational materials to the public promoting energy-efficient practices. Established in 2001, it's financed through government funding in addition to a tariff of 1 øre per kWh of electricity to consumers. The company is owned by the Norwegian Ministry of Petroleum and Energy and based in Trondheim [133].

The Hurdal Platform, of the new Labour and Centre Party coalition government announced in October 2021, upgrades the Norwegian GHG emission reduction target from at least 50% by 2030 to 55% and from 90-95% by 2050 to net zero. The new government platform pinpoints that the 55% reduction concerns the entire economy, including sectors in the present EU ETS-system. The Norwegian climate targets are aligned with those of the EU and require Norwegian policymakers to develop and implement measures to accelerate emission reductions accordingly [141]. If Norway followed the EU and moved to a GHG reduction of 55% below 1990 by 2030, its domestic target rating would be compatible with the Paris Agreement's 1.5°C limit when compared to modelled domestic emissions pathways [134]. To reach these goals, the government will implement a strengthened focus on hydrogen-related research and technology development. In many sectors, work is now being done to develop solutions for hydrogen as an energy carrier. Several projects are in the process of testing hydrogen for various energy purposes [135].

The Norwegian Government has put great emphasis on innovation policy, and it seems that the same emphasis will continue. The role of regions is also changing, as moves are underway to give more responsibility to the regional level. As a result of these changes, innovation and regional collaboration were introduced in 2005 as explicit mandates in the Act regulating the Higher Education Institutions (HEIs). The Government has substantially increased funding for industrial research and innovation activities with regional partners. Funding is channelled through the public policy instruments, of which the Research Council of Norway, Innovation Norway, and SIVA (Industrial Development Corporation of Norway) are included. These institutions are present in all Norwegian regions and operate a range of programmes to foster dialogue and cooperation between HEIs and regional stakeholders. Innovation Mid-Norway is a regionalised national innovation support programme, funded by national and regional actors, including RCN, SIVA and the two Trøndelag counties [136].

The Norwegian Government also focuses on digitalisation for a circular economy. Digital solutions make it possible to collect and analyse large amounts of data and make this available for use by business, research, and authorities. Digital product information, for example digital product passports, will increase the effectiveness of a stricter product policy framework. Digital marketplaces, for example for secondary raw materials or for sharing assets, are important for promoting re-use and the use of secondary raw materials. As part of its digitalisation policy, the Government will design national ICT and data policy to promote the green transition and growth in the business sector, and ensure progress towards Norway's climate, environmental and sustainability targets. The Government will support business-sector innovation to develop digital business models and marketplaces for secondary raw materials and secondary materials [137].

3.2.2 Economic

Trondheim's performance shows strong economic performance based on KPIs measuring how the city could improve progress towards the SDGs. Rates of unemployment in general and youth unemployment are extremely low and Trondheim spends 4.6% of its GDP on research and development, and 99.24% of its businesses are small and medium-sized enterprises. Economic development of the city is grounded in good access to well-developed urban infrastructure, including innovation and ICT infrastructures. The provision of and access to the internet is very high and all public sector services of the municipality are available online and easily accessible. The electricity supply is universal and widely monitored using smart electricity metres (98.56% of electricity metres in Trondheim are smart metres). The electricity supply is also very rarely interrupted with 0.7 interruptions per year per customer and each interruption lasting less than an hour on the average. A high amount of low-carbon emission passenger vehicles, a strong bicycle- and car-sharing rate, and a high percentage of people travelling by simply walking are all indicators of sustainable transport practices. Only 0.33% of public buildings have been certified as sustainable [138].

Norway's type of economy is situated between the extremities 'green' and 'red' (i.e., very environmentally unfriendly) and thus rather is a 'yellow economy' according to a 2011 report. On the one hand, a high level of education, a rich natural resource base, generally high environmental standards and resource-efficient production processes plus a number of policy initiatives to encourage a greener economy, provide Norway with strong green credentials. On the other hand, factors such as a dominating petroleum industry, an unsustainable and increasing pressure on natural resources, an unsustainable and increasingly large ecological footprint from consumption and a lack of an overall political plan for a transition to a more ecologically sustainable and low emission society, has the effect that the overall trend is that Norway's economy is on a trajectory making it increasingly less environmentally sustainable. In Norway green industries currently make up a limited share of the economy as such, about 2-4 % of GDP (a level typical for Western countries). We estimate that green industries in Norway (incl. public transportation) in 2008 was behind value creation of NOK 96 billion and employed 89 053 people [139].

In 2018, Norway had no direct goals for increased construction sector circular economy. Norway has, however, adopted requirements in the Building Regulation (TEK) for the preparation of waste plans when building a new building, when buildings are renovated and when buildings are demolished. There is also a requirement for the preparation of an environmental assessment plan prior to demolition to identify and remove hazardous waste separately. Further, it is required that at least 60% of the construction waste is sorted at the site of construction. Sorted combustible waste does not count as a separate fraction and mixed residual waste cannot exceed 40% of the total amount. In exceptional cases acceptance may be given to sort the waste at a sorting plant instead of at the building site. The Federation of Norwegian Construction Industries created the first national Action plan (NHP1) on construction waste in 2001. Then approximately 80% of the construction waste ended at a landfill while in 2018 more than 80% are recycled [140].

Norway has already begun the transition to a circular economy. The business sector has for example worked systematically on the preparation of roadmaps for green competitiveness in various branches (including the process industries, the waste management sector, retail and wholesale trade and the packaging industry). Circular solutions are a key element of these roadmaps. In the 2020 wage settlement, Virke, one of the main employer organisations, and the Norwegian Confederation of Trade Unions agreed to cooperate on workplace efforts to develop a circular economy. Many counties and municipalities are now taking a circular approach to the development of a low-emission society, their own operations and the services they deliver, and using this approach to enhance green competitiveness [137].

In Norway, 2020 GDP was €333 billion, while in 2050 it could rise to €534 billion. This implies a CAGR of 1.6% per year, including the effect of COVID-19. Productivity increases from €62,392 to €83,485 per person in the same period, measured in 2017 purchasing power parity terms. The GDP change for Norway is -0.5% in 2020, and +4.0% in 2021 and 4.1% in 2022. Economic growth will average 1.6% from 2020 to 2050, when the size of the Norwegian economy will be 60% higher than the €333 billion of 2021. Due to significant efficiency gains — largely enabled by accelerated electrification — energy demand growth will eventually track well below economic growth. expectations for Norway to align with best practice emission reduction trajectories are rising. The spotlight will be on how Norway manages to reconcile deep decarbonization with economic pressures associated with transitioning the composition of the Norwegian economy [141].

Norway's most bought car in 2020, the Audi E-tron, has a range of 436 km. Another low-emission solution is hydrogen-electric cars. Hydrogen-electric cars have a longer range and take less time to refuel. There are however fewer car makers to choose from, and the number of commercial filling stations in the entire country is currently only one. However, the fuel cost is higher, and in fact at the same level as the current diesel cars. The costs of battery production are falling, and EVs are getting ever larger battery packs and a longer range [142].

Oil and gas futures prices suggest that oil exports will remain at very high levels also in the years ahead. The consequences are manifold. It is good news for oil investment as it makes new investments on the Norwegian shelf more profitable. Companies have already started planning or initiated new investment projects following the adoption of the petroleum tax relief package in 2020. The high petroleum prices are another incentive for the petroleum companies to bring forward investments. This could add momentum to the Norwegian economic upswing in 2023 [143].

Norway is a leader in the global transition towards an inclusive green economy and is paving a path for nations to reduce climate change and pursue the 2030 Agenda for Sustainable Development. Partnership for Action on Green Economy (PAGE) is supported by

Norway's International Climate and Forest Initiative (NICFI). NIFCI supports several initiatives that create the enabling conditions for green economy and catalyse action to reduce emissions and conserve natural resources, such as the UN-REDD Programme - the United Nations Collaborative Programme on Reducing Emissions from Deforestation and forest Degradation (REDD+) in developing countries. In addition to supporting key initiatives such as NICFI, the Government of Norway has made great strides towards an inclusive green economy with the ratification of the Paris Agreement. Norway's contributions towards PAGE exemplify this commitment to partnership and inclusivity towards sustainable development. The support Norway provides to initiatives like UN-REDD and PAGE enables coordinated action to protect forests and biodiversity, reduce climate change, and achieve the ambitious goals of the Paris Agreement and the 2030 Agenda for Sustainable Development [144].

3.2.3 Social

Trondheim's performance in the society and culture dimension of the Smart Sustainable Cities (SSC) KPIs on how the city could improve progress towards the SDGs is broadly positive. Provision of affordable housing and the education system showed very strong performance. School enrolment is at 100% and all students have access to ICTs. Correspondingly, adult literacy is high at 94.8 percent and the presence of higher education degrees in the population is high. All inhabitants of Trondheim are covered by health insurance and almost all health records are kept electronically. Life expectancy is very high at 81.65 years. Voter participation is high with 65.85 per cent of eligible voters having voted in the most recent elections. The percentage of citizens living in poverty in Trondheim is also high at 5.7. Regarding safety, the city does not experience a high threat from natural disasters as there are only 2.7% of the population living in natural disaster-prone areas [138].

The role of citizens is especially relevant in the Nordic model of sustainable development, which focuses heavily on social inclusion to promote the energy transition amongst other sustainability-related practices and behaviours. The involvement of citizens in the development of PEDs can be seen as one means to foster social innovation in PED development. The Nordic setting presents favourable conditions for exploiting PEDs and other technical solutions for energy transition, in a way that emphasises social dimensions. Social innovation within the Nordic model relates to activities that are social in both needs and ends, such as collaborations between multiple stakeholders in a community that initiate and drive developments to meet new challenges of the future. Furthermore, in the Norwegian context, energy efficient solutions should become the preferred choice for consumers in the future. The National Water and Energy Directorate (NVE) introduced the plus-customer arrangement to enable the rise of prosumers in Norway. The country's clean and renewable energy resources for national demands, technological readiness, and orientation of sustainable development towards social objectives encourages the deeper analysis of the social dimension in PED development [132].

Norway is the most highly developed, happiest, and most democratic country in the world, and it's also one of the greenest: 98% of its electricity comes from renewable sources (almost entirely hydropower). It also has the largest share of electric car use in the world and ranks third among rich countries for its low carbon-intensive economy, behind only Sweden and Switzerland. But Norway's situation presents a paradox for environmentalists, as much of the country's vast wealth has been built on its fossil fuel exports — its Oil Fund is the largest sovereign wealth fund in the world with more than $1 trillion of assets. Some people are uncomfortable about some problematic aspects of the oil sector, but then it's also been one of the main reasons why Norway has one of the best welfare states in the world and people don't want to compromise on that [145].

There will be employment gains and losses in Norway from the transition to net zero GHG emissions. They may not be distributed in the same way across regions. Employment in sectors that may be subject to some job loss by 2040 because of policies to reduce emissions in line with the climate objectives in the Paris Agreement amounts to less than 5% in all Norwegian regions. Most Norwegian regions have more employment in these sectors than the Organisation for Economic Co-operation and Development (OECD) average. Western Norway, Adger, and Rogaland have larger shares, largely driven by transport and other manufacturing. The selection of sectors is broad and based on employment effects simulated across OECD countries [146].

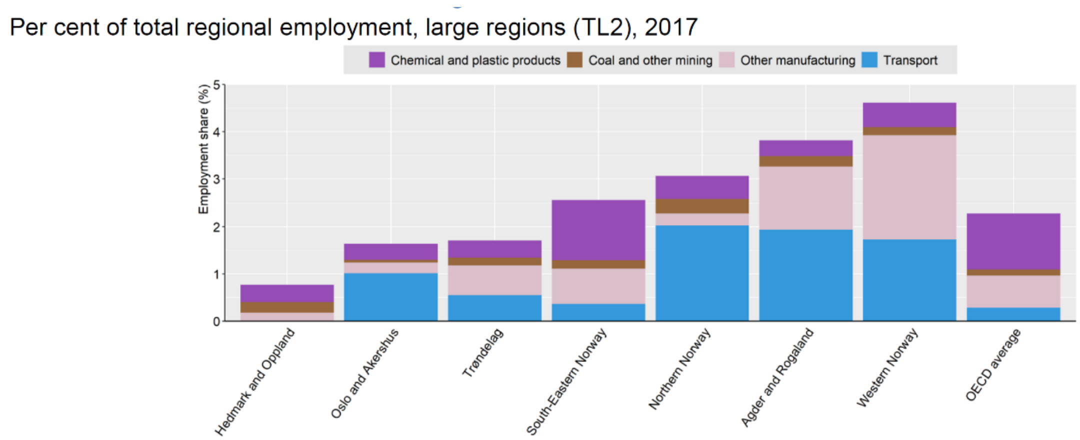

Figure 2. Employment in sectors subject to loss by 2040 with reduced emissions Source: [146]

In 2022, there are 4 284 703 buildings in the Norwegian stock, corresponding to 1 582 747 residential and 2 701 956 non-residential [147]. In the period from the 1990s to 2016, urbanisation in Norway was less pronounced and has happened, at least in major cities, in a context of city densification rather than expansion. This means that new dwellings may be created by down-sizing existing ones, i.e., during renovation work, and therefore part of the increase in the population's need for housing is covered without resourcing to new physical constructions. It is estimated that renovation work on average – per square metre of floor area – costs 72.5% of the cost of building new. Knowing the total investment that nation-wide goes into renovation work one can infer the amount of square metres renovated. Policy measures are needed to reduce the average time between deep renovations of dwellings and increase the deep renovation rate. For Norway, reaching an average renovation rate of about 2.5%

during 2020–2050 means that the average interval between deep renovations should be approximately 30 years. To reach 3% renovation rate by 2030 the average time between deep renovations of a dwelling should be reduced to about 25 years [148].

Norway's population could grow from 5.4 million people in 2021 to 6.4 million in 2050, 3% less than the UN median estimate of 6.6 million. Historically, energy demand has grown in lockstep with population growth and improvements in standards of living. Norway's population growth is slowing down, but still reaches 6.4 million people in 2050. Most onshore wind turbines in Norway are on the southwest, west and north shores. Favourable wind conditions exceeding 1000 W/m² wind speed density in some locations, proximity to the grid, and large areas with relatively sparse population makes the Norwegian west coast advantageous for wind developments. However, future onshore installations are likely to be delayed and/or scaled down by public concerns like noise, impact on birds, recreation and a desire to preserve untouched landscape and wilderness [141].

Some of the top global sustainability issues confronting Norwegian companies today are climate change and oil-price volatility. These challenges encouraged Innovation Norway - the Norwegian government's mechanism for developing enterprises and industries - to work more closely with companies to stimulate innovations that promote sustainable technologies globally in areas such as energy, renewables, environment and health. Setting up offshore wind and wastewater technology business clusters in Beijing, Innovation Norway has helped small Norwegian companies expand seamlessly across Asia by collaborating effectively with counterparts in China. With the Chinese government's marked commitment to fighting corruption and pollution, Innovation Norway sees China as a crucial market for Norwegian green technology services particularly in the maritime and offshore sectors, and environmental technologies [149].

Various public agencies provide funding along the Norwegian green innovation chain. Innovation Norway, the Research Council, Investinor, Enova, Norfund, GIEK and Export Credit Norway are a number of the institutions that provide funding in various segments. The Environmental Technology Scheme (Miljøteknologiordningen) is a green technology programme targeted at firms that 'help solve environmental problems' and Nysnø Climate Investments is a new state-owned investment company with the mission of reducing emissions through profitable investments in partnership with the private sector. However, as mentioned above, there is a lack of coordination between these public institutions supporting green industries. Excessive fragmentation of institutional and financial support measures is a serious impediment to the successful implementation of a mission-oriented approach to innovation and green growth [150].

3.2.4 Technological

As of 2021 Norway had three PED projects encompassing 12 PED demo sites in planning and early implementation stages. While all PED projects in the respective demo sites are aiming to become positive energy, either on an annual basis or over their lifetime, for each of the demo sites, an individual approach towards the PED concept, in general, and the energy system, specifically, is chosen, building on, e.g., reducing energy demand, energy flexibility and renewable energy production. To summarise the review of demo sites, great variation was found between the types of projects, size and planned construction covering both existing areas and new buildings with multiple functions. The areas for PED development range from 12,750 square metres of a residential site to 3,400,000 square metres of multi-functional city quarters [132]. In 2020, Norway had the highest number of PED (and towards PED) projects benchmarked. An example is represented by the ZEN Research Centre; nine pilot projects were spread over Norway with the aim of developing zero emission neighbourhoods. ZEN has public and industrial partners to guarantee a multidisciplinary approach that combines various stakeholders [151].

+CityxChange's automated local energy market trading solution pilot is in Trondheim, demonstrating tools to support the generation and trading of renewable energy by a connected community within a city. +CityxChange has published Deliverable 2.7 "Local DPEB trading market demonstration tool"[2] that discusses a demonstration tool for a local distributed positive energy block (DPEB) trading market. A DPEB is a group of three or more connected neighbouring buildings that generate more primary energy in a year than what they use. The report describes the design of a local energy market and trading platform which is developed for the purpose of large-scale operation of the local market [152].

Construction of the new National Museum in Oslo opened in 2021, it's the largest cultural centre in the Nordic region. A zero-energy building, it will be heated by water from the Oslo Fjord, among other renewable sources. The wave of new energy-positive buildings is led in good part by the Powerhouse collaboration: a network of leading actors in the Norwegian construction industry who are joining forces to fashion buildings that have a positive environmental footprint. Nordic Smart House has developed inexpensive, modular energy-efficient buildings that can help to cut emissions while housing the swelling urban population and Spacemaker AI to help real estate developers and architects to work together to create smart and sustainable urban spaces [153].

Norway is considered a world leader in the use of green technologies, renewable energy, and sustainable resource handling. Norway has accepted several international commitments to reduce emissions and is committed to match or exceed EUs ambitions on emissions and environmental standards. Emissions of carbon dioxide have proven to be a challenge for Norway, given its role as a significant exporter of oil and gas, as the production itself is carbon intensive. The rest of the society is already running on clean hydro power, so there are few low-hanging fruits for further reduction. The exception is the transportation sector, where Norway has taken a considerable lead [154]. Norway is one of the biggest investors in EVs, with 58% of all new cars sold in 2019 being fully electric. The Norwegians have a different solution

[2] https://cityxchange.eu/knowledge-base/d2-7-local-dpeb-trading-market-demonstration-tool/

to simplifying EV charging points and meeting the country's growing demand for EVs. The capital city of Oslo is set to be the first metropolitan area to introduce wireless charging for electric taxis, which will allow them to charge while they wait in a taxi rank. The technology uses electrical induction – like that used for wireless phone charging. The scheme is part of efforts to make Norway's taxi service zero-emission by 2023 [155].

Norway has one of the most decarbonized power sectors in Europe due to its renewable resources, primarily hydropower. These resources are an important part of the Nordic power market, helping to balance supply and demand efficiently and economically across the region. Construction of additional power lines to Germany and the UK will expand Norway's role as a key supplier of low-carbon electricity in Europe and, perhaps more importantly, provide increased system flexibility for the European internal electricity market – a vital element of a renewable energy-dominated power sector. However, system flexibility can come from different sources, for example an increase in the use of EVs will lead to lower battery production costs and the possibility of vehicle-to-grid balancing, both of which can change the economic value of interconnectors [156].

The potential to store hydro energy in Norway is high since the country has numerous and large reservoirs with significant head. In 2016 Norway had nearly 50% of the total reservoir capacity in Europe, about 85 TWh. Because of this the European Network of Transmission System Operator for Electricity (ENTSO-E) has asked Norway and Statnett (Norwegian transmission system operator) to verify the potential of building 14 000 MW pumped storage plant (PSP) in Norway. Study by SINTEF has calculated that the technical potential of balancing power in Norway is at least 20 000 MW by 2030. However, the economic uncertainty is high and today only a few PSP exist in Norway [014]. Norway has 32 GW installed capacity in the hydropower system and 85 TWh reservoir storage, providing 97% of its own electricity supply. It is possible to develop additional 20 GW of new capacity in the Norwegian hydropower without construction of additional reservoirs [157].

The Research Council of Norway (RCN) investigates Norwegian hydropower's potential in terms of the feasibility and consequences of balancing it with the European energy system, both from the technological and economic point of view. Energi21 is the Norwegian national strategy for research, development, demonstration and commercialisation of new energy technology. The recent update of this strategy highlights the role of integrated energy systems, including interconnectors with the EU. The Large-Scale Power Exchange project is one of the first projects, which also focused on hydropower capabilities for flexibility from existing Norwegian hydropower. Norway's hydropower capacity could be increased by 20 GW via upgrading existing hydropower plants and construction of new pumped-storage plants between existing reservoirs, following current regulation and concession requirements. However, the previous research projects did not include aspects like the political feasibility or environmental and societal consequences [158].

The Explorer is the official marketplace for sustainable technology from Norway. It connects international needs with Norwegian solutions. The Explorer is part of Innovation Norway's efforts to promote Norway as a sustainability pioneer. It was developed in 2018 in close collaboration with leading Norwegian businesses, organisations, and government bodies, and has a formal partnership with UN Global Compact. Innovation Norway is the Norwegian government body responsible for value creation, innovation and growth for Norwegian start-ups and established companies. Norway wants to take an active role in helping the world to achieve the SDGs. All solutions on The Explorer are linked to specific SDGs and none have a negative socio-environmental impact. Solutions on The Explorer are offered across a spectrum of industries, from green shipping, clean energy, and smart cities to health tech, EdTech and food production [159]. Norwegian providers have been vetted based on strict criteria, and over 250 providers of green technology are accessible [160].

Green Business Norway acts in the Environmental Energy & Technology sector. Their role is to contribute to innovation, cooperation, and project development on behalf of the members of our organisation. Their vision is to become Norway's leading authority in the field of Environmental Energy & Technology. Green Business Norway has its own set of rules and regulations and is led by a Main Board, elected each year at the General Assembly. The running costs are financed by membership subscriptions and contributions [161].

3.2.5 Environmental

Trondheim is committed to addressing climate change and improving its environmental conditions based on a very positive outlook on its performance against the KPIs for SSC in the areas of environmental quality and energy. The air quality and access to public space and nature are both very good. The contribution of Trondheim to GHG emissions is particularly low at 2.46 tonnes CO2/capita (lower than Helsinki at 7.4 tonnes/capita, Paris at 7.7 tonnes/capita, and Berlin at 10.4 tonnes/capita). The percentage of the population with convenient access to a green area is 98.7, and 40% of the city constitutes a protected natural area. The city has no problem with electromagnetic field (EMF) exposure; however, the percentage of city inhabitants exposed to excessive noise levels is slightly high at 44.9. On energy use and waste management, electricity consumption is high (13,424 kWh per year per capita). However, 100% of that electricity comes from renewable sources [138].

One of the world's most environment-friendly buildings is in Brattørkaia, Trondheim, Norway's third largest city. Designed by the internationally renowned architecture and design firm Snøhetta, the brand-new Powerhouse Brattørkaia is an energy-positive office building. That means a building that will produce more energy than was used during its entire life cycle, from production of building materials to construction, operation, and demolition. In fact, it generates twice as much electricity as it uses, and has received a special permit for a microgrid to distribute electricity to neighbouring buildings, electric buses, cars, and boats, as well as to the national grid. And it is not the only one of its kind in Norway. A wave of new energy-positive buildings is led in good part by the Powerhouse collaboration: a network of actors in the

Norwegian construction industry joining forces to fashion buildings with a positive environmental footprint. By transforming buildings from a carbon source to a carbon sink, Powerhouse shows the path the construction industry should take if the world is to limit global warming to 1.5 °C [162]. Powerhouse Brattørkaia is the world's northernmost energy-positive building, and it is setting an example worldwide [163].

For decades Norway has led the charge towards renewable energy. In fact, since the late 1800s, the Norwegians have harvested energy from the many rivers that cascade into its fjords. The nation now sources most of their electrical energy from water, and hydro-electric power stations dot the dramatic Norwegian landscape. Norway's drive towards a cleaner, greener, more symbiotic relationship with Mother Nature is accelerating – and diversifying. While currently around 97% of Norway's energy already comes from hydropower, the government is ambitiously pushing its population to make that last 3% a reality [164].

In Norway, 98% of the electricity production comes from renewable energy sources. Electricity production in Norway is for the most part based on flexible hydropower, but both wind and thermal energy contribute to the Norwegian electricity production. In 2013, Norway produced 134-terawatt hours (TWh) of electricity. By comparison, the Norwegian capital, Oslo, consumes around nine TWh each year. In the last decade, wind power has increasingly become a part of Norwegian power production. For now, wind is still only a small part of the total output, but the number of wind turbines increases year on year [165]. In 2012 Norway was the main exporter of natural gas to the EU. By changing the price setting mechanism to gas-on-gas basis, Norway retained consumers and in 2012 increased market share to the detriment of other exporters [102].

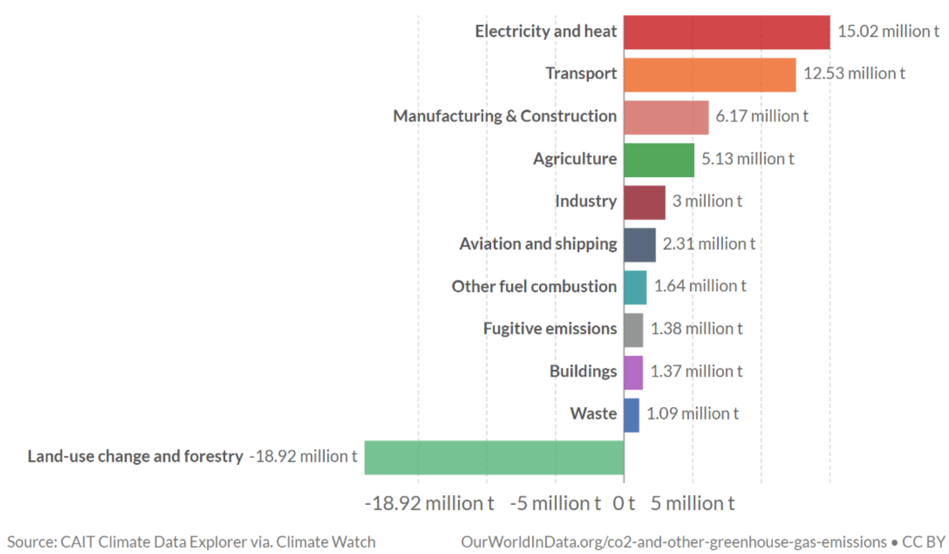

Figure 3. Greenhouse gas emissions by sector, Norway, 2018 measured in tonnes of CO2-equivalents (CO_2e) [166]

Fossil CO2 emissions in Norway were 43,456,012 tons in 2016. CO2 emissions increased by 0.85% over the previous year, representing an increase by 364,737 tons over 2015, when CO2 emissions were 43,091,275 tons. CO2 emissions per capita in Norway are equivalent to 8.28

tons per person (based on a population of 5,250,949 in 2016), a decrease by -0.01 over the figure of 8.29 CO2 tons per person registered in 2015; this represents a change of -0.1% in CO2 emissions per capita [167]. Norway produced 31.7 million metric tons of CO2 (MtCO2) emissions in 2020, a year-on-year reduction of nearly 6%, but an increase of more than 9% compared to 1990 levels. CO2 emissions in Norway peaked at 37.7 MtCO2 in 2004 [168].

Norway's GHG emissions profile is unusual in several ways. Using data from 2012, the country is a very large producer and exporter of fossil fuels, but also produces some 98% of its electricity from renewable sources, mostly large-scale hydro. Extensive use of electricity for space heating and industrial processes means the energy intensity of the Norwegian economy does not translate into particularly high CO2 emissions per GDP. GHG emissions are above the 1990 level but grew at a slower pace than GDP [169].

Direct GHG emissions from construction and buildings in Norway are low, but the sector generates large indirect emissions, for example with construction products. It also generates large quantities of waste. The most important way of increasing circularity in the sector is to maintain buildings and other structures and lengthen their lifetime. A larger proportion of building materials should also be returned to the cycle for re-use. The Government is preparing better guidance on the re-use of building materials and is considering changes to national requirements so that they do more to promote re-use. The Government has also taken the initiative for cooperation with the construction and buildings sector on digitalisation and better ways of distributing product data, for example for construction products with a high potential for reuse [137].

3.2.6 Legal

There is no specific regulation for PEDs in Norway, but the policy framework consists of different laws and regulations, guiding principles, white papers and standards which influence the implementation of PEDs. Prominent amongst these are EU directives with relevance to the EEA (including Norway): The EPBD and EE Directive (EED). Through these, which have yet to be completely transposed and adopted in Norway, progressively stricter efficiency requirements are being put into force. For the energy sector, national laws require the development of energy and climate plans at municipal level [132]. An overview of national regulations that influence market based operation of PEB, is provided in Deliverable 2.1 "Report on Enabling Regulatory Mechanism to Trial Innovation in Cities"[3], which also contains an analysis of the Identified demands for regulatory exemptions to implement and execute PEB/PEDs. Regulatory barriers and their consequences for the Trondheim case are described in Deliverable 5.9 "Playbook of regulatory recommendations for enabling new energy systems"[4], together with a process on how to overcome regulation obstacles.

[3] https://cityxchange.eu/knowledge-base/report-on-enabling-regulatory-mechanism-to-trial-innovation-in-cities/

[4] https://cityxchange.eu/knowledge-base/d5-9-playbook-of-regulatory-recommendations-for-enabling-new-energy-systems/

Cars were banned from central Oslo from 2019 to help reduce pollution, in what was the first comprehensive and permanent ban for a European capital. The city council, made up of the Labour Party, the Greens, and the Socialist Left, built at least 60 kilometres of bicycle lanes by 2019 under the plans to provide a “massive boost” of investment in public transport. Buses and trams continue to serve the city centre, and arrangements were found for cars carrying disabled people and vehicles transporting goods to stores. Oslo has around 600,000 inhabitants and almost 350,000 cars in the whole city. Most car owners live outside the city centre but within Oslo’s boundaries [170].

Norway has some of the strictest technical construction requirements in Europe. The Planning and Building Act of 2008 and the Pollution Act of 1981, together with various regulations, contain provisions which aim to protect the environment and breaches can be criminally liable. Protection of the environment is also constitutional. These provisions contain requirements for buildings/construction projects and for products used in buildings/construction projects. The aim is to reduce pollution during the building phase and during the building's lifetime. Requirements are set regarding the energy consumption and the environmental impact of the building materials used, the completed building's indoor environment, energy used during its lifetime and the external environmental impact [171].

The main sources of law that regulate contracts for building design or carrying out of building works are the standard documents agreed and developed by contractors and builders in collaboration. Different standard documents apply depending on the type of work being undertaken. The NS 8405 is designed for a contractual relationship in which one party (contractor) agrees to undertake building or civil engineering work for another party (client), where most of the drawings, descriptions and calculations are to be provided by the client. NS 8407, though, is a classic procurement and construction document [172].

Most construction work in Norway requires a specific permission from the relevant building authorities before the work can be started. Smaller projects are often exempt from the duty to obtain a specific permission although they must still be carried out legally and in accordance with the Planning and Building Act, derivative regulations, and the applicable zoning plan. For larger building projects the building permission is normally obtained in two stages. First, an application needs to be made for a general permission before an application for a project start-up permission can be made (which provides the right to begin the work). The next stage following the granting of the general permission is the project start-up permission. Before a project start-up permission is granted, the building authorities must also approve the developer's co-workers responsible for the sections of the work [173].

Norway’s energy legislation intends to ensure that different interests are considered, and that projects are subject to government control and conditions that safeguard different interests. Another important objective is to ensure effective management of resources. Security of energy supply and a well-functioning power market are key considerations, establishing a Norwegian market for electricity certificates, linked to the Swedish electricity certificate market of 2012. The electricity certificate market is a constructed market in the sense that the demand for certificates arises from a statutory purchase obligation [174].

The Energy Act, N° 50 of 1990 is a Norwegian law with provisions for EE. It also covers the generation, conversion, transmission, trading, distribution, and use of energy in Norway. It regulates exports and imports, the licensing, metering and settlements of power trading, energy pricing, and responsibilities for energy system operations, rationing and supply quality. It establishes the role of the Power Supply Preparedness Organisation in controlling power supplies in states of emergency, as well as taking on some responsibilities during peacetime. It confirms the government's decision authority on the protection of power supply installations against damage, and to set forth related contingency measures [175].

Commission regulations ("binding guidelines") are detailed technical rules in Norway that contribute to the power market and power system operations in a coordinated manner between countries. These Commission regulations apply in Norway in the same way as other regulations adopted based on the Energy Act. The Commission regulations and the amendments to the Energy Act entered into force in Norwegian law in 2021 [176].

The Norwegian Water Resources and Energy Directorate (NVE) holds the managing responsibility according to the Energy Act and the Water Resources Act. Furthermore, NVE is assisting the Ministry of Petroleum and Energy managing the Industrial Licensing Act and the Act Relating to Regulations of Watercourses. NVE has the legislative power to issue regulations and to make individual decisions and perform preparatory procedures of cases to be resolved by the Ministry of Petroleum and Energy. A collection of (not legally binding) translations initiated by the Ministry of Petroleum and Energy and NVE are unofficial but aim to provide any interested party with information about the Norwegian legal framework [177].

4 Feasibility assessment of replication in Follower Cities

Chapter 4 presents the feasibility assessment for the four market sectors as defined in Chapter 2, Urban Digital Twin, Local Energy Systems, e-Mobility, and Renewable Energy Sources. The purpose of this assessment is to identify which of the market sectors has the most favourable conditions in the target countries. The following methodology has been used:

1. The scope of the assessment is based on the secondary target markets for the short-term replication of the +CityxChange solutions, in line with +CityxChange's replication strategy of LHCs and FCs. As a result, the five Follower Countries, Bulgaria, Czech-Republic, Estonia, Romania, and Spain, have been selected for the assessment.
2. For each of the target market sectors, a set of evaluation criteria has been defined. The criteria have been defined by expert-analysis after desk research of the sectors involved.
3. Each target country has been indicated as Green, Yellow or Red with respect to the individual evaluation criteria and has been assigned preliminary scores of 1, 0.75 and 0.5 for Green, Yellow or Red. These traffic light indicators can be found in Annex 1.
4. Expert-analysis has applied a weighted scoring to each of the criteria based on the relevance to each market segment and attaining a collective score. The group of criteria which is more relevant is given with higher scores assigned to criteria assumed to be more critical to the success of the sector and lower scores assigned to criteria that are assumed to be less critical to the success of the sector.
5. A relative comparison of the countries has been conducted. The resulting sector and subsequent country score is the sum of each individual criteria multiplied by the weights of that criterion. From the resulting data, conclusions have been drawn about the relative favorability of the market segments in the target countries.

Since multiple categories criteria are considered, the methodology aims at comparing the relative market feasibility of only the chosen sectors in the chosen countries. Therefore, the assumptions derived utilise empirical evidence to objectively determine which countries are the most or least favourable for immediate deployment of solutions within the sector in question. There is no target score which makes a country considered to be favourable, the final scores are arbitrary in the sense that they simply show the comparison between the assessed countries within the aforementioned assessment methodology

The following section presents the results of the feasibility assessment for the four market sectors in the five target countries. An overview of the datasets used for the analysis is listed in Annex 1.

4.1 Urban digital twin

Assessment rationale and criteria

Four criteria were chosen for analysing the feasibility of digital twins for urban planning. The technological maturity is assigned a higher weighted score, followed by policies adopted by governments focused on digitisation. The criteria ``C3-Technological adoption" is kept separate from criteria ``C1-Technology '', as the former is based on a survey by the ECSO (European construction sector observatory) (Annex 1, [UDT-2]). It is considered relevant as it gives overview of know-how or extent of which digital technologies are used in the countries accessed.

Table 2. Criteria for urban digital twin

Criteria	Description	Weight
C1 - Technology	To access the technological maturity of digital transformation	3
C2 - Policies	The government's policies towards the adoption of digital transformation	2.5
C3 - Technology Adoption	To access the extent to which the digital technologies are currently used	2
C4 - Market status	To access current trends construction sector that will indirectly related to future digital transformation	1.5

The following table contains various criteria and related datasets along with the weighted scores assigned.

Table 3. Criteria and related datasets along with the weighted scores for urban digital twin

Criteria	Datasets	Ref year	Weight
Technology	BIM maturity level	2020	3
	Digital Innovation Hubs and Digital Innovation Hubs contribution to digital transformation in Construction sector	2020	3
	Enterprises having medium/high intensity of green action through ICT (% of enterprises),	2021	3
Policies	Overview of energy efficiency policy initiatives by country - Fiscal, Financing measures, Non regulatory, strategy	2018	2.5

	The policy measures related to skills in construction are tackling broad trainings, apprenticeships and VET, digitalisation and energy efficiency skills, image of the sector or mobility of workers	2020	2.5
	Policy or measure in place to support BIM adoption, beyond public procurement (BIM/Digital Construction Strategy, BIM Standards and/or guidance, National working group on BIM)	2020	2.5
	The policy measures related to skills in construction are tackling broad trainings, apprenticeships and VET, digitalisation and energy efficiency skills, image of the sector or mobility of workers	2020	2.5
Technology Adoption	Extent of Building Information Modelling (BIM) adoption	2020	2
	Utilisation of Digital Twins	2020	2
	Disruptive technologies for digital twin adoption - Sensors, Extent of IoT, 3D scanner and drones' adoption	2020	2
Market status	Future employment growth in construction sector across Member States in 2018-2030, %	2019	1.5
	Renovation spending as % of disposable income, EU-28, 2016 (%)	2016	1.5

Results

Estonia is seemingly most favourable follower country closely followed by Spain

Table 4. Results of feasibility study for urban digital twin

Criteria	Bulgaria	Czech Republic	Estonia	Romania	Spain
C1 - Technology	2.25	5.25	6.75	4.5	8.25
C2 - Policies	5	4.375	5.625	5	6.25
C3 - Technology Adoption	2	3.5	6	3.5	3
C4 – Market status	2.25	2.25	1.875	2.25	2.625
Total	**11.5**	**15.375**	**20.875**	**15.25**	**20.75**

4.2 Local energy systems

Assessment rationale and criteria

The following table summarises the 5 different criteria that has been chosen for analysing market feasibility of Local energy systems. The current issues pertaining in the electricity market are weighed more as they act as a bottleneck for smooth transition to renewables. The measures ensuring network stability is also key owing to the need for resource adequacy and government policies to address capacity mechanism and Interruptibility.

Table 5. Criteria for local energy markets

Criteria	Description	Weight
C1 - Barriers	Access the current barriers preventing the entry of new entrants or smaller players into electricity markets.	3
C2 - Network stability	Access the existing measures ensuring network stability i.e. increasing share of variable renewable energy sources – such as wind and solar – in the electricity mix, leads to a growing need for backup generation capacity. [1]	2.5
C3 - Policies	The government's policies & programs helps in overcoming existing barriers	2
C4 - Environmental	Access the current environmental impact related to electricity generation.	2
C5 - Market status	To access the current statistics related to electricity generation and transmissions.	1.5

The following table contains various criteria sand related datasets along with the weighted scores assigned

Table 6. Criteria and related datasets along with the weighted scores for local energy markets

Criteria	Datasets	Ref year	Weight
Barriers	Restrictive requirements in pre-qualification or the design of products for balancing	2020	3
	Lack of a proper legal framework to enable new entrants and small players	2020	3
	Limited competitive pressure in retail markets	2020	3

	Limited incentive to contract dynamic retail prices	2020	3
Network stability	Interruptibility schemes in Europe	2020	2.5
	Capacity mechanism for electricity - Availability	2020	2.5
	Percentage of time when the 70% min. target is met (%)	2020	2.5
	Day Ahead (DA) price spikes across Europe	2020	2.5
Policies	Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) (%)		2
	National target/contribution for renewable energy: Share of energy from renewable sources in gross final consumption of energy (%)		2
	Level of electricity interconnectivity (%)		2
Environmental	Total emissions of electricity generation	2020	2
	Average emission intensity	2020	2
Market status	Share for transmission and distribution in the network cost for gas and electricity	2020	1.5
	Market share of the largest generator in the electricity market	2020\2021	1.5

Results

Spain is seemingly the most favourable follower country based on the assessment. Romania and Czech Republic came second and third respectively

Table 7. Results of the feasibility assessment for local energy markets

Criteria	Bulgaria	Czech Republic	Estonia	Romania	Spain
C1 - Barriers	1.5	6	9.75	7.5	9.75
C2 - Network stability	5	4.375	1.25	3.125	7.5
C3 - Policies	3	4	5.5	3.5	5
C4 - Environmental	3	2.5	3	3	3
C5 - Market status	1.125	2.25	1.5	2.625	1.875

Total	**13.625**	**19.125**	**21**	**19.75**	**27.125**

4.3 E-Mobility

Assessment rationale and criteria

The following table summarises the 4 different criteria that have been chosen for analysing market feasibility of the e-mobility sector. This quantitative assessment is to understand e-mobility sector maturity in 5 follower countries.

Table 8. Criteria for e-mobility

Criteria	Description	Weighted score
C1 - Infrastructure	The infrastructure availability is key for widespread adoption e-mobility	3
C2 - Policies	The government policies, tax benefits, subsidies and other incentives are key for stimulating the e-mobility sector	2.5
C3 -Environmental	To access the current environmental footprint of passenger car fleets.	2
C4 - Market status	To access the sales of passenger car sales in past years and thus discerning customer trends towards EV adoption	1.5

The following table furnishes a detailed list of datasets, reference year and the weighted score that has been identified for each criterion.

Table 9. Criteria and related datasets along with the weighted scores for e-mobility

Criteria	Datasets	Ref. year	Weighted score
Infrastructure	Charging stations	2020	3
	Fast Charging stations	2020	3
	Charging points per 100km of road	2020	3
Policies	CO_2 based vehicle taxation	2019	2.5
	Charging points and national policy frameworks (NPFS) 2020 targets	2020	2.5
	Electric vehicles: Purchase incentives or tax benefits	2019	2.5

Environmental	Average age of the EU vehicle fleet by country, in years	2020	2
	CO_2 emissions of new cars by country in g CO_2/km	2020	2
Market status	Share Passenger cars (Battery electric, Plug-in hybrid) in the total fleet	2020	1.5
	Passenger cars sales (Battery electric, Plug-in hybrid) to total car sales	2020	1.5
	Motorisation rates in the EU vehicles per 1,000 inhabitants	2019	1.5

Results

Based on the assessment, Spain is deemed the most favourable follower country outscoring other follower cities in all 4 criterias.

Table 10. Results of the feasibility assessment of e-mobility

Criteria	Bulgaria	Czech Republic	Estonia	Romania	Spain
C1 - Infrastructure	5.25	6.75	5.25	6	9
C2 - Policies	6.25	6.875	5	5	7.5
C3 -Environmental	1	2.5	3.5	2.5	3.5
C4 - Market status	3.75	2.625	2.625	3.375	3.375
Total	**16.25**	**18.75**	**16.375**	**16.875**	**23.375**

4.4 Renewable energy sources

Assessment rationale and criteria

The following table summarises the 3 different criteria that has been chosen for analysing market feasibility of the renewable energy sector. This quantitative assessment is to understand renewable energy sector maturity in the five follower countries.

Table 11. Criteria for renewable energy sources

Criteria	Description	Weighted score
C1 - Policies	The government policies and long-term strategies are instrumental wider adoption of renewables and thus reduction in GHG emissions	3

C2 -Environmental	To access the current GHG emission trends and reduction potential	2
C3 - Market status	To access progress made in sustainable energy consumption and production	1.5

The following table furnishes a detailed list of datasets, reference year and the weighted score that has been identified for each criterion.

Table 12. Criteria and related datasets along with the weighted scores for renewable energy sources

Criteria	Datasets	Ref year	Weighted score
Policies	Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) (%)		3
	National target/contribution for renewable energy: Share of energy from renewable sources in gross final consumption of energy (%)		3
	Level of electricity interconnectivity (%)		3
	Share of environmental taxes in total tax revenues		3
Environmental	GHG emissions intensity of energy consumption (Index 2000 = 100)	2020	2
	Air-source heat pump CO2 emissions reductions by country relative to the most efficient condensing gas boilers	2020	2
Market status - Consumption	Primary energy consumption	2020	1.5
	Final energy consumption	2020	1.5
	Final energy consumption in households per capita (kgoe)	2020	1.5
Market status - Production	Energy productivity (€\kgoe)	2020	1.5
	Share of renewable energy in gross final energy consumption (% of gross final energy consumption)	2020	1.5
	Energy import dependency (% of imports in total gross available energy)	2020	1.5
Market status - Social	People unable to keep home adequately warm (% population)	2020	1.5

Results

Based on the assessment, Spain is deemed the most favourable follower country, closely followed by Estonia.

Table 13. Results of the feasibility assessment of renewable energy sources

Criteria	Bulgaria	Czech Republic	Estonia	Romania	Spain
C1 - Policies	7.5	8.25	10.5	7.5	9
C2 -Environmental	2.5	3.5	2	3.5	3.5
C3 - Market status	7.125	6.75	7.875	7.5	9
Total	**17.125**	**18.5**	**20.375**	**18.5**	**21.5**

5 Analysis of the +CityxChange solutions value chain stakeholders

This chapter presents the analysis of PEB stakeholders involved in the set-up, deployment and operation of the +CityxChange solutions which combined result in an operational PEB/PED. The power vs. interest matrix visualisation tool (Mendelow, 1991) is used to map the stakeholders and then describes the roles of each profile segment.

Table 14. Classification of different stakeholder types with associated strategies for engagement

Level of importance	Category & classification	Strategy to maximise their interest and involvement
Primary stakeholders	1. Drivers: High influence & high Interest	• Focus effort on this group • Engage and consult regularly • Involve in governance
	2. Blockers: High influence & less interest	• Engage and consult in their interest area • Try to increase level of interest • Aim to move into Drivers
Secondary stakeholders	3. Supporters: Less influence & high interest	• Make use of interest through involvement in low-risk areas • Keep informed and consult on interest areas • Potential ambassador
	4. Bystanders: Low influence & low interest	• Inform via general communications • Aim to move into group 3

Actors are condensed into the main relevant categories. Actors in an operational local energy market have been categorised according to the categories as presented in D2.4 "Report on Bankability of the Demonstrated Innovations" who identified four types of actors, being Customer, Producer, System Operator and Market Operator. Since this model only covers actors involved in the operation of a PED, the model has been extended with a second set of actors consisting of those stakeholders who are involved in the initiating and set-up of a PED. Partly these are the same actors but their role changes during the PED lifecycle.

Actors involved in the initiation and setting up of a PEB have been extracted from Deliverable 6.4 "Technical feasibility study of the potential PEB replications in each FC for +CityxChange project" and clustered into the following five main categories: Orchestrator, Designer, Technology Provider, Regulator and Financer.

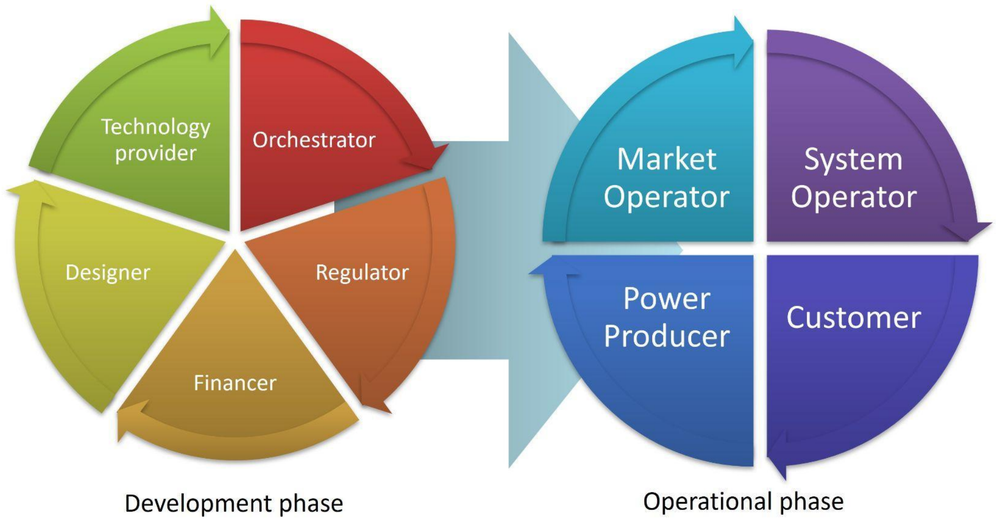

Figure 4. Basic roles during the development and operational phases of a PED (expanded from [Deliverable 2.4](https://cityxchange.eu/knowledge-base/report-on-bankability-of-the-demonstrated-innovations/))[5]

Each of the categories is assigned to a class, according to Figure 2.

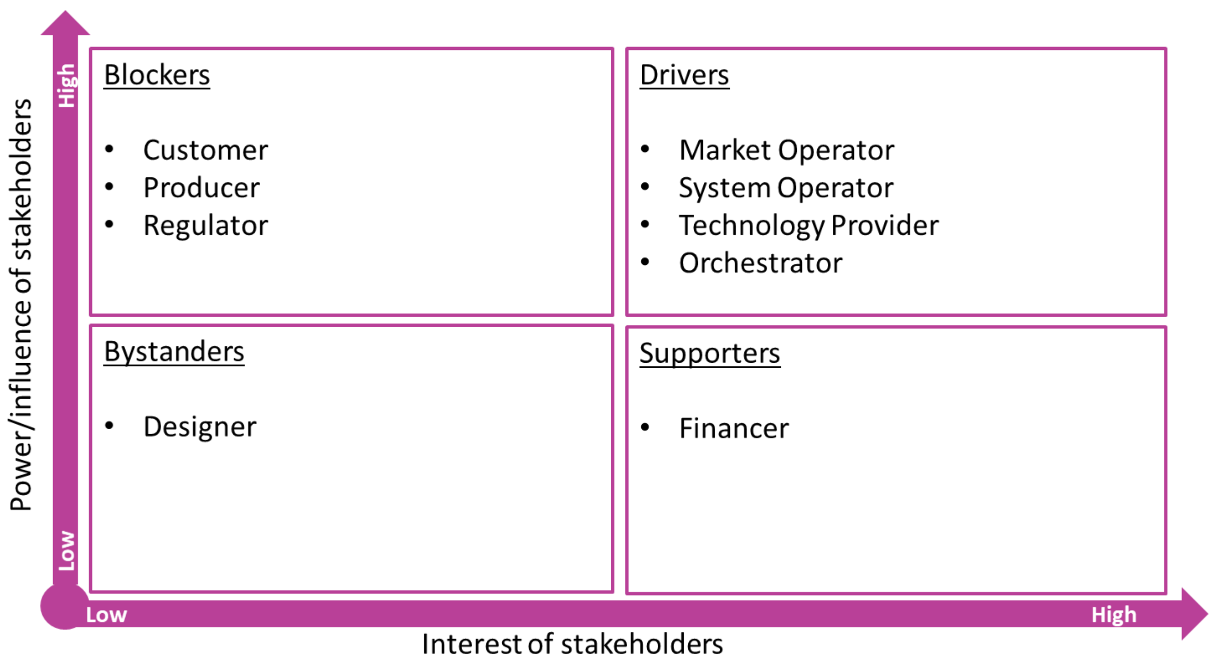

Figure 5 - Classification of different relevant stakeholders in the power vs interest chart

The following sections highlight the needs, challenges, barriers and benefits of each of the listed actors with respect to the successful diffusion of PEBs in cities.

[5] https://cityxchange.eu/knowledge-base/report-on-bankability-of-the-demonstrated-innovations/

5.1 Primary stakeholders

Primary stakeholders are those that have high influence and power with respect to PEBs. They include city management, TSO/DSO/CSO, aggregator, e-mobility providers, building owner/manager, and policymakers. Table 2 summarises the relevance, needs and benefits for each primary stakeholder that is then discussed in further detail in the remainder of chapter 5.1.

Table 15. List of primary stakeholders with associated relevance, needs and challenges, and benefits with respect to PEBs.

Category	Actors	Role	Needs and challenges
Customer	Building owner / tenant DSO Energy supplier Aggregator e-MaaS provider BESS company	Purchases goods and services traded on the local energy market	Needs affordable energy
Producer	Prosumer Energy Cooperative Real Estate firm e-MaaS provider BESS company Aggregator	Offers products and services to the local energy market	Use assets to generate revenues
System Operator	DSO CSO Energy Cooperative Dedicated company	Managers of energy fluxes and grid stability	Needs ICT infrastructure and forecasting Challenge is to minimise imbalances
Market Operator	Energy Cooperative Dedicated company	Provide access to local energy market Operates the local market both for internal trade and for trade with the global market.	Challenge is to provide fair returns for all participants
Orchestrator	City management Energy Cooperative ESCO	Initiate and coordinate the set-up of a PEB	Challenge is to adopt an open innovation way of working
Technology Provider	Technology provider Installer Refurbishment company	Technology enabler Visibility and control of assets	Needs interoperability with surrounding systems

	Construction company		
Regulator	Policy Maker Energy auditor	Align between local and national energy strategies and other policies. Granting non-discriminating access to the energy markets to all users	

5.1.1 Customer

Customers are those actors that purchase energy or flexibility from other participants in the PEB. Examples are DSOs that obtain energy flexibility and capacity, eMaaS providers that purchase locally generated energy for charging their electric vehicles or aggregators that aggregate flexibility from other participants. One of the key actors in this category are the building owner and the building manager. It is likely that the owner of a (block of) building(s) will consist of multiple persons like a board of directors or some other organisational structure. The owner is the one that decides to invest or not in energy efficiency and building smartification measures and does so on the basis of several considerations that may differ per situation (e.g. the state/quality of the building, costs, benefits, energy prices, policies). It is likely that building owners do not make investment decisions on their own but instead they will be advised by and discuss with building managers, consultants and other relevant stakeholders.
Building managers are responsible for the daily management of buildings and we can distinguish several types that are likely to be present in a (block of) building(s) for instance facility-, building-, energy -, and property managers. These different building managers may fulfil different roles and they may differ in terms of needs, responsibilities and mandates.

Some of the needs and challenges building owners and managers have are:

- A lack of interest and need to connect
- Perceived complexity of the system and expertise required. Different building types have different flexibility based on the structure and equipment they have, the occupant's profiles and the services offered. For example, a university may only require energy during daytime since the buildings are barely used during nights and may also remain empty during certain periods of the year while it is likely that a hospital needs energy and a healthy and stable indoor climate continuously.
- Uncertainty on future energy prices and regulations. Investment decisions are, amongst other indicators, based on pay-back times and are difficult to make when

Benefits for building owners and building managers may consist of cost and energy-savings as well as in improved operation of equipment as a result of increased ability to locate problems and fluctuations in energy usage. Offering flexible load and energy to a local energy market unlocks additional revenue streams. Another benefit is related to a green innovative image that could be marketed to consumers and other relevant actors due to participation in solutions that should favour the spreading of renewable systems.

5.1.2 Producer

Producer is defined as every actor that offers products and services in the local marketplace. This category includes a broad range of actors, from prosumers, individual households that offer excess energy to the local energy market, to energy co-operations where residents collaboratively offer their energy, flexibility or capacity to the market or commercial actors like aggregators, energy storage providers, DSOs or ESCOs.

eMaaS or Charging-as-a-Service (CaaS) providers can also fulfil the role of producer by providing capacity/balancing services to the grid when the local infrastructure supports bidirectional charging. V2G or V2B applications. One example of a V2B application is from fleet charging specialist AMPLY Power who provides charging services to a school bus operator. Electric school buses are used as assets in the grid that provide flexibility and capacity services and allow for participation in DR programs[6].

By coupling multiple energy systems and storage solutions, the energy system can be optimised. DHC networks can store energy in times of low demand or low electricity prices and release excess energy when needed, unlocking new types of services and customer segments for DHC operators. Local storage of excess energy by DHC operators fits with the trend towards distributed energy sources and avoids costs for transporting energy between remote areas (Lyons, 2019). By integrating the electricity/ gas grids and heating/ cooling networks, the DHC operator becomes a producer in a local energy market.

5.1.3 Regulator

The role of the regulator is to ensure that policies and regulation is in place that supports the development of PEBs/PEDs and that the involved actors comply with these policies and regulations. D2.1 - "Report on Enabling Regulatory Mechanism to Trial Innovation in Cities" states that the project demonstrations will be executed under actual national regulatory regimes with relevant dispensations. However, a widespread implementation and upscaling of the tested solutions require compatibility with current and future EU regulations. The +CityxChange regulatory sandbox approach as described in the same report, provides a tool to set-up a PED in an environment that is non-favourable from a regulation point of view and shows when and how to involve regulators best in the PED development process.

5.1.4 Market operator

The Market Operator represents the financial part of the local energy market. As such the

[6] https://chargedevs.com/newswire/v2g-and-v2b-whats-currently-operational-and-whats-still-years-away/ accessed February 15, 2022

market operator needs to be a part of the process of both designing the local energy market/flexibility market, but also the trading platform within the PEB. The role of Market Operator is relatively new and can be fulfilled by DSO's, energy communities or new market players.

5.1.5 System Operator

The Transmission System Operator (TSO) is responsible for the energy grid infrastructures, mainly the high-voltage grid. Due to the cost of establishing and maintaining an electricity transmission infrastructure, a TSO is usually a natural monopoly, and as such is often subjected to regulations. TSOs need to coordinate the supply and demand for energy, avoiding fluctuations in frequency and supply interruption. The Distribution System Operator (DSO) is responsible for the final stage of the electric power delivery to the customer premises, i.e. the medium- and low-voltage grid, carrying electricity from the TSOs to the consumers. The role of the DSO in the +CityxChange demonstrations is further described in Deliverable 2.1 "Report on Enabling Regulatory Mechanism to Trial Innovation in Cities"[7]. Retailers are the first contact for the household customer regarding billing, house moves, retailer switching requests and energy supply. They are also the last value adding party before energy is delivered.
TSO, DSO and Retailer are one of the most important categories for PEBs since they control the distribution grids, the tariffs/programmes offered and need to ensure adequate balancing of the grid by matching the generation with the production. The penetration of RES and the policymakers push toward more sustainable energy systems have brought with them increasing pressure to modify their business-as-usual from highly controlled and centralised power generation and delivery to end-users, to a prosumer model that supports both consuming and generating energy via highly fluctuating renewable and sustainable sources. The uptake of local energy markets provides opportunities for DSOs who can become both market platform operators and/or buyers of flexibility in local flexibility markets, as presented in Deliverable 2.3 "Report on the Flexibility Market"[8]. In the Trondheim demonstration the DSO filled the role of local market owner and operator which is further described in Deliverable 5.5 "Deployment of the +CityxChange Energy Trading Platform"[9].

Potentially, TSO, DSO and retailers could have great benefits from PEBs. Specifically, they would have:

- Additional solutions to manage reliability and grid imbalances. With the entry of distributed RES, TSOs/DSOs are facing major challenges that DR could help reduce with limited infrastructural investment from their part. Instead of investing in traditional generation systems and in grid reinforcement at critical points to cover limited number of peak events, they would be provided with cheaper solutions in line with global trends toward sustainability.

[7]https://cityxchange.eu/knowledge-base/report-on-enabling-regulatory-mechanism-to-trial-innovation-in-cities/
[8] https://cityxchange.eu/knowledge-base/report-on-the-flexibility-market/
[9] https://cityxchange.eu/knowledge-base/d5-5-energy-trading-market-demonstration/

- Happy policymakers. The energy sector is highly regulated and incentivized in several ways. Therefore, through satisfactory cooperation with policymakers can ensure a favourable environment to continue doing business. As an example, DSO could take the role of supervisor over Community System Operators (CSO) who operate a local community grid. This concept is further explained in Deliverable 2.6 "Report of the Framework for Community Grid Implementation"[10].
- Greener and attractive image. Smarter and greener infrastructure and services delivering TSO/DSO/Retailer an attractive and positive image.

5.1.6 Technology providers

Manufacturers and providers of enabling technologies for smart grids and local grids provide the core infrastructure that enables prosumers, building owners and e-mobility providers to participate in local energy markets. Examples are providers of building management systems, energy storage solutions, EV charging systems, smart home systems or demand-response management systems. The technology providers are relevant for PEBs for a number of reasons:

- Their technologies enable households and businesses to effectively monitor energy consumption, equipment operation, occupant comfort conditions, and forecast future load profiles etc.
- Their technologies provide a means for remote automation and control, allowing building- and house owners to connect to a local microgrid and participate in a local energy market
- Their technologies enable devices like PV panels, EVs, thermostats, load controllers, HVAC systems or energy storage systems, to communicate bi-directional and become an active node in a local smart grid.

Their main benefit is the increase of sales and revenues of equipment and services in an upcoming market.

5.1.7 Orchestrator

The Orchestrator initiates the development of a PED and coordinates the planning and the design of a PED. As such, it brings together the various stakeholders and performs citizen engagement actions. In most cases, local politicians or city administration are the ones initiating PED projects and taking the lead in PED projects. Also in the participating LHCs and FCs, the City and City Council have taken on the role of Orchestrator. D4.4: "Limerick DPEB Implementation Guide 1" presents the relevant stakeholders and the stakeholder engagement process for each of these stakeholder groups as applied in the City of Limerick. Special attention is given to citizen engagement and activities have been defined to engage with three specific types of stakeholders being building owners, prosumers, and CSO-DSO.

[10] https://cityxchange.eu/knowledge-base/d2-6-framework-for-community-grid-implementation/

5.2 Secondary stakeholders

Secondary stakeholders are those who, although they do not have great power/interest in PEBs, still play a role and influence the success of PEBs. Additionally, some secondary stakeholder could move toward becoming a primary stakeholder in future developments or in specific situations/contexts. The first step in dealing with secondary stakeholders is identifying everyone who might fall into this group and afterwards, the subject of interest can start reaching out to them. This lets secondary stakeholders know that the project recognises they have a stake in it and cares about them. The following sections describe the relevance, needs and challenges and main benefits of the secondary stakeholders that were identified.

Table 16 - List of secondary stakeholders with associated relevance, needs and challenges, and benefits with respect to PEBs.

Category	Actors	Role	Needs and challenges
Designer	Urban planner Architecture companies DSO Technology providers Service designer Business designers Policy makers	Design the infrastructure, technologies, services and policies, needed for PEDs	Knowledge on PEB/PED concept Knowledge on smart grid technologies Find the value of PEDs for their clients
Financer	Bank Investor Crowdfunding platform	Provide funding for capital investments	Insight in risks and long-term revenues Access to new markets Green investment portfolio

5.2.1 Designer

In a PED, buildings, local and regional energy systems, e-mobility systems need to interact seamlessly with each other. Not only technology but also the spatial, regulatory, financial, legal, social and economic aspects need to be designed in such a way that they well integrate and contribute to an optimal functioning of the PED. This calls for an integrated planning and design approach. Designers from various sectors, like architects, energy, urban planning, real estate, governance or finance, but also involved citizens, need to establish a common understanding and preferably a common language in order to collaborate successfully. Tools such as citizen engagement strategies might help to get commitment and involvement from participating citizens and co-create PEDs together with citizens.

The European Commission is striving for a single digital market and lack of interoperability is one of the barriers identified hampering the large-scale uptake of IoT- and AI-enabled services. One of the supported initiatives to overcome this barrier is the development of the SynchroniCity Framework, formed around the Open & Agile Smart Cities (OASC) global network of cities and communities which encompass over 150 cities worldwide. SynchroniCity aims to enable local authorities and technology providers to easily exchange digital products, services, and data by providing the technical foundation for procurement and deployment of IoT- and AI-enabled services for cities and communities. The benefits for local authorities are a faster procurement and deployment process and reduces the risk of vendor lock-in. For technology providers the SynchroniCity Framework enables easier integration of digital technologies coming from different vendors and provides them access to new markets through the wider ecosystem of SynchroniCity cities.

5.2.2 Financer

Typically two types of investments are needed for the development and setting up of a PED. The cities need capital to invest in new infrastructure and suppliers need to invest in product and service development. The role of the financier is to provide the primary funding for the development and upgrading of energy infrastructure facilities and services, required for the deployment of PEDs. Examples of public and private investors are:

- Public funds
  - European funds
  - National funds
  - Regional/city funds
- Development banks, international financial institutions
- Commercial banks
- Investment funds
- Private equity
- Crowdfunding platforms

When compared to the demands, private investments are frequently insufficient. There might be a variety of causes for this. Energy-related projects are fraught with uncertainty, making them look extremely risky to investors. Uncertainty is mostly associated with the inability to make correct predictions about the learning curve, energy prices, current financial data, realistic investment schemes, new technology dangers, and so on. This is especially true when it comes to early-stage interventions, such as the research and development and pilot stages of the technological innovation chain. These initiatives necessitate the use of public funds. Public funds can be used to attract additional private investment, increasing the visibility of the renewable energy sector. Because investors typically have few incentives to invest, due to the traditional energy costs being cheap, public involvement can encourage investors in new industries that would otherwise stay undiscovered. Deliverable 2.4 - "Report on Bankability of the Demonstrated Innovations" proposes an integrated investment model which supports market players in developing and adopting financial solutions to invest in energy infrastructure facilities and services and Public Authorities drive development policies by planning and sharing investments thus increasing social responsibility in all involved stakeholders. Other examples of financial models that support the energy transition are:

- Direct loan
- Equity financing
- Crowdfunding
- Public Private Partnerships (PPP)
- Forfaiting model
- Tax incentives
- Energy Performance Contracts
- Project bonds
- ESIF Financial instruments

At the time of writing, the +CityxChange project attracted about 145 million euro in investments for complementary and replication projects. When looking closer at the funding sources, it shows that the majority of the funding comes from public sources, 95%, almost equally divided between EU funding and national, regional or city funds, and 5% from private financial providers. From the EU funds, the European Regional Development Fund (ERDF) and the European Research and Innovation Programme Horizon 2020 (H2020) are the funds most used for obtaining finance for replication, complementary, or spin-off projects as shown in the figure below.

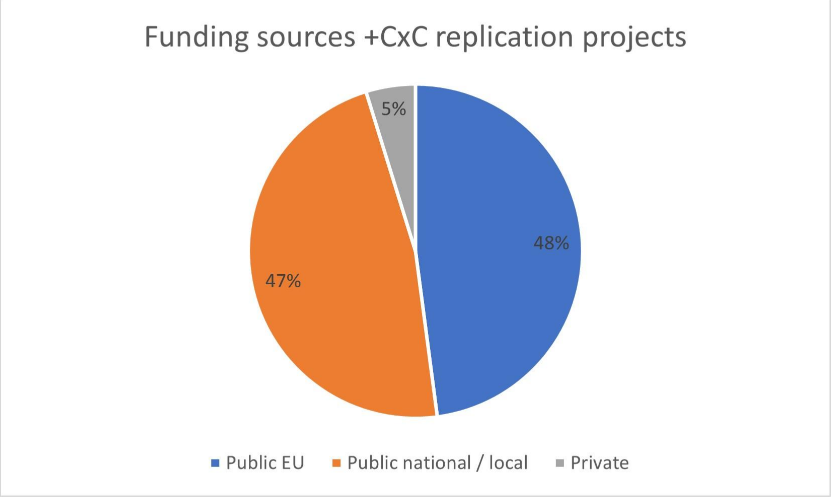

Figure 6 - Distribution of funding sources for +CityxChange replication projects

6 CityxChange-related projects and initiatives

This chapter provides a non-exhaustive overview of PEB/PED related initiatives, and includes a benchmarking of five related EU projects (Table 2). The results have been collected through literature review and discussion with project partners and with the Task Group Replication, one of the Task Groups supporting the cooperation of 18 Smart Cities and Communities projects funded by Horizon 2020 SCC01 calls, which includes +CityxChange. The case studies present some of the key publications of the PEB/PED concept supported by EU initiatives and the listed initiatives show how +CityxChange solutions fits in the European Commission's goals and objectives.

Six European PEB and PED case studies were described in 2018 and can be found in ANNEX 2 (pages 47-48) of the "SET-Plan ACTION n°3.2 Implementation Plan" report [178], in 2019 the "Best Existing Positive Energy Blocks" report was published by the ASSET (H2020) project [179], and there are several examples of EU-funded energy-efficient buildings applying innovative solutions from which to get inspiration to achieve PEBs [58].

Twenty-eight PEDs at implementation stage were presented in 2020 in the "EUROPE TOWARDS POSITIVE ENERGY DISTRICTS" published by the PED Programme Management of JPI Urban Europe as part of the Programme on Positive Energy Districts and Neighbourhoods which has the ambition to support the planning, deployment, and replication of 100 'PEDs' across Europe by 2025 for urban transition and sustainable urbanisation [180] (includes contributions from +CityxChange).

Also in 2020, The EU Smart Cities Information System's "PEDs Solution Booklet" was published, with themes varying from citizen engagement and urban planning to technical matters of district heating and cooling networks, refurbishment, local energy generation and batteries. Innovative business models and financial schemes are also considered [181] (includes contributions from +CityxChange).

In 2021, the Scalable Cities project started under the Horizon 2020 programme, representing 120 cities who are involved in 18 Smart Cities and Communities projects funded by Horizon 2020 SCC01 calls, which includes +CityxChange. The role of Scalable Cities is to identify and promote solutions and business models that can be scaled up and replicated across Europe and lead to measurable outcomes such as new jobs and energy savings [183]. The five themes defined by Scalable Cities match the sectors together covering PEDs and being addressed by +CityxChange. Scalable Cities is linked to the Horizon 2020 project Smart City Market Place that supports the European Commission's policy to finance the energy transition and Green Deal and acts as a one-stop shop for smart city projects.

In 2021, the EU Mission on Climate-Neutral and Smart Cities was published as part of the Horizon Europe programme. The two goals of the Cities Mission are to deliver 100 climate-neutral and smart cities by 2030, and to ensure that these cities act as experimentation and innovation hubs to enable all European cities to follow suit by 2050 [184]. To support the Cities Mission, the NetZeroCities project was started in 2021. NetZeroCities will help 100 selected cities overcome the current structural, institutional and cultural barriers they face in order to achieve climate neutrality by 2030 [185]. The goal of the EU Cities Mission is similar to the goal of the 18 Smart Cities and Communities projects,including +CityxChange.

The geographical imbalance of PED implementation can be explained in two ways: (i) policy priorities and implementation status of policies towards the energy transition vary between European countries, so specific national programs on PEDs or PED-related matters have only been implemented in some countries; and (ii) high support of national delegates for the PED Program in collecting information on PED projects in their countries [151].

In 2021, a PED benchmarking paper which included sixty PED projects was published under the title "Characterizing Positive Energy District through a Preliminary Review of 60 Existing Projects in Europe" [182].

Associations related to PEDs can be valuable tools when seeking advice or best practice literature. Some examples include IEA EBC - Annex 83 - Positive Energy Districts, COST Action 19126, and EERA Strategic Research Agenda just to name a few. Finally, five EU projects each dealing with PEDs are found within the following table comparing PED specifics.

Table 17 - Examples of related EU projects and their scope of activities

Project	Lighthouse city	Country	Energy efficiency		Renewable energy		Energy flexibility				Mobility		
			Building construction / renovation	Digital twin\EMS solutions	Renewables for H & C	Renewables for electricity	District H\C	Thermal energy storage	Electrical energy storage	Local energy market	Vehicle 2 Grid	EV charging	MaaS
MAKING-CITY	Groningen	Netherlands	X	X	X	X	X	X	NA	NA	NA	X	X
	Oulu	Finland	X	NA	X	NA	X	X	NA	NA	NA	NA	NA
+CityxChange	Trondheim	Norway	X	X	X	X	X	X	X	X	X	X	X
	Limerick	Ireland	X	X	X	X	NA	NA	X	X	X	X	X
Atelier	Bilbao	Spain	NA	NA	X	X	NA	NA	NA	NA	NA	NA	NA
	Amsterdam	Netherlands	X	X	X	X	X	X	X	X	NA	X	X
POCITYF	Alkmaar	Netherlands	X	X	X	X	X	X	X	X	X	X	X
	Evora	Portugal	X	X	X	X	X	X	X	X	X	X	X
SPARCS	Leipzig	Germany	X	NA	X	NA	X	X	X	X	X	X	NA
	Espoo	Finland	X	NA	X	X	X	NA	NA	X	NA	X	X
RESPONSE	Dijon	France	X	X	X	X	X	X	X	NA	X	X	X
	Turku	Finland	X	X	X	X	X	X	X	NA	X	X	X

7 Conclusion

This report presents the results of the market and stakeholder analysis as carried out in Task 8.3 "Market and stakeholder analysis to understand exploitation potential of +CityxChange solutions". The geographic scope of the market analysis is determined by the two Lighthouse Cities in Ireland and Norway, and the five Follower Cities in Bulgaria, Czech Republic, Estonia, Romania and Spain. The analysed industries in these countries are derived from the list of +CityxChange exploitable results which have been clustered around four industries, being Urban Digital Twin, Local Energy Markets, E-Mobility and Innovative Renewable Energy Sources. Together, these markets cover the PED domain. Input on the market characteristics for these markets has been collected through desk research combined with input from industry partners. The main results from the market analysis are:

- Digital Twin technology is already being used to improve the energy performance of buildings. It is expected that this technology will be extended to Urban Digital Twins which facilitate interaction and collaboration between all stakeholders involved in a PED's life cycle, from design and construction (renovation) to operational and demolishment, hence improving the sustainability by more resource-efficient, economic, and environmental decision making.
- Peer-to-peer (P2P) energy and flexibility trading is a business model that is gaining attention. With proper design, P2P energy and flexibility trading creates a triple win situation for customers, microgrids/local energy systems and wider bulker energy systems.
- Europe will remain the global leader in electrification in terms of EV market share. By 2030, electric vehicle-related energy demand is anticipated to be between 130 and 195 terawatt hours in the EU.
- The energy balance in PEDs needs to devise effective energy strategies, including power, gas, and thermal energy networks. The technology and knowledge required to achieve PEDs already exists—put simply, the use of renewable sources for building energy use needs to double and gas usage needs to be halved.
- Since the first mandatory Building Regulations in Ireland that explicitly addressed conservation of fuel and energy in buildings were issued in 1992 and some 58% of residential dwellings date from before this time, the data indicates that there is likely to be significant potential in the residential sector for major renovation works.
- The PED concept fits with Norway's high-level energy strategies and national policies, thereby positioning Norway in a prominent role towards decarbonization of the electricity system with focus on local energy generation.
- Spain has the most favourable market conditions for Local Energy Markets, E-Mobility, and Renewable Energy Sources.
- Estonia has the most favourable market conditions for the Digital Twin market.

The stakeholder analysis builds upon the four basic roles within an operational local power market as operated together with the PED as defined in D2.1 "Report on Enabling Regulatory Mechanism to Trial Innovation in Cities". Five additional basic roles have been identified that together are involved in the implementation and set-up of a PED. These five roles have been derived from the actors involved in the set-up of the PED in the Follower Cities and are the following: Orchestrator, Regulator, Financer, Designer, and Technology Provider. From the primary stakeholders, those stakeholders who have relatively high influence or power over a PED project, the Orchestrator, Market Operator, System Operator and Technology Provider are considered the drivers of a PED project. Other primary stakeholders, customer, Producer and Regulator are expected to be less interested so targeted measures need to be taken to engage with these stakeholders and try to increase their interest in the PED project. The secondary stakeholders, Designers and Financers, can be supporters of a PED initiative when involving them at the right time and keeping them informed by sharing relevant information and latest insights.

The case studies show that PED is a relatively new concept and there is no large-scale roll-out of PEDs or a mature PED-market yet. Most PEDs that are in operation or under development are pilots, originating from EU-funded research and innovation projects. Replication of PEDs to other districts or cities remains challenging.

This report will provide guidance to the project partners with the preparation of exploitation plans for the +CityxChange solutions related to the establishment of a number of Positive Energy Blocks (PEBs) or districts (PEDs) and the preparation of commercialisation plans. Furthermore, this report aids Task 8.2 “Replication across EU cities” with the selection of most favourable cities for replication of the +CityxChange solutions and Work Package 6 “+Followers” with the preparation of replication plans for the Follower Cities.

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Annex 1 - Market feasibility datasets

Individual criteria assessment	
Green	1
Yellow	0.75
Red	0.5

Market feasibility datasets for Urban Digital Twins (UDT)

Additional considerations
Whenever sufficient data is unavailable, a score of 0 is assigned (NA – Not available)
For C02.1, YES is considered 1 and No is considered 0.

C01.1 – Technology [UDT-1]					
Green – Already mandated / Yellow – Already planned / Red – Will be planned					
BIM adoption level					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	No	Will be planned	Already Mandated	No	Already Planned
Score	0	0.5	1	0	0.75

C01.2 – Technology [UDT-2]					
Green – 5 or more / Yellow – 2 - 5 / Red – less than 2					
Digital Innovation Hubs and Digital Innovation Hubs contribution to digital transformation in Construction sector					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	2	1	2	28
Score	0	0.75	0.5	0.75	1

C01.3 – Technology [UDT-3]					
Green – 70% or more / Yellow – 60% - 70% / Red – less than 60%					
Enterprises having medium/high intensity of green action through ICT (% of enterprises)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	68.00%	55.00%	62.00%	68.00%	75.00%
Score	0.75	0.5	0.75	0.75	1

C02.1 - Policy initiatives [UDT-4]					
Green – 2 / Yellow – 1 / Red – less than 1					
Overview of energy efficiency policy initiatives by country - Fiscal, Financing measures, Non regulatory, strategy					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	2	1	1	2	1
Score	1	0.75	0.75	0.1	0.75
C02.2 - Policy initiatives [UDT-5]					
Green – 12 or more / Yellow – 8 - 12 / Red _ Less than 8					
The policy measures related to skills in construction are tackling broad trainings, apprenticeships and VET, digitalisation and energy efficiency skills, image of the sector or mobility of workers					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	11	6	8	6	13
Score	0.75	0.5	0.75	0.5	1

C02.3 - Policy initiatives [UDT-2]					
Green – 3 / Yellow –2 / Red – 1					
Policy or measure is in place to support BIM adoption, beyond public procurement (BIM/Digital Construction Strategy, BIM Standards and/or guidance, National working group on BIM)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	1	2	3	2	3

Score	0.5	0.75	1	0.75	1

C03.1 - Technology Adoption [UDT-2]					
Green – 2.5 or more / Yellow – 1.5 - 2.5 / Red – Less than 1.5					
Extent of BIM adoption					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	1	2	2.7	2	1.5
Score	0.5	0.75	1	0.75	0.75

C03.2 - Technology Adoption [UDT-2]					
Green – Yes / Red – NO=0					
Utilisation of Digital Twins					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	Yes	Yes	No	NA
Score	0	1	1	0	0

C03.3 - Technology Adoption [UDT-2]					
Green – 1.5 or more / Yellow – 1 - 1.5 / Red – less than 1					
Disruptive technologies for digital twin adoption- Sensors ,Extent of IoT adoption, Extent of 3D scanner adoption, Extent of drones' adoption					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.5	NA	1.675	1.5	1.25
Score	0.5	0	1	1	0.75

C04.1 – Market status [UDT-5]					
Green – 20% or more / Yellow –10 - 20 % / Red – less than 10 %					
Future employment growth in construction sector across Member States in 2018-2030, %					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**

Data	15.00%	15.00%	10.00%	-25.00%	20.00%
Score	0.75	0.75	0.75	0.5	1

C04.2 – Market status [UDT-4]					
Green – 2% or more / Yellow –0.50- 2 % / Red – less than 1%					
Renovation spending as % of disposable income, EU-28, 2016 (%)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	1.00%	0.70%	0.25%	2.80%	0.75%
Score	0.75	0.75	0.5	1	0.75

Urban Digital Twin (UDT) References

[UDT-1] BIMSPEED, “BIM Guidelines and Mandates Across Europe.” [Online]. Available: https://www.bim-speed.eu/en/Project Results Documents/Dissemination Materials/BIMfographics/BIM Guidelines and Mandates Across Europe pdf.pdf.

[UDT-2] E. C. S. Observatory, “European Construction Sector Observatory - Digitalisation in the construction sector - Analytical Report,” 2021.

[UDT-3] European Commission, “Digital Economy and Society Index (DESI) 2021,” 2021.

[UDT-4] ECSO, “Analytical Report – Improving energy and resource efficiency,” 2018.

[UDT-5] ECSO, “Improving the human capital basis - Analytical Report,” 2020.

Market feasibility datasets for Local Energy Markets (LEM)

Additional considerations

Whenever sufficient data is unavailable, a score of 0 is assigned (NA – Not available)

For C02.1, C02.3, YES is considered 1and No is considered 0.

For C05.2, mean of 2020-Semester1, 2020-Semester2, 2021 Semseter1 is considered

C01.1 – Barriers [LEM-2]					
Green – 0.6 or more / Yellow – 0.5 / Red – 0.3					
Lack of a proper legal framework to enable new entrants and small players					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	0.30	0.30	0.50	0.30

Score	0	0.5	0.5	0.75	0.5

C01.2 – Barriers [LEM-2]					
Green – 0.6 or more / Yellow – 0.5 / Red – 0.3					
Limited competitive pressure in retail markets					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	0.5	0.5	0.5	0.6
Score	0	0.75	0.75	0.75	1

C01.3 – Barriers [LEM-2]					
Green – 0.6 or more / Yellow – 0.5 / Red – 0.3					
Limited incentive to contract dynamic retail prices					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	NA	0.6	0.3	0.6
Score	0	0	1	0.5	1

C01.4 – Barriers [LEM-2]					
Green – 0.6 or more / Yellow – 0.5 / Red – 0.3					
Restrictive requirements in prequalification or the design of products for balancing					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.3	0.5	0.6	0.3	0.5
Score	0.5	0.75	1	0.5	0.75

C02.1 - Network stability [LEM-2]
Green – Yes/ Red – No

Interruptibility schemes[11]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	No	No	No	No	Yes
Score	0	0	0	0	1

C02.2 - Network stability [LEM-2]					
Green – 50% or more / Yellow –10 - 50 % / Red – less than 10%					
Percentage of time when the 70% min. target is met (%)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.00%	46.00%	NA	2.00%	55.00%
Score	0	0.75	0	0.5	1

C02.3 - Network stability [LEM-2]					
Green – Yes / Red – No					
Capacity mechanism for electricity - Availability					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	Yes	No	No	No	Yes
Score	1	0	0	0	1

C02.4 - Network stability [LEM-2]					
Green – less than 30 / Yellow – 30 - 100 / Red – 100 or more					
Day Ahead (DA) price spikes					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	28	5	144	42	NA
Score	1	1	0.5	0.75	0

[11] Interruptibility schemes (ISs) normally refer to national programmes dedicated to DSR, organised by TSOs for temporary load interruption or reduction [LEM-2]

C03.1 – Policies [LEM-3][LEM-4][LEM-5][LEM-6][LEM-7]					
Green – 20% or more / Yellow – 10% - 20% / Red – less than 10%					
Binding target for GHG emissions compared to 2005 under the ESR (%) - by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.00%	14.00%	13.00%	2.00%	26.00%
Score	0.5	0.75	0.75	0.5	1

C03.2 – Policies [LEM-3][LEM-4][LEM-5][LEM-6][LEM-7]					
Green – 40% or more / Yellow – 30% - 40% / Red – less than 30%					
National target/contribution for renewable energy: Share of energy from renewable sources in gross final consumption of energy (%) by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	27.09%	22.00%	42.00%	37.00%	42.00%
Score	0.5	0.5	1	0.75	1

C03.3 – Policies [LEM-3][LEM-4][LEM-5][LEM-6][LEM-7]					
Green – 50% or more / Yellow – 25% - 50% / Red – less than 25%					
Level of electricity interconnectivity (%) by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	15.00%	44.10%	60.00%	15.40%	15.00%
Score	0.5	0.75	1	0.5	0.5

C04.1 – Environmental [LEM-2]					
Green – less than 2 % / Yellow – 2 - 5 % / Red – 5 % or more					
Total emissions of electricity generation					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	2.31%	4.9%	0.41%	2.29%	6.68%

Score	0.75	0.5	1	0.75	0.5

C04.2 – Environmental [LEM-2]					
Green – less than 200 / Yellow – 200 - 400 / Red – 400 or more					
Average emission intensity (kg CO_2e/MWh = g CO_2e/kWh)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	342.69	382.50	551.24	245.82	171.23
Score	0.75	0.75	0.5	0.75	1

C05.1 - Market status [LEM-8]					
Green – less than 10 % / Yellow – 10 - 20 % / Red – 20 % or more					
Share for transmission and distribution in the network cost for gas and electricity					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	10.67%	5.00%	43.00%	17.36%	36.34%
Score	0.75	1	0.5	0.75	0.5

C05.2 - Market status [LEM-9]					
Green – less than 25 % / Yellow – 25 - 50 % / Red – 50 % or more					
Market share of the largest generator in the electricity market					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	60.55%	76.36%	22.79%	31.80%
Score	0	0.5	0.5	1	0.75

LEM References

[LEM-1] Gregor Erbach, “Capacity mechanisms for electricity,” 2017.

[LEM-2] ACER/CEER, “ACER Market Monitoring Report 2020 – Electricity Wholesale Market Volume,” 2021.

[LEM-3] European Commission, “COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Bulgaria,” 2020. [Online]. Available:

https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_bulgaria.pdf.

[LEM-4] European Commission, "COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Czechia," 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_czechia.pdf.

[LEM-5] European Commission, "COMMISSION STAFF WORKING DOCUMENT Assessment of the draft national energy and climate plan of Estonia," 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_estonia.pdf.

[LEM-6] EUROPEAN and COMMISSION, "COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Romania," 2020.

[LEM-7] European Commission, "COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Spain," 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_spain.pdf.

[LEM-8] Eurostat, "Share for transmission and distribution in the network cost for gas and electricity - annual data," 2021. https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_206/default/table?lang=en (accessed Feb. 01, 2022).

[LEM-9] Eurostat, "Market share of the largest generator in the electricity market - annual data," 2021. https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_331a/default/table?lang=en (accessed Feb. 01, 2022).

Market feasibility datasets for E-Mobility (EMOB)

Additional considerations for the assessment

A score of 0 is assigned for the datasets, when data is not available for the reference year. For the C2-Policy, CO2-based vehicle taxation & Electric vehicles: Purchase incentives or tax benefits is a qualitative analysis with Yes\NO\NA. Hence if the data is available Green – Yes=1 and RED – No\NA = 0

C01 - Infrastructure availability
Green – 1000 or more / Yellow –250 - 1000 / Red – less than 250

Normal Charging stations (≤ 22kW) [EMOB-1]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	118	590	223	317	5279
Score	0.5	0.75	0.5	0.75	1

C01 - Infrastructure availability					
Green – 1000 or more / Yellow –250 - 1000 / Red – less than 250					
Fast Charging stations (> 22kW) [EMOB-1]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	76	610	176	176	2128
Score	0.5	0.75	0.5	0.5	1

C01 - Infrastructure availability					
Green – 1 or more / Yellow –0.5 - 1 / Red – less than 0.5					
Charging points per 100km of road [EMOB-1]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.8	0.9	0.7	0.5	1.1
Score	0.75	0.75	0.75	0.75	1

C02 - Policies					
Green – YES = 1 or more / Red – No = 0					
CO_2-based vehicle taxation [EMOB-2]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	Yes	Yes	No	No	Yes
Score	1	1	0	0	1

C02 - Policies					
Green – 100% or more / Yellow – 75% - 100% / Red – less than 75%					
NPF target vs. current attained number of recharging points [EMOB-3]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**[12]
Data	8%	92%	104%	172%	+100%
Score	0.5	0.75	1	1	1

C02 - Policies					
Green – YES = 1 or more / Red – No = 0					
Electric vehicles: tax benefits or purchase incentives [EMOB-2]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	Yes	Yes	No	Yes	Yes
Score	1	1	1	1	1

C03 - Environmental					
Green – less than 10 / Yellow – 10 - 15 / Red – 15 or more					
Average age of passenger cars in EU (years) [EMOB-4]					
Country	**Bulgaria**[13]	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	NA	15.3	8.9	16.9	13.9
Score	0	0.5	1	0.5	0.75

C03 - Environmental
Green – less than 115 / Yellow – 115 - 120 / Red – 120 or more
CO_2 emissions of new cars by country (g CO_2/km) [EMOB-2]

[12] Spain did not provide any target but have installed 7407 new charging stations. So 100+ is assumed
[13] NA= No data available for the reference year

Country	Bulgaria	Czech Republic	Estonia	Romania	Spain
Data	133	120.9	121	115.4	112.4
Score	0.5	0.75	0.75	0.75	1

C04 - Market status					
Green – 0.5% or more / Yellow – 0.25% - 0.5% / Red – less than 0.25%					
Share Passenger cars (Battery electric, Plug-in hybrid) in the total fleet – 2020 [EMOB-3]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.80%	0.16%	0.25%	0.12%	0.36%
Score	1	0.5	0.75	0.5	0.75

C04 - Market status					
Green – 4% or more / Yellow – 2.5% - 4% / Red – less than 2.5%					
Passenger cars sales (Battery electric, Plug-in hybrid) to total car sales -2020 [EMOB-3]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	2.5%	2.6%	2.3%	3.1%	4.9%
Score	0.75	0.75	0.5	0.75	1

C04 - Market status					
Green – less than 400 / Yellow – 400 - 500 / Red – 500 or more					
Motorisation rates in the EU vehicles per 1,000 inhabitants [EMOB-5]					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	407	554	598	357	519
Score	0.75	0.5	0.5	1	0.5

EMOB References

[EMOB-1] ACEA, "MAKING THE TRANSITION TO ZERO-EMISSION MOBILITY - 2021 PROGRESS REPORT," 2021.

[EMOB-2] ACEA, "The automobile industry - Pocket guide 2021/2022," 2022.

[EMOB-3] EAFO, "European Alternative Fuels Observatory," 2021. https://www.eafo.eu/ (accessed Jan. 24, 2022).

[EMOB-4] ACEA, "VEHICLES IN USE EUROPE 2022," 2022.

[EMOB-5] Eurostat, "Transport equipment statistics - Road transport equipment," 2021. https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=533776#Road_transport_equipment (accessed Jan. 24, 2022).

Market feasibility datasets for renewable energy sources (RES)

C01.1 – Policies [RES-3][RES-4][RES-5][RES-6][RES-7]					
Green – 20% or more / Yellow – 10% - 20% / Red – less than 10%					
Binding target for GHG emissions compared to 2005 under the ESR (%) - by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	0.00%	14.00%	13.00%	2.00%	26.00%
Score	0.5	0.75	0.75	0.5	1

C01.2 – Policies [RES-3][RES-4][RES-5][RES-6][RES-7]					
Green – 40% or more / Yellow – 30% - 40% / Red – less than 30%					
National target/contribution for renewable energy: Share of energy from renewable sources in gross final consumption of energy (%) by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	27.09%	22.00%	42.00%	37.00%	42.00%
Score	0.5	0.5	1	0.75	1

C01.3 – Policies [RES-3][RES-4][RES-5][RES-6][RES-7]					
Green – 50% or more / Yellow – 25% - 50% / Red – less than 25%					
Level of electricity interconnectivity (%) by 2030					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**

Data	15.00%	44.10%	60.00%	15.40%	15.00%
Score	0.5	0.75	1	0.5	0.5

C01.4 – Policies [RES-8]					
Green – 7.5% or more / Yellow – 5% - 7.5% / Red – less than 5%					
Share of environmental taxes in total tax revenues (%)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	9.89%	5.35%	7.20%	7.30%	4.74%
Score	1	0.75	0.75	0.75	0.5

C02.1 – Environmental [RES-8]					
Green – less than 75 / Yellow – 75 - 85 / Red – 85 or more					
GHG emissions intensity of energy consumption (Index 2000 = 100)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	97.1	73.7	85.4	79.8	79.7
Score	0.5	1	0.5	0.75	0.75

C02.2 – Environmental [RES-9]					
Green – 60% or more / Yellow – 50% - 60% / Red – less than 5%					
Heat pump emissions reduction potential (%)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	56%	54%	20%	67%	76%
Score	0.75	0.75	0.5	1	1

C03.1 - Market status – Consumption [RES-8]
Green – less than 82.5 / Yellow – 82.5 - 87.5 / Red – 87.5 or more
Primary energy consumption (index 2005 = 100)

Country	Bulgaria	Czech Republic	Estonia	Romania	Spain
Data	89.50	88.20	85.60	85.70	77.20
Score	0.5	0.5	0.75	0.75	1

C03.2 - Market status – Consumption [RES-8]					
Green – less than 80 / Yellow – 80 - 95 / Red – 95 or more					
Final energy consumption (index 2005 = 100)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	94.10	93.60	96.80	95.70	75.20
Score	0.75	0.75	0.5	0.5	1

C03.3 - Market status – Consumption [RES-8]					
Green – less than 350 / Yellow – 350 - 500 / Red – 500 or more					
Final energy consumption in households per capita (kgoe)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	344	668	711	416	307
Score	1	0.5	0.5	0.75	1

C03.4 - Market status – Production [RES-8]					
Green – 7.5 or more / Yellow –5 - 7.5 / Red – less than 5					
Energy productivity[14] (€\kgoe)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**

[14] Goal is to achieve an energy productivity of 11.1 euros per kilogram of oil equivalent by 2030: Energy productivity - The indicator is part of the Resource Efficiency Scoreboard. It is used to monitor progress towards a resource efficient Europe, complementing the lead indicator on the area of carbon. Energy productivity of the economy is a key indicator for measuring the Lisbon Process and its successor Europe 2020. It helps identifying whether there is a decoupling between energy consumption and economic growth. Changes in the indicator reflect changes in energy productivity and in the structure of the economy[1] . Goal is to achieve an energy productivity of 11.1 euros per kilogram of oil equivalent by 2030[2]

Data	2.47	4.61	4.17	5.27	8.96
Score	0.5	0.5	0.5	0.75	1

C03.5 - Market status – Production [RES-8]					
Green – 30% or more / Yellow –20 - 30 % / Red – less than 20%					
Share of renewable energy in gross final energy consumption (% of gross final energy consumption)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	23.32%	17.30%	30.18%	24.48%	21.22%
Score	0.75	0.5	1	0.75	0.75

C03.6 - Market status – Production [RES-8]					
Green – less than 25% / Yellow – 25% - 50% / Red – 50% or more					
Energy import dependency (% of imports in total gross available energy)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	37.88%	38.90%	10.50%	28.20%	67.89%
Score	0.75	0.75	1	0.75	0.5

C03.7 - Market status – Social [RES-8]					
Green – less than 5% / Yellow – 5% - 15% / Red – 15% or more					
People unable to keep home adequately warm (% population)					
Country	**Bulgaria**	**Czech Republic**	**Estonia**	**Romania**	**Spain**
Data	27.50%	2.20%	2.70%	10.00%	10.90%
Score	0.5	1	1	0.75	0.75

RES References

[RES-1] Eurostat, "Energy productivity," 2021. https://ec.europa.eu/eurostat/cache/metadata/en/t2020_rd310_esmsip2.htm (accessed Jan. 25, 2022).

[RES-2] F. P. Bureau, “Energy productivity.” https://www.indicators.be/en/i/G07_ENP/Energy_productivity (accessed Jan. 25, 2022).

[RES-3] European Commission, “COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Bulgaria,” 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_bulgaria.pdf.

[RES-4] European Commission, “COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Czechia,” 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_czechia.pdf.

[RES-5] European Commission, “COMMISSION STAFF WORKING DOCUMENT Assessment of the draft national energy and climate plan of Estonia,” 2020. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_estonia.pdf.

[RES-6] EUROPEAN and COMMISSION, “COMMISSION STAFF WORKING DOCUMENT Assessment of the final national energy and climate plan of Romania,” 2020.

[RES-7] European Commission, “COMMISSION STAFF WORKING DOCUMENT - Assessment of the final national energy and climate plan of Spain,” 2020. [Online]. Available: https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en.

[RES-8] Eurostat, “Sustainable development indicators.” https://ec.europa.eu/eurostat/web/sdi/affordable-and-clean-energy (accessed Jan. 25, 2022).

[RES-9] IEA, “Heat pump - Heat pumps could satisfy 90% of global heating needs with a lower carbon footprint than gas-fired condensing boilers,” 2021. Accessed: Jan. 25, 2022. [Online]. Available: https://www.iea.org/reports/heat-pumps.

Annex 2 - Results ER questionnaires

Integrated Planning and Support Tool

Owner: IES
Sector: Digital twin urban planning

Description of the ER
The exploitable result of the project is the integration of and enhancement of previously existing separate software that has been joined together for the specific purpose of creating PEB/Ds and accelerating cities towards net zero by 2050.

The integrated software allows for the assessment of energy consumption and supply at building, block/district and city levels to support cities in creating Positive Energy Blocks (PEBs) and in identifying replication opportunities.

As well as allowing users to gain a detailed understanding of their current energy demand, how this can be reduced, which renewable energy systems are most suitable, and potential constraints on the electricity network, the tool can also model the impact of energy related actions on the citizens of the cities through socio economic analysis. The addition of socio economic data means that the effect of decreasing carbon emissions can be viewed through the lens of health and economic prosperity as well as the environment.

The resulting visualisations can be tailored to different users (urban planners, building owners, citizens) enabling improved citizen participation and ownership of solutions for the transformation towards a positive energy city.

The tool goes beyond state of the art because it combines detailed current and future modelling of urban areas in terms of energy demand and supply as well as joining them with socio economic implications. The tools ability to show these implications in space (through interactive 3D map visualisations) and time (through the ability to simulate across given points in time to 2050) make this tool innovative and potentially disruptive to the market.

Market & trends
The sector as defined for the project is Digital Twin Urban Planning, which also is related to sectors known as:

- Digital Twins
- Smart Buildings
- Smart Cities
- Building Energy Management

The analysis of the market and trends focuses on Digital Twins, and more specifically Digital Twins at a large scale (ie more than one building and for cities) because this encapsulates the other areas to a degree. A Digital Twin is defined as "the virtual representation of a physical object or system across its life-cycle. It uses real-time data and other sources to enable learning, and reasoning: dynamically recalibrating for improved decision-making.[15]"

Key competitors

- *Autodesk Tandem: https://www.autodesk.com/solutions/digital-twin/autodesk-tandem?mktvar002=4284214%7CSEM%7C12602538204%7C122801727754%7Ckwd-1208799054467*
- Microsoft: Azure Digital Twins: https://azure.microsoft.com/en-gb/services/digital-twins/
- Bentley Systems iTWIN: https://www.bentley.com/en/products/product-line/digital-twins/itwin
- ESRI - https://www.esri.com/en-us/digital-twin/overview
- CityzenitH - https://cityzenith.com/

[15] https://www.ibm.com/blogs/internet-of-things/iot-cheat-sheet-digital-twin/

Enterprise Architecture Framework

Owner: NTNU
Sector: Digital Twin urban planning

Description of the ER

Enterprise Architecture Framework for ICT system interaction within a PEB – a structured way to model and describe the ICT components, data and other relevant entities to create value added services for cities and their citizens. The Enterprise Architecture Framework is designed to capture the context of the ICT ecosystem such as the needs of citizens, the value-added services and the collaborating organisations. It also provides a structured way to model the data and their sources. Furthermore, it takes into account the stakeholder and data perspectives to support data governance. Several "scenarios" or models describing the ICT ecosystem for PEB solutions are available.

The framework is innovative because it brings together the citizens' needs and the data and data sources. The core concept is based on a data Exchange, where data is identified and acts as a glue to support the creation of new ICT applications and services by new public and private collaborations.

Market & trends

The field of Enterprise Architecture and its application in the smart city domain is growing. Focus on citizens' needs – analogous to business strategy in organisations, cities are increasing their focus on the needs of citizens and meeting those needs. The following innovations are likely to be included in the future:

- Enterprise Architecture and its application in the smart city domain.
- Data exchanges and markets.
- Focus on citizens' needs.
- New collaborations – public private and research partnerships.

Monitoring and Evaluation Reporting tool

Owner: FAC
Sector: Digital twin urban planning

Description of the ER

The MERT provides an online platform where the performance of the 33 +CityxChange KPIs are tracked and disseminated. The user interfaces provided for each KPI also enables KPI/data owners to submit data points for the calculation of the KPI. Innovative elements of the tool are:

- The MERT provides a consolidated view of all KPI performance.
- Each KPI has a unique calculation that is performed in the back-end to calculate and track KPI performance.
- The MERT will enable automated data sharing with partners through the use of APIs.
- Each KPI has an individual interface with a summary overview, and downloadable data into various formats for external use.

Market & trends

The market for visual data dashboards is definitely large and growing. The use of smart online systems to disseminate project data is definitely in line with present trends. The developed innovations include the use of AI, more predictive software to adapt to users needs, the use of virtual consultation as part of dashboards where users enter a virtual space, segmented and categorised according to specific needs, but all in a very interactive, visual, space, similar to 'virtual reality'.

Grid optimisation and balancing technologies

Owner: Volue
Sector: Local Energy Market

Description of the ER
An IT-prototype for design of a positive energy block in a local energy system has been developed. The solution is developed in T2.2 and documented in D2.2. The prototype is not formally named, but for this purpose it may be called "Powel-PEDesign"

The prototype has a top down approach in the process of designing a positive energy block or district within a local energy system. Basic input data is total load curves, climate data and generation and flexibility data represented as time series linked to specific renewable technologies (wind, PV, flexible consumption, batteries) including investment and operational costs. It is then calculated how the resources should be scaled with the overall scope of creating a positive energy block or district. In addition, it is made advanced grid calculations which states how the local grid topology will be influenced by local renewables. The grid calculations are done with the purpose of identifying – and avoiding – local grid constraints due to the PEB design and operation.

The PEDesign development have two main innovative deliveries:
1. A top down approach of how dimensioning and mix of local renewables may help to establish a PEB/PED.
2. Use of advanced cloud based load flow calculations linked to actual local grid topology to analyse and operate PEB/PED without reduced quality of supply.

Market and trends
Growth of local connected renewable resources is significant. Flexibility in local energy resources are highly focused and discussed how to be realised and given the correct energy system value. The market consists of different segments like innovation projects, grid operators, local system operators, energy communities, technology providers, smart cities, and energy communities. All these market segments are emerging.
The innovation will most probably be linked to the overall system approach to gain the correct value from renewables and flexibilities. In addition, it will be innovation in optimising the location and operation of the resources to minimise system stress and investments. More specific it will be required optimal use of batteries and local markets.

Competitors
Some universities and research have developed prototypes, but for a global market it is maybe only Homer Energy www.homerenergy.com that address major parts of this innovative solutions, however mainly with a microgrid approach only.

Community grid technology

Owner: MPower
Sector: Local Energy Market

Description of the ER
ICT infrastructure that connects Community Grid participants into the local energy network (grid). The infrastructure enables two-way communication between each part of the Community Grid and empowers final consumers to actively participate on local energy/flexibility market with their available assets and flexibility. It gives necessary technical foundation for utilising the consumer centric approach in smart grid applications without disturbing the outer power grid (it is disturbance neutral).

Market and trends
Growing presence and urgent need to switch from traditional centralized energy sources to distributed sources based on renewable energy makes this solution attractive to make the transition easier, less costly without disruption in supply. ICT technology will advance especially in wireless communication like 5G enabling real-time acquisition of sensors and control devices, improving monitoring, controlling and forecasting of the local energy systems.

Competitors
ABB, Siemens, Schneider electric, IBM, Ericsson, Huawei, Energy Market Retailers

Energy Trading Platform

Owner: Volue
Sector: Local energy systems

Description of the ER
An IT-prototype for trade of power in a local energy market has been developed. The solution is developed in T2.5 and documented in D2.7 delivery. The delivered prototype is characterised by setting up a local trade platform which is accessible for all local energy resources with a digitalised communication and control. The solution is about to be implemented and demonstrated in the demonstration areas in Trondheim.
The prototype is not formally named, but for this purpose it may be called the "Powel-Trade Platform"
The trade platform for local energy resources is innovative in its design and operation due to that it gives all local energy resources – independent of size – market access. It operates the market by using algorithms in an intraday market. Trade verification inclusive dispatch is executed by ABB and IOTA technology.

Market and trends
Local markets are emerging firstly through pilots and regulatory sandboxes. However, this is mainly related to flexibility and use of aggregators. The +CC delivery will represent a first solution which will include all local resources and a generic local market operation based on experiences from global market operations all over Europe. Local markets will strengthen incentives for investments and operation of renewables and customer flexibility. The value of renewables including storage will increase due to system approach linked to a local marketplace.
Demand for flexibility in the energy system will increase and is supposed to be closely linked to market solutions for being realised. In addition it is obvious that reduced costs of chargers, storage, pv etc, the growth of these local markets will come fast.

Competitors
It is ongoing projects regarding flexibility and local trade all over Europe. However, it is mainly based on the role of aggregators. Competitors with similar approach as +CxC with digitalised operation and local marketplaces with well defined roles and responsibilities are so far not observed.

Energy Community Utility Franchise Model

Owner: MPOWER
Sector: Local energy markets

Description of the ER

Energy Community Utility Franchise Model is a business model for companies who are operating the Community Grid. Since it is a critical operation, and needs appropriate licence from the national energy system regulator, the management and operation must be unified based on the validated system concept of Community Grid. Franchising gives the necessary high standardisation of the operation and services.
Innovation is in the possibility to franchise the energy service where each part of the process is optimised, standardised, and validated so that the quality of the service meets the regulator's requirements.

Market and trends

The global energy market is currently experiencing a major shift, and key factors are decarbonisation, decentralisation and new technologies. Utilities, independent power producers and other energy companies are looking for effective ways to manage the imbalance between supply and demand due to the intermittent nature of the growing renewable energy sources in power generation. Business transactions based on energy transactions at the moment are limited and obstructed with rigid regulations that go in favour of big utility companies.
Such a trend will continue and a lot of effort will be put in development of different business models that will be coupled with digitalization, blockchain and virtual contracting enabling direct transactions without intermediaries (banks) and regulation will be changed, adapt to that so it would be possible, hopefully.

Competitors

ABB, Siemens, Schneider electric, IBM, Ericsson, Huawei, Energy Market Retailers

Enabled P2P energy marketplace

Owner: IOTA
Sector: Local energy systems

Description of the ER
IOTA-enabled P2P energy marketplace platform and IoT asset modules. The solution is described in D2.7 "Local DPEB trading market demonstration tool". It provides a decentralised energy marketplace for enhanced trust, auditability, interoperability and more adaptability to participants needs and preferences. The solution also provides the technological feasibility for real time M2M micropayment to allow future smart meters/devices to act as autonomous economic agents and settle transactions peer to peer without intermediaries. In the longer run, the platform can be expanded to serve open peer to peer energy trading.

Market and trends
The market addressed by IOTA is pre-commercial and currently in demonstration pilot phase. The number of public grant demo projects, startups and corporate initiatives in that field is increasing across the world. Market drivers behind this growth are the same as the one used for +CityxChange. IOTA ventures will enable further decentralisation, interoperability and tailoring to local needs and preferences of participants in the energy marketplaces. The solution has the ambition to serve a broader landscape of opportunities towards, in the future, open peer to peer energy trading (not contained in a local zone like it is the case in +CityxChange)

Competitors
There is now a fast growing international competitive space where startups, power system incumbents and grid operators are active.

Top 5 Blockchain based startups in the P2P/flexibility space

- Powerledger (AU)
- Grid singularity (DE)
- LO3 Energy (US)
- Electron (UK)
- Powerpeers (NL)

Most incumbents in energy utilities, transmission grid and power systems are monitoring the space and experimenting through pilots. Siemens Energy is one of the more proactive players in the space which has partnered early on with LO3 Energy and diversified its innovation through european initiatives.

A few consortiums / alliances are addressing the blockchain space through Technology enablement. For example:

- Energy Web Foundation promotes a specific technology competing with IOTA
- MOBI, the global Mobility Blockchain Alliance, is exploring V2G and P2P related standards
- The International Energy Agency (IEA) and INATBA, the International Alliance for Trusted Blockchain Applications, have launched a joint working group to monitor and study the Blockchain enabled P2P energy and transactive energy market
- Equigy is an initiative from European TSO to address the flexibility market Top Down by leveraging Blockchain.

Other European applied research innovation demo initiatives leveraging Blockchain are addressing the similar landscape including Pebbles, Quartierstrom and others. The startup PowerLedger has progressed most in securing pilot projects across continents.

Data integrity and trade verification service

Owner: IOTA
Sector: Local energy systems

Description of the ER

The Data Integrity service provides a way to prove the integrity and immutability of information previously stored centrally in various stakeholders systems, by using the IOTA Tangle through a set of provided APIs. Additionally the service provides the ability to verify integrity of specific type of transactions, such as energy trading ones. This component is utilised by the +CxC energy trading platform developed together with POWEL, ABB and Tronder Energi.
Heterogeneous cyber physical ecosystems such as smart grids and peer to peer energy marketplaces are subject to cybersecurity threats and risk of data tampering as the data is shared across silos. The services leverages a new Distributed Ledger Technology called the IOTA Tangle as a transparency and immutable data transaction layer to enable data integrity and trade verification.

Market and trends

The market for smart energy and smart grids is growing fast and the emerging opportunity of local energy marketplace demonstrated by +CxC opens up a new market segment.
The European Commission's push towards energy communities, flexibility market and the growing penetration of smart home/building energy management systems provide the basis for future demand for scalable decentralised and interoperable Internet of Energy ecosystem. More recently the growth of EV and upcoming V2G integration will catalyse radical new business models and will accelerate citizen centric and shared economy innovation. To enable this cross sectorial digital transformation a new type of e-infrastructure is needed which will include DLT.

Beyond the Energy domain, the European Commission is growing its Blockchain agenda through a number of initiatives:

- European Blockchain Service Infrastructure
- European Blockchain Partnership across EU member states and Norway
- New European Investment Fund for Blockchain and AI
- Initiator and sponsor of the European Blockchain Observatory
- Co-founding partner of the International Association for Trusted Blockchain Applications (INATBA)

Competitors

The functionalities provided by this service can be served by other DLT platforms competing with the IOTA Tangle protocol. IOTA is specifically designed to address the requirements and needs of decentralised digital ecosystem and IoT application and overcome the limitations of conventional Blockchain (lengthy validation of transactions, low throughput, unpredictable and too high fees, compulsory use of cryptocurrency, lack of scalability, energy consumption)

Other leading DLT / Blockchain protocols potential used in the energy sector

- Ethereum
- Hyperledger
- Corda
- Energy Web Foundation
- Hashgraph
- Polkadot
- Tezos

eMobility as a Service platform

Owner: FourC
Sector: Electric mobility

Description of the ER

Travellers are being encouraged and motivated into abandoning car ownership in favour of sustainable mobility services. Hence, the demand for an eMaaS solution that provides travellers with ready-to-hand access to nearby transport options, where they can evaluate, select, and possibly pay a trip.
FourC has developed a functional proof-of-concept eMaaS solution. It includes a backend system, named FourC Total Traffic Control (FourC TTC). FourC TTC retrieves, stores, and provides transport data. It collects data from various data providers and makes them available in a normalised and standardised format. A demonstration end-user apps has also been developed. It connects to the TTC backend and shows the mobility options that are available for the user near a chosen position on the map. Mobility objects on the map are interactive, and can show further information about the chosen object. Each mobility object is graded according to its environmental "friendliness". The user can choose the types of mobility modes they would like to see, create location favourites, and "auto-jump" to the nearest favourite. As the mobility modes have very different payment schemes, the app will redirect the user to the mobility provider's own app or webpage to reserve or order each type of mobility option. Ideally, payment would have been done through IOTA distributed ledger technology, with IOTA digital assets. Since a full integration was not possible, instead, as a proof-of-concept, a digital asset payment system was developed by IOTA , where users can book and pay for a multi-modal journey, offered by different transport providers, seamlessly in one step.
The eMaaS solution by FourC provides a one-shop stop for various mobility and micromobility modes in one solution. It facilitates the transition from traditional transport modes into eMaaS.

Market and trends

Recent environmental, social, and regulatory aspects enforce the transition into sustainable transport modes. For example, EU/EEA promotes interoperable Intelligent Transport Systems (ITS) and issued EU Directive 2010/40/EU to accelerate the provision of multimodal travel information services, and Delegated Regulation 2017/1926 that defines types of multimodal travel information required from transport providers.
Integration of various transport modes, where planning and payment for the whole trip can be seamlessly performed. Also, providing passengers with more information about the environmental friendliness of the available transport options.

Competitors

eMobility is a cross-disciplinary sector where eMaaS solutions are developed both by private and public companies, and by both transport and ICT companies. Examples of public companies in Norway that work on such solutions include Atb (atb.no) and Entur (entur.no).

Vehicle to Grid/Vehicle to Building technologies

Owner: ABB
Sector: Electronic mobility

Description of the ER
Vehicle to Grid (V2G) and Vehicle to Building (V2B) technologies. allow interaction and transaction of energy from a vehicle to the grid, or from a vehicle to a building. The innovative element is that these technologies could potentially generate new revenue streams for rental car services, or others. Where the battery of electric (rental) cars previously was kept idle when the car was not used, it can now be utilised for generating revenue through e.g. offering ancillary services, or peak loading or shifting. The battery can also function as an emergency energy provider.

Market and trends
This is an emerging market, which could provide considerable output for a car, or car fleet, owner. Bi-directional EV chargers are, and will be, launched by a multitude of vendors.
We consider the charger to be a part of the growing EV market, and we believe that this market will experience huge growth in the years to come. ABB finds it likely that innovations, like the bidirectional charger presented here, will be an integral part of the market in the future. The future mobility market is shaped by the European Commission's vision for a climate neutral economy which includes fast electrification of all transport modes. As an example, the EU-funded project V2Market (https://v2market-project.eu/) is exploring how to incorporate electric vehicle batteries into the electricity system as storage and flexibility capacity through V2G and V2B technology and promises to create value for EV owners, aggregators and flexibility buyers across Europe.

Competitors
Enovates (https://www.enovates.com/)
Easee (https://easee.com/uk/)
Siemens
Tesla

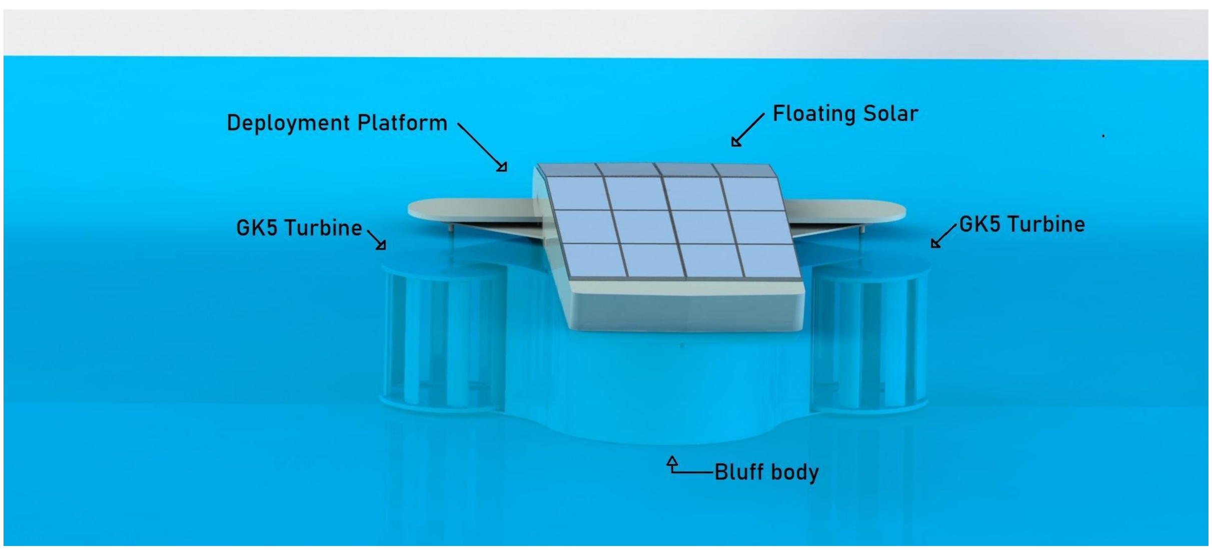
Tidal Turbine for Shallow Rivers

Owner: GKinetic energy
Sector: Renewable energy sources

Description of the ER
The name of the exploitable result from GKinetic's work is: 'Hydrokinetic Turbines for Distributed Energy Systems'.

GKinetic Energy Ltd is one of the 32 consortium partners in the +CityxChange project. The company was selected to join the project as a technology solutions provider for Limerick City in Ireland for the purpose of installing Hydrokinetic turbines in the local river Shannon. GKinetic's key deliverable within the CityxChange project is to demonstrate its tidal turbine technology as part of Task 4.6 and generate 630,720 kWh/yr of renewable energy within the PEB for Limerick City.

The exploitable result is a **10kW Hydrokinetic Turbine** that can be deployed in a variety of sites. Two vertical axis tidal turbines (GK5s) are fixed to a standard deployment platform to provide a 10kW floating hydrokinetic solution, the CEFA10.



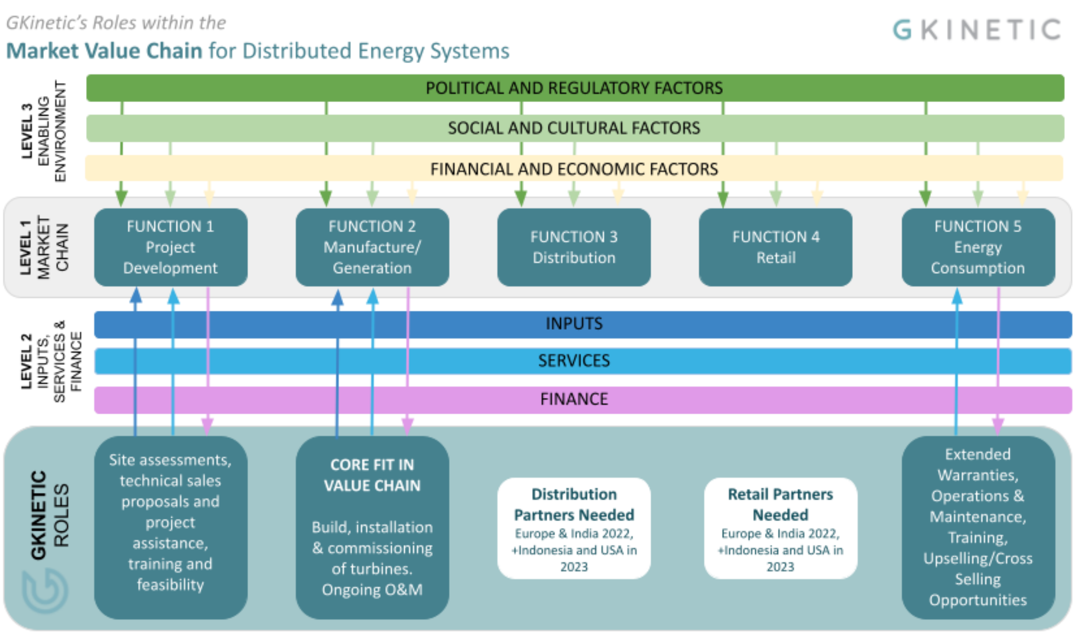
The CEFA10, is a plug and play hydrokinetic turbine that extracts the kinetic energy from flowing water and converts it to electricity. The power generated is clean, zero carbon, locally generated and 100% predictable unlike solar or wind.
The product is a complete solution that can be shipped in a crate (measuring minimum 5.8 M long X 2.3 M wide X 2 M high). It can fit inside a standard 20 ft container if needed. With minimal training, it can be assembled and launched in a day using basic tools and equipment. Operation and maintenance is simple for local trades people. It can be deployed in arrays for

increased output. It has a similar CAPEX cost to PV Solar and its footprint is 50 times smaller. It requires zero land space.

The product name **CEFA10 stands for Clean Energy For All**, a testament to GKinetic's vision and commitment to Sustainable Development Goal number 7. It can be deployed in rivers, canals and estuaries and is a floating unit, anchored by a mooring line. It is a free-flowing device meaning it does not block the water channel. From a visual aspect, all that can be seen from the surface is a floating platform similar to a barge that has been designed with a sleek low-profile. Submerged underwater beneath the platform is a "bluff body" structure with a vertical axis turbine attached on either side.

Alternatively, for very narrow sites or where there is existing infrastructure such as canal walls, bridge pillars, weirs or disused jettys etc. single GK5 turbines (without the floating platform) can be fixed to such structures.

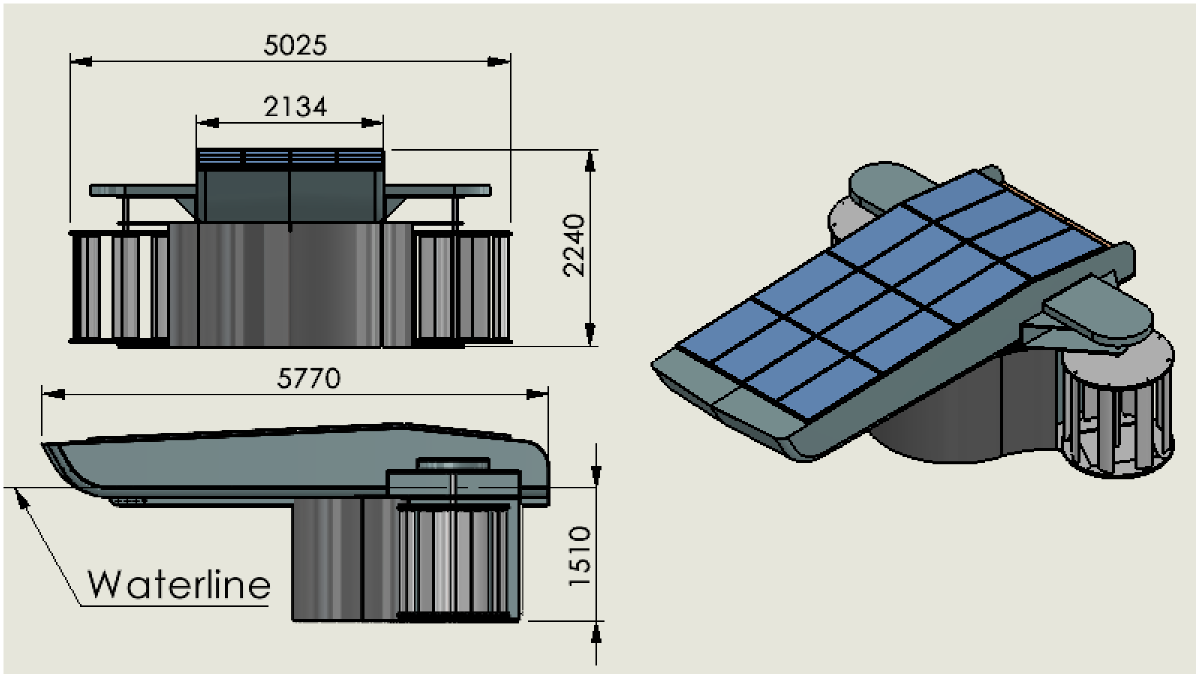
GKinetic's core function in the value chain is the manufacture, installation and commissioning of these turbines. Other services offered by GKinetic include site assessments and feasibility reports as well as project management and ongoing service and maintenance contracts.



Adaption of *'Figure 2'* from '**Building Energy Access Markets:** A Value Chain Analysis of Key Energy Market Systems' by EUEI PDF. Accessed online 15/01/2021: www.euei-pdf.org › download › file › fid.

The unique selling point of the GKinetic hydrokinetic turbine system is the ability to generate significant power at relatively low flow speeds, averaging 2 metres per second (mps).

Most competing devices require a minimum of 3mps to hit their rated capacity: speeds that are only found in a handful of sites. Thanks to the turbine's compact design, they can be deployed in a large variety of sites and are not as restricted by depth and channel width as competing solutions. Twin turbines are deployed either side of a bluff body that accelerates the flow to the turbines. This acceleration makes the GKinetic hydrokinetic turbines feasible in lower velocity flows than competing technology.



The bluff body along with the dual cam blade pitch control system are 2 unique design components that make this acceleration possible. The merit of this unique and simple design received National recognition in 2015 when GKinetic were named winners of the SEAI (Sustainable Energy Authority of Ireland) Design Award. The design, fabrication, installation and environmental impact of the turbine are all innovative in themselves and offer many benefits to the end user including:

- The bluff body doubles as a simple and cost-effective deployment system.
- The design allows for the device to sit on the riverbed or sea floor if necessary.
- The buoyant vessel acts like a duct to increase the ambient velocity to the turbine allowing the device to be deployed in lower velocity flows. Working in lower velocity flows reduces the technical challenges for deployment. ***It also expands the range of sites that are suitable for kinetic energy extraction.***
- The buoyant vessel can be towed to its deployment site by relatively small craft and simply secured to a pre-installed anchor.
- The design allows for operating costs to be significantly reduced and simplified by incorporating the use of a remote monitoring software system. This allows operators to quickly check the status of their device without having to physically check it. This system also allows for the collection of rich, insightful data regarding ambient flows and power generation, which can be used to contribute to ongoing research and development.

- The device is not permanently fixed allowing it to be moved easily, for example; if a more suitable site becomes available. The device also has a high residual value due to its mobile design.
- It minimises deployment costs of the turbines. The design allows for the use of cost effective materials such as steel to be used for the deployment vessel that supports the turbines and accelerates the flow of water. The accelerated water is diverted to the turbine in a concentrated flow and in a direction that enhances rotary power thereby enabling smaller turbines to be used to generate comparatively large amounts of power. This considerably reduces manufacturing and deployment costs and is more environmentally friendly. The design also allows the use of the interior of the vessel for machine rooms and energy storage.
- It minimises maintenance costs of the turbines. The design of the deployment vessel has sufficient buoyancy to float the turbines to the surface. This allows them to be easily raised out of the water for servicing.

Limerick city, being located on a waterway, is typical of many cities and towns all over the world. Using hydrokinetic power, many urban communities have the potential to generate significant power from their waterways. When compared with wind and solar power, which can be a good source of renewable energy, tidal power is very unique because it is predictable and is not dependent on weather conditions. It can be relied on to provide constant power. The turbines will facilitate the development of a local community grid incorporating storage and peer to peer trading.

Innovation

- The predictability of tidal energy can be accurately calculated to provide a constant power through an optimised battery system. This will help the integration in the wider energy system and provide flexibility for the participating buildings/blocks.
- The advantages of such a system could be enormous – more competition, lower cost infrastructure and more efficient use of resources. Each of those outcomes would have benefits for consumers, and the combination of all three could transform the industry and the role of consumers in it as part of the new Community Grid proposed by +CityxChange.
- To enable the Positive Energy Blocks/District a deployment in Limerick will involve innovation in how the public is informed about the introduction of this new technology is implemented and how it will provide a long-term benefit for the community as a whole.
- To demonstrate innovative systems integrations we will support as part of the +CityxChange the integration of tidal energy in the Community Grid and trading of energy using Distributed Ledger Technology developed by the IOTA Foundation.

The +CityxChange project has the potential of being the method to take GKinetic's pre-commercial technology to a deliverable commercial scale turbine.

Market and trends

GKinetic's product addresses a highly attractive gap in the market for clean, local distributed energy systems that wish to avail of nearby rivers, canals and estuaries for power generation in a simple and highly accessible way.

Our target market is Distributed Energy Systems (DES): a term which encompasses a diverse array of generation, storage and energy monitoring and control solutions. DES can be tailored to very specific requirements and users' applications including cost reductions, energy efficiency, security of supply and carbon reduction. DES categories include: power generation, combined heat and power, energy storage (including electric vehicles) and distributed energy management systems. DES covers energy in the forms of electricity, heating and cooling. GKinetic is focused on **the energy generation element for DES.** Hydrokinetic energy is a recognised 'Distributed Energy Resource' (DER). Distributed energy resources (DERs) are small and medium-sized power sources connected to the distribution network, that can potentially provide services to the power system (IRENA 2019 Report on DER[16]).

The market opportunity is to develop a simple, affordable small-scale hydrokinetic solution that can tap into thousands of suitable deployment sites: this is the 'gap' that we aim to address with our product. The 'market in this gap' relevant to Smart Cities is communities, projects or industrial customers with energy requirements of 600kW or less located within 10km of a suitable hydro resource. These end users wish to switch to a zero carbon, predictable energy source. In the case of the +CityxChange project, our target market is taking their ambitions one step further and striving to not only be energy neutral but actually energy positive, producing more power than they consume within a given region or specific area. These are known as prosumers, as they consume and produce energy.

Smaller scale turbine solutions are an up and coming market and have the potential to tap into thousands of sites where communities and businesses wish to produce independent, clean energy locally and have a natural hydrokinetic resource nearby. Hydrokinetic solutions have a distinct USP that cannot be copied, in that the energy resource is predictable. Competing clean alternatives such as small scale wind and solar cannot match this and so our product offers unrivalled reliability and guarantee of supply.

Large scale Hydropower plants are a well proven and mature technology and are recognised as the world's largest contributor of renewable electricity generation. In 2015, hydropower generated 16.6% of the world's total electricity and 70% of all renewable electricity. Despite the incredible success of large scale solutions, for smaller scale hydrokinetic devices, 80% of the market remains untapped. With approximately 1.5 billion people around the world living day-to-day with "broken" electricity grids and experiencing blackouts for hundreds of hours a

16 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Market_integration_distributed_system_2019.pdf?la=en&hash=2A67D3A224F1443D529935DF471D5EA1E23C774A

year, our abundant hydrokinetic resource is one we cannot afford to ignore. For this population, reliance on distributed diesel and gasoline backup generators is a common stopgap measure, but implies significant costs. According to the International Finance Corporation (IFC), annual spending on fossil fuel for backup generators is about €50 billion at an average cost of €0.36 per kW and up to €1.20 per kWh.

This global issue is actually increasing greenhouse gas emissions with sales of diesel generators increasing year on year for the past 10 years. These communities, which are often located near rivers, estuaries or by the coast, have no opportunity for real sustainable progress while this is the only means of electricity.

The participation of a significant amount of DERs in the wholesale electricity markets is expected to increase competitiveness in the electricity market, lowering the volatility of the prices by reducing price spikes and reducing the occurrence of negative prices. DERs could therefore contribute to a more competitive, well functioning market.

5 general market trends expected in the distributed energy space include (adapted from the following article: https://www.greentechmedia.com/articles/read/5-takeaways-on-the-future-of-the-u.s-distributed-energy-resources-market) :

1. Solar to retain its leading role in distributed generation and grow at a faster rate than fossil-fueled generation, making up roughly two-thirds of the 86 gigawatts of distributed generation expected for the U.S. market by 2025, according to Maze-Rothstein.
2. Resiliency will be a major driver for distributed generation and energy storage. Predictability and flexibility of energy supply will become paramount qualities that customers will be willing to pay a premium for. GKinetic's hydrokinetic solutions coupled with batteries will match this sweet spot perfectly.
3. Flexibility of energy supply and demand, mainly through use of batteries will become more sought after and a mobile energy storage market will be led by electric vehicles, whose sales are expected to grow significantly between now and 2025.
4. New markets and models for multi-asset aggregation will emerge. The mix of distributed generation, storage capacity and flexible load will require "multi-asset aggregations" to capture its full range of grid values. Aggregations in the form of microgrids, virtual power plants or integrated "connected homes" also need new market constructs to earn money for what they can do.
5. It is expected there will be increased pressure pushing large grid operators to adapt wholesale markets to permit the inclusion of energy storage in units as small as 100 kilowatts, enabling aggregations of behind-the-meter assets in some markets.

The global diesel generator market in our scale of power output (up to 600Kw) continues to grow despite pressing climate targets. Key applications for diesel gensets include health and government, industrial and community, where CAGR of between 14.6 and 33.3% are expected from now to 2025. The highest growth in demand for diesel gensets is expected from remote communities who are at the frontlines of the effects of climate change and are at most risk of "being left behind". This is a larger, global market for the GKinetic solution but for the very same principles that hydrokinetic turbines are an ideal solution for displacing diesel generators, they can also make a significant contribution to the Distributed Energy Market by enabling communities to tap into abundant local hydro resources.

Competitors

Direct competitors, i.e. other hydrokinetic turbines developers include:

- ➔ HydroQuest - https://www.hydroquest.fr/
- ➔ SmartHydro - https://www.smart-hydro.de/
- ➔ Guinard Energies - https://www.guinard-energies.bzh/en/guinard-energies-2/
- ➔ Emrgy - https://emrgy.com/
- ➔ ORPC - https://www.orpc.co/
- ➔ Orbital Marine Power - https://www.orbitalmarine.com/

High temperature heat pumps

Owners: SV, NTNU
Sector: Renewable energy sources

Description of the ER

Facing climate change there is a need for new technologies and better utilization of available resources. The goal of +CityxChange, a part of Horizon 2020, is to promote new and innovative energy solutions. The objective was to evaluate possible heat recovery heat pump configurations for waste heat recovery at Sluppenveien 10, a part of developing PEB at Sluppen-Tempe in Trondheim. This work was done between SV and NTNU, also concerning wider configurations and alternatives of heat pumps and district heating integration. Part of the work was performed within a Master Thesis at NTNU. Both heat recovery to the district heating grid and for hot water production are considered.
High temperature heat pumps (HTHPs) capable of heat sink temperatures >100°C exist, few are commercially available and even fewer capable of waste heat recovery below 30°C. The main obstacles to development in HTHP technology are limitations in compressor suction and discharge temperatures, high initial costs and few installations tested in real life conditions. It is therefore beneficial to have large scale pilot installations documenting the profitability and reliability under real life conditions.

The design study showed, based on detailed simulation models, that for heat recovery to the district heating grid two innovative R290/R600 (Propane/Butane = working fluids) cascade heat pumps have been developed and investigated, Model A1 and A2. The results show that these models achieved a steady state heating/ combined COP of 1.71/2.53 and 1.78/2.68 of the A1 and A2 configuration respectively. The Model A2 configuration achieved 11.3 K lower Propane compressor discharge gas temperature (results in longer lifetime of compressor) than the A1 configuration, and a higher COP as a result of increased specific cooling capacity. Both models were simulated applying realistic weekly cooling load curve estimated from electricity measurements taken by the building owner. The units were able to follow an average weekly cooling load curve of the cold store from 62.5 kW down to 45 kW. For cooling demands above 62.5 kW additional cooling has to be delivered by the existing chillers.

As an alternative to deliver the heat into the local district heating grid, the surplus heat could be upgraded to hot water, utilized by the local PEB.
Therefore, three hot water producing heat pump models; B1, B2 and C1 have been developed. Where the B1 and B2 models are R290/R600 cascade heat pumps similar to A1 and A2, and the C1 configuration is a more conventional CO2 (carbon dioxide as working fluid) heat pump. The model B1, B2 and C1 configurations achieved a heating/cooling COP of; 2.38/3.88, 3.06/5.23 and 3.28/5.66 respectively. Showing that the COP of the R290/R600 cascade heat pump can be significantly improved by adding a water pre-heater/propane

sub-cooler, but inferior to the COP of the CO2 heat pump. The cascade solution is also concluded to be too complicated for hot water production because the same heat sink temperature can be achieved with a less advanced heat pump. The operation of CO2 heat pumps is very dependent on receiving rather cold water to be heated, which might be a limitation, however, having a customer requiring a high amount of hot water on a regular base represents a good case.
Due to the uncertainty in cooling demand of the cold storage facility an energy- and economic analysis has been performed with the amount of full load hours (FLH) of the heat recovery heat pumps as an independent variable. The results show that at an assumed 8500 FLH 513.1 MWh of heat can be recovered and 705.0-1060.4 MWh of heat can be delivered depending on method of heat recovery and heat pump configuration. The hot water producing heat pumps achieved the highest COP and thus the best alternative from an energy point of view.

The simplified economic analysis shows that the Model A1 and A2 heat pump configurations, which recover heat to the district heating grid, have the highest investment costs estimated to 1 650 000 NOK. Similar for the hot water producing heat pumps B1, B2 and C1 the investment cost is estimated to be; 1 500 000, 1 230 000 and 1 205 000 NOK. At very low full load hours (FLH) the hot water producing heat pumps achieve the lowest annual costs, however at >1000 FLH the annual costs of heat recovery by hot water increases significantly due to the high cost of M-TES. The calculated Levelized cost of generation (LCOG) of the heat recovery to district heating and hot water production is approximately 0.31 NOK/kWh and 0.81-0.73 NOK/kWh respectively. Heat recovery by hot water production is not profitable compared to district heating due to higher LCOG than the average district heating price. For FLH over 3600 hours heat recovery to the district heating grid achieves a LCOG lower than the average district heating price and thus the best economical alternative. However, the highest amount of heat is likely to be recovered in the summer period, the value of the recovered heat is therefore low from the district heating company's point of view.

Market and trends

Market needs local heat pump solutions providing simultaneous heating and cooling. Market is requesting innovative and sustainable systems applying natural working fluids, as the availability of non-natural refrigerants already soon is rather unclear and would introduce a large risk for the owners. The heat pump market is growing very fast, as fossil fuel alternatives for heating are not an option anymore and bio fuelled alternatives are also having supply limitations. Market need local heat pump solutions providing simultaneous heating (space heating and hot water) and cooling (comfort cooling during warm periods and process cooling for local equipment sensitive to heat [server cooling, food, etc.])

Competitors

https://winns.no/no
https://www.abkqviller.no/
https://www.kelvinas.no/
https://www.eptec.no/

https://www.therma.no/
https://www.hybridenergy.no/