MAtchUP

D6.7.3: Market analysis: Smart City Energy solutions

(First release)

WP 6, T 6.6

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Authors: Niccolò Bertuzzi (ICE), Giuliana Folco (ICE), Claudia Crippa (ICE), Jardel Sestrem (ICE)

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0 Abstract

This document is part of a series of market analysis reports focusing on MAtchUP exploitable results. These reports aim to provide a comprehensive overview of all key factors that can drive or hamper their exploitation after the end of the project.

Considering the strong innovation of MAtchUP and the consequent high number of results (82), the reports:

- Have been clustered by MAtchUP pillar: ICT, Energy, Mobility, in order to have a more tailored focus on the different areas that the project covers.
- Address only technology solutions and services (with a commercial nature) developed by MAtchUP technical partners, and the potential for enabling/enhancing public services in MAtchUP Lighthouse cities.
- Will be released twice: the first release (D6.7) analyses overall smart city developments in the EU and introduces MAtchUP solutions. The second release (D6.8) will provide a deeper analysis of these solutions in order to contextualise their launch on the market.

This report is the first release of the analysis on Energy. Smart city energy solutions leverage new digital capabilities to make energy consumption intelligent and flexible, with positive returns in term of costs, grid sustainability, and reduction in GHG emissions.

Chapter 2 focuses on smart energy technologies and covers the current status of the art, the total market potential and the competitive landscape of the key Energy solutions underpinning smart cities' investments. Adopting a PESTEL approach, ***Chapter 3*** analyses the key drivers and barriers that affect smart energy deployments and that should be considered when building the go-to-market strategy of MAtchUP energy solutions. ***Chapter 4*** addresses the new and enhanced services enabled by the deployment of these technologies. Lastly, ***Chapter 5*** introduces the specific technologies developed by MAtchUP, which will be further studied in D6.8.

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1 Introduction

1.1 Purpose and target groups

WP6 of MAtchUP project is focused on exploitation and market deployment as well as on the identification and analysis of innovative business models defined and tested within the project. Specifically, Task 6.6 aims to provide a comprehensive view of the market of reference for MAtchUP results (identified in Task 6.5) and to understand how the external environment affects their exploitation and replicability. Focus is on commercial results (mainly new products, services and technologies introduced by the project) and enabled public services in the non-commercial area. These insights are collected in a series of market analysis reports, which address results by MAtchUP pillar: ICT, Energy and Mobility. This document focuses on Energy and provides a preliminary assessment of Energy solutions: the final assessment will be released in D6.8 “Market Analysis: Final”.

The document is public and its target groups include:

- The partners in the MAtchUP project, which can leverage these market insights for the correct positioning of their MAtchUP solutions on the market.
- Technology solutions’ providers in advanced energy management systems.
- Energy providers offering services to smart cities.
- Local and city authorities, which are embracing a smart city journey.
- Any other stakeholder interested in smart city deployments and in the solutions that MAtchUP is developing to speed up the smart transformation process of European cities.

1.2 Table of acronyms

Table 1.1 provides the general acronyms used in this document and throughout the library database.

Acronym	Definition
AEE	Institute for Sustainable Technologies - Austria
BM	Business model
CAGR	Compound Annual Growth Rate
CEC	Citizen Energy Community
CCTV	Closed-Circuit Television
CHP	Combined heat and power
COP21	2015 United Nations Climate Change Conference
C40	Cities Climate Leadership Group
DER	Distributed Energy Resources
DG ENER	Directorate-General for Energy
DHW	Domestic Hot Water
DSO	Distribution system operator
EC	European Commission
EIP-SCC	European Innovation Partnership on Smart Cities and Communities

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ESCO	Energy Service Company
EU	European Union
FP7	Seventh Framework Programme
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICT	Information and Communication Technology
IEA	International Energy Agency
IoT	Internet of Things
IPCC	International Panel on Climate Change
IRENA	International Renewable Energy Agency
IT	Information Technology
ITAS	Institute for Technology Assessment and Systems Analysis
kW	Kilowatt
kWH	Kilowatt-hour
LCOE	Levelized Cost of Energy
LED	Light-emitting diode
LFG	Landfill gas
LMOP	Landfill Methane Outreach Program
M&A	Merger and acquisition
NDCs	National Determined Contributions
NMOC	Non-methane organic compound
OEM	Original equipment manufacturer
P2P	Peer-to-peer
P2X	Power-to-anything
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
PPP	Public Private Partnership
PV	Photovoltaic
RES	Renewable Energy Sources
RESC	Renewable Energy Storage Company
ROI	Return on investment
PRB	Population Reference Bureau
SDG 7	Sustainable Development Goal 7
SECAP	Sustainable Energy and Climate Action Plan
SET	Strategic Energy Technology
SME	Small and Medium Enterprise
ST	Solar Thermal
TES	Thermal Energy Storage
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WEC	Wave energy converter
WHO	World Health Organization

Table 1-1: List of Acronyms

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1.3 Contribution from partners

The following table depicts the main contributions from participant partners in the development of deliverable D6.7.

Partner	Task	Contribution
ICE	6.6	Clusterisation of MAtchUP results; Desk Research; Document writing

Table 1-2: Contribution from partners

1.4 Relation to other project activities

Table 1.3 depicts the main relationship of this deliverable to other activities developed within the MATCHUP Project and that should be considered along with this document for further understanding of its contents.

Partner	WPs	Relation to other project activities
VAL, LNV, WIT, UPV, ETRA, ITE, KVELOCE, DRE, DWG, DVB, VON, FHG, TUD, ANT, SAM, DEM, ANP, TAY, AKD	WP2, WP3, WP4	The document provides an analysis of the market context surrounding MAtchUP exploitable results within the Energy pillar. This analysis aims to identify those demand and supply factors that can drive or hamper an effective exploitation and go-to-market approach of MAtchUP Energy solutions.

Table 1-3: Relation to other project activities

2 Energy Solutions for smart cities' deployment

This chapter provides a detailed analysis of effective energy solutions for smart cities projects. The smart energy sector has its "natural" market in urban environments. Quoting Masera et al. (2018), "smart energy and electricity networks are a crucial component in building smart city architectures; they are a key constituent of the strategies toward a sustainable energy future".

2.1 State of the Art

In February 2015, the European Commission launched a strategy for a resilient Energy Union with a forward-looking climate change policy. From the beginning, the goal of Energy Union was to give to EU consumers – intended both as households and businesses - secure, sustainable, competitive and affordable energy. This strategy was implemented by other further initiatives, the most important being the "Clean energy for all Europeans package", which is the European first practical response to the issues posed by the 2015 Paris Agreement.

Europe is a leading actor at global level on energy and climate policies since long before launching the Energy Union Strategy. Already in 2010, ambitious targets to be achieved by 2020 were identified: reduction of GHG emissions by 20% compared to 1990, 20% of the need for energy to be obtained from renewable sources, and 20% increase in energy efficiency (targets mentioned with the acronym 20-20-20). The Juncker Commission posed the objectives of a 32.5% EU-wide energy efficiency by 2030 and of a climate neutrality to be achieved in all sectors of the economy and society by 2050. Recently elected Commissioner Ursula Von der Leyen stated that Europe will reduce by 50% its GHG emissions by 2030; in the same direction, the new Commission launched the EU Green Deal, with an Investment Plan of at least EUR 1 trillion over a decade.

Energy transition (in particular the implementation of renewable energy) and reduction of GHG emissions are not the same thing. However, they have strong connection. Renewable energy sources don't produce carbon dioxide and other GHGs that contribute to global warming. As visible from the following figure, Europe is considerably reducing GHG emissions, especially in the period 2010-2014, but the hypothesized roadmap will require further efforts.

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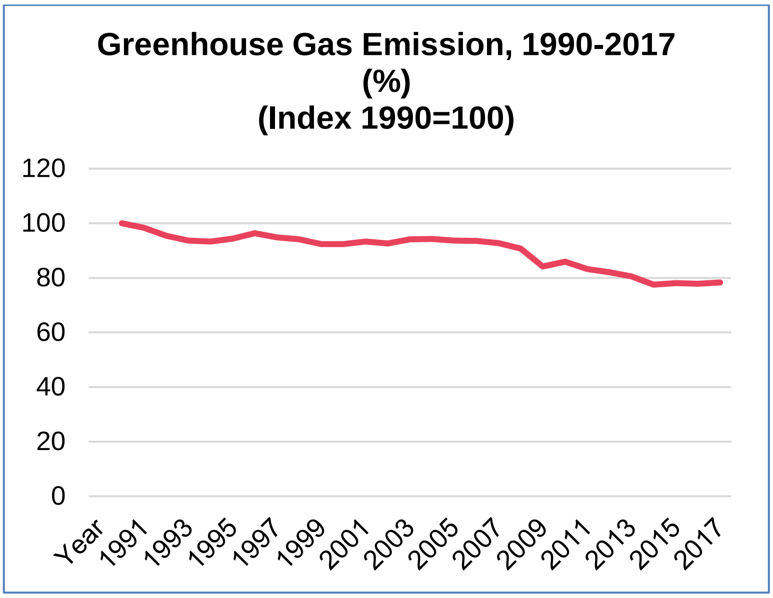

Figure 2-1 Greenhouse Gas Emission, 1990-2017 (EEA, 2019)

The transition of energy systems from fossil towards renewables sources is not a mere replacement of a polluting technology with a "clean" technology; it is a profound revision of the economy and society model. Technology is not enough, if not accompanied by equally important social visions and political policies, in the direction of an effective involvement of consumers/citizens. The contemporary socio-economic model is, with all its pros and cons, the result of fossil fuels' exploitation: according to the great majority of sociologists and historians, modernization corresponds to the emergence of the Industrial Revolution and the centrality assumed by fossil fuels. Going towards renewable sources and clean energy calls for a social revolution, even before than a technological one. The involvement of different types of stakeholders and civil society at large is necessary for a profound revision of the current models of organization, production and consumption, which accompany technological innovation.

In this scenario, cities represent a fundamental actor, especially because of the growing urbanization at global level. Within cities, residential buildings are of central relevance, being particularly popular in urban settings. Considerable improvements occurred in energy consumption across Europe in the last 10 years, and this is especially due to the efforts observed in the residential sector. Policies launched by the EU and national governments, adoption of new technologies, and the economic issues tied to the 2008 crisis that implied an increase in energy prices are all factors driving demand for smart energy solutions.

Residential and commercial buildings together account for around 40% of primary energy consumption, emitting around 36% of EU GHG emissions. Service buildings are on average 60% more energy intensive than residential buildings (300 kWh/m^2 compared to 170 kWh/m^2). Indeed, two thirds of the EU final energy consumption can be attributed

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to residential buildings. According to the EU Commission website[1], residential buildings in Italy, Malta and Estonia use by far the largest amount of energy per m² (more than 1.5 time higher than the EU average), while the other countries use between 200 and 300 kWh per m².

Smart city energy projects aim at enabling greater and cleaner energy generation, lower energy consumption, and improved grid performance. Smart cities include a wide range of initiatives and solutions with different focus areas, applications and stakeholders involved. Several factors such as the continuous growing population, technological disruption, change in societal and environmental needs towards a more sustainable living, disrupted the ways in which energy solutions are deployed in urban areas and increased the demand for completely new energy services and solutions, often ICT-based. Examples of cross-cutting energy solutions fall into the areas of smart buildings (smart solutions to develop new buildings and buildings components, renewable energies), smart services for citizens (energy consumption monitoring, smart metering, smart home), smart public safety (street lighting), and sustainable infrastructures (smart grids) (European Commission, 2016).

Smart meters and smart grids are at the core of smart energy solutions in cities. Smart meters are meters that record consumption of electricity usage and communicate it to the energy providers in real time. Smart grids are electrical networks that combine electronics and digital technologies allowing two-way communication between the various points of the network. This gives the possibility to monitor, analyze, control and exchange information in real time between the subjects involved, to improve network efficiency, and reduce energy consumption and costs.

The potential benefits of smart meters are numerous and have been recognized since their launch on the market. Already in 2010, the Smart Meter Alliance identified 22 possible applications of smart meters in EU cities:[2]

Smart meters' applications
1. Services for monitoring and improving energy efficiency of end use and dispersed generation. 2. Customer information feedback 3. End use energy management 4. Tariff setting (Time of Use, Maximum Demand, Seasonal) 5. Energy saving 6. Demand response for electricity market and for network operation support, peak load limitation 7. Smart homes, home automation, remote control of appliances by the energy or energy service company 8. Connect, disconnect, limit load remotely

[1] European Commission, available at: https://ec.europa.eu/energy/eu-buildings-factsheets-topics-tree/energy-use-buildings_en

[2] Smart meter alliance, available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/esma_publishable_report_en.pdf

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9. Load analysis, modelling and forecasting (for energy markets, network operation and planning, energy saving, etc.)
10. Settlement and billing
11. Virtual Power Plant, embedded renewables and cogeneration
12. Improving competition and efficiency in energy markets
13. Customer service by DSO, RESC and ESCO including improved switching of energy retailers
14. Fraud detection
15. Providing information for authorities and researchers
16. Meter management
17. State estimation of power distribution networks
18. Monitoring of power quality and reliability
19. Prepayment
20. Ancillary services such as frequency controlled reserve, voltage and reactive power control
21. Analysis of failures and preventive maintenance
22. Safety, security, telemedicine, social alarm services

Table 2-1 Smart meter applications (Smart meter alliance, 2010)

The importance of smart grids and meters rely therefore on the several applications they can enable. Within MAtchUP, their potential will be experimented at district, building and home level.

Beyond smart grids and metering, other key technologies deployed in smart city settings are those allowing the generation of renewable energies. They include PV systems, Solar Thermal (ST) collectors, sewerage energy systems, wave converters, etc. Considering the intermittence of renewable energies generated through these innovative technologies, storage solutions have emerged to balance out energy demand and supply. This has in turn led to the proliferation of energy generation sources throughout the city. Distributed energy generation and the advent of microgrids (i.e. local grids usually attached to the national grid but able to work independently) are indeed key features of today's modern cities.

2.2 Smart city Energy Market Potential

The market potential for energy transition is extremely promising, especially in Europe. Important advancements occurred in the past few years towards the sustainability goals described above, and a very ambitious roadmap was put on the table for the coming years.

It is difficult to make precise forecast for the future of the energy market, due to different variables: some structural, other contingent (such as the current pandemic Covid-19).

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According to IEA[3], the global energy demand increased by 2.3% in 2018, registering a 4% net growth and confirming its relevance in the global energy segment (20% of total energy consumption in 2018). In 2019, for the first time in decades, fossil-fuel-based generation declined while renewable electricity generation continued to increase.

Covid-19 had enormous impacts on a social and economic level. In April 2020 the price of US crude oil went negative for the first time in history. In such situation, GHG emissions decreased substantially, but the situation could return to pre-crisis level if no political measures are taken soon (and even rebound effects cannot be excluded). Moreover, the economic slowdown caused by the pandemic may delay many projects from the world's largest energy companies. Electricity demand, in particular, is set to decline by 5% in 2020, the largest drop since the Great Depression in the 1930s. Following such general trend, 2020 will see the first annual decline in the last 20 years also for renewable energies. As reported in the "Renewable energy market update" released by IEA at the end of May 2020, "almost all mature markets are affected by this decline, except for the United States where investors are rushing to finish projects before the tax credits expire. After an exceptional growth last year, the addition of new renewable energy in 2020 should be one third compared to last year, the largest annual decline since 1996 (IEA, 2020).

Following pre-COVID trends, the share of renewable energy in final energy supply would increase to 17% by 2030 and 25% by 2050. At the time of finishing this report, only partial data are available. The Global Energy Review" by IEA projects that energy demand will fall by 6% in 2020 – seven times the decline seen in the 2008 global financial crisis (IEA, 2020). Nonetheless, IEA anticipates that already in 2021 the construction of renewable energy plants should start growing again because most of the projects that are suffering delays will come back in operation and government support policies will continue.

In this context, urban settings is expected to keep on driving high energy demand: 72.5% of EU population live in cities[4] and households represent more than 26% of final energy consumption[5]. As such, the transition towards renewable energy in smart city contexts can strongly support the EU environmental sustainability goals. More specific data on cities - always provided by IEA[6] but referred to 2013 - highlighted that urban areas at global level accounted for about 64% of global primary energy use and produced 70% of the planet's carbon dioxide emissions. Energy demand will increase by 57% in cities, reaching 73% of the world energy demand in 2030. The role played by urbanization is

[3] IEA, available at: https://www.iea.org/news/global-energy-demand-rose-by-23-in-2018-its-fastest-pace-in-the-last-decade

[4] Eurostat, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs_%E2%80%94_patterns_of_urban_and_city_developments#Patterns_of_urban_and_city_developments_in_the_EU

[5] EEA, available at: https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-9/assessment-4

[6] IEA, available at: https://www.iea.org/news/cities-are-at-the-frontline-of-the-energy-transition

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particularly evident from the following figure: energy demand will remain unvaried outside of cities, and will exponentially increase in cities.

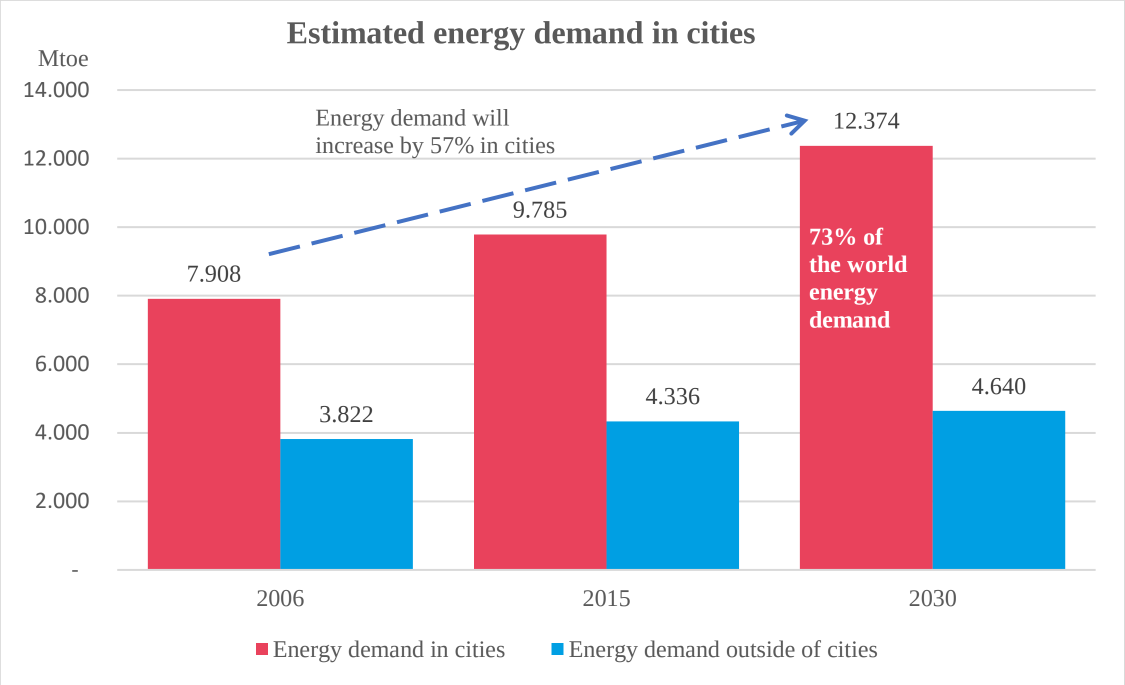

Figure 2-3 Estimated energy demand in cities (OECD, 2016)

The increasing demand of energy in cities will keep on driving demand for smart energy solutions. According to IDC, energy will absorb one third of total investments in smart cities[7]. Smart grids, in particular, are the largest segment. The “Networked Grid 150, Report and Rankings” published in 2013 by GMT Research[8] forecast that a total of $ 500 billion will be spent globally on smart grid initiatives by 2030.

In the EU, the commission mandated the roll out of smart meters to 80% of consumers by 2020, subject to the positive results of a cost benefit analysis. By 2020, 123 million smart electric meters are expected to be installed in the EU, representing a EUR 18.8 billion investment. Denmark, Estonia, Finland, Italy Malta, Spain and Sweden have already hit or surpassed the 80% target. Italy is entering into the second stage of the roll-out. The other countries will not meet the 2020 targets, in some cases as a result of a negative cost benefit analysis that delayed national roll-outs. Nonetheless, they are expected to catch up in the years ahead. By 2024, 243 million electric meters will be installed, representing a total EUR 37.3 billion investment. Gas and water meters are lagging behind, but growth is expected to be strong in the years ahead (European Commission, DG Energy 2019).

[7] IDC, available at: https://www.idc.com/getdoc.jsp?containerId=prUS45303119

[8] GMT, available at: https://www.greentechmedia.com/articles/read/gtm-research-names-top-150-vendors-in-smart-grid-across-12-market-segments

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The market potential of technologies enabling the generation of renewable sources is also promising. An analysis by technology is provided in the last chapter of this report.

2.3 Smart City Energy Competitive Environment

As smart energy solutions penetrate the energy market, the ecosystem is changing accordingly.

The energy ecosystem has always been complex, with a wide network of players that develop, operate, and maintain the mix of energy solutions, infrastructures, and services. As per the nature of this market, the energy system has always been very fragmented. This is mainly due to the fact that different types of players are needed to sustain the end-to-end energy value chain, and technologies, solutions and services, are heterogeneous in their nature and objectives. Moreover, when it comes to take advantage of emerging technologies and opportunities, fragmentation is even more evident.

With the introduction of new technological solutions, along with the change in societal needs, the overall city ecosystem changed, becoming smart and opening opportunities for a wide range of energy products to be deployed. They include home energy generation solutions, energy storage and energy collectors, smart control and domotics, smart meters and lighting, and grid technologies. Even though some of the new energy solutions are enabled by the evolution or invention of new technological and technical components, the changes in societal dynamics introduce opportunities for new services with ICT as a key enabler. ICT layers apply on top of existing applications and services – enabling their integration and mutual communication but also the development of new services and applications based on data and information management (European Commission, 2016). The need of resources' optimisation is a key factor that ensured the proliferation of monitoring and management solutions also in the energy domain.

This setting leads ICT players to be dominant also in the energy market, such as telecommunications operators, connectivity players, software companies, devices and components' manufactures and providers. As ICT-enabled services proliferated in cities, several are the ICT companies that developed energy-specific business strategies, to capitalise on the market opportunities. A detailed description can be found in the report "D6.7.1 Market analysis: Smart City ICT solutions (First release)".

Some of the new market players are focusing on the development and provision of very specific solutions – trying to gain market share in fewer segments, others try to operate more horizontally and to get higher market share in different segments of the market of reference. Many are also the recently founded companies that entered the market to launch new energy services and solutions, such as for energy management systems, metering and monitoring, storage, energy consultations, and energy performance. Even though traditional energy providers can easily reach economies of scale and are capable of significant up-front investments to enter new segments and testing new high-techs, start-ups can benefit from higher agility and process flexibility and might be less risk adverse (Accenture, 2015).

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The changing dynamics in urban areas led always new needs to be constantly met by energy solutions and service providers. Well-established energy specialists find themselves to compete not only with start-ups that try to catch new business opportunities in the market, but also with big companies that operate in different markets but want to diversify their business portfolio finding energy market segments at an early stage of development. For example, Google, Apple, Samsung, Walmart, Verizon, are partnering with hardware and software providers to develop IoT technologies for new energy management products and services at high value (Accenture, 2015). Several are also the pure digital competitors that offer energy services' packages at high value for consumers. Market giants are trying also to put in place cross-vendors collaborations, in order to gain a dominant position in the market, where they become intermediary between customers and vendors aggregating products and services in the area of energy that can be compatible and integrated to each other. Indeed, rather than the vertical development of tools and products, those companies try to build flexible platforms that can be potentially enabler for a variety of other services and products owned and developed by different companies.

As mentioned, new opportunities made the energy market – which was already complex and fragmented - more dynamic, and competitive. This has opened up a range of services and solutions that can be implemented. Several are the factors that contributed, such as new technologies disruptive trends, and changes in societal needs.

In addition, as energy efficiency and renewables' paradigms proliferated, opportunities for new products and services in this specific area, arise too, and so the market players. Sales of energy-efficient and green products is expected to keep growing in the future (McKinsey, 2010). Actors operating in this area try to catch opportunities in the provision of energy-efficiency and renewable services and solutions, such as efficiency improvements, energy saving, monitoring, or to provide auxiliary services such as advisory for such implementations (QualitEE, 2018). As the market demand for energy efficiency solutions and services remains strong, new operators progressively enter the market such as energy distributors, funds investing in new solutions; it is showed also that as opportunities arise, the number of both SME and large ESCOs in the market grows accordingly. In addition, mergers and acquisitions occur, to share capital for entering the market. There is a growing tendency of some market players to acquire solution-specific ESCOs to integrate their resources and expertise into energy-efficiency market (Joule, 2018).

From the analysis, it seems that the energy efficiency market – as per the energy market as a whole, is experiencing a constant growth, with a progressively higher competition, the proliferation of new players, ESCOs and completely new energy service models.

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3 Smart city Energy drivers and barriers

This chapter provides an analysis of Energy solutions drivers and barriers in smart cities, in order to understand what factors can foster or hamper investments in MAtchUP, and be prepared to capitalise on opportunities.

3.1 Energy Drivers in smart cities

Drivers for the investment in energy solutions within urban environments are numerous. The analysis is presented following the PESTLE scheme, underlying political, economic, social, technological, legal and environmental drivers and barriers towards an energy transition, with particular reference to urban environments.

Political & Legal factors	Social factors
EU regulatory frameworks EC smart meter mandate Global, European and national environmental policies Government incentives	Growing urbanisation Public health concerns Citizens’ role (prosumers) Millennial and Generation X (both familiarity with technology and concerns for climate change) General increase of citizens’ awareness and concerns about environmental problems, climate and ecosystems breakdown Energy Communities
Economic factors	**Technology factors**
Ageing grid infrastructure Utilities’ economic benefits (Demand-response, tariff plans, avoidance of losses) Public sector’s cost reduction Savings from renewables and ROI on companies’ image PPP and ESCOs Smart energy control reducing households’ bills Prosumer model	Deployment of smart meters and grids Digital infrastructure (IoT, Big data, connectivity, cloud) New solutions around BEMSs and connected appliance Blockchain Performance and costs of renewable energy technologies Storage solutions

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Positive economic impact (employment) on cities	
Environmental factors	
EU and international environmental policy objectives Air pollution and health issues Climate change Reliance on several technologies and appliances demanding energy	

Table 3-1 Summary of key smart cities' drivers

3.1.1 Political & Legal drivers

The first real regulatory framework in the energy sector at EU level was released in 2007, with the Lisbon Treaty. Before then, the EU energy legislation was mainly based on the EU authority in the area of the common market and environment. It is always in 2007 that the FP7 programme has been launched, a real turning point for energy investment and research in Europe, especially thanks to the Strategic Energy Technologies Plan (SET Plan). The relevance assigned to energy issues has been confirmed by the H2020 program and it is likely to be with Horizon Europe.

In 2009, another package of legislative proposals was adopted by the EU, with the aim to drive suppliers' choice and enhance the benefits for consumers by promoting liberalisation. In particular the Electricity Directive 2009/72/EC requires the EU Member States to roll out electricity smart meters to 80% of consumers by 2020, unless the result of a Cost Benefits Analysis is negative. The roll out of smart meters is the prerequisite to the move to smart energy in EU cities, and the EU mandate represents a key driver for the development of smart energy solutions.

In 2015, the Energy Union Long-term Strategy was launched with the objective to coordinate the transformation of European energy supply, and the definition of five main priorities: energy security, solidarity and trust; fully integrated European market; energy efficiency; decarbonisation; research, innovation and competitiveness.

Lastly, in 2019, the European Union updated its energy policy framework, by introducing an ambitious package called Clean Energy for all Europeans, consisting of 8 legislative acts. The package updates EU decarbonisation targets and foresees a 40% reduction in GHG emissions by 2030 compared to 1990 levels, a 32% share of renewable energy sources in European final consumption, and a 32.5% improvement in energy efficiency. Moreover, it promotes local energy communities and energy performance in buildings.

The European Union power sector has been traditionally characterised by centralised generation. However, smart energy solutions require a move to decentralised generation and microgrids. The 2018/2001/EC (so called RED II – Renewable Energy Directive) sets the framework for the EU renewable energy policy for 2021–2030, and recognises

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prosumers and renewable energy communities as key RES (Renewable Energy Sources) actors. They can generate renewable energy, including for own consumption, store and sell their excess production. Article 15 of the Internal Market Directive (IMDII – 2019/944/EC) goes into the same direction by allowing consumers to operate directly or through aggregation, self-generating electricity also through PPAs, participating in flexibility and energy efficiency schemes and be subject to cost effective and non-discriminatory network charges. With IoT being largely adopted in smart cities, other legal drivers include those related to the monitoring and controlling aspects (including the updated Energy Performance Building Directive, 2018/844/EC). The three directives must be transposed in national laws by 2021 and are expected to be a game changer towards the decentralisation of energy consumption and the automation of EU buildings.

Moreover, the EU Commission launched an Investment Plan of at least EUR 1 trillion over a decade to sustain the EU Green Deal, to lead the continental action during the next decades. The first step of this ambitious plan entails the "Just Transition Mechanism", which aims to mobilise at least EUR 100 billion over the period 2021-2027. The financial support to this action should come from the following sources:

- "Just Transition Fund" with EUR 7.5 billion in fresh EU funds. Matching funds from Member States, the European Regional Development Fund and the European Social Fund Plus will bring funding to EUR 30-50 billion;
- "Just Transition Scheme" under InvestEU, with the objective of attracting private investment to support regions in decarbonising, diversifying and strengthening their economies, may mobilise up to EUR 45 billion;
- "Public Sector Loan Facility" from the European Investment Bank, backed by the EU budget, is to mobilise EUR 25-30 billion for purposes such as district heating networks and building renovation.

Global initiatives and policies related to environmental issues are also crucial: the effectiveness of international politics and policies will be a central driver for energy transition. The Paris Agreement (2015) has been a turning point. The summit posed ambitious objectives related to climate change, namely to limit the rise of global temperature of "well below" 2° C and ideally to 1.5° C, compared to pre-industrial levels, by the end of this century: this would correspond to a reduction by a minimum of 3.8% per year from now until 2050, with continued reductions thereafter. Considering clean energy, the Sustainable Development Goal 7 (SDG 7) identified by the UN requests to "ensure access to affordable, reliable, sustainable and modern energy for all". A Climate Investment Platform was announced in September 2019 by the International Renewable Energy Agency, the United Nations Development Programme, the multi-partner Sustainable Energy for All initiative, and the Green Climate Fund.

The pandemic Covid19 posed new challenges, strengthening even more the importance of effective policies in order to face economic and environmental issues. Numerous national governments and international institutions claimed that one emergency should not overshadow other crucial issues. The same EU, through the voice of President Von der Leyen, stated that COVID-19 emergency will not affect the timeline of the EU Green Deal. It is early to say if these declarations will be followed by effective results, but the political line is to not change the objectives posed before the outbreak of the pandemics.

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The latter, beyond representing a dramatic challenge for the planet, could also result in an opportunity to change the priority of government policies and budgets, driving the market towards important changes, and also implying disruptive social and behavioural impacts.

At local level, politics can have important influence too. Beyond the role of single administrators and political figures, other initiatives were started, the more relevant being the Covenant of Mayors, launched by the European Commission to engage local authorities in the 20-20-20 targets and following targets. Local administrations implement the single projects under the Sustainable Energy and Climate Action Plans (SECAPs), written and signed by the cities members of this network. Furthermore, a European Innovation Partnership on Smart Cities and Communities (EIP-SCC) was established, with the objective to sponsor the collaboration between cities, industry, SMEs, banks, research and other smart city actors and stakeholders: the EIP-SCC was involved in 370 projects related to the intersection of energy, mobility and ICT solutions with 4000 partners from 31 countries. Similar networks exist also in other world region, and at global level (involving European cities). Among them, C40 Cities is particularly relevant, a network composed by more than 90 of the world's greatest cities, representing 650 million people and one quarter of the global economy. Created and led by cities, C40 is focused on tackling climate change and driving urban action that reduces greenhouse gas emissions and climate risks, while increasing the health, wellbeing and economic opportunities of urban citizens. Finally, Smart Cities Lighthouse projects are integrated commercial-scale solutions with the aim of bringing together cities, industry and citizens to demonstrate solutions and business models that can be scaled up and replicated, and that lead to measurable benefits in energy and resource efficiency, new markets and new jobs.

With smart buildings being a key component of smart cities, government incentives can also play a very relevant role. Fiscal incentives have been introduced in several EU countries, with the aim of supporting buildings renovation through the adoption of advanced energy technologies.

The combined action of all these governmental levels, and their awareness about the centrality of urban settings for energy transition, is a fundamental driver for the development of effective innovative solutions.

3.1.2 Economic drivers

Beyond the actions of governments and institutions, also companies and corporations played (and continue to play) a central role in energy transition dynamics. The liberalization of the market, involving increasing competition, has contributed to end-users' price reduction. Wholesale prices decreased in 2019, and the increasing adoption of renewables is expected to lower electricity prices further. Nonetheless the market is still dominated by fossil fuels (European Commission, 2019). This exposes the EU energy sector to a strong volatility, in consideration also of its strong dependence on energy provision from external markets.

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	2012	2013	2014	2015	2016	2017
EU 28	**53.7**	**53.3**	**53.6**	**53.9**	**53.8**	**55.1**
Belgium	75.8	77.1	79.8	83.9	75.4	74.8
Bulgaria	36.9	38.5	35.3	36.5	38.6	39.5
Czechia	25.3	27.4	30.1	31.9	32.6	37.4
Denmark	-2.7	12.4	12.3	13.0	13.4	11.7
Germany	61.9	63.0	61.9	62.2	63.7	63.9
Estonia	19.8	13.9	11.1	9.6	7.9	4.1
Ireland	83.8	91.7	86.2	88.9	69.1	67.1
Greece	65.8	61.7	65.4	71.0	72.9	71.1
Spain	73.0	70.2	72.7	72.9	71.5	73.9
France	48.4	48.1	46.2	46.0	47.4	48.6
Croatia	49.9	47.5	44.3	48.9	48.5	53.3
Italy	79.1	76.7	75.8	77.0	77.7	77.0
Cyprus	97.0	96.3	93.2	97.7	96.2	96.3
Latvia	56.4	55.9	40.6	51.2	47.2	44.1
Lithuania	80.5	78.5	78.3	78.4	77.6	75.6
Luxembourg	97.5	97.1	96.5	95.9	96.1	95.4
Hungary	50.1	50.1	59.8	53.9	55.8	62.6
Malta	101.0	104.2	97.7	97.0	100.6	102.8
Netherlands	30.6	23.7	30.9	48.4	45.9	51.8
Austria	64.5	61.5	65.7	60.6	62.5	64.4
Poland	31.8	26.4	29.5	29.9	30.8	38.3
Portugal	79.5	73.3	72.1	78.2	74.0	79.9
Romania	22.3	18.1	16.4	16.4	21.6	23.1
Slovenia	52.1	47.8	45.5	49.7	49.3	50.4
Slovakia	61.6	60.8	62.1	60.1	60.6	64.8
Finland	47.2	50.0	50.2	48.2	46.0	44.0
Sweden	29.8	32.5	31.9	28.9	31.9	26.4
United Kingdom	43.4	47.8	46.8	37.5	35.7	35.4
Norway	-549.3	-482.4	-575.4	-575.1	-631.9	-603.3
Turkey	75.6	75.4	76.3	77.9	75.5	77.1

Table 3-2 Energy import dependency, EU-28, 2012-2017 (Eurostat, 2018)[9]

Classic energy sources and in particular their infrastructures are also conditioned by their “ageing” process, that makes them economically disadvantageous. More than 80% of energy infrastructure globally was built prior to the 1970s, and another 20% was built in the 1970s and 1980s (US Department of Energy 2015). Outdated infrastructures mean a considerable public cost for reparation, maintenance and performance, driving an increase in the levelized cost of energy (LCOE), namely the price of the produced electrical energy calculated considering the economic life of the plant, the costs incurred in the construction, operation and maintenance, and fuel costs. This has been a

[9] Eurostat, available at: https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-2c.html

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considerable driver for the deployment of smart meters and grids in the EU. A smart energy infrastructure provides many economic benefits to utilities. They can better match demand and supply through demand response programs, and avoid losses in the grid. On the other hand, data from smart meters can provide guidance on optimal prices and tariff plans that can support utilities in gaining a competitive advantage.
Another extremely important driver is the reduction of public costs involved by the adoption of smart energy solutions. Smart energy enables other public services, for example in the public safety (e.g. humble lampposts) or in the mobility areas (e.g. public transportation based on e-fleets), and, by supporting the transition towards renewable energies, has also a positive impact on public health costs.

Beyond utilities and public authorities, other companies can drive and benefits from smart energy. According to a study on 2,400 large global companies conducted by IRENA in 2018, renewable sources are a “mainstream pillar of business strategy”. More than 200 of these companies get at least half of their energy from renewables, while 50 are even totally powered by renewables. Going a step further, two-thirds of Fortune 100 companies have set renewable energy targets. Some European leading companies have got an explicitly green approach, such as Unilever (UK-The Netherlands), which is powering its offices and factories with renewable energy, Ikea (Sweden), which claims to produce more renewable energy than it uses for its building and stores, or AXA (France), which claims to have become 100% renewable and have reduced its energy consumption and CO2 emissions by a third. Although contribution of big companies is important, a key push will come from small and medium size companies, as observed in the dossier “Serious business: Corporate procurement rivals policy in driving growth of renewable energy”, published by Deloitte. This interest from private companies is related to the perceived, and especially potential, economic benefits of clean energy and renewable sources in particular, at the point that specific campaigns have been launched such as RE100, supporting companies that publicly committed to 100% renewable electricity. With consumers placing a stronger attention to green issues, companies expect also to benefit from a positive ROI on their brand image.

Furthermore, within a very competitive and changing market in which not always public interventions are affordable and/or sufficient, collaborations and alliances between economic stakeholders are of fundamental importance and represent a key market driver. Such alliances can be public, private or combined (Public Private Partnerships – PPP). PPP can be complex, but provide fast delivery of the project, high efficiency, risk sharing and improved quality of services, because of the involvement of both parts with different specific tasks and competences. Green bonds also deserved to be mentioned. They consist in debt instruments designed to raise capital for specific eco-sustainable projects. Their success is due to the fact that they provide companies and governments with a way to finance projects and are also an excellent alternative for investors who want to improve their environmental, social and governance credentials.

Lastly, economic benefits for single consumers/households are also important to consider. Smart meters and smart energy management systems allow them to control and decrease energy consumption. Moreover, in a smart grid, consumers can produce and share energy surplus with the grid. The advent of this prosuming model has also substantial economic benefits. On the one hand, prosumers contribute to the sustainability of the grid, on the other hand, they benefit from energy self-consumption and of possible Feed in Tariffs or Purchasing Power Agreements when selling their energy surplus. These agreements set an agreed rate or discount per kWh of purchased power and are adopted also by utilities when selling their energy services. They enable cost savings for customers and higher revenue for generators as the agreed price is generally higher than the wholesale price but lower than the retail one.

Lastly, smart energy has a positive impact on employment and local wealth. The current EU plan for energy transition involves the expected creation of 70,000 full-time jobs, which will be especially generated in urban environments (JRC, 2020).

3.1.3 Social drivers

As reported by the Population Reference Bureau (PRB), the global population is expected to grow by 75 million annually, reaching 9.9 billion in 2050. Such a rapid increase poses serious challenges to energy provision. IEA forecasts that global energy demand will increase by over one third up to 2035, driven by improvements in living standards in the developing world (IEA, 2013). Cities consume (two-thirds of the world's energy) and produce a considerable amount of carbon emission; at the same time, 80% of global GDP is generated in cities. Therefore, urbanization is a pivotal element in the possible changes that will affect smart energy markets.

Public health is another social driver. Fossil fuels still have important impact on the health systems worldwide: air pollution still causes 7 million premature deaths per year, as reported on the World Health Organization (WHO) website[10]. Important investment in clean energy would mean important savings in the health sector: according to IRENA Global Renewables Outlook, "total savings in improved health, reduced subsidies and lower impacts of climate change would be worth as much as $160 trillion cumulatively over a 30-year period. Every dollar spent in transforming the global energy system provides a payoff of at least $5, and potentially more than $7, depending on how externalities are valued" (IRENA. 2019).

Along with the impacts of urbanization and health care, individualization is another driver to consider when analysing smart energy solutions. Contemporary Western societies are characterized by the increasing role assumed by individual actors, and by the prominence of consumption activities. French philosopher Jean Baudrillard among others defined the current one as a "consumer society": beyond some possible negative sides, this definition recognizes the power in the hand of single individuals and their possibility to influence the market. In recent times, the even more explicit term of "prosumer" is acquiring visibility, meaning that individuals would be at the same time consumers and producers of the same assets. The term, coined by sociologist George Ritzer analysing the supposed McDonaldization of Western societies, helps explaining one fundamental engine of contemporary markets. Solutions are and should be even

[10] WHO, available at: https://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

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more citizen-centric: citizens are a fundamental source of data and can become co-designers of new solutions.

While there is a general increase in citizens' awareness and concerns about environmental problems, climate and ecosystems breakdown, the younger generations are even more sensitive to environmental issues. On the one hand, they are more used to new technologies, being digital natives; on the other hand, they are more conscious of the importance assumed by energy transition and by the adoption of renewable energies for the future of the planet. A research conducted by Yale University and George Mason University considered the opinions of 2,000 registered US voters about their interest in clean energy[11]. Millennials and members of Generation X declared to be disposed to spend an average of extra $22 on a monthly base, while Baby Boomers would only consider an average of extra $1111. Such findings are not unpredictable, if we consider the huge participation of very young people in mass protests during 2019 asking for a decarbonized future society able to face global warming, in particular those of the so-called Fridays For Future movement. The increasing interest of young people in renewable energies, as well as the collective perception of younger generations about the necessity of an energy transition will contribute to the implementation of technological solutions in smart cities and to the investments in renewable energies. Young people will also be the decision makers of the future. Furthermore, higher predisposition to technology among Millennials can be considered a driver.

Beyond the role of single citizens/prosumers, it is worth mentioning the role assumed by so called energy communities and energy cooperatives. The creation of a sense of community, is a driver for the investment in energy transition, and also more specifically for smart cities projects. Having the possibility to share responsibility with other people belonging to the same community can increase the willingness among citizens to increase resilience. Germany is the world leader of energy cooperatives: two-fifths of renewable energy installed in the country last year was cooperative-owned. Second to Germany is Denmark. Energy communities play a central role in citizens' engagement and in building social acceptance of clean energy projects and solutions, representing a fundamental source of social capital.

3.1.4 Technological drivers

The deployment of smart meters and smart grids is at core of smart energy technology transformation in cities. The EC pushed the development of interoperability and standards to drive their roll-out across EU cities (See paragraph 3.2.4 Technological barriers).

This couples with advances in IoT, big data, connectivity and cloud computing, already analysed in the market analysis of ICT solutions (see D6.7.1 Market Analysis: Smart City ICT solutions – First release), which have allowed the emergence of new systems able to control energy usage (e.g. Energy Management systems) and the development of

[11] Yale, available at: https://climatecommunication.yale.edu/about/projects/climate-change-in-the-american-mind/

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connected appliances, including home appliances (e.g. managed real time and able to stop consuming energy when demand and prices are higher).

At the same time, the advent of “blockchain” drives the development of decentralized systems in which the intermediaries are no longer needed, because transactions can be started and managed directly through the "peer to peer" logic, recording all the data in a system of secure and decentralized storage.

Lastly, the improved performance and lower prices of technologies enabling the generation of renewable energy (e.g. PV, ST collectors, etc.) make them more affordable to building owners in the commercial and residential segments. The availability of storage solutions is a very effective driver in this area, as it guarantees the continuity of energy services, independently from weather conditions. Stationary storage enables this via load control, frequency regulation and energy integration.

3.1.5 Environmental drivers

Environmental concerns for implementing innovative energy solutions in urban settings have already been mentioned in the previous paragraphs. The current energy system is environmentally unsustainable. Constant deployment of sustainable energy solutions is paramount to reach the milestones and objectives posed by international governance, from the UN Sustainable Development Goals to those established by the European Commission: this is true in particular for cities.

The WHO estimated that air pollution causes around 3 million premature deaths per year and that 92% of the world's population is exposed to annual concentrations beyond the recommended limit (World Health Organization, 2017). In Europe, about 10% of the population breathes an average annual concentration of PM2.5 above the legal limits, leading to an estimated reduction in the average life expectancy of 8.6 months[12][13].

Beyond the impact on human health (with the correspondent public costs), climate change should be considered as a driver pushing in the direction of energy transition. Climate change involves floods, drought, extreme weather, rising seas and other natural events with huge social impacts: investing in clean energy will help to diminish these events, that always more affect also urban environments. According to the research “Building a Hyperconnected City” by ESI ThoughtLab[14], 44% of cities worldwide deploying smart environmental and energy initiatives are reducing pollution.

Cities are not only massively inhabited by human beings but also extremely modified by them. The amount of machines, appliances and devices that we use every day rely strongly on energy consumption. The environmental impact that they can have is huge.

[12] WHO, available at: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

[13] European Commission, available at: https://ec.europa.eu/jrc/en/news/air-quality-atlas-europe-mapping-sources-fine-particulate-matter

[14] ESI ThoughtLab, available at: https://econsultsolutions.com/wp-content/uploads/2019/11/ESITL_Building-a-Hyperconnected-City_Report.pdf

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Smart energy solutions become therefore essential to offset the increasing demand for energy and support the shift towards a low carbon economy.

3.2 Energy Barriers in Smart Cities

Given the drivers for the smart city Energy market described above, it is essential to highlight some of the conditioning aspects that could act as barriers and in some way affect the degree to which a Smart City advances and develops. The analysis is necessary to be ready to face the eventual risks that can hamper MAtchUP market uptake and foresee appropriate actions.

MAtchUP solutions hold a strong replicability potential. Before going into the detailed analysis of barriers, it is important to stress that every region of the world, as well as every single country and city, face different challenges when speaking about energy transition and smart energy solutions. The peculiarities of each local context should always be kept in particular consideration in terms of legal, economic and social characteristics.

Political & Legal factors	Social factors
National legislation and requirements Political parties and innovation National decisions regarding international policies	Rooted habits and lifestyle Education and salary levels Centre-periphery divide Digital divide Consumers' concerns over solutions' accuracy, safety and privacy
Economic factors	**Technology factors**
Investments costs ROI Decentralisation of energy generation challenging traditional energy players National differences in energy production and electricity costs	Standards Security Skills
Environmental factors	
Concerns over possible negative environmental impact Environmental issues not always being a priority	

Table 3-3 Summary of key smart cities' barriers

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3.2.1 Political & legal barriers

Despite a common EU framework, national implementations can result in different legal requirements on a country level. An example was already given in the State of Art regarding the current roll-out of meters. Not all EU countries will reach the 80% target foreseen by the Electricity directive, in some cases due to political responses to consumers' concerns.

Moreover, political parties can also represent an obstacle, being some at local, national and also European level more resilient to innovation and changes.

At international level, the scenario is based on the roadmap of the Paris Agreement, on the documents presented by the International Panel on Climate Change (IPCC) and on the regional proposals of Green Deals (beyond the EU Green Deal, at least the US Green New Deal should be also mentioned). However, national decisions still remain crucial. The backbone of the Paris Agreement, for example, is represented by the National Determined Contributions (NDCs) signed by the 197 member states of the United Nations Framework Convention on Climate Change (UNFCCC). However, at the moment only 135 countries have renewable electricity targets in their national and sub-national energy plans, and especially only 85 countries have included unconditional renewable power pledges in their current NDCs. The NDCs will be updated in 2020, confirming the crucial role of this year in terms of energy politics worldwide (IRENA, 2019).

3.2.2 Economic barriers

As with other smart cities' interventions, the cost of deploying the solutions and the capital investments required are key economic barriers. It is estimated that the roll-out of gas meters only would require more than EUR 12 billion by 2024 (European Commission, DG Energy, 2019). This couples with cost of ownership issues, with particular reference to maintenance and upgrades of the equipment. Moreover, ROI of smart energy might not be always evident in the short-term. New services and models need time to produce economic benefits on a large scale.

In the short term, COVID-19 can represent a specific economic barrier, as some projects may be delayed and investments temporarily redirected to support local economies.

Beyond that, the decentralisation of energy generation poses competitive challenges to traditional energy players, which could have a private interest in contrasting the energy transition process. With prosumers selling the energy produced in excess, utilities could be disintermediated, losing market share and revenues.

Also very important national differences in energy production and costs should be considered. These differences can represent an obstacle for the common development of innovative energy solutions in European states, and cities in particular. For example, France still relies on nuclear energy for some 79% of the total national energy production, while in countries such as Malta, Latvia, Cyprus, Portugal and Lithuania renewable energy is already the main source of energy produced. Finally, crude oil still remains very relevant in Denmark (44%) and the United Kingdom (41%), solid fossil fuels in Poland

(79%), Estonia (73%), Greece (61%) and Czech Republic (57%), while natural gas is the main source of energy produced in the Netherlands (80%)[15]. Shifting to new energy sources can be therefore challenging and expensive. Furthermore, the public perception of the energy transition effectiveness at European level is extremely influenced by national differences in the cost of energy (electricity in particular) to the final consumers.

3.2.3 Social barriers

Rooted habits and lifestyles are not easy to change, and this is especially true in some sectors of civil society. Scepticism towards innovative solutions, along with a business-as-usual mentality, can be an obstacle to the development of effective smart energy solutions.

Moreover, different incomes and educational levels can result into different attitudes especially to green and environmental issues. So-called post-materialist values, a term introduced by sociologist Ronald Inglehart, are more likely to be accepted by well-educated high-middle classes. Another divisive axis is the “centre-periphery”. Innovative solutions driven by smart approaches are likely to be better welcomed among people living in city centres of contemporary cities. The disenchantment and opposition of suburbs’ inhabitants can represent a barrier to the development of smart solutions.

Furthermore, resilience to innovation can be a barrier, as well as the still widespread digital divide, both cross-country and within the same European country. The digital divide also reflects some of the social inequalities previously mentioned, such as educational level, income opportunities and centre/periphery.

Lastly, smart energy solutions can raise specific consumers’ concerns. Some of them became evident during the mandated roll-out of smart meters in EU countries. They included accuracy of the smart meter, the electromagnetic radiation they produce and privacy related issues (European commission, DG Energy 2019). Accuracy, safety and privacy issues can apply to several solutions underpinning the smart city energy transition.

3.2.4 Technology barriers

Two key technology barriers hamper the development of smart energy solutions: lack of standards and security issues. In an attempt to face these issues, the European commission mandated CEN, CENELEC and ETSI to develop an open architecture for utility meters (mandate M/441) involving communication protocols enabling interoperability and cyber-resilience. This led to the development of standards including a common set of security requirements, and a Protection Profile for smart meters, which could bring a positive contribution to the security certification of smart meters in Europe (Tractebel, 2019). Beyond meters, other efforts should be made across all solution areas

[15] Eurostat, available at: https://ec.europa.eu/eurostat/web/energy/data/database

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underpinning the smart energy transformation. Not all smart solutions are interoperable and may not even use the same communication protocol.

Lack of technical skills is another key technology barrier. In some cases, even awareness of smart technologies is an issue. Big data, for example, calls also for advanced analytics skills to derive value from the huge amount of data collected through meters. IoT calls for new planning, implementation and maintenance skills. The overall smart city energy transformation requires a vision of how different stakeholders and technologies can be connected to produce the expected benefits.

3.2.5 Environmental barriers

Environmental issues are clear drivers of smart energy solutions in cities. Nonetheless, two key barriers can still impact their deployment:

- Public concerns over safety of certain solutions, including their possible negative impact on the environment (e.g. radiation).
- Environmental objectives have been set on an international level, and, as said, represent a key driver of energy transformation also in cities. Nonetheless, they are not always perceived as a priority. No matter the objectives posed by the Paris Agreement, global energy-related CO_2 emissions rose 1.7% in 2018 to a record high of 33.1 Gt CO_2[16] and concentrations of particulate matter (PM) continued to exceed the EU limit values in large parts of Europe in 2017 (EEA, 2019).

[16] IEA, available at : https://www.iea.org/reports/global-energy-co2-status-report-2019/emissions

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4 Smart city energy services

Smart city energy solutions drive several opportunities to enhance existing services, launch new ones and leverage new business models.

4.1 Enhancement of existing services

New technologies are changing the way energy is generated, distributed, and consumed. Growing urban populations, associated with an increased number of electrical devices impose an important demand issue for cities, and require more efficient ways of managing and consuming energy. Many IoT technologies are helping to solve these issues, by providing consumers with insights and control over how much energy they consume. As said, the first developments were around smart grids, which consists of a modern form of conventional power grids, empowered by new technologies, which make energy production and distribution more efficient, reliable, safer, and greener. These grids facilitate the energy flow between power generation companies, distribution centers, and end consumers, and positively impact the consumption of energy in various ways. The enhancement of network monitoring, for example, reduces the amount and duration of electricity outages. Smart grids are also able to reroute power, allowing faster electricity restoration after an outage. Another relevant contribution of smart grids is the positive impact in the production and distribution of electricity for energy providers.[17] Moreover, smart grids facilitate the integration of renewable power sources that do not emit greenhouse gases, such as wind or solar energy (IEEE, 2016).

While Smart grid refers to the broad concept of energy delivery improvement, consumption awareness, and environmental impact reduction, smart meters allows consumers to track their energy consumption, who can benefit from cost reductions. Decisions from, for example, turning up the heater or simply switching lights off that are not being used can help the user to behave more cost-efficiently. On the other side, utility companies benefit by providing more accurate billing, according to real-time energy consumption, and carefully control and balance demand and supply.[18] In sum, smart meters allow companies to meet increasing consumer demand without building new infrastructure (Maltese et al., 2016). With the use of sensors, smart meters can transmit data about energy supply and use it to improve efficiency, contributing to minimize the environmental impact, and as mentioned, reduce overall costs.

Another technology providing an enhancement of the traditional electric power grids are the Distributed Energy Resources (DER), which consist of small-scale power generation sources located close to the end users, as houses or business. They have been available for several years, and are known by different names such as generators, back-up

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[17] ITProPortal, avaiable at: https://www.itproportal.com/features/paving-the-way-for-lower-energy-consumption-in-smart-cities/

[18] Thales Group, available at: https://dis-blog.thalesgroup.com/iot/2019/01/31/the-internet-of-energy-delivering-safe-smart-energy-in-the-smart-city-era/

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generators, or on-site power systems[19]. DER are mainly renewables and can include small-scale storage and internal combustion generators.

More and more existing devices are embedded with connected technologies that integrate the activities with flow of real-time information exchanged between existing physical objects and the digital world. The most important connected technologies that enable to make the existing energy ecosystem smart are LTE & 5G, metering equipment, AI, big data platform with cloud computing, asset performance management, cybersecurity, robots, blockchain and bi-directional connectors that enable remote management, data storage and computing (Deloitte, 2018).

The collection and processing of real-time data creates continuous flows of information along the entire value chain. The existing value chain can be in this way controlled, and the different stakeholders can take advantage of data for their own purposes. System operators can balance energy flows, analyse resources for better asset management. Suppliers can actually make reliable predictions on behaviors and preferences coming from consumers. Consumers can have a higher control of their consumption levels and information of their energy profile so to choose more sustainable solutions, buying energy with different pricing schemas, actually contribute to the energy generation process, and store energy and sell it back or used when needed (Deloitte, 2018).

4.2 Opportunities for new services

As said, technological advancement along with changes in societal dynamics and needs, reformed the energy system, which is now more interconnected, intelligent, efficient, and sustainable. A wide spectrum of energy products and services are being deployed. And as infrastructures will become more distributed, technologies will evolve, and become more cost-efficient, their integration will unlock new opportunities for completely new services.

For examples, as digital technologies will increasingly apply to energy infrastructures, and distributed generation and storage innovative solutions will evolve, grid technologies will become more and more distributed. The development of battery back-up systems, grid storage solutions, distributed storage solutions, and batteries systems, better off the overall storage process, and combined with the development of infrastructures and the advent of distributed power sources, microgrid can become more common and distributed in urban areas. The grid becomes smart, using ICT to enable communication, improving efficiency, energy saving, decreasing wastefulness, and increasing sustainability and reliability of the whole energy production and distribution system (Smart Grid Insights 2014). Following this, the traditional relation between customer and the grid changes with the introduction of the “prosumer”.

To put in place this emerging infrastructure, several energy services will be needed that will empower users and enable the actual interactions within the community. As solutions and energy systems are getting more and more distributed and heterogeneous, a

[19] WBDG, available at: https://www.wbdg.org/resources/distributed-energy-resources-der

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multitude of new solutions and services will provide varying functionalities and ensure the sustainability and flexibility of the overall system (Accenture, 2015).

As this process evolve, emerging platforms and in general ICT-based solutions facilitate and unlock the hidden potential. IoT, cloud computing, and in general integrated information and communication systems enable smart operations, and have a determinant role in managing energy supply and demand and integrated distributed energy sources and systems.

Intelligent devices, high-speed communication and real-time processing of data, enable the creation of an Internet of Energy, meaning a single ecosystem of smart energy infrastructures and components, unlock a wide range of energy management services, such as meter data management, grid analytics, distributed energy resource management[20].

This setting enables the creation of an energy as a service schema, which is the possibility to provide bundled data-driven solutions and services to the final user. An analysis from Deloitte shows how the adoption and implementation of new energy services lays in the intersection between digital technologies and new energy paradigms and solutions. Key digital technologies to be mentioned are IoT, sensors and controls, cloud platforms, cyber security, 5G connectivity, cognitive and robotic automation, advanced analytics, drones and robots, augmented reality and blockchain. Blockchain, as explained in the next chapter, is unlocking completely new business models for prosuming. Energy factors that coupled with digital solutions enable the provision of bundled or single innovative services in the energy market, are the development of energy efficiency paradigms, wind and solar, biofuels and biochemicals, maturity of the renewables, geothermal technologies, fuel cells and microturbine technologies, regulation towards decarbonisation and large-scale storage (Deloitte, 2018).

[20] Smart Energy International, available at: https://www.smart-energy.com/industry-sectors/smart-grid/from-a-smart-grid-to-the-internet-of-energy/

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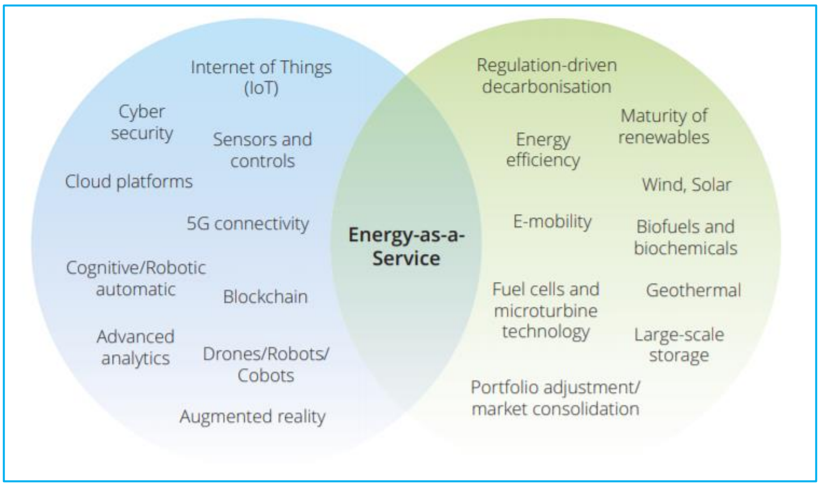

Figure 4-1 Tech + Energy = Energy-as-a-Service (Deloitte, 2018)

Even though the rising attention towards energy transition, the offerings unlocked by new technologies, integration, and connectivity, encompass several other applications and unlocked a multitude of services. Areas of applications are the supply of energy, energy transition and energy demand optimisation. Key services are for energy storage, distributed generation, energy load balancing, energy saving and external supply optimisation, and ancillary services for supply management.

Application	Service	Technology	Examples
Energy Supply	Ancillary services	Platform	Distributed energy resources interconnection portal, transactive energy
	Energy storage	Batteries; Power-to-anything (P2X)	Microgrid, residential and commercial energy storage
Energy transition enabler	Distributed generation	Renewables	Solar, wind, fuel cell, combined heat and power (CHP)
	Energy Load Balancing	Front-end algorithm	Monitoring and load management services
Energy (demand) optimisation	Energy savings	Smart meter	Demand response, building energy management, advanced metering services, energy efficiency
	External Supply Optimisation	Software app	P2P trading, real-time pricing

Table 4-1 Energy as a Service Offerings (Deloitte, 2018)

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Smart cities encompass more than energy only - with ICT as a key enabler, exploring synergies also with mobility, transportation and water. Several are the cross-cutting initiatives falling in the areas of sustainable urban mobility solutions, smart building, smart services for better informed citizens, and smart infrastructure (European Commission, 2016). Other than intra-sector integration, a progressive combination and inter-sector solutions and services are expected to flourish in the future.

4.3 Change in energy business models

As the energy ecosystem becomes more dynamic due to technological changes and increased competition, players started to leverage market opportunities offered by new energy and digital technologies to deploy and launch new energy business models. As per an IDC study, the key contributors of this shift – which is happening and will continue, are EV services, generation and storage, microgrid as a service, energy and comfort as a service (IDC, 2018). The introduction of new paradigms and services enabled by new technologies, have a direct impact on the ways in which companies provide solutions and services and make revenues, and the ways in which users and citizens are involved and used such new implementations.

The change in value creation mechanisms and new technologies enabling a multitude of solutions and services to be deployed, led players to engage in more end-to-end approaches towards the provision of energy services and solutions. Energy suppliers are moving towards the adoption of energy as a service and comfort as a service approach, meaning the possibility to sell in the market a wide range of energy-related technologies and solutions, but also analytics, personalized services, access to grid. New energy and digital technologies unlocked the potential of all stakeholders involved in the energy ecosystem, and open opportunities for the provision of new data-driven energy products and services – such as energy platforms that distribute real-time information on energy performance and usage, or P2P platforms through which users can actually exchange energy surplus (Deloitte, 2019). The provision of bundled energy services is usually based on customer subscription-models. The rising complexity of the energy market, let digital aggregators of solutions and services to act as a single point of information and services through which clients can pick up personalized solutions for fixed monthly payments (Deloitte, 2019). In this way, companies benefit from predictable subscription models, avoiding excessive capital expenditure. The users actually pay for the usage of an asset, not for the asset itself.

This approach is an example of the value added led by increasing integration of solutions and services that can create enhanced value propositions for businesses. Indeed, energy as a service combined hardware, software, and services to deliver a single offering. And, as integration of solutions, infrastructures and buildings will develop over time, companies will be able to offer more and more combined and tailored services.

Comfort as a service works in a very similar way, where the generation of automatic control strategies for domestic equipment release households to operate directly the equipment, and switching from pricing models based on consumption to "paying for comfort provided" (MDPI, 2018).

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Other models to consider in the analysis are related to generation and storage, which resulted in one of the most disruptive phenomena of the energy sector in the past few years. Consumers are not seen any more as “passive” but become prosumers – actively participating in the process. The different prosumer models that have been implemented recently are unlocked by technological innovations and solutions, such as micro-generation, smart metering, and energy management systems (ENABLE, 2016). Different types of prosumers exist: residential prosumers that produce energy at home, citizens cooperatives, commercial prosumers whose business is not energy-related, and public entities or institutions. IDC highlights that the decreasing costs of small-scale production and storage and the drop in prices of PV and storage, can let this model grows more and more in the next few years (IDC, 2018). The active participation of consumers in the energy value chain, transforms the traditional business models and allows prosumers to create new services to be offered in the market. Prosumers are directly connected with grid services and they can consume part of the energy they produce and sell the surplus to the collective grid. The prosumer can receive energy from the utilities, own its own sources, or from other prosumers in its collective grid.

The level of profitability of prosuming depends on the quantity of energy that is actually consumed, but in general self-consumption is beneficial to the ecosystem since it reduces transmission losses and peak demand (European Parliament, 2016). Different are the pricing models that can take place when a prosumer schema is put in place in a community. The net-metering model entails that prosumers feed their energy surplus into the grid and can consume it later when needed, paying the net difference. In feed-in tariffs, prosumers pay the retail price for what they consume, but at the same time energy providers offer them long-term contracts that entails compensation for the surplus energy that get back to the grid. Feed-in premium is similar to the previous one, but remuneration takes the form of bonus (European Commission, 2019).

As mentioned, technologies as smart metering, smart grids, cloud-based applications are the real enablers of these new models entering the energy market. To be mentioned also blockchain technology, whose application can simplify the applicability of prosumers schemas, since as per its nature, it allows users and consumers to directly participate in the process at a higher level of autonomy. With the use of a distributed network, blockchain systems enable the implementation of peer-to-peer models (P2P) of power production and distribution where prosumers buy and sell energy directly between each other. Energy is tokenized and exchanged directly between peers. The meters exchange tokens which represent the amount of energy they can retrieve from the energy providers. If other business models are entering a more mature stage and higher margins are expected for operators, local P2P energy platforms are still in their emerging phase, and their implementation at larger scale are expected later in time. Despite this, blockchain-based platforms are considered very much disruptive models that can radically change the utility sector and drastically change utility business models.

Another model to be mentioned is flexibility as a service, meaning that different types of flexibility can be merged using the concept of service. The provision of flexibility as a service arises in order to manage the increasing share of distributed generation in the energy mix in a more efficient way.

Most of the models mentioned here are often offered in combination. However, the complexity in implementing those models individually or combined, and the need of a distributed infrastructure, can slow their implementation. For specific business models, a distributed physical infrastructure is required for their deployment at a large scale, as per microgrid as a service. Microgrid as a service means investment arrangements where investors own and operate the grid and in turn the users sustain payments to the owners for generated energy (IDC, 2018).

As mentioned, recent developments in technology and cloud-based technology services enable the delivery of innovative services along the chain utilities-consumers and open up to new or enhanced value propositions, which are exploited by a wide range of new business models. A report from IDC states that the expected growing development of IoT, the huge amount of data which will be collected in cities soon, and the development of distributed infrastructures, will make the sector more appealing in the next few years and will boost even more the adoption of new digital business approaches.

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5 MAtchUP Solutions

The last chapter of this report introduces key MAtchUP solutions in the Energy pillar, including:

- Smart control and domotics
- Electric and thermal storage (building and district)
- Urban renewables including LFG for electricity generation, Wave Energy Converter (WEC) and Sewerage energy recovery system
- Building Integrated RES including PVs and solar thermal collectors
- Smart meters
- Public lighting

5.1 Smart controls & domotics

Smart controls & domotics are at the core of the smart home, namely a home that uses Internet-connected devices to enable the remote monitoring and management of appliances and systems. Ranging from energy monitor to smart home appliances, thermostats, security cameras, smart locking and lighting systems, the market has seen increasing demand driven by the direct benefits and improved quality of life they bring to EU consumers. High costs, concerns over data privacy and perceived complexity of use by elderly people are still key barriers. Nonetheless, the market will keep on growing double digit. Focusing on Europe, Frost & Sullivan's forecasts that the home automation market is estimated to reach $806.1 million by 2022, with a CAGR of 15.8%[21].

North America is the leading regional market at global level. 23.9% of US households rely on smart home devices, representing 33.8 million smart homes. Europe is growing consistently and reached 30.5 million smart homes in 2018, or 13.2% of all households. 144 million homes in Europe and North America will be smart by 2023 (Berg Insight, 2014).

Numerous companies are investing in this market, including Samsung, Amazon, Apple and Google, but also more specific companies such as SmartThings Inc., Arlo or Nest. Currently, 75% of connected-home devices are purchased through service providers[22]. However, according to Frost & Sullivan's, partnerships or agreements between original equipment manufacturers (OEMs) and service/platform providers, such as Lutron and Apple Homekit, will characterize the future market, along with a rise in merger and acquisition (M&A) activities, as key companies try to strengthen their market position.

The solutions can be multifunctional (also defined as whole-home systems) or point solutions. The most successful point solutions, in terms of sold units, are: smart thermostats, smart light bulbs, smart plugs, connected security cameras, multi-room

[21] Frost & Sullivan's, available at: https://store.frost.com/european-home-automation-systems-market-forecast-to-2022.html

[22] McKinsey, available at: https://www.mckinsey.com/spcontent/connected_homes/index.html

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audio systems, and voice controlled smart speakers with built-in voice assistants. The latter, in particular, had a major impact on the smart home industry in recent years. Amazon and Google are the largest vendors of such devices, having a combined market share of about 90% in North America and Europe (Berg Insight, 2014).

5.2 Electric & Thermal energy storage

Electricity storage supports in addressing the intermittency of solar and wind power and guarantees no interruption in the delivery of electricity to final users. Its effectiveness depends on several variables including capacity, speed of recharge, energy losses and ability to react to changes in demand.

Thermal district storage are facilities that provide an optimized heat reservoir at district level, improving the reliability of the heating and/or cooling source. TES stocks thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for heating and cooling applications and power generation (IRENA 2013).

Both solutions are extremely important to support the move towards renewable energy. They both address the need of reduction in energy costs and increased local renewable energy production, contributing to the decrease of EU fossil fuel footprint. MAtchUP will deal with electrical storage for buildings and charging stations, electricity district storage and thermal storage for district heating

The use of electric energy storage could allow an increase self-consumption from around 30% to 60% of energy use (Power Circle, MälarEnergi, Kraftringen and InnoEnergy, 2016). The reliance on TES can save around 1.4 million GWh/year and 400 million tons of CO2 emissions avoided, in buildings and in industrial sectors (IRENA 2013).

In 2017, the global capacity for electricity storage, was 176 gigawatts (GW), less than 2% of the world's electric power production capacity. Demand for heating and cooling is of fundamental importance, as it is responsible for half of all consumed final energy in Europe. Buildings in particular would be responsible for around 40% of the CO2 emissions. While it is important to intervene on single buildings, even more important is to think in terms of groups of buildings and entire districts/neighbourhoods. However, despite the advantages of energy storage, only 2.5% of the total electric power output relies on it (Rajib P. et al, 2019).

Considering TES, the global market is anticipated to reach $8.8 billion, growing at a CAGR of 10.9% from 2017 to 2023, driven by demand in heating, ventilation, and air conditioning (HVAC) for district heating & cooling. However, lack of awareness, additional cost associated with the use of thermal energy storage system, and need of highly skilled technicians are still expected to hamper demand[23]. Denmark is a leading country regarding thermal storage in the EU. As reported, some 60% of Danish buildings are served by district heating systems (Pernille Almlund, 2012). For example, the Ringkøbing district heating system consists of a solar thermal collector system gas boiler,

[23] Allied Market Research, available at: https://www.alliedmarketresearch.com/thermal-energy-storage-market

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electric boilers, a gas turbine and an internal combustion engine, with the capacity to store 400 MWh. It can absorb or generate electric power and stores more than 30 hours of average heat use, or about 20 hours of peak day usage.

5.3 LFG for electricity generation

As defined by the “LFG Energy Project Development Handbook” released by the Landfill Methane Outreach Programme, landfill gas (LFG) is a “natural by-product of the decomposition of organic material in anaerobic (without oxygen) conditions. LFG contains roughly 50 to 55 percent methane and 45 to 50 percent carbon dioxide, with less than 1 percent non-methane organic compounds (NMOCs) and trace amounts of inorganic compounds” (Landfill Methane Outreach Programme, 2020).

LFG can be used mainly for electricity generation and for direct use. Before the usage, it needs to be collected and treated. LFG collection system consists of vertical wells drilled into the landfill with horizontal piping to transfer the LFG. The collected LFG needs to be treated to remove excess moisture, particulates and other impurities; then, it is gathered at several manifolds where each incoming gas pipe is coupled to system to measure the flow rate, gas concentrations, and the calorific value of the LFG in order to effectively monitor and optimize the well operating conditions.

According to Market Watch24, the global LFG market size is estimated to grow by $ 1.68 billion at a CAGR of 4% in 2020-2024. This solution is particularly adopted in the US, where the Environmental Protection Agency instituted the Landfill Methane Outreach Program (LMOP). The main driver for LFG is represented by the reductions in GHG emissions that it allows. Furthermore, LFG improves local air quality, minimizing the amount of oxygen going into the waste, and controls odours. The abundant availability of municipal solid waste is another important driver. LFG can be an inexpensive alternative for the final disposal of solid waste, especially in developing countries.

LFG energy projects involve engineers, construction firms, equipment vendors, and utilities or end users of the power produced, leading new businesses to locate near the landfill to use LFG. In addition, landfill owners can have economic benefits thanks to LFG, as they receive revenue from the sale of LFG to a direct end user or pipeline, or from the sale of electricity generated from LFG to the local power grid. Furthermore, businesses and other organizations, such as universities and government, may save significantly on energy costs by choosing LFG as a direct fuel source.

A particular barrier to the effective development of LFG is represented by the necessity of moisture presence for the survival of the bacteria that are necessary for LFG solutions.

The three most commonly used technologies for LFG energy projects are: internal combustion engines, gas turbines and microturbines. More than 75% of the projects use internal combustion engines, which are well-suited for 800-kW to 3-megawatt (MW)

[24] Market Watch, available at: https://www.marketwatch.com/press-release/landfill-gas-lfg-market-size-share-trends-analysis-2020-global-overview-industry-scope-regions-by-countries-forecast-to-2025-2020-03-27

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projects; multiple internal combustion engines can be used together for larger projects. Gas turbines are more likely to be used for large projects, usually 5 MW or larger. Microturbines, on the contrary, are smaller than gas turbines, with a single unit having between 30 and 250 kW in capacity; they are generally used for projects smaller than 1 MW. Other LFG electricity generation technologies include boiler/steam turbines and combined cycle applications (Landfill Methane Outreach Program, 2015).

5.4 Sewerage energy systems

Sewerage systems can be used as energy resources in two different ways. One of them based on by the integration of a sewer retrofitting system which includes an in-sewer heat recovery system. It is based on the installation of a tubular heat exchanger inside the sewer, immersed into the waste water flow. During winter, waste water is warmer than ambient air and can be used in the evaporator of the heat pump.

The other type of sewerage energy systems consist in the removal of contaminants from municipal waters and its transformation in energy. Wastewater is the water contaminated with human, agricultural, or industrial wastes from sewerage systems. This water can become energy, after being "transformed" by its previous nature of methane gas. Considering that methane gas corresponds to 16% of total GHG emissions at global level[25], this gives an idea of the environmental relevance of sewerage energy systems and wastewater usage.

Moreover sewerage treatment plants are self-sufficient because can use biogas generated from their own sludge to power their operations. However, costs of installations are rather high and technical high skills are necessary for their maintenance. Furthermore, there is a physical barrier represented by the space need for the plant.

The energy generated from a sewerage system can be used for domestic or industrial applications.

According to the report "Water and Wastewater Treatment Market - Global Opportunity Analysis and Industry Forecast (2019-2025)", published by published by Meticulous Research[26], the global water and wastewater treatment market is expected reach $211.3 billion by 2025. Asia Pacific will be the leading region, but also North America and Europe will experience considerable progressions. Energy production is only one of the possible applications of wastewater treatments, but it is one of the most innovative and is expected to increasingly gain a stronger share of the total market.

On the technical side, different treatment chemicals are used: coagulants and flocculants are expected to be those with better growth perspectives. They are in fact cheaper than other technologies (such as scale and corrosion inhibitors, disinfectants and general biocidal products, pH conditioners, antifoam chemicals) and more efficient

[25] EPA, available at: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[26] Meticulous Research, available at: https://www.meticulousresearch.com/product/water-and-wastewater-treatment-market-5026/

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5.5 Wave energy converter

Wave energy converters (WEC) convert the kinetic and potential energy associated with a moving wave into useful mechanical or electrical energy. It is not a recent idea, as the first patent goes back to 1799; however, it was particularly resumed after the 1973 oil crisis. At the moment, more than 1700 patents exist in this area (Aderinto and Lin, 2018).

WEC is a source of energy with very low costs of maintenance and quite easy to install. WEC's main benefit is to constantly provide energy production, no matter the direction of the waves, and can be adaptable to different weather conditions. This makes WEC a great contribution to global energy supply, also thanks to its high scalability and replicability in different wave conditions.

Barriers to WEC adoption are still numerous, and it will be important to overcome them to fully exploit the great potential of this solution. The almost total absence of a specific measurement for WEC is one of the key factors hampering adoption. Information must be retrieved from other data collection sources. Ocean wave property data are normally collected from weather stations, ocean buoys and the satellite: normally they do not refer to WEC, but to seafaring vessels, offshore structures for oil and gas exploitation activities, weather stations, and even for recreational activities such as surfing (Li, 2020). These data are useful also for WEC, but specific data would make the system more efficient.

Up to now, there is also a lack of analysis that ensure that the WEC facility have little or no negative effects on the aquatic plant and marine life. Furthermore, there are some concerns that WEC structures can introduce new species into the immediate environment and also become artificial reefs.

Possible negative effects can be produced during the construction: drilling and other construction activities can cause pollution or generate unbalance in the natural habitat of the ocean plants and animals. Other adverse effects on marine life could be trapping, collision, etc.

Another issue is the 'aesthetics', especially for shoreline devices since the local coastal community may want to resist the installation of a large structure close to them.

The environmental impacts of wave energy converters might not be easy to evaluate since very few systems have been deployed long enough to comprehensively determine the environmental impacts both at the coastal areas and offshore locations. Another major challenges for WEC design and deployment is that the technologies are still at an early stage compared with other renewable energy technologies such as wind and solar. Different technologies are being considered for harvesting wave energy, which also means that there has not been any convergence on a single wave conversion technology (Aderinto and Lin, 2018).

Lastly, one of the issues affecting the commercial use of wave energy is the difficulty in integrating power from large WECs into the electricity grid due to the high variability of the wave properties.

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The wave power energy market is predicted to have a CAGR of 10.2% between 2017 and 2023[27]. According to the European Ocean Energy Association, ocean energy has got very promising potential, and more in general "wave energy could reach 529 MW installed by 2020 and nearly 100 GW by 2050. This represents 1.4 TWh/ year by 2020 and over 260 TWh/year by 2050, amounting to 0.05% and 6% of the projected EU-27 electricity demand by 2020 and 2050 respectively" (ICOE, 2010). However, it is still quite difficult to exactly make realist forecast on this industry, because of the absence of large-scale wave farms.

Recent advancement in the assessment of ocean wave energy resources progressed from merely predicting ocean wave properties, to computer tools to better evaluate the temporal and spatial variability of the resource. These ocean energy assessment methods provided very good framework for WEC designers. Nonetheless, despite a widespread interest, WECs are still underdeveloped. The following table provides the number of planned, installed and operational WECs. Adoption is stronger in the EU, particularly relevant for countries surrounded by the ocean or the sea.

Country	Planned	Installed	Operational	Total
Canada	0	0	11	11
New Zealand	0	20	0	20
Denmark	39	12	1	52
Italy	0	150	0	150
Mexico	200	0	0	200
Ghana	0	0	450	450
Spain	0	230	296	526
Korea	0	0	665	665
China	0	400	300	700
Portugal	350	0	400	750
United States	1335	500	30	1865
Sweden	0	0	3200	3200
Ireland	5000	0	0	5000

Table 5-1 Wave Energy Converters Installations (kW) around the World (Aderinto and Lin, 2018)

5.6 PV generation system

Photovoltaic energy is the energy produced by the radiation of the sun, and transformed into electricity. This is among the most known solutions when speaking about renewable

[27] Power Technology, available at: https://www.power-technology.com/features/wave-power-energy/

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sources. PV collectors can be used for different commercial uses: solar lamps, parking meters, emergency telephones, trash compactors, temporary traffic signs, charging stations, and remote guard posts and signals, solar panels, solar cars, solar drying to dry crops. The main difference with solar thermal collectors is that solar PV systems are used to create electricity, whereas thermal systems are used directly for heating water or air.

Beyond the high social acceptance and the proved environmental benefits, drivers for the development of PV generation systems are especially to be ascribed to economic reasons. A rapid decline in the cost of solar technology constitutes an important vantage point for adopting this solution. Moreover, PV energy is particularly cheap for providing power to remote locations. At the same time, and differently from other alternative sources, the infrastructure can be placed very close to where they are needed (directly on a roof for example), reducing cost of energy transport/transmission. Sun is also more predictable as a weather forecast than other renewable sources, such as rainfall or wind.

At the same time, the increasing continuous development and improvement in the state of the art about energy storage technologies coupled with supportive government policies make PV a viable solutions to many building owners and managers in the EU.

The role of energy communities is very relevant in driving cities' projects. If a single household or consumer cannot host a solar rooftop for space reasons, community energy enables them to buy electricity from a shared solar project and receive a credit on their utility bill.

Although general social acceptance is generally high, costs of installation, storage, and power conversion devices still remain relevant. Current and future evolution of different storage technologies may define the convenience of the chosen solution.

Between 2010 and 2018, the global weighted average LCOE from solar PV fell by 77%, reaching $58.7 per megawatt-hour (MWh) (IRENA, 2019). Led by Chinese manufacturers, global cell production increased from 50MW in 2004 to 55GW in 2015. It is expected that solar energy will reach grid parity in numerous countries in the next few years.

In 2019, for the ninth year in a row, solar power attracted the largest share of new investments in renewable energies, followed by wind power. The $ 140 billion (EUR 122 billion) investments in solar energy, accounted for 42.5% of all new renewable energy investments. While the annual investment decreased by 13%, the newly installed capacity of solar photovoltaic power increased by about 5% to over 107 GW in 2018. Solar assets are always more appreciated also by pension funds, sovereign wealth funds, local authorities and insurers: this involves important investment resources (JRC, 2019).

The forecast for the next years are also particularly promising. According to BNEF, PV will account for around 26% of the global installed generation capacity, considerably more than any other source (BNEF, 2016).

PV solutions can be effective both for residential and non-residential use. Over the last decade, prices for residential grid-connected PV systems decreased significantly. Despite huge request of PV for the residential system, the industrial segment is expected

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to lead the PV market in terms of application. Beyond individual (or family) consumption, also collective projects should be considered, such as those of the "Renewable Energy Community" (REC), or "Citizen Energy Community" (CEC), particularly developed in the past years and also sustained by European policies and projects.

China is currently the leading country at global level: in 2018, China reached a total PV power capacity of 175 GW: this means the 34% of PV systems installed at global level, followed by Europe with 23% (RECP, 2018).

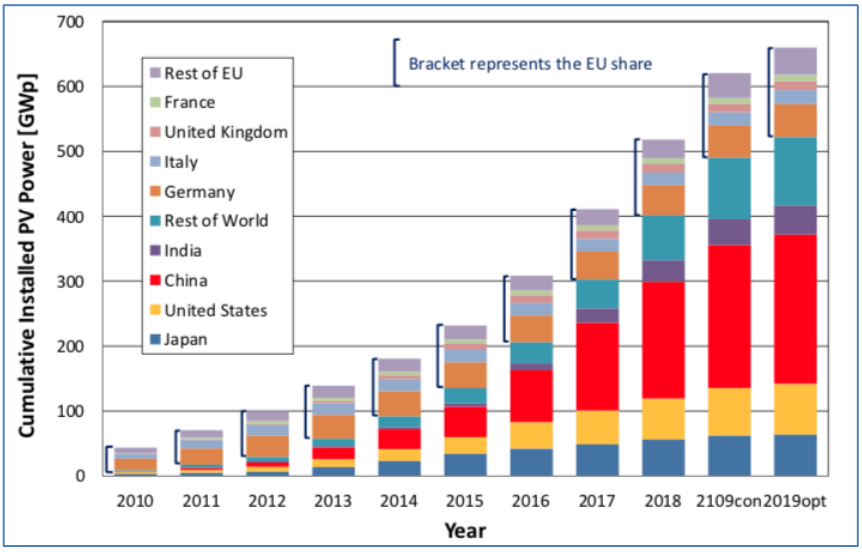

Figure 5-1 Cumulative PV system installations from 2010 to 2019 estimates (JRC, 2019)

With the existing PV installed capacity, Europe can provide about 4.5% of its electricity demand. Since the first European Renewable Energy Directive went into force in April 2009, grid connected PV systems in the EU increased tenfold (JRC, 2018).

There are in principle two methods to optimise the direct consumption of solar electricity. One is to use intelligent behaviour or control systems, which switch on major loads (washing/dryer machines, heat pumps, refrigerators, air conditioners) when the sun is shining. However, there are limitations to such measures. The second one requires a means to store the energy, either as electricity with accumulators, or as 'product', (heat-storage, cold-storage or pumped water), for use at night or rainy days.

Some electricity providers in Europe are offering PV systems and local storage to their customers, often including maintenance services. The packages also include apps to monitor the performance of the system, use of electricity and often functionality to control the match between demand and supply. In addition, there is a number of companies, which offer the management of swarm or cluster storage facilities in cooperation with distribution network operators. However, precise business models is still very limited (JRC, 2019).

5.7 Solar thermal collector

A solar thermal (ST) collector consists of a system used to convert solar radiation into heat energy. These collectors are generally mounted on a roof. The most important application for solar thermal systems is domestic hot water heating, but could also be used for space heating or solar cooling.

The main drivers for ST collectors is represented by reductions in CO2 emission and in annual energy consumption. They can be included in urban renovation plans and are often combined with other solutions, such as geothermal energy.

Space constraints and roof orientation of the buildings, architectural limitations due to heritage conservation, as well as changes in legislation and in market dynamics could negatively affect the market for ST collectors-.

According to Eurostat, 51,953.899 sq mt were covered by solar thermal collectors in 2018 (data referred to EU27). Important differences emerge across countries, ranging from the 66.196 sq mt in Luxembourg to the 19,269.000 sq mt in Germany[28]. This is of course also due to the dimension of each single country but cultural and economic reasons should be considered as well.

At global level, the market grew constantly for 10 years, from 2005 to 2016, before flattening in 2017-2018, due to the increasing role assumed by wind energy and PV solutions. The decline is in particular for small-scale solar thermal heating systems, namely those used for single-family houses and apartment buildings.

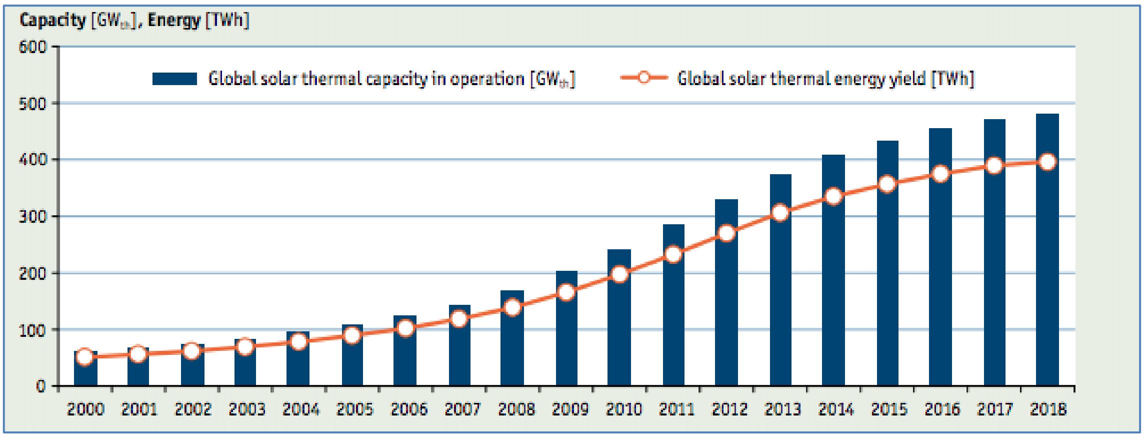

Figure 5-2 Global solar thermal capacity in operation and annual energy yields 2000 – 2018 (IEA, SHC, 2019)

Europe is among the most relevant regions in the world, and in particular some European countries, such as Germany, Poland and Denmark. The first large-scale solar thermal heating system was implemented in 1988 in Denmark, and at the moment, according to Solar Heat Worldwide (edition 2019, published by Werner Weiss and Monika Spörk-Dür of the AEE - Institute for Sustainable Technologies, and supported by the Austrian Ministry for Transport, Innovation and Technology), "most of the Danish installations are

[28] Eurostat, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

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ground mounted flat plate collector fields hydraulically connected to load-balancing storages in close distance to the district heating main distribution line. Six new solar district heating systems with collector areas between 900 m² (Jerslev, stage 2) and 26,195 m² (Aabybro) were built in 2018" (IEA, SHC, 2019).

The two main ways to obtain water from solar thermal collectors are evacuated tubes and flat plates. The latter is particularly adopted in Europe, while the evacuated tubes are the leading solution at a global level, as visible from the two following graphs. Other possible solutions are represented for example by line focus collectors or point focus collectors.

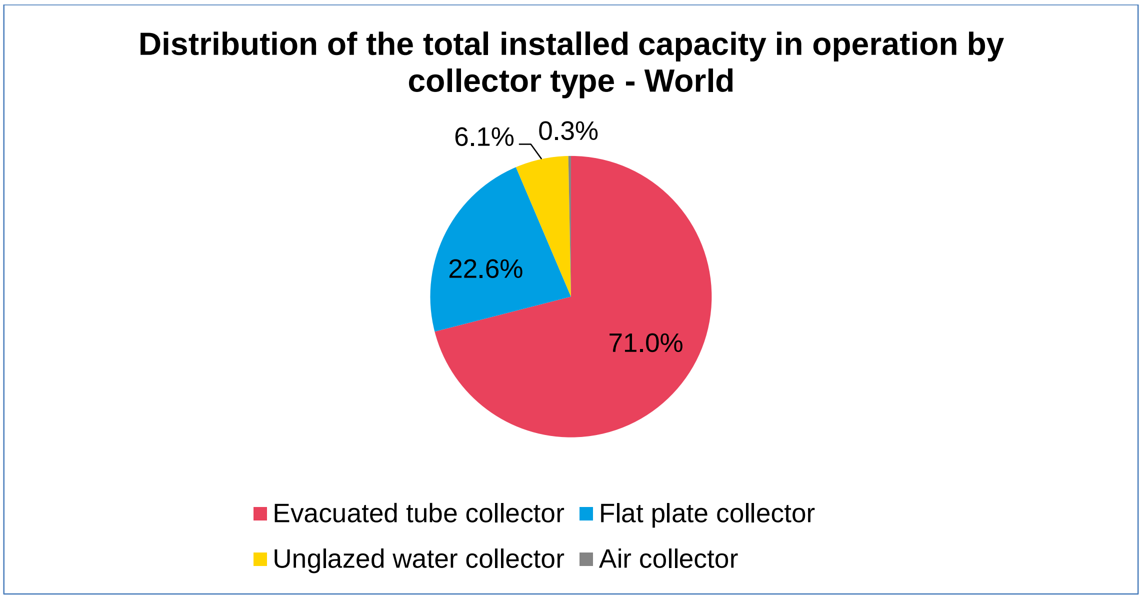

Figure 5-3 Distribution of the total solar thermal installed capacity in operation by collector type in 2017 – WORLD (IEA, SHC, 2019)

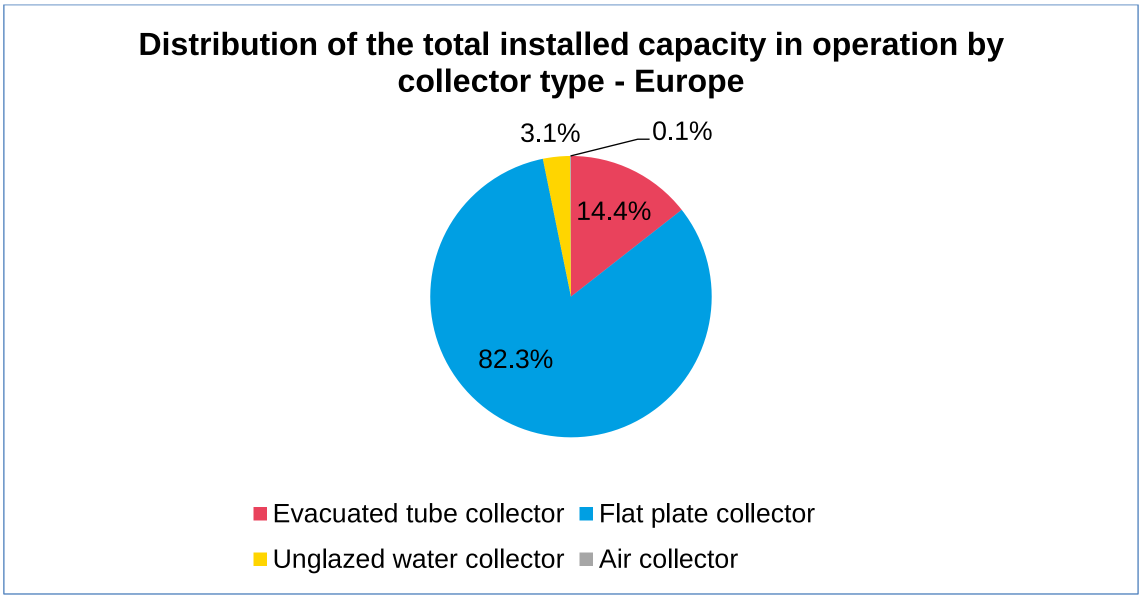

Figure 5-4 Distribution of the total solar thermal installed capacity in operation by collector type in 2017 – EUROPE (IEA, SHC, 2019)

The evacuated tube solar thermal systems are probably the more efficient solution, having a rate of efficiency of 70%. Water is heated in the collector and is sent through the pipes to the water tank. If it is the more efficient, it is also quite expensive[29].

Flat plate solar thermal systems are composed of a dark coloured absorbing flat plate, and are already used since decades.

Considering together evacuated tubes and flat plates, market penetration is particularly good in China, followed by Europe.

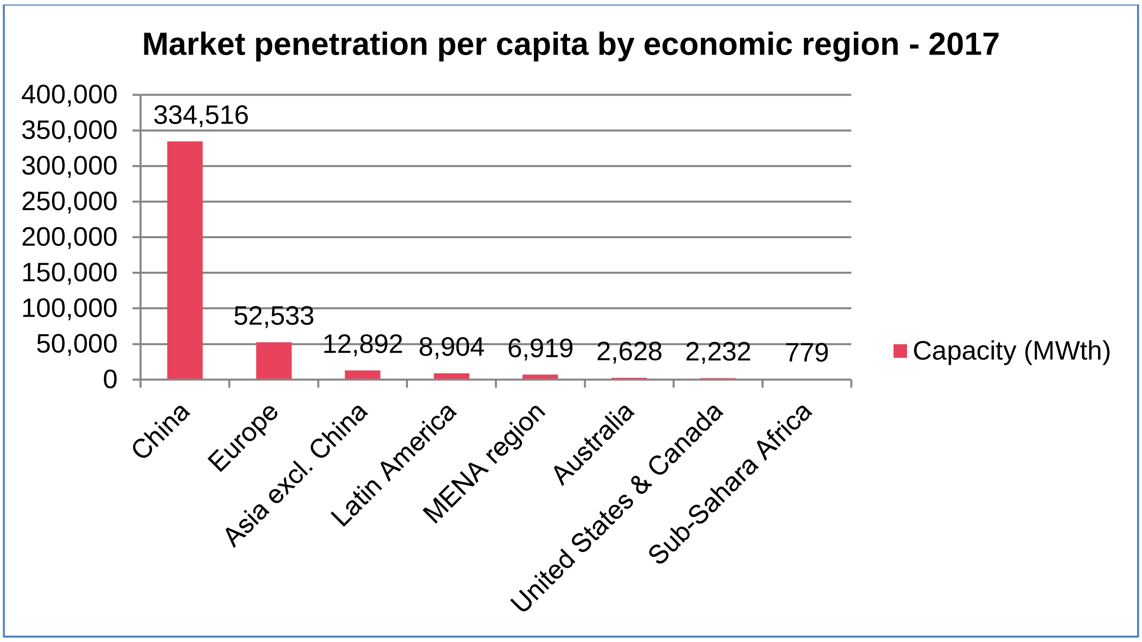

Figure 5-5 Market penetration per capita by economic region – 2017 (IEA, SHC, 2019)

Solar thermal collectors are useful for different reasons, but in particular for provision of domestic hot water (DHW), followed by swimming pools. DHW systems (multi-family houses, tourism and public sector) is also the fastest growing sector.

[29] The Renewable Energy Hub, available at: https://www.renewableenergyhub.co.uk/main/solar-thermal-information/the-different-types-of-solar-thermal-panel-collectors/

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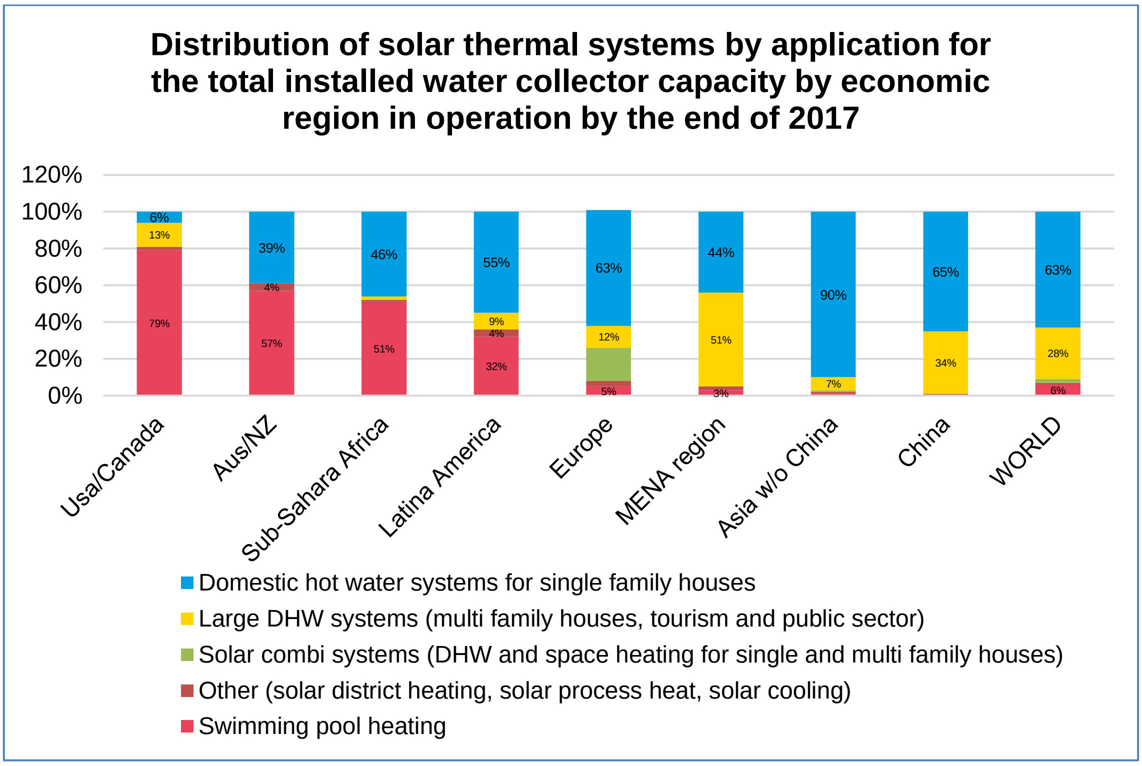

Figure 5-6 Distribution of solar thermal systems by application for the total installed water collector capacity by economic region in operation by the end of 2017 (IEA, SHC, 2019)

5.8 Smart meters

Smart meters have been already mentioned several times in the first chapters of this report as one of the key enabling technologies in smart city energy. Substituting classic meters, smart meters can record and transmit more efficiently the information of electricity, water or gas consumption, allowing important energy and financial savings: such transmission is automatic and not manual. In the next years, utilities are likely to gain an increasingly relevant role in smart cities as suppliers of energy to keep connected and functioning energy equipment. In such scenario, smart meters can supply the basic infrastructure on which to build additional applications.

Beyond the EU mandate to roll out smart meters to 80% of consumers by 2020, the drivers of this solution are numerous. First of all, real-time reporting of energy consumption directly to consumers improves their awareness, leading to reduced consumption and lower expenses. Furthermore, using the possibilities offered by the digital revolution, smart meters also give the possibility to monitor and control electricity consumption remotely and in real-time[30].

[30] JRC, available at: https://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union

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Moreover, smart meters allow to produce considerably less carbon emissions. Smart meters should reduce emissions in the EU by up to 9% and the annual household energy consumption by a similar amount[31].

On the suppliers' side, algorithms enable utilities and energy distributors to manage their supply and demand in real-time, and to tailor offers according to consumers' needs: smart meters give an effective opportunity to design customer centric strategies.

As already mentioned, perceptions over the accuracy of the systems, concerns over safety and privacy issues are key barriers of deployment, which delayed the roll out in some EU countries.

According to the research firm Wood Mackenzie (2020)[32], the number of smart meters in the world is expected to increase exponentially in the next 5 years, from the current 665.1 units to over 1.2 billion. At the same time, the sector will see investments in advanced metering infrastructures, reaching cumulative global spending of $ 145.8 billion by the end of 2024.

As of 2020, the EU has the second highest smart meter penetration rate, after North America. The electric market was the biggest in 2019, with gas and water still lagging behind[33].

Smart meters also involve a very relevant social change: until now, the relation between buildings and their users was one-directional. New technological and digital advancements give the possibility of interaction between buildings and occupants, and put the role of consumers at the centre. This change of paradigm already had, and is likely to increasingly have, a disruptive effect on the market.

5.9 Smart lighting

Smart lighting systems are designed to increase energy efficiency by adapting light intensity according to various parameters (natural light, occupancy, etc.).

According to Smart City Press[34], "conventional lighting systems are responsible for a staggering 19% of the global electricity consumption and 5% of worldwide GHG emissions"; at the same time, "universal adoption of LED lighting will result in global electricity consumption of just 7%. This will lead to savings of €272 billion and reduction in global CO2 emissions of around 1,400 megatons by 2030".

The major *drivers* for deploying smart lighting in cities include:

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[31] European Commission, available at: https://www.energypoverty.eu/news/new-research-reveals-importance-additional-support-engaging-vulnerable-consumers-smart-0#_ftn1

[32] Wood Mackenzie, available at: https://www.woodmac.com/news/editorial/global-smart-meter-total-h1-2019/

[33] IOT Analytics, available at: https://iot-analytics.com/smart-meter-market-2019-global-penetration-reached-14-percent/

[34] Smart City Press, available at: https://www.smartcity.press/smart-cities-smart-lighting-solutions/

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- The advent of integrated lighting control systems, IoT and cloud developments, which can also enable new services (e.g. movement detection, air pollution detection, CCTV cameras, traffic sensors, etc.);
- Demand for public safety;
- Reduction of public lighting cost and maintenance costs, thanks to real time management of on/off switches and real time monitoring of maintenance requirements;
- Ageing lighting infrastructure. There are currently between 60 and 90 million streetlights in Europe, and 75% of them are more than 25 years old. A very small percentage of them presently use modern low energy (LED) lamps (Gassmann et al., 2019);
- Increasing concerns over the environment. In this sense, the relevance of smart lighting is undoubtable, especially considering the forthcoming increase of global urban population. LED technology and intelligent light management have the potential to cut by 80% of the resource consumption of traditional outdoor lighting[35];
- Aesthetic, as, in some cases, important urban designers have been involved, and some projects became real symbols of the respective cities.

The high cost of installation, the quick evolution of this technology and the possible risk of obsolescence as well as episodes of vandalism can still restrain market growth

Smart lighting is a growing trend worldwide. Considering the outdoor lighting revenue, analyst company Strategies Unlimited forecast that the global market will nearly reach $3 billion already in 2022, representing a CAGR over 40% from 2014. North America and Europe will lead. Smart outdoor lighting also makes into the top 5 smart cities use cases up to 2023 reported by analyst company IDC.[36]

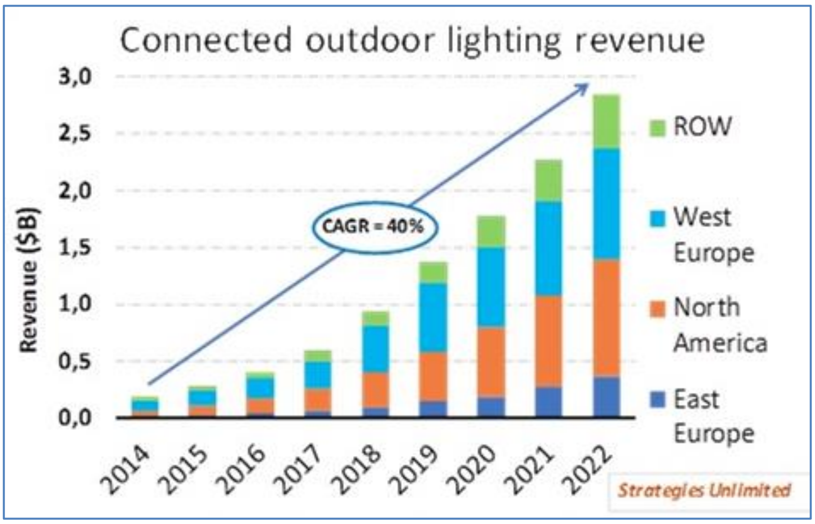

Figure 5-7 Connected outdoor lighting revenue, 2015 (Strategies Unlimited, 2015)

[35] US Energy Department, available at: https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/led-lighting

[36] IDC, available at https://www.idc.com/getdoc.jsp?containerId=prUS45303119

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6 Conclusions

This report is the art of a series of market analysis focusing on the 3 MAtchUP pillars. The report provides a contextual initial assessment of the Energy solutions addressing smart cities' needs by analysing the current state of the art, the overall market potential, the complexity of the supply ecosystem, key drivers & barriers, and the opportunities tied to the new smart city services. The analysis is necessary to define a business framework in view of the launch of MAtchUP Energy solutions on the market.

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