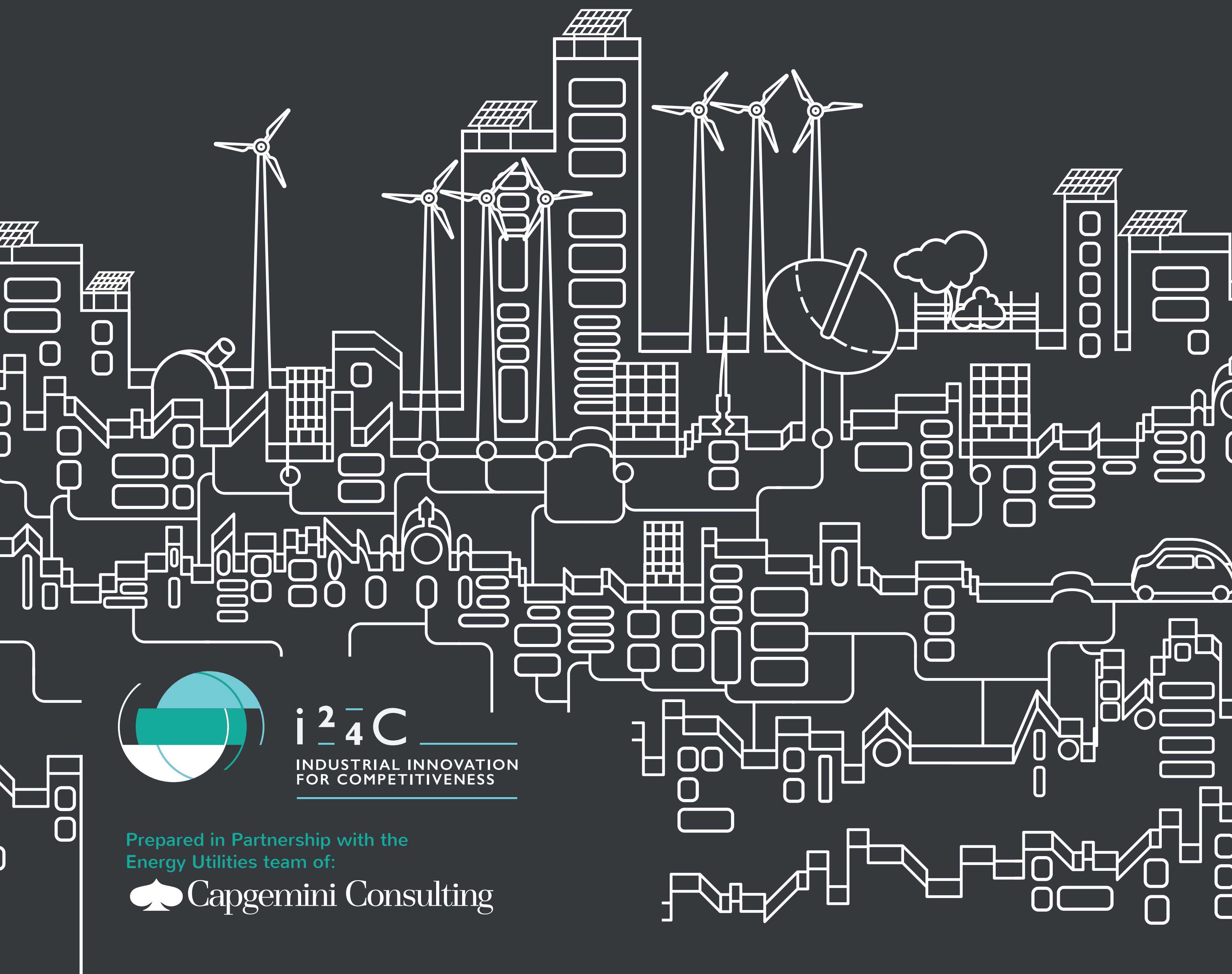
SCALING UP INNOVATION IN THE ENERGY UNION TO MEET NEW CLIMATE, COMPETITIVENESS AND SOCIETAL GOALS

Scoping the future in light of the past



i2-4C
INDUSTRIAL INNOVATION FOR COMPETITIVENESS

Prepared in Partnership with the Energy Utilities team of:
Capgemini Consulting

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1. EXECUTIVE SUMMARY

This i24c report has been developed with the aim of providing evidence-based analysis to inform the debate on what an integrated, forward-looking research, innovation and competitiveness strategy for the European Energy Union should seek to achieve and prioritise.

To do this, the report assesses Europe's ability to deliver and succeed along the whole energy innovation cycle, from basic research to large-scale market uptake. Based on desk research, interviews, a dedicated survey and workshops with key European stakeholders and experts, including leading thinkers and players in all relevant parts of the energy industrial innovation ecosystem, the report draws on and synthesises evidence from past and present experiences of the policy framework. It assesses how well Europe has done to date in spurring and scaling energy innovation to its advantage, from an industrial economic as well as energy and climate perspective. In the context of the EU's new climate, competitiveness and societal goals, the report draws conclusions and offers ideas for how policy can further evolve to help Europe reap further advantage from the even greater energy-related innovation challenge to come.

A significant disruption in the energy innovation ecosystem

Beginning with an overview of the new energy landscape, the report provides a synthesis of what is driving change. It describes a paradigm shift towards low-carbon and user-centric economies, driven by digital and integrated flexible solutions that serve to put end-users in the driving seat. As the strategy behind Europe's Energy Union recognises, Europe's entire energy system and related value chains are profoundly changing due to four fast emerging and inter-related megatrends: sustainability, digitalisation, integrated services and local-level empowerment.

As a result, we are witnessing the emergence of new technologies and services, such as energy storage, demand side management and electric vehicles, which are blurring the traditional boundaries of the energy sector. New actors, such as electricity aggregators and car-sharing platforms, are putting end-users at the centre of decision-making. We observe that even incumbent energy companies are moving from selling electrons or energy equipment to offering services that satisfy customer needs such as comfort, independence or security. The 'pro-sumer' is now an established feature of the energy system, and growing in importance: for instance, private citizens and farmers now own almost half of Germany's renewable energy installed capacity, while in Denmark, private individuals own 85% of its wind turbines. Similarly, crowdsourcing and crowdfunding are enabling citizens to actively participate in financing the deployment of renewable projects and energy efficiency measures.

Energy innovation cannot be understood or fostered by a focus on a single actor. Instead, it results from contributions from a wide range of stakeholders from various horizons, be they driven and stimulated by cities and/or end-users, initiated by new players disrupting traditional value chains, emerging from traditional energy players (e.g., equipment providers, power utilities, grid operators and public research institutions), or involving financial and academic communities.

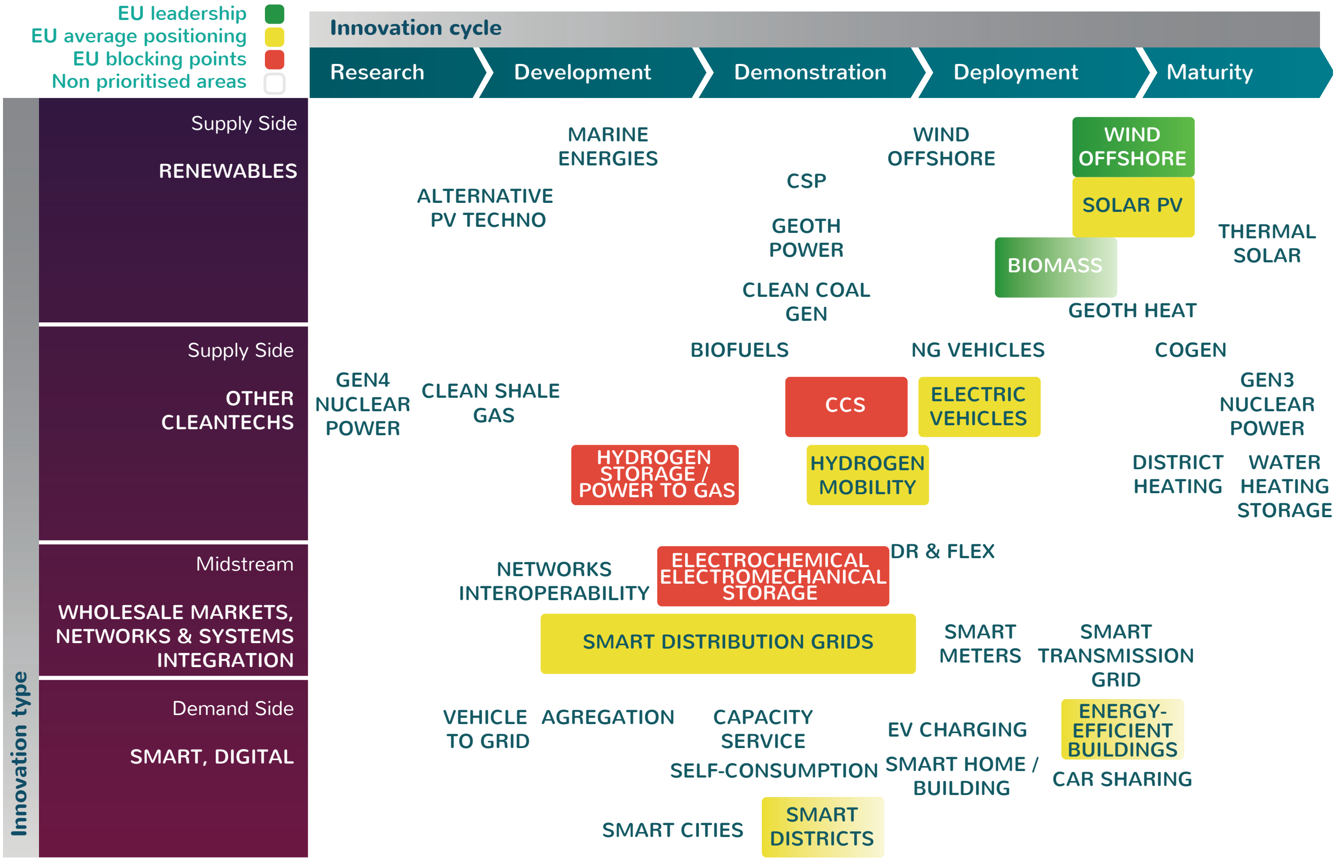
Europe therefore needs to consider energy innovation in a broad sense: in addition to the traditional energy sector and its related infrastructure, it should involve all sectors that consume, supply and balance the system: transport and mobility, industry, telecoms and new technology, buildings and agriculture. It must understand how all these blocks interact and can transition systemically to deliver simultaneously on Europe's decarbonisation, affordability and security objectives. Innovation in this energy system is not only about new technologies. It's also about new disruptive business models and services (such as electric car sharing, vehicle-to-grid applications, smart home technologies and energy-as-a-service platforms), societal innovation (as was enabled by the Dutch Green Deals that bring together multiple societal actors) and new policy and financial mechanisms.

EU innovation successes to date are positive but below potential

With ambitious domestic targets and the pioneering of new instruments to decarbonise its economy, Europe's policy framework has undeniably played an important role in paving the way to a global clean energy transition. European policies have been successful in initiating energy-related innovations such as in large renewable technologies (e.g. onshore wind). At the same time, looking at carbon capture and storage (CCS) or hydrogen storage, it may have failed so far to industrialise deployment of promising innovations, where other economies and their companies have either already succeeded, or are better positioned to reap the benefits than Europe is.

With 18% of global climate change mitigation technology inventions (CCMT) and 40% of the high value ones, Europe has been a major contributor to energy-related research and innovation efforts over the last decades. Europe is also the largest investor in renewable energies R&D, accounting for $4.3 billion in 2014 (36% of the total). In this area, investments and supporting policies (such as the Danish wind power market framework, the Swedish bioenergy programmes and several other countries' market-pull instruments) have been rewarding. Today, 1.2 million jobs are linked to renewable energy in Europe (with solid biomass amounting for 50% of the related jobs). Europe's renewable energy capacity has doubled in the last 15 years, to 472 GW (26% of the world's total), making it the world's biggest renewable energy market. And European companies are global leaders – for example, of the top five wind turbine manufacturers, three are European.

General assessment of Europe leadership on selected energy-related innovation areas, based on its ability to innovate and create value and competitiveness



A deep dive into a selection of 11 energy-related innovations[1] and expert interviews highlight that, in several energy-related areas, Europe has a deployment deficit, and it struggles to bring to market promising innovations (see Figure, General Assessment). For example, market penetration of low-carbon technologies, such as electric vehicles, remains slow in Europe (accounting for less than 1.4% of new car sales in most EU countries).

[1] These include: wind onshore, solar PV, biomass, carbon capture and storage, hydrogen storage, hydrogen mobility, electro-chemical and mechanical power storage, electric vehicles, smart distribution grids, smart districts and energy efficient buildings

Europe has seen many cities and districts taking the lead on developing low-carbon or energy efficient solutions, but their replicability remains a challenge. Amidst the innovation cycle, Europe struggles to industrialise promising energy-related demonstration projects. Some innovation areas are caught in the so-called 'valley of death' in Europe, while large-scale deployment is more advanced in other geographies (e.g. power storage).

In targeting and facilitating innovation support, we identify successes where the entire ecosystem of actors is brought together 'on the ground' – such as is the case for smart districts, which are systemic by nature and link buildings, energy, ICT and transport.

However, our analysis reveals that, without a comprehensive and operational strategy for research, innovation and competitiveness, bringing together supply, demand and regulatory aspects, the EU risks losing its comparative advantage to Asian and American competitors. This is true in both Europe's supply of innovation, and in the deployment taking place in Europe. This is already the case with some specific technologies such as solar photovoltaics (PV). In 2013 alone, the EU-28 lost 50,000 jobs in renewable energy, mainly in solar PV. The EU faces similar risks in other areas such as in battery storage and in electric, hybrid and hydrogen mobility. The forthcoming European Research, Innovation and Competitiveness Integrated Strategy (EURICS) is an important milestone to redefine Europe's competitiveness and innovation strategy, and to align all the pieces of the puzzle.

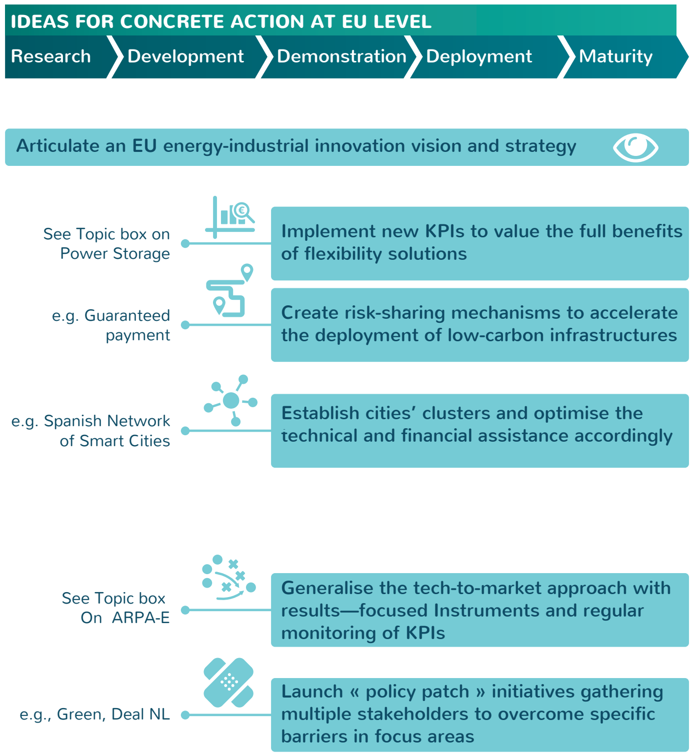
There is no room for complacency and much room for improvement, in particular to reap the benefit from investments made early in the innovation cycle (i.e. research and innovation). But Europe's starting position is a relatively strong one. It has structural strengths that it can build upon, including the size of the European market, the recognised skills of its workforce, and the quality of its research institutes. For instance, Europe holds nine out of the Reuters' Top 25 Global Innovators ranking of publicly funded research institutes in advanced science and technology. Beyond these research institutes, emerging energy-related innovation is strongly driven by start-ups, large industrials and European-funded programmes.

Guiding principles to efficiently scale up innovation in the Energy union

Scoping the future in the light of the past, the report identifies policy options and key choices available to policy-makers to help the EU scale its energy innovations, reaping the resulting social and economic benefits, as well as achieving the core Energy Union objectives in relation to security, affordability and decarbonisation. Five guiding principles, ten key success factors and a range of concrete ideas are set out that should be at the core of this new approach, and give coherence and strength to an important new strategy for both the Energy Union and also Europe's wider growth, jobs and competitiveness agenda.

Key findings and suggestions along the innovation cycle

5 GUIDING PRINCIPLES	10 KEY SUCCESS FACTORS
1. PROVIDE CLARITY ON THE LONG TERM DIRECTION	1. Enable long term choices at local level and ensure their consistency at EU level 2. Set integrated energy-industrial priorities
2. DESIGN THE MARKET TO BETTER PULL ENERGY INNOVATIONS ACROSS THE 'VALLEY OF DEATH' AND TO SCALE	3. Adapt regulation and value the benefits of low-carbon technologies and energy efficient innovative solutions 4. Mitigate financial risks
3. ACCELERATE THE EMPOWERMENT OF LOCAL AND REGIONAL AUTHORITIES	5. Provide local and regional authorities the right technical, regulatory or financial assistance 6. Reinforce data and knowledge sharing
4. EMPOWER CUSTOMERS & CITIZENS FURTHER YET	7. Foster customer-centric approaches 8. Mobilise citizens
5. ENCOURAGE MORE EFFICIENCY IN NURTURING ENERGY INNOVATION	9. Foster collaboration and pool resources 10. Generalise results-oriented approaches, ensure consistency of instruments, and use of metrics



First: **<u>Provide clarity on the long-term direction.</u>** Europe has an energy vision, embodied by the Energy Union strategy and built into the European Commission's 2050 energy Roadmaps, which provide a long-term European energy transition project and defines where the energy system, in its broadest sense, should move. It now needs to deliver and implement this vision. Europe needs to ensure consistency with the visions that are emerging at the national, regional and local levels, and develop an accompanying economic vision of success and a clear and powerful energy industrial strategy to reap the benefits.

Second: **<u>Design the market to better pull energy innovations across the 'valley of death' and to scale.</u>** Two major levers can be used to increase the attractiveness of low-carbon solutions: (i) revealing and valuing their full benefits (such as for energy storage), and (ii) reducing the level of risk faced when investing in these solutions. Market design and public authorities play a key role in setting the right market conditions to bridge the demonstration phase and foster a mass-market deployment, as well as in opening these markets to new entrants. Predictable market-pull instruments (such as feed-in premiums, certificates, bonus-malus schemes or public procurement) must also be available for energy-related innovations, to create investor confidence and help move them from the demonstration to the deployment phase.

Third: **Accelerate the empowerment of local and regional authorities.** Encouraging differentiated collaboration between, and assistance for, innovative districts, cities, rural areas and regions will scale the deployment of energy efficient and low-carbon technologies and services, and in particular more systemic transitions that link buildings, energy, ICT and transport. A segmentation could be developed according to robust criteria, which could include: the type of energy-related innovation they are seeking to deploy (e.g., electric mobility, smart grids, etc.); their level of maturity when it comes to the penetration of renewables in their energy system; or the type of challenge they are meeting when seeking to push the energy transition further (e.g., citizen engagement). Further clustering opens the door to the exchange of best practice, pooling of investments, the better assessment of the 'bankability of projects', and the development of financing strategies (e.g. business cases, use of public procurement, of loans, etc.). In addition, to scale the wide-spread deployment of smart district (or smart cities) initiatives, more effort will have to be made to help identify, measure, access and share the "right" data, such as traffics flows and energy demand, while simultaneously ensuring data security and privacy guarantees.

Fourth: **Empower customers and citizens yet further.** Empowering consumers with the establishment of a regulatory framework will drive demand-response and energy efficiency services. Citizen engagement in the energy transition is key to create desire and buy-in for change. Local leaders or organisations are the closest to consumers, and have a clear role in communicating and working with citizens. For instance in France, Paris has chosen to make citizen participation a top priority of its Smart City project. One of the most notable examples is the introduction of a participatory budget, corresponding to 5% of the overall investment budget (i.e., €0.5 billion over 2014-2020).

Last but not least: **Be more results-oriented and selective in nurturing energy innovation.** Finite budgets need to be allocated to different technologies and solutions. In Europe, public funding is particularly important, all along the energy innovation cycle, but especially at the early stage. In that sense, Europe could be inspired by the ARPA-E approach in the United States – its motto, "if it works, will it matter?" implies that, from the beginning of the process, the final impact on energy use, and the adoption of the technology, is at the heart of funding decisions. In Europe, incubators such as KIC InnoEnergy have started to adopt this perspective, with a strong focus on the business plan of candidates. However, an end-to-end approach throughout the innovation cycle still seems to be missing, especially when it comes to connecting technology and non-technological energy innovation, or encouraging cross-sectoral innovation. But evaluation of the efficiency of investments in energy-related research and innovation will not be sufficient if it does not lead to concrete actions. An evaluation process that requires an assessment of remaining gaps or inconsistencies, e.g., a lack of supportive policy/political environment, other market factors or developments not previously anticipated, can help achieve this. Establishing so-called policy patch initiatives could help policy-makers detect specific barriers or anticipate market rules adaptations.

Conclusion

In reviewing progress to date, and drawing lessons for policy-makers, this report confirms the need for an integrated approach to the research, innovation and competitiveness agenda of the Energy Union. In listening to the full spectrum of relevant stakeholders, and learning from failures as well as successes, it offers a realistic but positive assessment of the current situation. It confirms the opportunity that this agenda presents for the EU to demonstrate that leadership on climate change can not only be successfully married to the achievement of its energy security, affordability and environmental sustainability goals, but should also be at the centre of its industrial economic strategy. With the right innovation-enabling policy framework and strong related signals to investors, the Energy Union can ensure that the EU is the world leader in renewables, achieving one of Commission President Juncker's specific goals. In the context of a fast-changing and competitive global environment, it can also deliver strongly on the wider jobs, growth and competitiveness agenda that is at the top of his Commission's overall priorities. We hope the principles, success factors and concrete ideas for action are a helpful contribution to making the European Commission's future strategy on EURICS a powerful one.

Pascal Lamy **Sir Philip Lowe**

High Level Group members of i24c

President Emeritus, Jacques Delors Institute

Former Director-General for Energy and Competition, European Commission

2. FOREWORD

Modern economies face a profound and urgent challenge: they must meet the needs of their societies for affordable and reliable energy at the same time as fully phasing out the fossil fuels that are causing climate change. Last December's successful climate talks in Paris have shown, at last, that the world is taking decarbonisation seriously. For the EU, which has been forcefully advocating action on climate change for 30 years, this presents an opportunity to transform its leadership into global comparative advantage, and deliver sustainable growth.

Indeed, the EU's proposed Energy Union could enable this advantage, at the same time as putting in place an affordable, secure and low-carbon energy system. But, for this to happen, it must unlock and enable innovation.

In its focus on putting the citizen-consumer at the heart of the design of the new energy market, and combining this with 'smart' systems capable of integrating decentralised renewables as base-load, the European Commission's plans are already proving to be an important driver of innovation geared towards meeting all three objectives. And the forthcoming and final dimension of its Energy Union strategy, which integrates thinking on research and innovation with competitiveness, should add a crucial additional component, by linking these changes clearly to its future economic and industrial success.

Scaling up innovation in energy-related technologies, services and business models is now delivering the cost reductions that will be needed to meet the goals of the Energy Union. Recent years have witnessed dramatic falls in the costs of renewable power generating technologies, for example, falls that European governments helped facilitate through policy and financial support. But without a continuing emphasis on supporting innovation, further cost reductions are not guaranteed.

This innovation will help Europe's economy modernise, grow and deliver shared prosperity and well-being for its citizens, within planetary boundaries. It will also help deliver wider competitive advantage for the European economy. The historic Paris Agreement has fired the starting pistol on a global clean energy race, a race that innovation will help Europe's exporters win.

The most dynamic engines of global growth in the coming decades will likely be found outside the EU, particularly in the emerging markets of Asia, Latin America and Africa. Their growth will spur enormous demand for energy services, and they will share the EU's desire for that energy to be generated, distributed and consumed cleanly, securely and cost-effectively. Investments made by the EU in energy-related innovation will be handsomely repaid in tomorrow's export markets.

How is Europe to encourage this innovation such that it delivers industrial and economic benefits as well as the other objectives of the Energy Union? As we seek to do with this report, prepared for i24c by Capgemini Consulting, the EU can find lessons in the past – not least in how European standard-setting created global benchmarks and, in doing so, gave its domestic companies a competitive head-start. What Europe achieved in mobile telecoms, through the introduction of the GSM standard, can now be achieved in clean energy.

Substantial progress has already been made. Europe's long-standing commitment to industrial research, development and innovation has enabled the emergence of technology leaders, brought distinctive advantages to our industries and created hundreds of thousands of jobs. Policies and regulatory frameworks are crucial to build trust, provide market predictability and stimulate investments. However, they are not the only drivers that facilitate the development and scaling-up of innovation, which requires the involvement of all public and private stakeholders.

Europe might also look to the local level, in both urban and rural settings, where forward-thinking authorities are bringing together building owners, energy suppliers, ICT firms and transport networks. These new ecosystems are enabling new low-carbon technologies and services, delivering energy efficiency improvements and facilitating new means of deploying renewable energy generation.

But the EU must be ever mindful of the absolutely central role of its citizen-consumers. The EU has not always, in the past, given sufficient weight to their interests – but citizen engagement will be vital in building support for the low-carbon transition. The immediate benefits of low-carbon energy services may not be apparent to consumers, and the costs may be higher than for conventional energy. The right price signals and incentives must therefore be put in place to underpin energy-related innovation.

The EU must also recognise the extent to which new business models, emerging from the private sector, will change behaviour and deliver on EU objectives. Disruptive energy providers, the next generation of mobility companies, the application of big data – innovation promises to transform how we provide and consume energy.

Ultimately, however, innovation in the EU's energy system is about more than new technologies. It's also about bringing together new disruptive business models and services, societal innovation and new policy and financial mechanisms.

We believe that the EU Energy Union's Research, Innovation and Competitiveness strategy presents Europe with enormous potential for sustainable growth, additional employment and new export industries – if policymakers can help nurture the innovation required. We hope that this report will make a valuable contribution to that effort – at a truly important time for the EU to demonstrate such success is possible.

3. APPROACH AND METHODOLOGY

Objectives of the project

i24c (Industrial Innovation for Competitiveness) with the leadership of Pascal Lamy and Sir Philip Lowe, two members of i24c's high-level group, initiated this project to help frame the contours of a forward-looking integrated strategy for "research, innovation and competitiveness" for the European Energy Union and support the public debate on this issue. In partnership with Capgemini Consulting, i24c conducted a four-month project providing a strategic assessment of past and present innovations in energy-related industries linked to technological, business model, financing, policy and societal innovations. This has enabled the elaboration of guiding principles and recommendations on how Europe can scale up innovation in, and reap the benefits of, the low-carbon energy race both in Europe and in growing overseas markets.

The project sought to answer the following questions, over various time horizons:

ASSESS: PRESENT SITUATION – where does Europe stand in terms of energy-related innovation?

- What are the current megatrends influencing innovations in the energy sector?
- Where does energy innovation occur? Who is doing it?
- In which innovation areas is Europe particularly strong?
- What are the benefits of energy-related innovation for Europe?

UNDERSTAND: ANALYSIS OF THE PAST – What has led to the success or failure of energy-related innovation in Europe?

- What have been the main drivers of, barriers to, and success factors for energy innovation?
- Did Europe create the right incentives and enablers for energy innovation?
- What have been the socio-economic benefits of energy research and innovation for and in Europe? How did research and innovation support industrial competitiveness in Europe?

RECOMMEND: LOOKING TO THE FUTURE – What should be the role of different stakeholders in accelerating energy-related innovation and securing industrial competitiveness and value creation in and for Europe?

- How can Europe remove constraints to the various types and stages of innovation?
- What are the contours of an effective strategy for research and innovation that ensures the leadership of energy-related European industries and the competitiveness of European Member States?

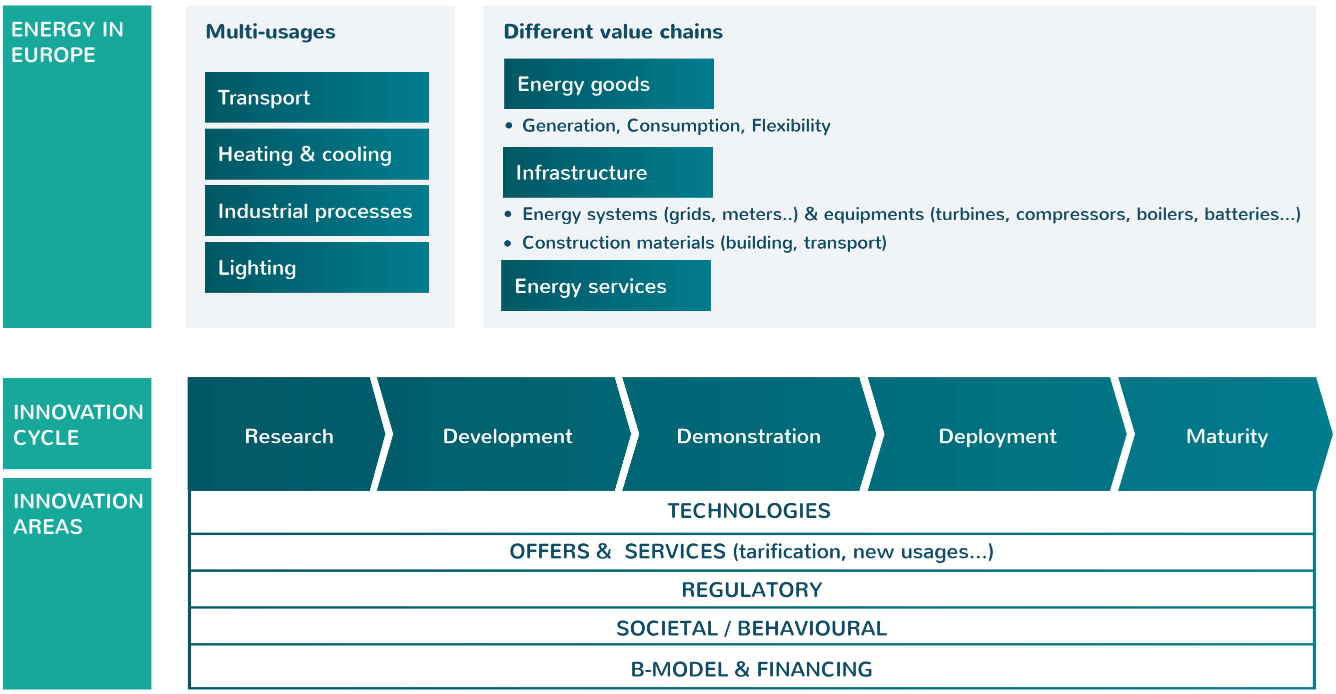
Scope

Energy-related innovation has been broadly defined as any new idea (including new technologies and materials, services, business models, and changes in behaviour and energy usage) that impacts energy supply, infrastructure or demand (including mobility, heating, cooling, lighting, etc.). The innovation cycle (from research and development to mature deployment) has been used as a framework to map the different energy-related innovations considered in the project scope. (See Figure 1.)

The report's primary geographic scope is Europe, including the 28 Member States of the European Union and Norway or Switzerland when relevant. International comparisons have been made, primarily with Asia and the United States.

This report has sought to cover all energy-relevant areas, including energy (generation, transport, distribution and use), transport, industry and agriculture (focusing on bioenergy). Using a sampling approach (see Figure 3), the study dived deeper into 11 specific energy innovation areas.

Figure 1: Energy-related innovation



Approach

A diverse panel of experts from various geographies, innovation areas and organisations was involved in the report. Its members were drawn from research centres, large industrials, start-ups, investors, European and national policymakers, and municipalities. Outputs for this project were gathered through interviews (with 30 high-level energy industry experts and/or CxOs), workshops and desktop analyses (see Figure 2). More details are provided in Appendix 1.

A two-month online survey was also carried out in early 2016 to collect the views of a larger panel of high-level experts and business leaders about Europe's progress, barriers and key success factors regarding energy-related innovation. More details are provided in Appendix 1.

Two workshops were organized in March 2016 to complete and challenge our first assumptions. They involved more than 20 senior executives, entrepreneurs, academic and research experts, and representatives of public authorities. These expert workshops enabled us to more deeply explore how Europe can best enable the deployment of energy-related innovations to meet our new climate goals, while securing socio-economic benefits, addressing energy-system challenges and providing European companies with a global competitive edge. The first workshop took a technology value chain approach, focusing on clean technologies such as wind, solar PV, bioenergy and power storage technologies. The second workshop took a more systemic approach to energy innovation, focusing on smart districts as the most appropriate geographic size when it comes to integrated energy-related innovation and its implementation.

Figure 2: Overall approach

December - January

Phase 1

LESSONS LEARNED FROM PAST & PRESENT

Approach

- Quantitative analysis
- **30 focused high-level interviews**
- **Launch of a European-wide survey**
- Deep-dive on **specific case studies**

February - March

Phase 2

HIGH-LEVEL WORKSHOPS & FINAL POLICY RECOMMANDATION

Approach

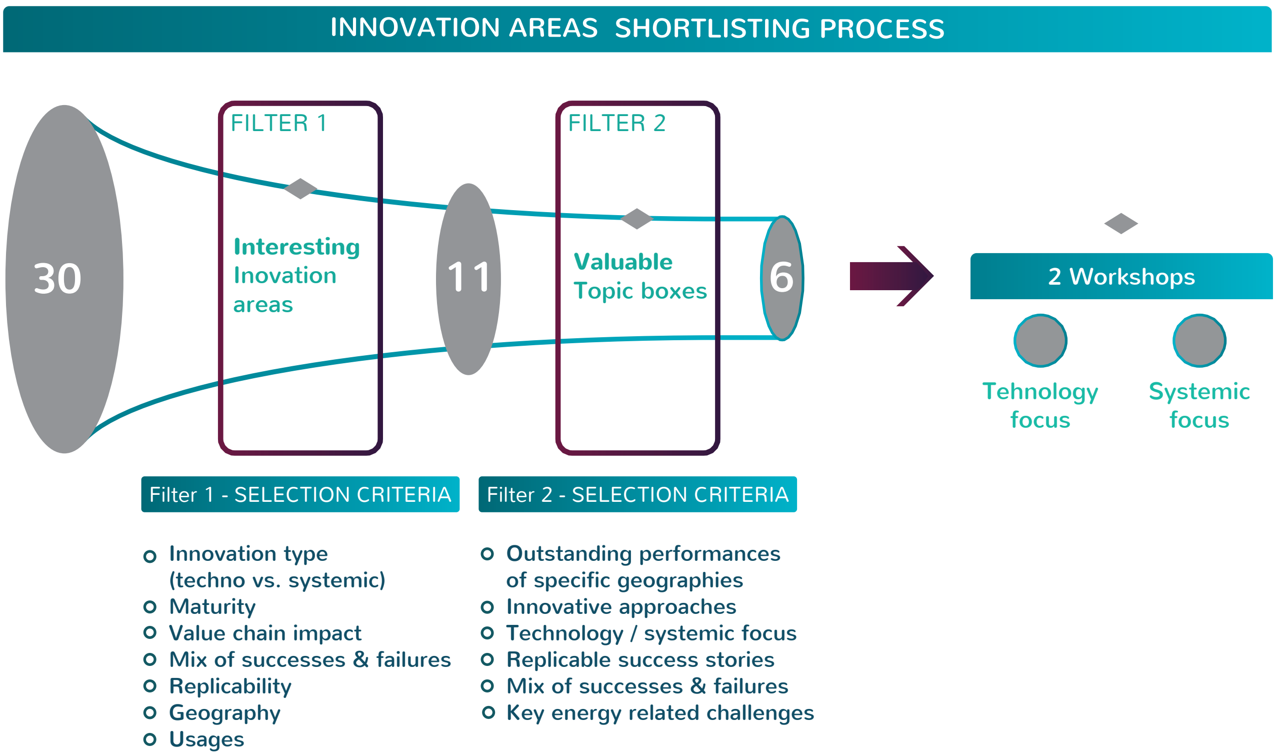
- **Expert workshops** to discuss main findings from Phase 1 & inform recommendations: motto be specific & extrapolate; Phase 1 report as pre-read for workshops
  - **Workshop#1 – March 15th 2016**: How to scale up cleantech market adoption and maximise value of innovation for and in Europe
  - **Workshop#2 – March 22th 2016**: How to accelerate the deployment of smart & energy efficient initiatives in European urban districts
- Outcomes to feed into **recommendations** for the final report

Methodology

Using a sampling approach, 11 innovation areas were selected based upon a qualitative set of criteria (see Figure 3). These include: onshore wind, solar PV, biomass, carbon capture and storage (CCS), hydrogen storage, hydrogen mobility, electro-chemical and mechanical power storage, electric vehicles, smart distribution grids, smart districts and energy efficient buildings.

Six topic boxes (wind in Denmark, biomass in Sweden, power storage in the USA, smart distribution grids, smart cities and the ARPA-E approach in the USA) were also selected to gain a better understanding of key success factors and challenges related to these energy-relative innovation areas and/or initiatives. For each topic box, we sought to identify best practices that could be replicated, and understand the role of public and private stakeholders in driving innovation.

Figure 3: Energy-related areas selection methodology



Europe's performance was then assessed, based on its ability to innovate, to support the competitiveness of European industries, and to generate value for and in Europe in terms of jobs, growth and exports. Figure 4 describes key performance indicators used. Europe's competitiveness was defined as its ability to generate or deploy products and services resulting in jobs, growth or cost-reduction in Europe, as well as exports to other geographies.

Figure 4: Key performance indicators used to assess the competitiveness of Europe in selected energy-related areas

Innovation cycle

Research	Development	Demonstration	Deployment	Maturity
Ability to innovate			Ability to suport the competitiveness of European industries and to generate valuefor Europe	
• **Number of patents** on Climate Change Mitigation technologies • **Top ten countries and organisations on emerging technologies** • **% of investments in R&D** • **Number of demonstration projects** • **Size of demonstration projects**			• **Market penetration:** installed capacities and market share in Europe vs. other main geographies • **Number of jobs/ inhabitants** in Europe vs. other main geographies • **Exports:** trade balance or % of sales outside the domestic market • **Origin of TOP global leaders by innovation areas** (in terms of sales)	

Outline of the report

This reports first sets out the context of the energy world today, which is highly influenced by four major megatrends, namely sustainability, digital, local empowerment and integrated services (Chapter 4). It discusses the importance of innovation in this context, and how innovation and its related ecosystems are helping to further accelerate these trends.

It then provides a high-level assessment of Europe's position in 11 selected energy-related innovation areas, in terms of its ability to innovate, support the competitiveness of European industries, and to generate value for Europe, in terms of jobs, growth and exports (Chapter 5).

Chapter 6 briefly lays out some of the main barriers to and success factors of Europe's performance, and proposes five guiding principles for how Europe can best scale up energy-related innovation and reap the benefits thereof today. The five guiding principles and associated actions provide more detail on how the public sector, including the EU institutions and national, regional, city-level and local decision-makers, can ensure the more efficient use of public funds, attract more private sector investors, accelerate the energy transition, and best position European companies in the global race. These recommendations and examples have been drawn by extrapolating lessons from past and present experiences and from the feedback of a panel of industry experts and leaders (see Appendix 1). It also makes suggestions for near-term, concrete action at the European level, with relevant examples of how these have been pursued in Europe or elsewhere.

Concluding thoughts are offered in Chapter 7.

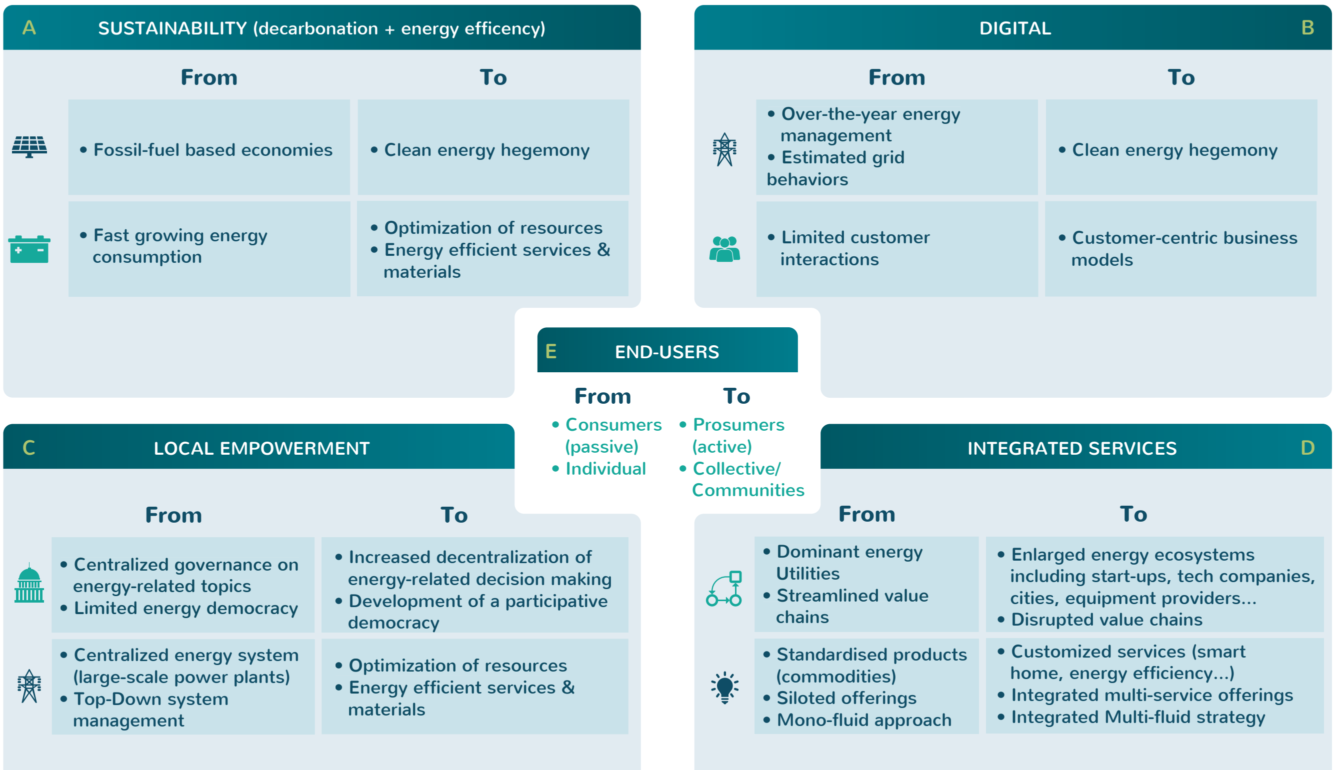
4. A PARADIGM SHIFT TOWARDS LOW-CARBON AND USER-CENTRIC ECONOMIES, DRIVEN BY DIGITAL AND INTEGRATED FLEXIBLE SOLUTIONS

The energy world is undergoing a paradigm shift, influenced by both global and local megatrends. New behaviours and technologies have fundamentally shaken up established energy markets and are beginning to do so in the mobility and construction sector too, opening up a world of opportunities for the taking. These transformations are also disrupting established business models, consumption modes, and mindsets. And, while they offer enormous opportunities for Europe, they also represent potential challenges. In response to this changing context, innovation is essential, and not only in technology. This need for innovation embraces a wide range of stakeholders, whether traditional energy players such as utilities, or new players in the energy landscape (e.g., telecom operators, start-ups providing energy and efficiency services, equipment suppliers, IT providers, and construction and mobility companies).

4.1 Four dynamic megatrends are reshaping all energy-related value chains and usages

The profound changes to the energy over the past decade have been driven by four major megatrends, set out below and in Figure 5, and dynamic socio-economic drivers (i.e. urbanisation, servitisation of the economy, the global financial crisis, new consumer expectations, a changing geopolitical context, and evolving energy commodity prices). These all contribute to making the energy sector increasingly end-user-centric. They are also adding to the growing interdependence of energy, transport, industry and the bio-economy, as well as between the megatrends described. Europe's competitiveness partly depends on its ability to adapt to this new energy world.

Figure 5: A paradigm shift of our economy driven by four megatrends[2]



A First, the drive for sustainability is impacting all energy-related sectors and industries. Clean energy production has become a priority and a reality in Europe: from 2000 to 2013, 80% of investments in the European power generation sector were directed towards renewable electricity. Similar trends are seen at the global level. Since 2013, the world has added more power capacity from renewables (143 GW)[3] than fossil fuels (141 GW) . According to IEA data (2016), over 90% of electricity generated by new installations globally in 2015 came from renewable sources, the highest level seen since 1974, with half the growth coming from wind farms alone.

In the mobility sector, new vehicles are becoming more efficient[4] and car manufacturers are increasingly offering alternative vehicles using low-carbon fuels (e.g., electricity, hydrogen or hybrid solutions). In Norway, 13% of new cars sold are electric, the highest proportion globally. New energy efficient modes of transportation have also appeared, such as car-

[2] Source: Capgemini Consulting analysis
[3] Bloomberg News, 'Fossil Fuels Just Lost the Race Against Renewables', 14 April 2015)
[4] Even if there is a gap between laboratory and real statistics, official average CO2 emissions of new passengers cars in Europe declined from 184 gCO2/km in 2001 to 123 g CO2/km in 2014 (source: ICCT, TNO IFEU white paper From Laboratory to Road, December 2015)

pooling and car sharing, promoted by new players such as BlaBlaCar. The French ridesharing company is Europe's newest 'Unicorn'[5], with 25 million members in 22 countries and 10 million travellers per quarter.

In the buildings sector, new construction methods as well as energy monitoring and optimisation tools are being deployed and could drastically reduce the energy needs of both new and existing buildings or even enable buildings to become net energy producers.[6]

The Paris Climate Change agreement will accelerate this trend. Philanthropists, the private sector and cities have already made commitments that go beyond national or international political targets. The new Breakthrough Energy Coalition, which includes tech titans such as Bill Gates and Mark Zuckerberg, illustrates the unprecedented commitment of private and public stakeholders to solve energy and climate issues. In addition, 436 institutions and 2,040 individuals across 43 countries representing $2.6 trillion in assets, have committed to divest from fossil fuel companies.[7]

"Taking into account the exploding costs of climatic disasters, insurance companies are disinvesting from the fossil world".

Fabio Ferrari, CEO, Symbio FCell

B The digital revolution is enabling the development of smart energy solutions and creating new markets, which European companies can seek to profit from. The total value of digitalisation is estimated by Cisco to be around $14.4 trillion over 10 years.[8] In the energy field, digital technologies are beginning to be deployed, mainly in retail and energy distribution applications. Utilities, energy equipment providers, service providers from other sectors (e.g., telecom operators, IT companies, building security specialists and giant consumer goods retailers), start-ups and end-users expect additional value both from new services and from costs savings.

Digitalisation is accelerating and supporting further sector and consumer integration. New players have appeared, providing new and disruptive business models based on low-carbon technologies or energy efficient services. For example, companies such as Solease in the Netherlands or DZ-4 in Germany are pioneering the solar services market: rather than selling solar PV systems, they offer solar electricity produced on the customer's roof as a service. Another example is provided by EnerNOC, a US company present in Europe, and named as the number two demand-response vendor by Navigant Research analysts. The company began developing integrated demand management solutions in the early 2000s, helping utilities ensure grid reliability, reduce energy costs, meet regulatory demands, and

[5] Start-up for which the valuation exceeds $1 billion
[6] See for instance i24c/BPIE report *Driving Transformational Change in the Construction Value Chain* (2015)
[7] Arabella Advisors, *Measuring the Growth of the Global Fossil Fuel Divestment and Clean Energy Investment Movement*, 2015
[8] Cisco, Embracing the Internet of Everything To Capture Your Share of $14.4 Trillion, 2013

enhance the customer experience. In France, start-ups such as Avob, Smart Impulse or Ubigreen have developed specific solutions to better manage energy demand in buildings. Utilities, equipment providers and building facility managers are carefully watching their development, looking for new business opportunities or means to keep value from their historical relationships with their end-users.

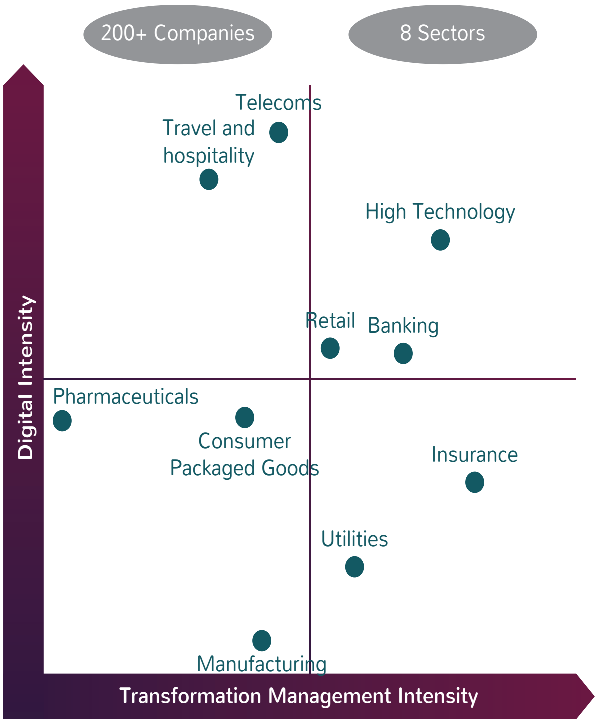
Meanwhile, new players are disrupting the traditional industrial and energy value chains, leveraging the new ecosystem of technologies grouped under the acronym "SMACT", which stands for 'Social' (two billion have an active social network account[9]), 'Mobile' (four billion people on the planet use a mobile device), 'Analytics', 'Cloud computing' and 'The Internet of Things' (80 billion connected devices are expected by 2020[10]). Entire value chains are being upended by the new services powered by these technologies, such as real-time energy management, predictive asset maintenance, in-field geolocation, and advanced training through augmented or virtual reality.

Digitalisation can also bring cost and resource savings for energy-sector incumbents and end-users. Estimates show that the ICT sector has the potential to cut economic costs across sectors by $4.9 trillion by 2030, while enabling a 20% reduction of global CO2 emissions. The use of ICT in energy, manufacturing, buildings and mobility can lead to savings of $1.1 trillion in reduced fuel expenditure, and $1.2 trillion from reduced electricity use globally by 2030.[11] Smart metering, for example, is expected to have a high impact on energy consumption. By 2020, an estimated 72% of European customers will have had smart meters installed.

ICT opens up a world of opportunities. Almost all European energy utilities have begun their digital transformation, even if this transformation is taking place later than in other industries (see Figure 6). According to analysts at IDC, by 2018, 20% of energy utilities' revenues should come from new products or services; in 2019, they expect utilities to spend an average of 2.5% of their capital expenditures on the so-called 'Internet of Things' to either improve the performance of their assets (such as centralised power generation, grids, etc.) or develop new revenue streams.

[9] We Are Social (2015) Digital, Social and Mobile in 2015
[10] The National Business (UEA): Forecast for region to be a web of 4 billion connected devices by 2020 (May 10, 2014)
[11] Source see E3G (2016) and http://smarter2030.gesi.org/

Figure 6: Perceived digital maturity by sectors[12]



Fashionistas
- Many advanced digital features (such as social, mobile) in silos
- No overarching vision
- Underdeveloped coordination
- Digital culture may exist in silos

Digirati
- Strong overarching digital vision
- Good governance
- Many digital initiatives generating business value in measurable ways
- Strong digital culture

Beginners
- Management skeptical of the business value of advanced digital technologies
- May be carrying out some experiments
- Imature digital culture

Conversatives
- Overarching digital vision exists, but may be underdeveloped
- Few advanced digital features

Source: Capgemini Consulting, MIT Digital Center, 2013

C Consumers, regional and local governments are playing a growing role in the energy choices that are being made. This is particularly visible when considering decentralised energy production (electricity and heat) and mobility. In Germany, private citizens and farmers own almost half of Germany's renewable energy installed capacity.[13] Similarly, there are an increasing number of examples of initiatives in rural areas that have successfully enabled the agricultural sector to make use of wasted energy or to produce energy from waste.

Citizens are also increasingly actively participating in energy choices over how they consume energy – in how they heat their homes, how they travel, but also more broadly.[14] They are more and more able to act collectively and make more autonomous energy choices thanks to new private stakeholders such as aggregators and cooperatives. Public authorities have also started to include them in decision-making processes. In France, for example, Paris has chosen to make citizen participation a top priority of its Smart city project. Among other things, the city has introduced a participatory budget, corresponding to 5% of the investment budget (ie. €0.5 billion over the period 2014-2020). Over the first quarter of 2015, city services have received more than 5,000 proposals from citizens. Furthermore, crowdsourcing and crowdfunding are also enabling citizens' active participation in financing the deployment of renewable projects and energy efficiency measures.

[12] Capgemini Consulting and MIT Digital Research Center, 2013
[13] ECIU, Germany's energy transition
[14] E3G (2016): https://www.e3g.org/docs/E3G_Brief_-_Consumer-focused_energy_innovation_%28Apr_2016%29.pdf

The role of local authorities in making energy choices is also growing. For example, large cities around the world such as Frankfurt, Copenhagen, Sydney and San Francisco have taken decisive steps towards climate leadership by setting targets to source 100% of their energy from renewables, and they are well on their way to achieving them. Similarly, the city of Paris has been closely involved in the decision to develop its first fully electric and open-access car sharing service, AutoLib'.

Regions can also play leading roles in managing the autonomy and flexibility of their energy systems. A good example of this is Texel in the Netherlands. This island, with a population of 14,000, has set an ambitious target to become 'energy neutral' (self-sufficient) by 2020. A variety of stakeholders has been involved in the project: the Texel municipality, TexelEnergie (the energy community), the Province Noord-Holland, Agentschap NL, the Distribution System Operator (DSO) Alliander, and technology enablers Capgemini, Siemens and Quby.

D Finally, energy-related industries are increasingly offering "integrated solutions". They are shifting from their role as manufacturers of goods or commodity suppliers to becoming providers of integrated solutions (products and services). For example, incumbent utilities such as E.On, Centrica, RWE, and Eneco, and energy equipment suppliers such as GE, are trying to move from selling electrons or energy equipment to offering services that satisfy fundamental customer needs: comfort, independence, security, entertainment, and so forth.

E End-users, citizens, industry, cities and regions are helping to accelerate these four megatrends. They generate sustainable power; are empowered by digital levers; are playing an increasing role in energy choices; and are open to adopting integrated solutions. Incumbents and new players have to continuously adapt to the evolving energy needs of end-users, and must innovate to remain competitive.

In this context, energy innovation is essential, and not only in technological terms. Enlarged ecosystems and collaboration between multiple stakeholders (across value chains, sectors and geographies) are required to make the energy transition happen and help Europe meet its climate, competitiveness and societal goals.

4.2.These megatrends are both reinforced by and drive the need for energy-related innovation in technology, products and services

Innovation is not an objective in itself. It is an essential means to meeting our economic, climate and societal goals. Even though we have seen some major steps forward in recent years (for instance, dramatic falls of the cost of solar PV modules and wind turbines), there are still major obstacles in the way of the objectives of the EU's Energy Union for more secure, affordable and sustainable energy. Some of the main challenges relate to (i) maintaining high levels of energy security in the transition to a low-carbon energy system, (ii) reducing the cost of key technologies and finding the best solutions to drastically reduce carbon emissions and use of energy while at the same time maintaining economic competitiveness, (iii) giving end-users real control of their energy consumption and allowing them to make sustainable energy choices, (iv) ensuring consistency and cost-effectiveness of energy-related choices made at EU, national and local levels. This begs the questions: what is the purpose of energy-related innovation, and in what areas is it needed? A few examples are provided below.

> **"Future innovation will be much more linked to energy services and organisation of usages by end-users, rather than focused on technology"**
>
> **Jean-Michel Guéry, Deputy CEO, Bouygues Energy Services**

To ensure resilient, secure, flexible and cost-efficient energy systems, innovation in technology and in business and operational models is required. Smart energy systems will be based on innovative power electronics, efficient heating and cooling technologies, and power storage and demand response solutions, with increased synergies between energy vectors. According to a recent report from the Energy Union Choices partnership, a smart and integrated approach to energy security can reduce investments required in gas infrastructure to deliver security of supply by up to 80%.[15] Power-to-gas offers an example of emerging energy innovation to balance electricity grids. In France, Jupiter 1000 is the first power-to-gas project seeking to store renewable electricity by injecting hydrogen and methane synthesis into the gas transmission supply network. GRTgaz, the project's orchestrator, recently announced the signature of industrial agreements that set the stage for the deployment of the solution.[16] Smart energy systems also call for innovation around physical asset management: digital technologies and advanced big data science offer new opportunities to reduce costs of business operation (e.g., maintenance, surveillance) while increasing security.

To help reduce energy demand and meet customers' new expectations, there are opportunities for innovation in energy retail offerings and services. Stakeholders are beginning to shift from the sale of commodities to an "energy-as-a-service" model. For example, the Dutch energy company Eneco has partnered with Quby, a manufacturer of smart thermostats, to develop a smart home service. The service offers customers the device, charges them for the technology and installation, and provides various energy management services through a subscription-based model. This approach is not yet widespread; it requires the building of the right partnerships between historical incumbents, small and medium-sized companies, and new digital players. Innovative business-to-business solutions are also expanding that aim to reduce energy use in industrial processes, equipment or product strategy. In the UK, the Industrial Energy Efficiency Accelerator (IEEA)

[15] Energy Union Choices, A Perspective On Infrastructure and Energy Security In The Transition, March 2016.
[16] More details on Jupiter1000.com and in the press

worked with 14 industry sectors with medium levels of energy intensity, and identified a potential to reduce energy and carbon emissions by 29%, using existing solutions.[17]

Similarly, innovations in processes and materials used in the building and transportation sectors offer high potential for energy savings. Over the past decade alone, green construction-related patent filings (including energy efficient lighting technologies, constructional and architectural innovation, efficient home appliances, and energy management solutions) have tripled.[18] In the mobility sector, new techniques have recently been developed that reduce energy consumption for all modes of transport. For example, an increased use of carbon fibre in the construction of the Airbus 350 XWB and improvements in the performance of motors have resulted in a 25% decrease of the airplane's fuel consumption compared to its current aluminium-based long-range competitors.[19]

Finally, to meet Europe's sustainability goals, innovation and the deployment of clean energy technologies and products (e.g., renewables, electric vehicles and bioenergy) will be key, but equally non-technological innovations (e.g. on services and solutions), will play a central role in achieving a low-carbon, decentralised energy system. **Non-technological innovation** can provide the means for consumers to play a more active in the energy transition and promote their buy-in and acceptance of large-scale technological change.

Decarbonisation strategies in European countries will take various routes, depending on the local market context, resources and energy choices. But what is clear is that managing innovation efficiently throughout the innovation cycle, maintaining technology leadership, and ensuring the full commitment of all stakeholders will necessitate **a coordinated approach at the European level, as well as at more local levels,** and in most instances will also call for innovation in policy, finance and governance structures.

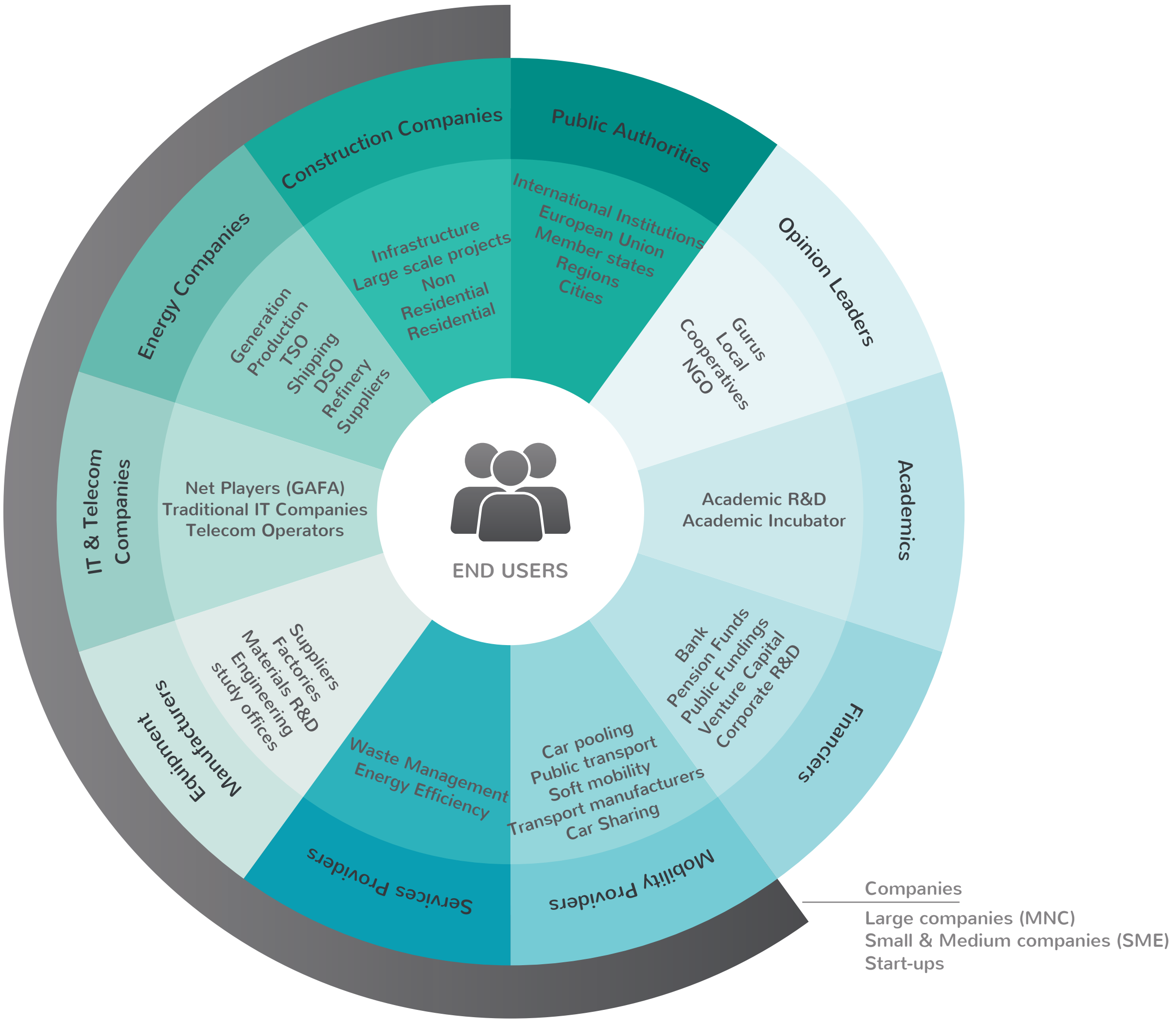
4.3. Enlarged complex ecosystems are required to make the energy transition a reality

Energy innovation is often not the result of one actor, but is rather depends upon contributions of a wide range of stakeholders, as represented in Figure 7. In fact, an enlarged ecosystem of stakeholders contribute to energy innovation, whether they are driven and stimulated by **local and regional authorities and/or end-users**, initiated by **new players** disrupting traditional value chains, or emerge from **traditional energy players** (e.g., equipment providers, utilities, grid operators and public research institutions).

Smart energy systems also call for innovation around physical asset management: digital technologies and advanced big data science offer new opportunities to reduce costs of business operation (e.g., maintenance, surveillance) while increasing security.

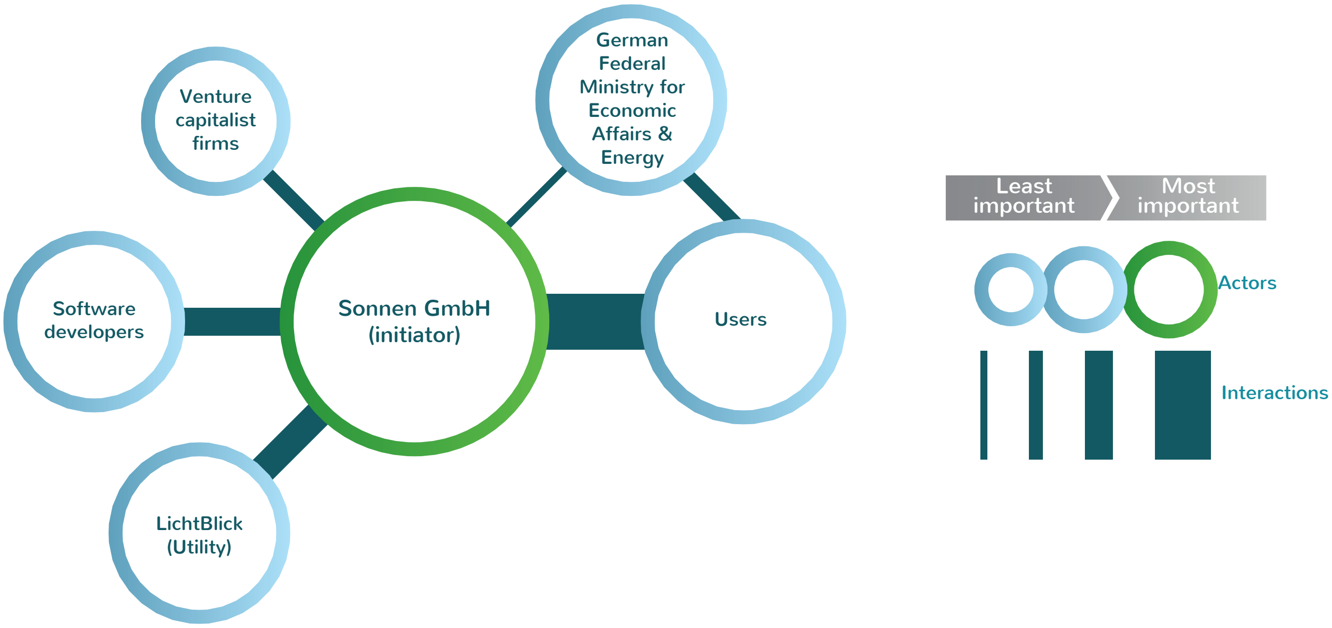
[17] Carbon Trust, Industrial energy efficiency
[18] European patent office, see article
[19] Airbus website

Figure 7: An enlarged ecosystem of energy innovation stakeholders



In many cases, the success of energy-related innovations relies on **cross-sector collaborations,** as demonstrated in the example of Sonnen GmbH (see Figure 8) or for City Sonnen. SonnenCommunity is a virtual power plant that connects a German-wide community of distributed generators and energy storage users. It enables members to purchase excess energy located elsewhere within the community, creating revenues for users and exploiting under-used energy resources. The concept has been developed by the SME Sonnen GmbH, which previously supplied domestic battery systems. The cross-value-chain collaboration that the company initiated beyond its hardware market was crucial for changing its business model. This bottom-up collaboration with software developers, an energy utility and domestic users, was key to the development of new skills and technology that enabled it to build the SonnenCommunity and learn how to effectively manage an electricity grid.

Figure 8: Cross-sector collaboration in the example of Sonnen GmbH[20]



In a similar way, Forcity, a French start-up that offers services to help urban planning decision-making, uses data to simulate the dynamic development of a geographic area by modelling the territorial evolutions resulting of public authorities' choices. With the EcoCité program in Lyon, Forcity has developed a consortium including EDF, Veolia and CoSMo. The main challenge is to simultaneously consider the economy, energy and urban development in an integrated fashion.

Research and academic stakeholders are also strong enablers of large cooperative ecosystems and have developed partnerships with private companies, mainly from their local domestic market. French public research institute CEA for example is working on hydrogen technologies with a consortium of large French companies, including Air Liquide, PSA, EdF, ENGIE and Safran. On photovoltaic modules and systems, the research institution is collaborating with Total.

Bridging the gap between industry, academia and research across Europe is one of the goals of KIC InnoEnergy, the European structure set up to promote innovation, entrepreneurship and education in sustainable energy. To do so, it has created a network of more than 160 companies, at the heart of which is its 27 shareholders, including Vattenfall, ABB, Schneider Electric and Gas Natural Fenosa.[21]

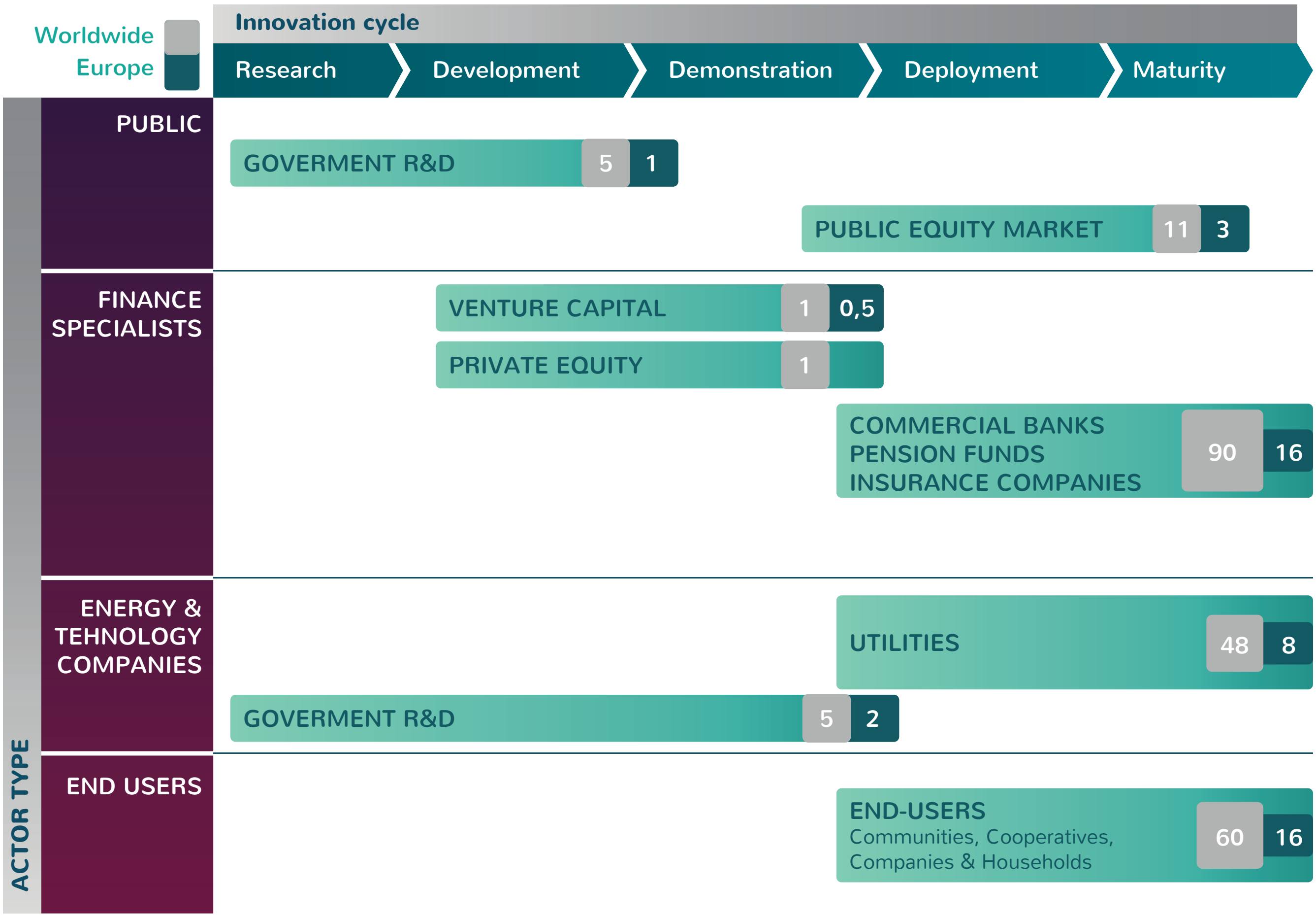
[20] i24c and Carbon Trust, Industrial innovations driven by multi-stakeholder ecosystems (2016)

[21] Born under the umbrella of the European Institute of Innovation and Technology (EIT), KIC InnoEnergy supports entrepreneurs and startups building sustainable businesses that expand and enhance Europe's ecosystem (133 supported as of May 2016).It connects innovators and business partners by investing in commerically viable products and services (71 launched as of May 2016) and runs Master's, PhD and further educational programmes at European universities.

Local public authorities are often initiators or key enablers of challenge-driven energy innovative projects, requiring enlarged ecosystems. For example, the city of Malmö in Sweden has launched an ambitious project in collaboration with a large energy company and a wastewater utility. The project's goal is to supply the district of Hyllie, near Malmö, with 100% renewable and reusable energy by 2020. Similarly, in Germany, the city of Hamburg has initiated a challenge-led process to redevelop a former port area with innovative sustainable solutions. HafenCity GmbH has taken a leading role as the facilitator for multi-stakeholder cooperation, coordinating top-down cross-value-chain collaboration.

Further, many **energy and technology companies**, like EDF and RWE, have set up Open Innovations units in which they pursue new technologies and solutions. **Corporate venturing** is also increasing, with the majority of the main players in the energy sector such as Engie, Siemens, Iberdrola, E.On, RWE or ABB, now having their own corporate venture arms that invest in startups.

Figure 9: Global transactions in renewable energies by stakeholders along the innovation cycle (round figures of 2013, $ billion)[22]



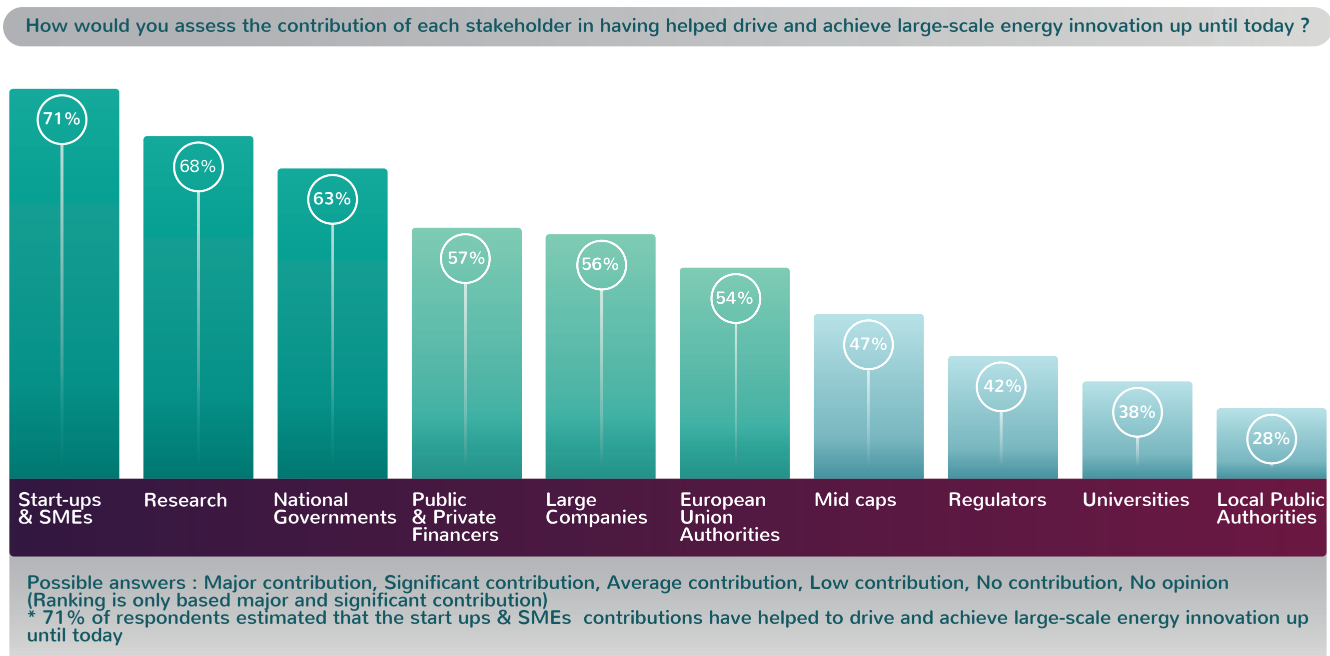
[22] Capgemini Consulting analysis, based on data available in the Frankfurt School-UNEP Centre/Bloomberg (2015) Global Trends in Renewable Energy Investment 2015

Finally, the financial sector is also a key stakeholder in the energy innovation ecosystem. Banks and insurance companies are involved in the vast majority of the late-stage transactions related to energy innovation (see Figure 9).[23] Earlier in the innovation cycle, equity capital is an essential means of financing innovative projects and moving beyond the demonstration stage. Public-private financing models have also appeared with the aim of increasing investments in low-carbon technologies and energy efficiency and maximising the impact of public funds in accelerating clean energy deployment and economic development. Such examples include public-private energy investment partnerships, also referred to as Green Banks.

Yet financing energy innovation remains a major challenge throughout the innovation cycle, and in particular between the demonstration and commercialisation phases. In recent years, global investments in clean energy have remained relatively flat ($179bn in 2010 compared to $186bn in 2015), and they have significantly decreased in many important geographical areas, including Europe (down 50% to $40 billion in 2015 compared with 2012).[24] Much of investment in Europe has been directed towards large offshore wind projects. Furthermore, there have been lower volumes of venture capital (VC) and private equity (PE) investment in renewable energy, down to $2.2 billion in 2013 at global level (-46% year-on-year) and $500 million in Europe (-17% year-on-year). Only wind projects showed growing investments from VC/PE in 2013 (+70% globally), so that there is now more VC/PE investment in the wind industry than solar and biofuels combined.

According to a survey conducted by i24c and Capgemini Consulting, the stakeholders that have contributed the most to large-scale energy innovation are: start-ups and SMEs, research centres, and national governments (see Figure 10).

Figure 10: Perceived contribution of stakeholders in large-scale energy innovation [25]



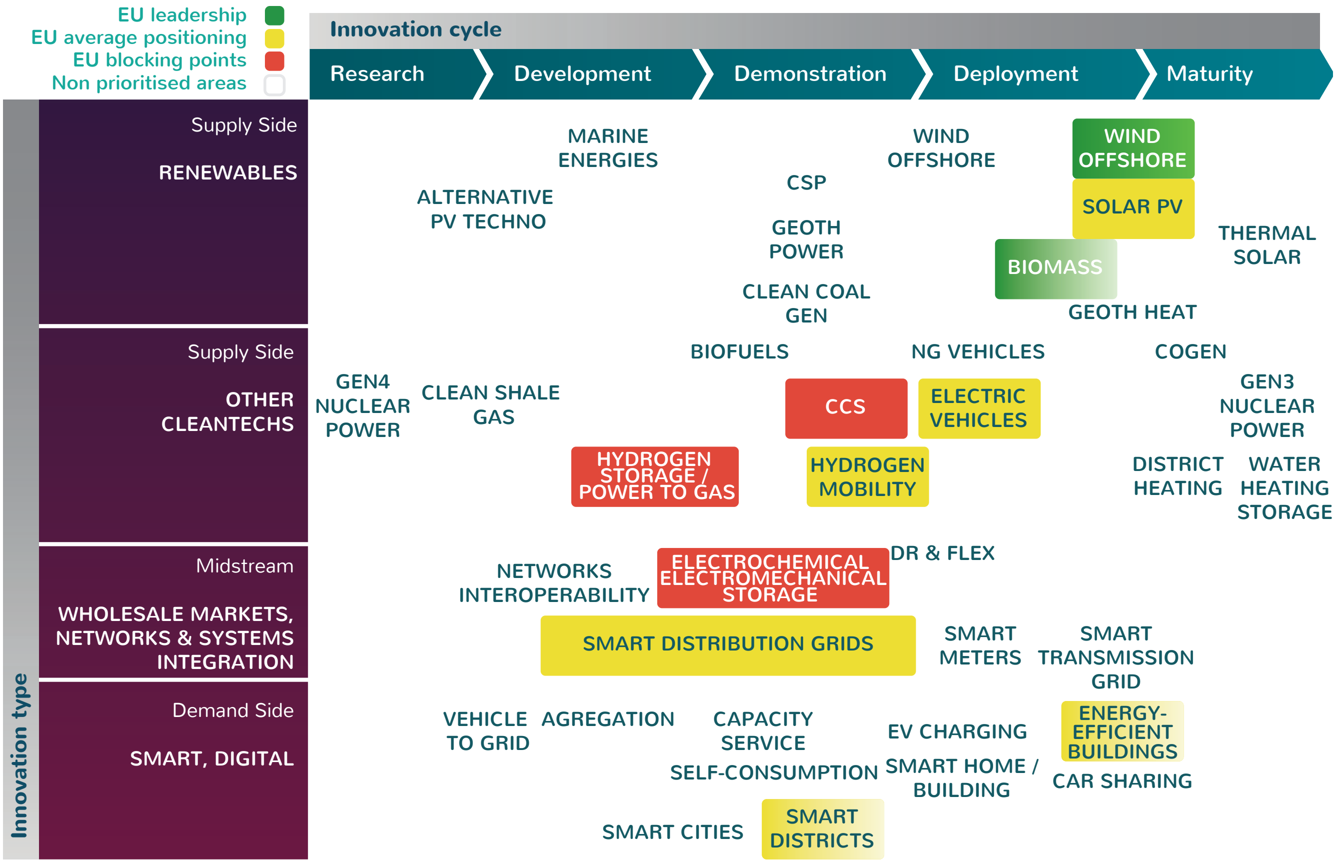
[23] Global Capital Finance and Clean Energy Pipeline, The European renewable energy investor landscape. See also the Bloomberg report, Global trends in renewable energy investment
[24] See Bloomberg New Energy Finance (2015 data).
[25] i24c - Capgemini Consulting, survey on energy innovation (2016) based on 73 mostly CxO respondents

5. IN THE ENERGY SECTOR, EUROPE HAS NO IDEAS DEFICIT, BUT IN MANY INSTANCES, A DEPLOYMENT DEFICIT

With ambitious domestic targets and the pioneering of new instruments to decarbonise its economy, Europe has undeniably paved the way towards a global clean energy transition. Expert interviews and deep-dive analysis suggest that European policies have been successful in initiating energy-related innovations, but more needs to be done to accelerate their deployment and reap the expected socio-economic benefits, as well as to best position Europe for the future.

This section provides a high-level assessment of where Europe stands in 11 selected energy-related innovation areas in terms of its ability to innovate, support the competitiveness of European industries, and generate value for Europe, in terms of jobs, growth and exports (see Figure 4).

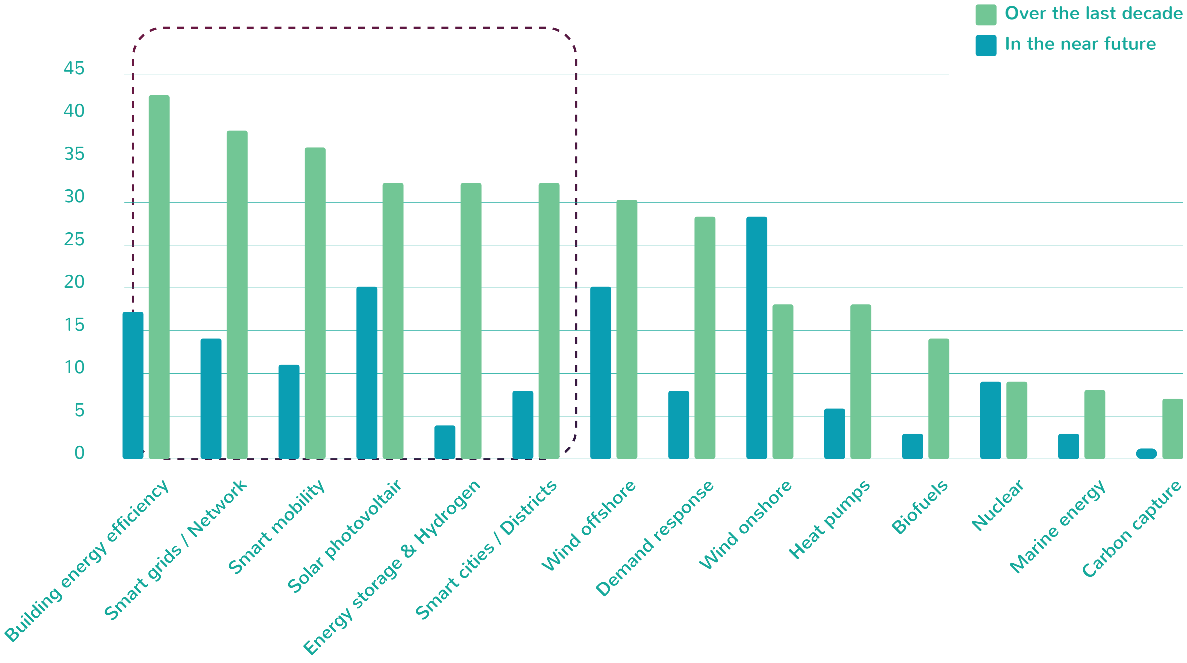
Figure 11: General assessment of Europe leadership on selected energy-related innovation areas, based on its ability to innovate and create value and competitiveness



Europe's comparative advantage has historically lay in research and development (R&D). If the development of some renewable energy technologies has led to clear socio-economic benefits (in terms of jobs, growth, and exports), Europe has, however, struggled to industrialise other promising energy innovations – particularly for demand-side and midstream innovations (see Figure 11).

This performance assessment is not static, and there are reasons to believe that Europe can succeed in creating jobs and growth from other energy-related innovation areas in the near future. To illustrate this point, participants to our online survey highlighted areas where they expect to see the highest value potential for Europe in the future. These are primarily in energy efficiency solutions for the buildings sector, smart technologies (for grid, mobility, districts, etc.), energy storage and demand response. This shows confidence (or at least expectations) from those participants that future markets in these areas will grow in Europe and beyond. Solar PV and wind offshore are equally seen as potential growth areas (see Figure 12).

Figure 12: Perceived value potential for and in Europe of selected innovation areas (in number of answers, multiple choices were possible)[26]



[26] i24c - Capgemini Consulting, survey on energy innovation (2016) based on 73 mostly CxO respondents

5.1 Europe has remained a fertile area for emerging energy-related innovations

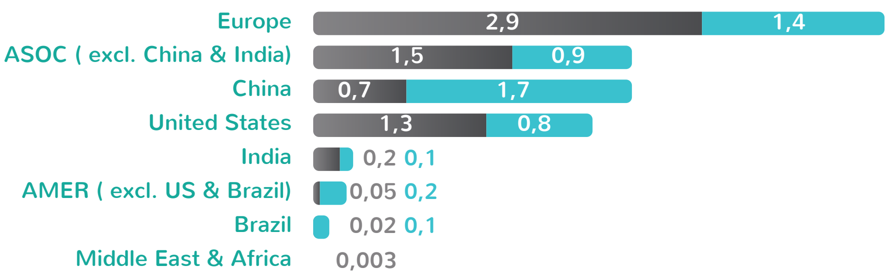
At the global level, recent decades have seen a continuous expansion of inventive activity in climate change mitigation technologies (CCMTs[27]). These now represent nearly 6% of global invention activity, up from 1.5% in 1990. Below, we assess Europe's performance in terms of its ability to innovate, mainly focusing on two KPIs: research and innovation (R&I) investments, and number of patents. More data is available in Appendix 2.

5.1.1 Europe is the world leader in terms of investments on renewable energy R&D, especially thanks to corporate R&D

The latest data on R&D investment shows that Europe is still the largest 'green' investor in renewable energy R&D.

Europe has been a major contributor to energy-related research and innovation efforts in recent years, and is still the largest investor in renewable energy R&D ($4.3 billion in 2014, or 36% of the total) (see Figure 13).

Figure 13: Corporate and government R&D on renewable energy investment by region, 2014, and growth from 2013, (in billion dollars)[28]



	Growth	
	Corporate R&D	Government R&D
Europe	0%	1%
ASOC (excl. China & India)	0%	1%
China	-2%	7%
United States	1%	2%
India	111%	5%
AMER (excl. US & Brazil)	-2%	2%
Brazil	-4%	2%
Middle East & Africa	12%	0%

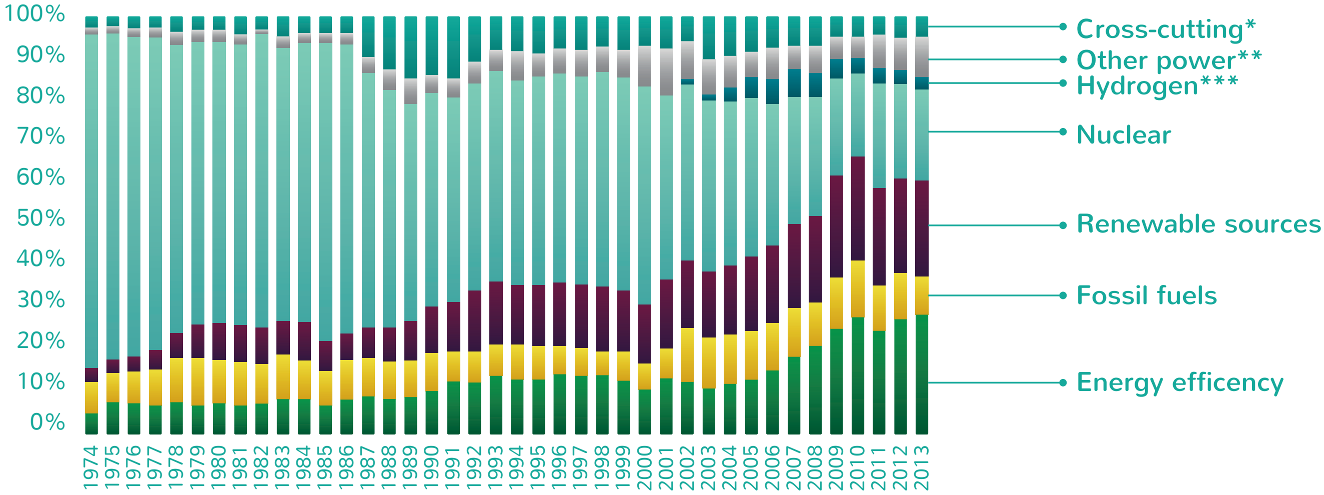
Within the renewable energy mix, solar PV attracted more investments globally than all R&D spending in other renewable energy technologies combined, and almost three times more than the wind industry in 2013. Despite shrinking subsidies in Europe, Europe's corporate spending on solar R&D reached $793 million, higher than corporate spending in the US ($584 million) or in China ($364 million).[29]

[27] In a broad sense, CCMTs include technologies related to energy generation, transmission and distribution, but also carbon capture and storage, and technologies related to buildings, including housing appliances and end-user applications. It also includes technologies related to transportation and system-integrated technologies such as smart grids, NICT, and others.
[28] Frankfurt School-UNEP Centre/Bloomberg (2015) *Global Trends in Renewable Energy Investment* - . ASOC = Asia Oceania
[29] Frankfurt School-UNEP Centre/Bloomberg (2015) *Global Trends in Renewable Energy Investment*,. In China, however, solar PV R&D is mainly supported by Chinese government spending ($995 million in 2014).

In Europe, energy R&D investments mainly come from the corporate sector. According to Bloomberg New Energy Finance, European companies committed more than governments in 2014 ($2.9 billion compared to $1.4 billion in government spending). Nevertheless, public funding continues to play a pivotal role in Europe, and increased public R&D&D spending has coincided with more patents in the corresponding technologies.[30] Public funds are also a key source for the support of early-stage innovation in targeted sectors, notably through the European Strategic Energy Technology (SET) Plan funds.

Over the last decade, European public spending has progressively evolved to grant a higher portion of support to renewable energy and energy efficiency projects (see Figure 14).

Figure 14: Share of energy RD&D spending by governments in OECD Europe by technology sector[31]



5.1.2 In terms of patent registration, Europe remains a major centre for climate change mitigation technology inventions

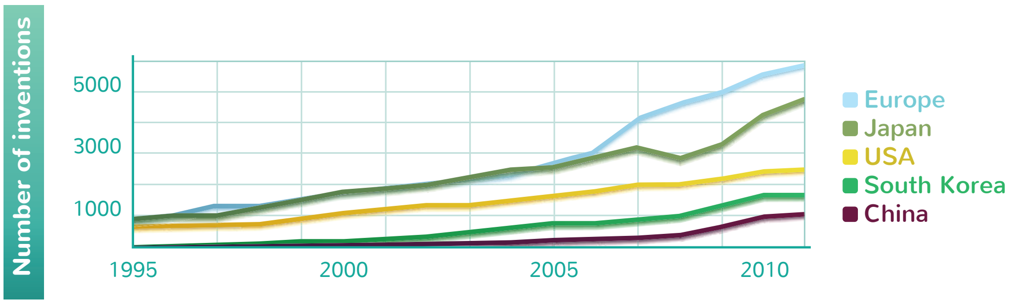
Europe is the global leader in terms of high-value CCMT inventions (i.e., for which patent protection is sought in at least two jurisdictions), with around 6,000 inventions in 2011, or 40% of the total (see Figure 15). According to the European Patent Office, European inventors were responsible for around 18% of global CCMT inventions developed during the period 1995-2011[32], despite the increasing competition from China and Korea.

[30] Zachmann G., A. Serwaah and M. Peruzzi (2014) 'When and how to support renewables? Letting the data speak', Working Paper 2014/01, Bruegel

[31] Bruegel policy brief, by G. Zachmann, Making low-carbon technology support smarter (2015), based on IEA) estimated RD&D budgets by region. Note: *= Others cross-cutting technologies/research; ** = Other power and storage technologies; ***= Hydrogen and fuel cells. OECD Europe = Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

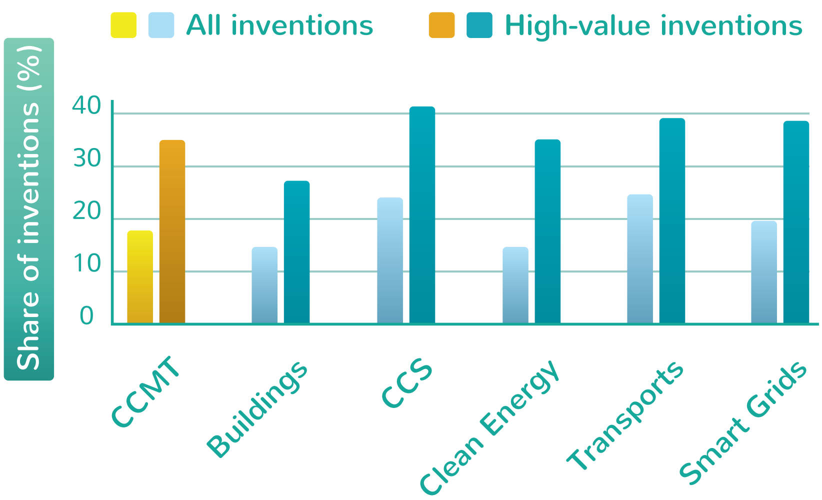
[32] As a reference, European Union stands for 17.2% of global GDP (IMF, 2013) and for 6.9% of global population (Eurostat, 2015 and World Population Prospects, 2015)

Figure 15: High value CCMT inventions in the major innovation centres 1995-2011[33]



The contribution of Europe to global inventive efforts varies across technologies, however. It is highest in CCMTs related to transport and in carbon capture and storage, where Europe produces over 40% of the world's high-value inventions (see Figure 16). The contribution of Europe to clean energy technologies, smart grids and CCMTs in buildings is slightly lower, but still significant, especially with regard to high-value inventions.

Figure 16: European share of global CCMT inventions by technologies 1995-2011[34]



Research and development in energy-related technologies is highly concentrated within Europe: five European countries represent 80% of CCMT inventive activity. Germany is a clear leader, accounting for more than 50% of European CCMT patent applications from 1995 to 2011, followed by France, the United Kingdom, Italy, and

[33] European Patent Office (2015) Climate change mitigation technologies in Europe
[34] European Patent Office (2015) Climate change mitigation technologies in Europe.

Sweden. Germany also steers invention in other European countries, playing a role in 83% of European co-inventions between European countries over 1995-2011.

Between 1995 and 2011, 3.2% of European inventions resulted from cooperation between inventors located in at least two different European countries. This number is comparable to the proportion of inventions developed between European countries and the rest of the world. And this trend has accelerated, growing from 1.7% in 1995 to 4.1% in 2011.

Emerging energy-related technology innovation is strongly driven by world-class European public research institutes and large industrials from the energy and transport sectors. The top five worldwide applicants in CCMT patenting from 1995 to 2011 include two European-headquartered industrial companies, second-ranked Siemens and Robert Bosch, in fifth place (See Figure 17).

Figure 17: Top 5 worldwide applicants in CCMT patenting 1995-2011[35]

Applicant	Country	Inventions	Main CCMT category
Toyota Motor Corporation	Japan	10743	Transportation (Y02T)
Robert Bosch	Germany	6009	Transportation (Y02T)
Honda Motor Company	Japan	4951	Transportation (Y02T)
GE (General Electric Company)	USA	4932	Clean energy (Y02E)
Siemens	Germany	4818	Clean energy (Y02E)

Europe also holds nine out of the Reuters' Top 25 Global Innovators ranking of publicly funded research institutes in advance science and technology. The French Alternative Energies and Atomic Energy Commission (CEA) appears at the top of the list for its research into areas including renewable power, public health, and information security. It is followed by Germany's Fraunhofer Institute and Japan's Science and Technology Agency.

5.1.3 Other KPIs confirm European leadership in the upstream energy-related innovation cycle

Looking at KPIs beyond patent data (e.g., the capacity to attract early-stage private investment, and the number of start-ups), other European countries are also driving emerging cleantech innovation. The Cleantech index 2014 ranks six European countries in the Top 10 countries on emerging cleantech innovation: Finland, Sweden, Ireland, UK, Netherlands and Germany.[36]

[35] European Patent Office (2015) Climate change mitigation technologies in Europe
[36] Cleantech Group, WWF and the Swedish Agency for Economic and Regional Growth (Tillväxtverket)

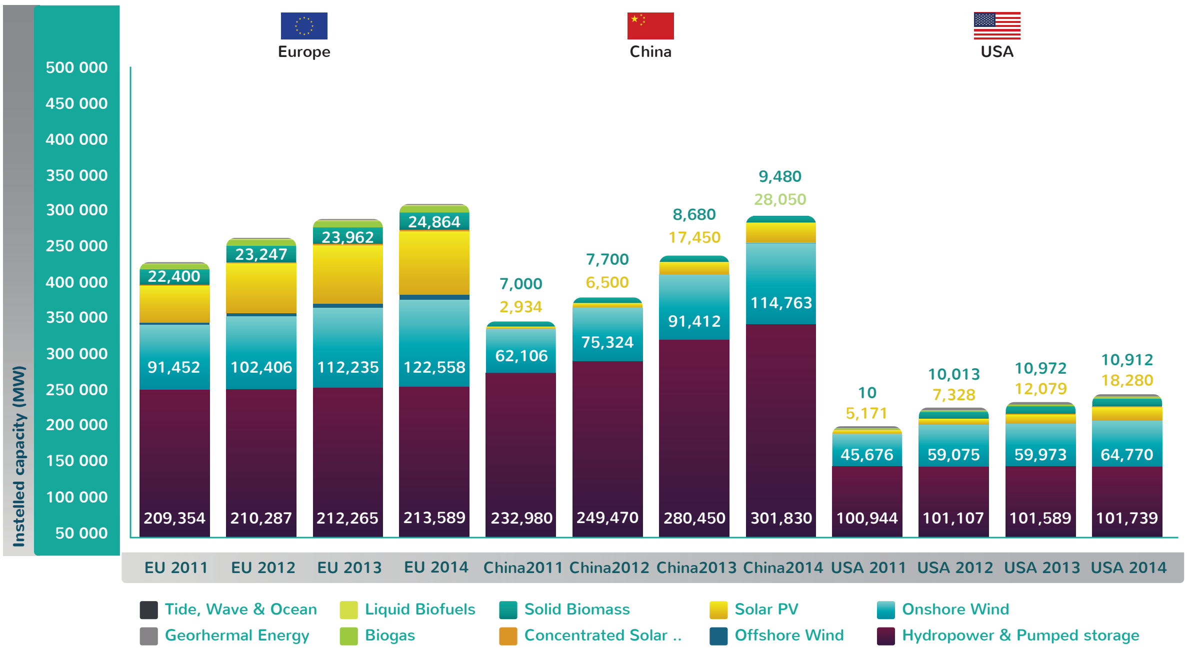
5.2. Europe's challenge is to secure the benefits from energy-related R&I

Europe has proven capability to invent low-carbon technologies and energy efficient solutions. So a key question is whether Europe is succeeding in deploying them and reaping the related socio-economic benefits. This section focuses on the value generated from R&I in Europe, looked at from the perspective of market penetration, jobs, exports, and the presence of global leaders.

5.2.1 R&I efforts have more or less paid off for large mature renewable energy technologies

MARKET PENETRATION: Pioneering regulation in Europe has driven investments and installation of significant renewable energy capacity. Europe has undeniably played a central role in making renewable technologies affordable, encouraging the deployment of renewable energy worldwide. Since 2000, the world added 986 GW of renewable energy generation. Europe has seen rapid growth, with total renewable energy capacity more than doubling from 217 GW to 472 GW over 2000-2014, making Europe the world's biggest market (see Figure 18). If China now leads the way in terms of annual renewable power additions, Europe is still the leading renewable energy market on a per capita basis.

Figure 18: Installed capacity of renewable energy in key regions, 2011-2014 (MW)



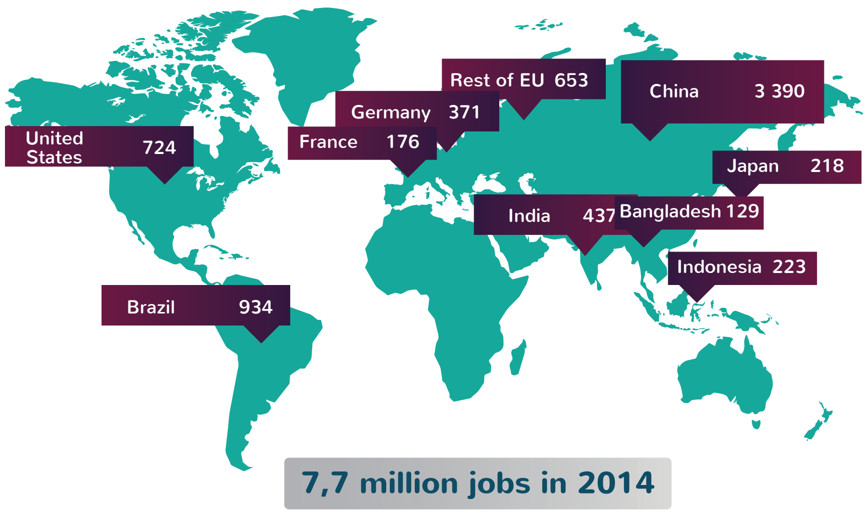
This expansion in terms of installed capacity is explained by major cost reductions, linked to technological progress and economies of scale. This is particularly true for solar PV, where recent years have seen a 20% drop in prices with every doubling of cumulative output.[37]

The use by several Member States of market-pull instruments such as feed-in-tariffs and green certificates explain in large part the rapid growth of solar PV and wind in Europe. The UK market has grown exponentially since 2011 and has become one of the main drivers of the European solar market, along with Germany and Italy. An important factor for the increase in the UK is the introduction of a feed-in tariff scheme in April 2010. It resulted in the installation of 869 MW of capacity in 2011, almost 13 times higher than the capacity installed in 2010.

However, start-and-stop national policies for feed-in tariffs have had a long-term negative impact on renewable energy markets and resulted in a significant decrease in the annual volume of new installed capacities. Germany still leads the solar PV market in terms of cumulative installed capacity, but annual additions dropped from 4,454 MW in 2008 to 1,898 MW in 2014.[38]

JOBS: In terms of domestic jobs, Europe has not always reaped the benefits of its R&I efforts. Overall, 1.2 million jobs are linked to renewable energy in Europe, representing 15% of the global total (see Figure 19).[39] In 2015, some European member states, notably Germany and France, had among the world's largest renewable energy employment in absolute terms (after China, Brazil, the United States, India, Indonesia and Japan).[40]

Figure 19: Renewable energy employment in selected countries in 2014[41]



[37] Stanford University, Cost- and Price dynamics of solar PV modules (2015), based on Swanson analysis over 1979-2010
[38] EY (2015) Solar PV jobs and value added in Europe
[39] This correlates to 0.49% of the European active population, slightly more in percentage than the largest renewable employer, China with 0.42% of the active population.
[40, 41] IRENA (2015) Renewable Energy and Jobs, Annual Review

However, the European renewable energy employment rate declined in 2013 – with the EU-28 losing 50,000 jobs year-on-year[42] – mainly because of adverse policy conditions such as start-and-stop policies. In particular, the solar PV industry suffered job losses (falling 35% in 2013, to 165,000 jobs), due to lower cost-competitiveness in manufacturing activities and slower installation rates in many Member States. Other renewable energy technologies experienced weak growth and were unable to compensate for the loss in solar PV jobs.

Domestic jobs are not proportionally linked, however, to installed capacity or R&I investments. Bioenergy[43] industries represent almost half of renewable energy-related jobs in Europe (507,000 jobs[44]), whereas it only represented 7% of the total renewable installed capacity in 2014, and received 16% (€373 million[45]) of energy-themed funds allocated by FP7.[46] Sweden is a remarkable example of bioenergy development: the country has completely adapted its national energy mix over the last decades, by introducing long-term policies to promote bioenergy. As a result, in 2015 bioenergy jobs represented more than 69% (32,800 jobs) of renewable energy employment in Sweden (see Topic Box A on bioenergy in Sweden).

TRADE BALANCE & GLOBAL RANKING: Looking at the trade balance, some energy industries have managed to maintain their manufacturing activities and export technology and services. Europe is particularly strong in the wind industry, where some European countries have managed to develop a large ecosystem of companies and keep manufacturing activities, which enable them to export their technology and services worldwide (e.g., Denmark in the wind industry – see Topic Box B in the report).

European companies are recognised leaders, with global industry champions based in Denmark (Vestas), Germany (Siemens) and Spain (Gamesa). In 2015, a Chinese manufacturer, Goldwind, topped for the first time the world's ranking for annual installations of wind turbines (with 7.8 GW), followed by Vestas (7.3 GW) and General Electrics (5.9 GW), (see Figure 20). However, it is worth mentioning that all Chinese companies' sales are linked to the rapid growth of their domestic market, while European wind manufacturers export their technology to North America and China. Europe registered a trade surplus of €2.45 billion in wind components in 2012.

[42] IRENA (2015) Renewable Energy and Jobs, Annual Review
[43] Bioenergy includes solid biomass, biofuels, biogas, and waste to energy. About 70% of the total bioenergy feedstock originates from forest and forest industries, while the rest is based on waste and agriculture.
[44] IRENA (2015) Renewable Energy and Jobs, Annual Review
[45] European Commission, Horizon 2020 focus on bioenergy.
[46] FP7 is the EU seventh research framework programme.

Figure 20: Top 10 Wind Turbine Manufacturers (Ranked by Global Market Share)[47]

TOP 10 Wind Turbine Manufacturers (Ranked by Global Market Share)			
1.Vestas	6.Sulzon	1.Goldwind	6.Enercon
2.GE	7.Sinovel	2.Vestas	7.Guodian
3.Gamesa	8.Goldwin	3.GE	8.Ming Yang
4.Enercon	9.Dongfang	4.Siemens	9.Envision
5.Siemens	10.Nordex	5.Gamesa	10.CSIC
2008		2015	

In contrast, Europe has not succeeded in maintaining the leadership it had before 2007 in solar PV manufacturing (see Figure 21).[48] Since 2007, Europe has become a net importer of solar components, mainly produced in China. In 2012, Europe's trade deficit in solar components was €9 billion.

Figure 21: Top 5 Solar Panel Manufacturers [Ranked by shipment guidance (GW)][49]

TOP 5 Solar Panel Manufacturers [Ranked by shipment guidance (GW)]	
1.Sharp	1.Trina Solar
2.First Solar	2.Yngli Green Energy
3.Yngli Green Energy	3.Canadian Solar
4.Kyocera	4.Hanwha SolarOne
5.Trina Solar	5.Jinko Solar
2008	2015

5.2.2 Other energy-related innovation areas show high value potential but slow deployment in Europe

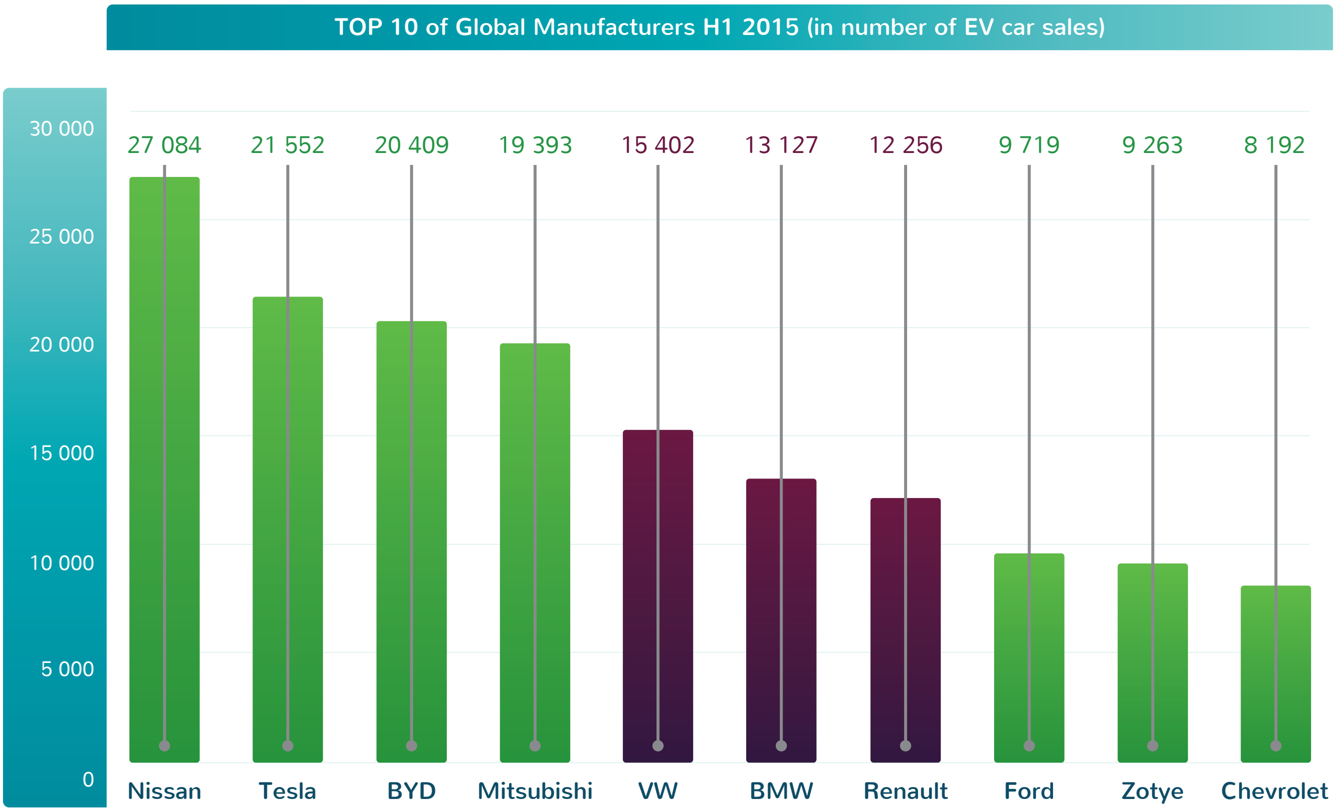
Europe has strong leaders in electric vehicles and energy efficient building technologies and services, exporting globally despite slow domestic market deployment.

For electric vehicle-related innovation, European manufacturers are competing for leadership in the electric vehicles market. Three European companies (Volkswagen, BMW and Renault) are in the top 10 for global electric car sales (see Figure 22). However, their

[47] Bloomberg (2015) China's Goldwind Knocks GE From Top Wind Market Spot
[48] STEP (2015): How Did China become the largest Solar PV Manufacturing Country?
[49] IHS Research (2015) Top Solar Power Industry Trends for 2015

positions are vulnerable since demand remains slow for e-vehicles in their key home markets. While a few European countries are seeing significant electric vehicle uptake rates[50], such as Norway with the highest market penetration of electric vehicles at 12.5% of new car sales in 2014, or the Netherlands with 4%, other EU countries do not exceed 1.4%. In addition, the IEA estimates that there is no more than 10 different models of battery electric vehicles available in European countries, compared to 28 models in China and 13 in Japan. This slow deployment is partly linked to the limited rollout of the charging infrastructure.

Figure 22: Top 10 Global Manufacturers, H1 2015 (in number of EV car sales)[51]



In terms of the market penetration of **energy efficiency in new buildings**, Europe has only three countries in the top 10 in terms of average green share of construction (the UK, Norway, and Germany). However, Europe has the resources to strongly position itself in the global race in this innovation area: six of the top 10 construction and civil engineering companies are European (Vinci, ACS, Bouygues Construction, Skanska, Strabag and Bilfinger), and they export globally. ACS, for example, made 84% of its sales internationally in 2012.[52]

[50] IEA (2015), Global EV Outlook
[51] IEA (2015) Global EV Outlook
[52] Xerfi Global with McGraw – Hill Construction (2015)

In terms of more systemic energy innovation, numerous examples show how European city mayors have taken decisive innovative and effective climate action. However replication and large-scale diffusion remains a challenge. There are no readily available indicators available to assess the performance of Europe when it comes to systemic energy-related innovation in urban districts. Yet more qualitative measures show that Europe is a fertile area for cities' low-carbon energy-related solutions. Focusing on environmental indicators such as energy consumption, renewable power use and greenhouse gas emissions, eight out of the 10 most sustainable cities in the world are European (including Frankfurt, Madrid or Rotterdam – see Figure 23).[53] Several European cities and urban districts are recognised as hubs of sustainable energy innovation, such as Barcelona (see Topic Box D on Smart Cities).

Figure 23: Top 10 Sustainable Cities in 2015 in terms of Environmental Indicators[54]

TOP 10 Sustainable Cities in 2015 (Environmental Indicators)	
1.Frankfurt (EU)	6 .Amsterdam (EU)
2.Berlin (EU)	7 .Singapore (Asia)
3.Copenhagen (EU)	8 .Rome (EU)
4.Madrid (EU)	9 .Toronto (North America)
5.Rotterdam (EU)	10.Birmingham (EU)

To meet demand for integrated energy-related solutions, consortiums of European headquartered companies from different sectors, including equipment providers, utilities, and technology providers, are involved in some of the world's largest smart city initiatives, in New York, Mexico, Rio de Janeiro and Singapore.

"The age of demonstrating Smart Districts is over. Technologies are now mature for large scale deployment and cities ready to embrace the Internet of Things for real"

Anne Lange, CEO of Mentis

Many solutions exist that offer great potential to accelerate energy innovation at the local level. However, replicating and scaling the deployment of smart and energy efficient initiatives remains challenging outside big cities. According to the OECD, "a lot of relevant technology for building solutions or smart cities is available, but institutional rules, political choices and socio-cultural attitudes prevent implementation." [55]

Regarding the business environment and its conduciveness to company creation, many energy start-ups are set up in Europe, but these then struggle to grow in size and/or market capitalisation. Start-ups are at the forefront of demonstrating consumer-

[53] Arcadis (2015) Sustainable Cities Index
[54] Arcadis (2015) Sustainable Cities Index

driven energy innovation, creating disruptive solutions and attracting strong interest from large companies in terms of partnerships and acquisitions. Several hundred European start-ups are currently working on the low-carbon transition.[56] Among them are such companies as Sonnenbatterie (Berlin), which is developing battery storage technologies (created in 2010), Actiwatt (France) conceiving and implementing smart building solutions, and Wello (Espoo, Finland), which, since 2008, is developing technology to generate energy from ocean waves.[57]

Start-up ecosystems have been growing in Europe. Yet there remains a limited number of energy-related "scalers", that is, start-ups that have been able to break the "early-stage barrier", have raised more than $100 million, and have the potential to grow in size, expand internationally and create significant numbers of jobs. Indeed, in 2015, out of 37 scalers (mapped in five major European countries) only two are focused on energy-related issues[58]: Sigfox, active in the Internet of Things and smart buildings space, which has raised $150 million, and BlaBlaCar in the mobility sector, which has raised $110 million. The objective of KIC InnoEnergy is specifically to help European start-ups to grow but, given the size of the challenge, additional efforts are required.

High job creation potential remains untapped, in particular in the area of energy efficiency solutions. About one million jobs are related to energy efficiency activities in Europe, including 443,000 jobs related to energy saving building materials, compared with 817,000 jobs in the US.[59] However, in Europe, the current annual energy-efficient renovation rates stands at only 1% of the existing stock[60], which suggests that many more jobs could be created if the retrofit rate was to increase. There are a number of bottlenecks and challenges preventing the building sector from innovating more rapidly and more thoroughly.

One of these barriers is the multiplicity of the stakeholders involved in renovation, and particularly the sharing of the renovation value between them. High upfront renovation costs, requiring a shift in investment from capital expenditure to operational expenditure, is challenged by split incentives, income/debt restrictions and competing household/corporate priorities.

[55] OECD, System innovation: synthesis report, 2015
[56] Techberlin (2015) 65 green startups will meet in Berlin to discuss new eco-technologies
[57] Ecosummit (2015) Ecosummit participants
[58] Startup Europe Partnership – SEP Monitor from Unicorns to Reality – No. 2 – July 2015
[59] Assessing the Employment and Social Impact of Energy Efficiency, Cambridge Econometrics (2010)
[60] The Economist (2013) Investing in energy efficiency in Europe's buildings: A view from the construction and real estate sectors

5.2.3 Amid the innovation cycle, Europe struggles to commercialise promising energy-related innovation projects

In several areas, Europe has developed demonstration projects but at a smaller scale than other geographies. In the field of smart grids for example, more than 450 projects had been developed in the EU-28 by 2014.[61] But these projects are often smaller than the ones developed elsewhere: as of 2012, the average amount invested in a smart grid project in Europe was around €8.5 million, compared with more than €30 million in China or €50 million in the USA.[62]

For some specific energy-related innovation areas, developing large-scale projects would help to tackle some issues that are not seen at a smaller scale (e.g., related to telecom infrastructure in smart grid projects, for which scale-up significantly increases the complexity), and to test and develop business models that would then be more easily replicable at scale.

Some innovation areas are stalled in the demonstration phase (TRL 5[63]) in Europe, while successfully being deployed in other geographies. One of the main examples of such a 'trapped' innovation is energy storage (see Topic Box E on Power Storage). Europe has developed more than 100 energy storage demonstration projects, particularly in Spain and Germany. The absence of a clear business case has prevented these technologies from being deployed in the market, due to high costs and benefits that cannot currently be monetised. Meanwhile, the United States, thanks to long-term targets and a technical regulation review, has started deploying energy storage, for example in California and on the East coast, where more than 200 MW is already on line.

Similarly, Europe has significantly invested in the early stages of development of CCS technologies – support funding in excess of €2.5 billion was made available from various EU sources to complement contributions by Member States.[64] However, out of the 15 large-scale projects in operation globally, only two are based in Europe (in Norway specifically).[65] Future developments are expected to widen this gap, with 11 large-scale projects expected to be developed by 2018, all outside Europe.

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[61] JRC (2014) Smart grid projects outlook 2014
[62] Capgemini Consulting analysis, 2012, based on a compilation of sources (IEA 2011, JRC 2011, GSGF 2012, smart grid.gov 2012, SGclearinghouse 2012, UFE 2010, Zpryme 2010 to 2012)
[63] Technology Readiness Level (TRL) is a method to estimate technology maturity. TRL 5 is the first demonstration stage
[64] Namely from the New Entrant Reserve (NER) 300, the European Economic Recovery Programme for (EERP) and other EU research funding sources.
[65] Global CCS Institute (2015) The global Status of CCS in 2015

Overcoming the deployment deficit is key for European competitiveness in terms of jobs, growth and exports, but also for cost competitiveness. European policy-makers have already recognised this, and their recent focus has been on deployment[66]. Public spending on the deployment of wind and solar technology has, for example, been vastly greater (about €48 billion in the five largest EU countries in 2010) than spending on RD&D support (about €315 million).[67] Welcome though this is, it will not address fully the issues preventing the industrialisation of energy innovation in Europe revealed in our study. So, two key question remain:

1. How can energy-related innovation – not only in technologies, but in business models, processes and behaviours – be scaled up to deliver the Energy Union's objectives of more secure, affordable and sustainable energy while also delivering economic growth, prosperity and competitive advantage for Europe?

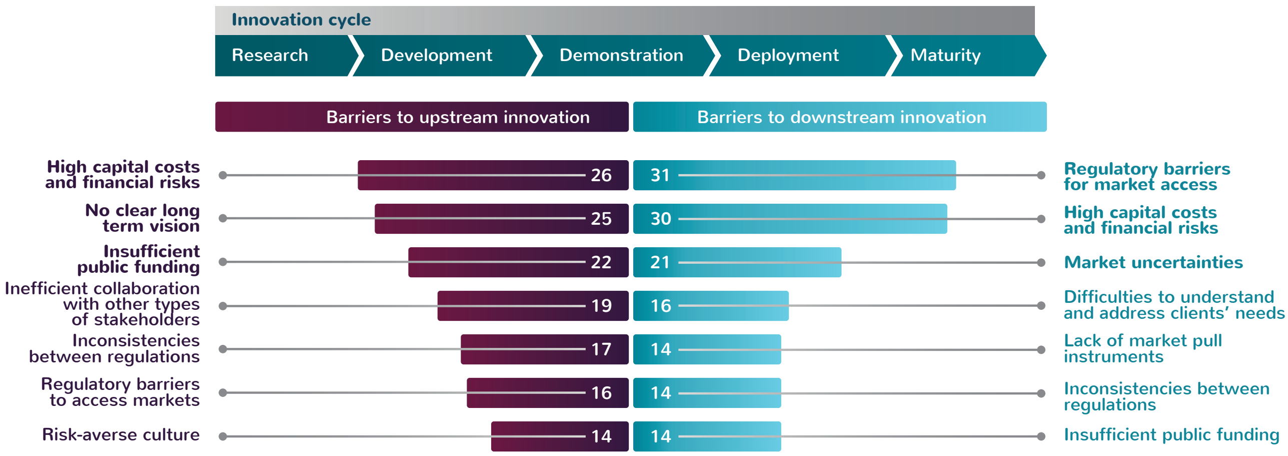
2. What should be the role of the public sector, from the EU institutions through to national, regional and city-level and local decision-makers, in setting the enabling conditions for industrialising energy innovation, and how do the regulatory frameworks, financing and related policies being pursued under other dimensions of the Energy Union best facilitate this for the competitive advantage of the European economy and society?

[66] G. Zachmann (2015) Making low-carbon technology support smarter, Bruegel policy brief
[67] op.cit

6. LESSONS LEARNED FROM THE PAST SUGGEST VARIOUS WAYS TO SCALE ENERGY-RELATED INNOVATION AND REAP MORE BENEFITS FROM IT

According to the energy leaders and experts who participated in the online survey carried out by i24c and Capgemini Consulting in January-February 2016 (for more detail, see Appendix 1), the top three barriers to energy innovation deployment in Europe are: regulatory barriers to access markets; high capital costs and financial risks; and market uncertainties (see Figure 24).

Figure 24: Main barriers perceived by survey respondents (by number of answers; multiple choices were possible)[68]



In addition to the survey participants, discussions with a wide range of experts (see Appendix 1) have enabled us to look more closely to the reasons why some geographies have succeeded in deploying and taking advantage of specific energy-related innovation.

Five principles emerge on how Europe can overcome the so-called 'valley of death' and increase Europe's competitiveness, in terms of jobs, growth and exports, in energy-related innovation areas. These guiding principles do not apply in the same way for each different innovation area, and must be tailored depending on the nature of the innovation, whether technological or more systemic, centralised or decentralised, etc.

[68] i24c - Capgemini Consulting, high-level survey on energy innovation (2016) based on 73 participants

As shown in Figure 25, this section is structured around these five guiding principles and the key associated factors of success. In each section, recommendations are made along with suggestions for concrete action at EU level. These ideas for action are indicated with the "lightbulb icon" sign.

Figure 25: Synthesis of the lessons learnt from the past and present (five guiding principles and 10 key success factors)

5 GUIDING PRINCIPLES	10 KEY SUCCESS FACTORS
1. PROVIDE CLARITY ON THE LONG TERM DIRECTION	1. Enable long term choices at local level and ensure their consistency at EU level 2. Set integrated energy-industrial priorities
2. DESIGN THE MARKET TO BETTER PULL ENERGY INNOVATIONS ACROSS THE 'VALLEY OF DEATH' AND TO SCALE	3. Adapt regulation and value the benefits of low-carbon technologies and energy efficient innovative solutions 4. Mitigate financial risks
3. ACCELERATE THE EMPOWERMENT OF LOCAL AND REGIONAL AUTHORITIES	5. Provide local and regional authorities right technical, regulatory or financial assistance 6. Reinforce data and knowledge sharing
4. EMPOWER CUSTOMERS & CITIZENS FURTHER YET	7. Foster customer-centric approaches 8. Mobilise citizens
5. BE MORE RESULTS-ORIENTED AND SELECTIVE IN NURTURING ENERGY INNOVATION	9. Foster collaboration and pool resources 10. Generalise results-oriented approaches, ensure consistency of instruments, and use of metrics

6.1 Principle #1: Provide clarity on the long-term direction

6.1.1 Key success factor #1: Enable long-term choices at local level and ensure their consistency at EU level

A long-term vision is essential to provide the framework for consistent and coherent policies and governance, to establish confidence in the innovation agenda (see Examples 1 and 2), and to provide clarity to stakeholders involved in the energy transition. Within the context of the Energy Union, achieving clarity on the long-term direction implies a clear and ambitious long-term energy vision for Europe, defined at the national, regional and local levels. It also entails articulating needs and choices made at these different levels.

EXAMPLE 1: WIND INDUSTRY IN DENMARK

Denmark is a wind energy leader in Europe, with more than 40% of electricity consumption supplied by wind power. Wind energy also represents 74.1% of total renewable energy employment in Denmark (around 27,500 jobs). In terms of employees per MW installed, the country ranks number one in Europe, with around seven employees per MW, exceeding by far Germany or the Netherlands (with two employees per MW). According to local stakeholders, the success of the wind industry in Denmark is largely due to the consistency over time of the country's energy strategy and the policies and instruments implemented to deliver it (see Topic Box B for more information on the success factors for the Wind Industry in Denmark).

Since the 1970's, a series of political decisions have provided stable and transparent plans for investment in R&D (1978-1989), financial support for renewable energy sources through feed-in tariffs (1984-2000), and a carbon tax (since 1991). In the same way, significant public investment was made available to laboratories and universities to encourage research and deployment of large wind demonstration projects.

EXAMPLE 2: SETTING SHORT- AND LONG-TERM OBJECTIVES THROUGH PRODUCT STANDARDS

Long-term product standards play a key role in creating effective market demand and access for low-carbon technologies or products. Product standards have been used in Europe not simply as a means of developing a Single Market, even where they have incorporated environmental, public health or consumer protection provisions, but also been as a means of driving innovation, by setting performance levels that require best available technology and setting ambition beyond that.

In the case of the transport sector, short-term (e.g., by 2021) mandatory fuel efficiency standards for cars and light commercial vehicles have been the primary driver for automotive companies to work with their suppliers to innovate in emissions technology for the European market and for more efficient vehicles to replace the existing stock – despite the potentially higher costs of new vehicles. Fuel efficiency standards have mandated manufacturers to put efficient vehicles on the market and, in doing so, have created a new market for efficient components and added value for companies such as Bosch, Valeo and Continental.

Europe has a vision, embodied by the Energy Union strategy and built into the European Commission's 2050 low-carbon economy and energy roadmaps, which sets out a long-term European energy transition project and defines where the energy system, in its broadest sense, should move. It now needs to further detail and implement this vision. But Europe also needs to ensure consistency with both the national and local visions, some of which are still to be defined (at the city level especially).

To achieve this objective, two actions seem essential. First, it is necessary to anticipate and/or manage the interdependencies between energy-related choices (made by the various public layers, countries, and different sectors). Long-term visions and strategies are being (or have been) developed at the national, regional and local level, with Member States' national climate and energy plans (NCEPs) and cities' Sustainable Energy Action Plans (SEAPs) (see Example 3). In this regard, it will be important that local plans and strategies under the SEAPs are fed into the European governance process.

EXAMPLE 3: CITY LONG TERM SUSTAINABLE ENERGY ACTION PLANS

Under the Covenant of Mayors – a political movement of mayors that has proved to be one of the most successful instruments of EU energy policy – some 6,500 cities have made climate commitments to 2020, and have produced more than 4,600 city/regional delivery plans, known as Sustainable Energy Action Plans (SEAPs). Many of the commitments in these SEAPs are more ambitious than the EU and national climate and energy targets: signatories have committed to an overall average of a 28% reduction in GHG emissions by 2020 compared with the EU target of 20%, and have recently endorsed an at least 40% CO_2 emission reduction target by 2030. City targets and strategies across the EU show that local actors want to do more and are striving to lead the energy transition to improve the quality of life for their citizens.[69]

Second, cities and regions can play an important role in accelerating the energy transition and stimulating innovation. To do so, they must ensure they have access to the required tools to design new sustainable energy models and optimise energy sources with energy use and infrastructure. Providing a framework that highlights the many different ways to devolve the energy transition at regional or local level with generic energy models may also help to facilitate local decision-making within specific regional and/ local market contexts.

Overall, closer coordination between all government layers regarding energy choices could help facilitate the setting of long-term visions, thus giving a clear push to innovators and actors in this space.

[69] E3G (2016), Rebooting Europe's Energy Leadership – Consumer-focused energy innovation is an opportunity for Europe

6.1.2 Key success factor #2: Set integrated energy-industrial priorities

In designing policies to foster the innovation necessary to deliver this transition, however, the EU also needs an economic vision of success to accompany it, and the development of an energy industrial strategy focused on innovation that builds confidence among relevant stakeholders in the long-term goal and the EU's determination to deliver it, all within a global context and a dynamic of international competitiveness. **Experts in our study are clear in asking that the Commission leads in the development of a European energy-industrial strategy**, which links all the elements together: energy, transport, agriculture, infrastructure, digital, consumers and jobs, housing, environment, investment, cities, SMEs, and Industry.[70] Using the Research, Innovation and Competitiveness dimension of the Energy Union provides the opportunity to do so.

Making energy secure, affordable and sustainable is one of 10 priorities of the European Commission, set by President Jean-Claude Juncker in July 2014.[71] It is closely linked to other main priorities of the European Commission such as, in order of importance, (1) to strengthen Europe's competitiveness and to stimulate investment for the purpose of job creation; (2) to unlock opportunities brought by digital technologies; and (3) to complete the internal market and to strengthen its industrial base.

"Europe has put too much focus on the free-market competition rather than on developing a European Industrial Strategy around the energy transition".

Nicolas Blanc,
Deputy head of Strategy VP,
Groupe Caisse des Dépôts

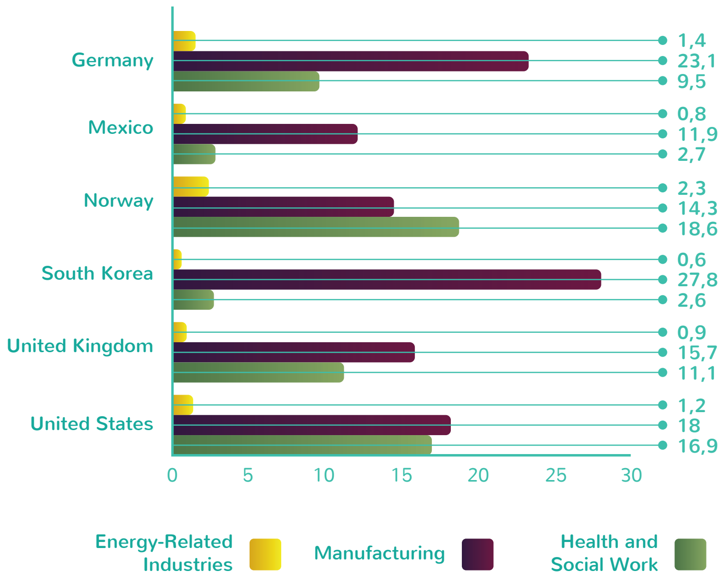
There are surprisingly few studies on the impact of energy-related industries on GDP or employment – but the potential for these industries to grow as a result of the transition to a new energy model is becoming clearer and clearer, as the industry extends into the provision of services as well as manufacturing, increasing net employment opportunities in the process, while inevitably disrupting some incumbent interests.

Focusing on the energy sector alone (excluding the other sectors that are make up the European Energy Union such as mobility), the latest data from the Bureau of Economic Analysis suggests that it contributes 7% of global GDP.[72]That is consistent with figures from the American Petroleum Institute, which calculated that the energy industry supported in 2009 a total value added to the US national economy of more than $1 trillion, representing 7.7% of US GDP.[73]

[70] As listed by the European Commission in its presentation of the Energy Union to the European Council, 19 March 2015.
[71] EC, Political Guidelines for the next European Commission, July 2014
[72] Estimation made by considering the share of mining, utilities, electrical equipment, petroleum and coal products and pipeline transportation in 2014 total GDP.
[73] World Economic Forum, Energy for Economic Growth, 2012

The energy sector currently directly employs fewer people than other industries (see Figure 26). The total number of direct jobs provided by the EU energy sector in 2011 was estimated at between 1.5 million (DG Energy) and 2.2 million (Eurostat, LFS), representing a share of 0.7-1% of the total employed workforce. Norway has the highest share in Europe of jobs in energy-related industries (2.3% of business sector employment). However, recent research in the United States demonstrates that the energy industry supports many more jobs than it generates directly.

Figure 26: Share of Business Sector Employment, Energy Compared to Other Industries[74]



The energy transition now, however, generates opportunities to create new jobs and GDP in energy-related industries, both in manufacturing and services. But to seize these opportunities, **an explicit energy-industrial strategy is required. It will help to maintain and reinforce the leadership of European industrial champions** in low-carbon and energy efficient solutions and help the phasing out or business model transformation of past declining industries.

As the distinction between manufacturing and services blurs more generally, increasing the value of energy industrial activity across both would also enable energy-related industries to play a key role in demonstrating how to best understand and advance the EU's stated objective of increasing the contribution of industry to EU GDP to 20% by 2020, from less than 16% in 2014.

The EU internal market could be an engine for the uptake of new technologies and solutions at significant scale, but cooperation between Member States and between sectors should be reinforced to win the economic race associated with the energy transition.

IDEAS FOR CONCRETE ACTION AT EU LEVEL

Research › Development › Demonstration › Deployment › Maturity

Articulate an EU energy-industrial innovation vision and strategy

[74] IHS CERA and OECD Structural Analysis Database. Note: Data are 10-year averages of the most recent data available – 2000-2009 for the United States, 1993-2002 for Norway and 1994-2003 for all other countries

6.2 Principle #2: Design the market to better pull energy innovations across the 'valley of death' and to scale

Scaling up the deployment of energy-related innovation and securing benefits for and in Europe raises the major question of how to attract more private investment along the innovation cycle, and in particular at the deployment phase. Large upfront investments are often required when it comes to energy innovation, which makes attracting investors a critical issue.

Two major levers can be used to increase the attractiveness of low-carbon solutions: (i) revealing and monetising their full benefits, in order to increase their value, and (ii) reducing the level of risk faced by investors. Market design and public authorities play a key role in setting the right market conditions to bridge the demonstration phase and foster mass-market deployment, as well as in opening markets to new entrants. Looking for "better regulation" should not only be about simplifying and making EU or national laws more effective and efficient, it should also be about how regulation can enable innovation and socio-economic benefits for citizens and industries.

6.2.1 Key success factor #3: Adapt regulation and value the benefits of low-carbon technologies and energy-efficient innovative solutions

Market mechanisms and signals must create opportunities to value promising energy innovations. Quantifying and monetizing the benefits of low-carbon technologies or enabling solutions, such as power storage technologies and demand response services, is essential to increase the share of low-carbon energy sources and make our energy systems more flexible and secure.

Carbon pricing is one way to monetise the benefits of low-carbon technologies or energy efficient solutions. The Paris Agreement on Climate Change sets some of the essential foundations for global carbon trading, recognising the role of carbon pricing as a means for countries to meet their greenhouse gas emission reduction objectives.

The European Union has played a pioneering role in setting up in 2005 the world's first – and still by far the biggest – Emissions Trading System (EU ETS), covering 40% of the EU's total GHG emissions. Overall GHG emissions covered under the EU ETS have decreased by 24% in 2015 compared to 2005, but there has been vigorous debate about whether the EU ETS has induced companies to develop new emissions-reducing technologies or not. Studies have shown that the EU ETS has had a positive and notable impact on low-carbon patenting among EU ETS companies.[75]

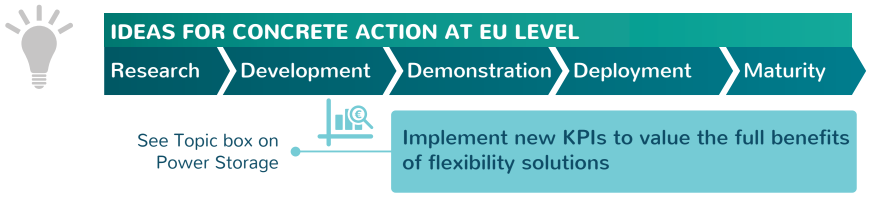
Some Member States have set up complementary CO2 pricing mechanisms to stimulate

[75] Calel R. and Dechezleprêtre A., Environmental policy and directed technological change: evidence from the European carbon market, Grantham Research Institute on Climate Change and the Environment, Centre for Climate Change Economics and Policy

GHG emission reductions. For example, in 2013 the UK introduced progressive CO^2 floor prices (rising from £15.70 in 2013 to £30 in 2020), applied to British electricity generators. Other countries including France and Sweden have set carbon taxes, which apply specifically to sectors that are not covered under the EU ETS (e.g., building heating and transport).[76] In Sweden, two levels of CO^2 taxation have been chosen for heating fuels: high for households and services (€29/t in 1991; €125/t in 2014) and low for sectors subject to international competition and risk of carbon leakage (€7/t in 1991; €37/t in 2014).[77] According to experts, this system has been a major driver in the development of bioenergy in Sweden (see Topic Box A on Bioenergy in Sweden).

In addition to CO_2 emission reductions, other benefits from promising energy innovations could be valued to unlock their potential.[78] Existing electricity market arrangements are unlikely to deliver anywhere near the full economic potential of demand flexibility. Accurate and timely price information reflecting the full value of energy and grid services is often obscured from market stakeholders. Prevailing wholesale market rules and practices routinely prevent, discourage or ignore the potential for demand-side participation. As a result, market participants best placed to search out and underwrite the most economic options for flexibility have little incentive to do so. Market design rules should be upgraded to ensure that wholesale prices accurately reflect the value of flexibility, including through sharper balancing market pricing and the lifting of price caps and floors, and by ensuring that demand response can compete on an equal footing with generation, by defining the roles and responsibilities of market participants so that existing and new market participants are treated equitably.[79]

Power storage technologies, for example, have the potential to become a key means to manage the balance between power generation and consumption. When connected to the grid and used to balance it, power storage becomes flexible. Today's storage technologies are more rapid and reactive in comparison with other flexibility solutions, such as demand response or power generation. However, in many European countries, current electricity market design does not value the speed or flexibility of response solutions, as it rewards only the load capacity. The EU should encourage energy regulators and system operators to implement new indicators to value flexibility solutions according to the benefits they provide (e.g., valuing their responsiveness). Recent examples show that it could help to foster the deployment of new technologies or solutions (see Example 4).



[76] Mostly industries, agriculture and combined heat and power plants (CHP) outside of the EU ETS
[77] Carbon leakage: risk of the outsourcing of carbon-intensive industries
[78] These economic and non-economic benefits can be energy-related, but also include benefits such as health, productivity, jobs and other measures related to quality of life.
[79] RAP, E3G, ClientEarth (2016) The Market Design Initiative: Enabling Demand-Side Markets; Energy Union RAP, E3G, Agora, IDDRI, ClientEarth (2016) Priorities for the Market Design Initiative: What's Missing? What's Most Important?

EXAMPLE 4: PAY-FOR-PERFORMANCE FOR POWER STORAGE IN US PERFORMANCE FOR POWER STORAGE IN US

Local initiatives in the United States show that small regulatory changes can help value the additional benefits provided by storage technologies and thus accelerate their deployment. In 2011, the US East coast local system operator, together with the Federal Energy Regulatory Commission, introduced a new indicator to monetise the benefits of storage for frequency regulation, in a pay-for-performance law. Valuing the responsiveness of the related solutions was sufficient to enable the development of the power storage without subsidies (see Topic Box E on power storage).

In the UK, the transmission system operator National Grid announced in April 2016 a tender for 200 MW of Enhanced Frequency Response using a similar indicator to deploy storage assets.

New revenue models for regulated system operators are also required to accelerate the deployment of energy efficient and flexibility solutions. At the city and regional level in particular, distribution system operators (DSOs) have a central role to play in the energy transition. Further refining the role and revenue systems of DSOs and considering their potential role as market facilitators could help accelerate the deployment of energy innovation – both for new technologies such as storage but also for new services such as energy aggregation.[80] The European Commission has already recognised this: "*Regulatory incentives should encourage a network operator to earn revenue in ways that are not linked to additional sales, but are rather based on efficiency gains and lower peak investment needs, i.e., moving from a 'volume-based' business model to a 'quality- and efficiency-based model'*".[81]

Initiatives from the State of New York and the UK show that it is possible to adapt the role and business model of network operators. The UK energy regulator, Ofgem, specifically developed an innovative framework called RIIO (Revenue = Incentives + Innovation + Outputs) to encourage network operators to innovate and play a full role in making optimal and cost-efficient investment choices aligned with the achievement of policy goals (see Topic Box F on Power Distribution).[82]

[80] Keay-Bright, S. (2016). Electric Cars, the Smart Grid and the Energy Union. Montpelier, VT: The Regulatory Assistance Project. http://www.raponline.org/ document/download/id/8112
[81] European Commission, Smart grids: from innovation to deployment, COM(2011)202, 12 April 2011.
[82] Op.cit 80

6.2.2 Key success factor #4: Mitigate financial risks

Ensuring that market-pull instruments (such as feed-in premiums, certificates, bonus-malus schemes and public procurement) are available for demonstrated energy-related innovation is central to large-scale deployment and creating investor confidence.

Different market pull instruments have been used in European member states and have proven to be effective in attracting private capital at all stages of the innovation cycle. Such instruments include: technology specific feed-in tariffs, for example for onshore wind, solar PV and biogas; tendering schemes first experimented with by the UK, Portugal and Ireland; guarantee schemes for loans for wind technology in Denmark; a bonus/malus system to promote the sales of alternative fuel vehicles; and public procurement for electric ferries (see Examples 5 and 6). For certain sectors (such as buildings, cars or appliances), predictably tightening product standards also provides the prospect of deployment of as-yet uncompetitive technologies and services.[83,84].

EXAMPLE 5: MARKET-PULL INSTRUMENTS IN THE ELECTRICITY SECTOR

- Several EU Member States have introduced feed-in-premium (FIP) schemes, usually with floor prices, to reduce the market price risks faced by renewable energy investors. Such schemes involve granting a premium to renewable power producers on top of the market price they can earn from their electricity production. They are used to foster the integration of renewables while ensuring balanced electricity supply and demand. FIP schemes are currently in place in the Czech Republic, Denmark, Germany, Italy, the Netherlands, Estonia, Finland, Slovenia, Slovakia and Spain.

- As part of the Danish Promotion of Renewable Energy Act (2008), the Danish government established a new guarantee scheme with a total of DKK 10 million (€1.3 million) to foster the deployment of wind technologies. This scheme provides guarantees for loans taken out by local groups such as wind turbine associations. The guarantee acts as a security when external uncertainties remain and might impede the installation of a turbine (e.g., preliminary investigations of the area, nuisance for neighbours, financial aspects etc.). A guarantee is granted for a maximum of €67,000 per project. The system operator Energinet.dk agrees to cover the risk if the project is not implemented and the loan cannot be repaid. The money for the guarantee fund is recouped from electricity consumers as a "public service obligation" contribution.[85]

- The UK has experimented with an auction-based mechanism to foster the deployment of large-scale renewables and stimulate innovation. Regular auctions are organised to allocate "Contracts for Difference" (CfDs) to electricity generators. Introduced in February 2015, the CfDs are private law contracts signed between electricity generators and the government-owned Low Carbon Contracts Company. The aim is to give greater certainty and stability of revenues to electricity generators by reducing their exposure to volatile wholesale prices, whilst protecting consumers from paying for higher support costs when electricity prices are high

[83] Transparent, comprehensible and comparable (energy) labeling schemes could also incentivise introduction of products not yet on the market via the Energy Labelling Directive and the Energy Performance of Buildings Directive.
[84] As an example, the building retrofit market comprises more than just the individual technologies. Services that package it all together and guarantee the quality of total performance needs to be considered.
[85] Danish Energy Agency, 2016

EXAMPLE 6: DRIVING INNOVATION THROUGH PUBLIC PROCUREMENT– PROCURING THE WORLD'S FIRST ELECTRIC FERRY[86]

In 2010, the Norwegian Ministry of Transport launched a competition for an energy-efficient and low-emission car ferry to link two villages in the Sognefjord. The successful bidder would be awarded a 10-year concession contract. The Norwegian Public Roads Administration, in charge of the competition, required a minimum 15-20% improvement in energy efficiency over that of the existing diesel-powered ferry. Four consortia, each comprising a ferry operator, a shipyard and an engineering company, competed for the contract. The ferry tender did not specify a technology but rather a clear objective (higher energy efficiency), with innovation and sustainability criteria carrying significant weight in the final evaluation (40%). Competition was also encouraged with compensation of NOK 3 million to the three unsuccessful bidders. [87]

The winning consortium, comprising Norled, a ferry operator, the Fjellstrand shipyard and Siemens, proposed Ampere, the world's first electric car ferry. Ampere offers a 37% reduction in energy use per passenger car-km, a 60% reduction in total energy use, the elimination of NOx emissions and an 89% reduction in CO_2, compared with the electricity mix in Scandinavia's NordPool. The 80-metre long ferry, which can transport 120 cars in 34 daily trips across the Sognefjord, is now in operation.

Making all future ferries low-carbon is now under consideration. Tenders opened recently for another electric ferry and an unspecified zero- or low-carbon emission one which could run on biogas, biofuel, or electricity, or any combination thereof. The procurement of the Ampere ferry triggered these opportunities and helped to launch the market for low-carbon ferries.

The main lesson from past experiences in Europe is that stress-testing these instruments by properly anticipating the successes and failures of the schemes is necessary to provide predictable market conditions and generate confidence in risky projects. Stop-and-start policies create distrust in the programmes and impact investor confidence, as was the case with feed-in tariffs in several EU countries, which resulted in a significant decrease in the growth of new installed renewable energy capacity.

[86] Baron, R. (2016), The Role of Public Procurement in Low-carbon Innovation. Background Paper for the 33rd Round Table on Sustainable Development. OECD. http://www.oecd.org/sd-roundtable/

[87] Bids were evaluated on the basis of the following criteria and weights: Price (60%); Quality (40%), as the sum of: energy use per passenger car-km (18%); total energy use per year (6%); tons of CO2 emitted per year (6%); kilograms of NOx emitted per year (4%); innovation (6%).

EXAMPLE 7: THE IMPACT OF FEED-IN TARIFFS ON SOLAR PV IN GERMANY

Germany offered strong and stable solar PV feed-in tariffs (FiT) until 2012, which saw the installed base grow from nearly zero in 2000 to 33 GW in 2012 (i.e., over 20% of total power generation capacity) and helped to significantly bring down the cost of solar PV panels. (Between 2000 and 2010, solar cells costs have fallen from close to €5/Watt to €1/Watt.)[88] Thousands of new jobs were also created in Germany – as many as 107,000 jobs in 2010.[89] However, as the FiT was gradually revised down in response to falling technology costs[90], the number of workers employed by the German PV manufacturing industry collapsed, falling by almost 50% in one year (56,000 jobs in 2013), partly because the installation rate of new solar PV installations drastically decreased (by 55% in 2013[91]) and because cheaper PV equipment from China flooded the German market. While this impacted manufacturing jobs, maintenance and installation-related employment remained at 11,000 in 2013 (compared to 5,700 in 2010).

To attract more private investment, risk mitigation instruments are also key. Such risk mitigation is often missing for new infrastructure and/or the modernisation of existing infrastructure, for example. In particular, for the rollout of electric and/or hydrogen-fuelled transport, the availability of public charging points, the readiness of the electricity networks, and the lack of hydrogen fuelling stations present a significant challenge.[92] In addition, the financing of alternative infrastructure outside of an experimental framework is currently being impeded by the risk of under-use in the start-up phase, representing an obstacle to the involvement of the banking sector and of those manufacturers in a position to offer solutions. In these instances, establishing a mechanism whereby there is a guaranteed payment by the government at the end of the deployment programme (e.g., in 2026), linked to the rate of utilisation, could help accelerate the rollout of the needed infrastructure (see Example 8), in addition to or in replacement of subsidies (see Example 9). Another promising mechanism could be to extend the existing guaranteed loans (such as loans backed by the European Investment Bank) used in the Junker plan for the EU's regional and city funding for local energy transition projects.

"Europe has to develop a financial mechanism to cover regulatory risk, which is considered as a major challenge today",

Laurent Schmitt, Smart Grid Strategy Leader, General Electric Grids Solutions

[88] Zachmann, G. (2015) Making low-carbon technology support smarter
[89] IRENA Reports
[90] The feed-in tariff paid for electricity from large-scale photovoltaic installations in Germany fell from over 40 ct/kWh for installations connected in 2005 to 9 ct/kWh for those connected in 2014: www.fvee.de/fileadmin/publikationen/weitere_publikationen/15_AgoraEnergiewende-ISE_Current_and_Future_Cost_of_PV.pdf"
[91] Fraunhofer ISE, Recent facts about Photovoltaics in Germany, December 2015
[92] In the mobility sector, however, experts foresee that the majority of charging infrastructure for EVs will be private, so owned and acquired by the consumer (e.g. currently Wallbox for normal charging or Mode 4 of Tesla systems which will soon provide Vehicle to grid (V2G) solutions when smart meters are installed).

EXAMPLE 8: ETICCS (ENERGY TRANSITION INFRASTRUCTURES WITH CARBON REDUCTION CERTIFICATES)[93]

To accelerate the roll-out of low-carbon mobility infrastructure, proposals for a new scheme have been put forward using certificates as a guarantee mechanism to reduce capital risk and increase the financial potential of low-carbon projects for private investors. These certificates would be created from the outset of the project and issued at a time to be determined at the beginning or on completion of infrastructure rollout, up to the total emissions potentially avoided up to the end of its lifespan, on the basis of functioning at full capacity. This mechanism is proposed to cover the risk of under-utilisation of infrastructure by providing a guaranteed payment by the government at the end of the deployment programme (e.g., in 2026), the amount of which is proportional to the rate of under-utilisation of the infrastructure. If the infrastructure is not used, or not used enough, and in case no market allowing the developer to sell the certificates for a similar price has been put in place in the meantime, the government (or a public bank) undertakes to buy back the certificates issued on maturity at a previously guaranteed price. This mechanism could be organised in the form of a private contract between those making the investments and the public sector through a public bank (e.g., the European Investment Bank).

EXAMPLE 9: PUBLIC CHARGING STATIONS FOR ELECTRIC VEHICLES– THE CASE OF THE NETHERLANDS

In the Netherlands, over a period of five years, the number of public charging stations grew from zero to more than 7,000. Large cities such as Amsterdam, Rotterdam, The Hague and Utrecht are organising tenders for the installation and operation of public charging infrastructure. Since most public charging stations are still not commercially viable, public authorities and the business community have used shared financing to create new charging stations. The national government is helping to remove financial barriers in the form of a Green Deal for charging infrastructure, making €5.7 million available to grow the public charging network. Additional financing will come from local governments and private entities.

The rapid growth in fast chargers is also attributable in part to Fastned's new stations, where the goal is to have more than 200 fast-charging stations by 2020. The European Union has granted Fastned €2 million to install a corridor of 94 fast-charging stations for electric cars along major northern European motorways, in Germany and other countries.

[93] This mechanism has been suggested by several French experts from the public bank Caisse des Dépôts, I4CE (former CDC Climat Research), Air Liquide and the Polytechnic School. For more details, see www.chair-energy-prosperity.org/pdf/PresentationAtelier/eTICC%20Laffitte%20Leguet%20Ponssard.pdf

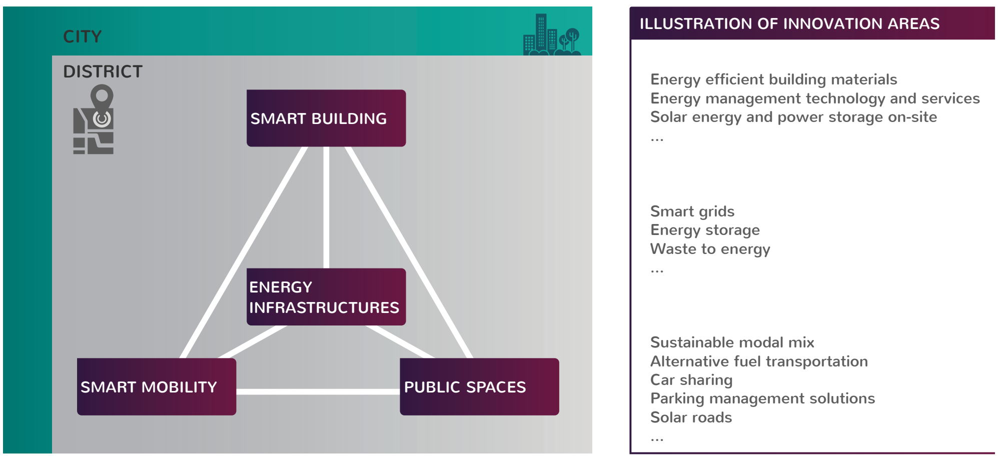
6.3 Principle #3: Accelerate the empowerment of local and regional authorities

6.3.1 Key success factor #5: Provide local and regional authorities with the right technical, regulatory or financial assistance

Districts, cities and regions have shown leadership in deploying energy efficient and low-carbon technologies and services – whether to develop a city district with 100% renewable and reusable energy, establish a citywide electric car-sharing platform, or create the conditions for energy neutral homes. They have also often been instrumental in leading innovation-linked ecosystems (see Topic Box D on smart cities)[94], and have been active in creating investment platforms that, for example, aggregate small-scale energy efficiency or solar projects.

At the local and/or regional level, some innovation areas (such as smart districts – see Figure 27) **are systemic by nature**, linking buildings, energy, ICT and transport, or linking energy and the agriculture sector, and require the involvement of an ecosystem of actors working together to achieve these goals. Their deployment often necessitates enlarged consortiums of stakeholders that are often complex to orchestrate. In some instances, the economic viability and the replicability of these solutions also needs to be proven, which is key to attracting investors and ultimately to create new markets and new jobs.

Figure 27: Energy-related innovation in urban districts



[94] For instance in Germany, the city of Hamburg initiated a challenge-led process to redevelop a former port area with innovative sustainable solutions. HafenCity GmbH has taken a leading role as the facilitator for multi-stakeholder cooperation, coordinating top-down cross-value-chain collaboration. Innovation hubs are also a way to foster innovation and cooperation between key players. The Mars Discovery District's Advanced Energy Center in Toronto, Canada, has set up an urban innovation hub that works closely with energy utilities, start-ups, and public authorities to identify high-priority and cost-effective solutions and help the adoption of innovative energy technologies and leverage value from promising ideas into international markets.

Several instruments, some of which are available today, can accelerate the deployment and scaling of smart and energy-efficient initiatives. Providing cities and territories with funding instruments that encourage the set-up of multi-sector consortiums can enable more systemic energy innovation. Targeted advisory and technical assistance available through comprehensive instruments, such as the ELENA (European Local Energy Assistance) facility, or the European Investment Advisory Hub, can help increase the bankability of projects that deploy energy-related innovations.[95] Investment platforms, such as that foreseen in the European Fund for Strategic Investments (EFSI), can pool small-scale energy efficiency or renewable power projects and provide investors with better investment opportunities and reduced risk[96,97].

In some instances, **cities and regions face numerous legal barriers when implementing the low-carbon transition.** These range from legal barriers to setting up local energy utilities – such as in France – to national taxes hindering renewable energy deployment, as in Spain, or accounting rules that hinder energy efficiency projects across Europe.[98] Reviewing the legal barriers to local actors implementing the low-carbon transition is a necessary step as part of a review of energy market design and, in particular, in the revision of the Renewable Energy, Energy Efficiency, and Energy Performance in Buildings Directives.[99]

To speed up the deployment of energy-related innovation, more generally what is required is greater segmentation and clustering of districts, cities and regions according to different criteria, which could include: the type of energy-related innovation they are seeking to deploy (e.g., electric mobility, smart grids, etc.), their level of maturity when it comes, for instance, to the penetration of renewables in their energy system; and the types of challenges they are facing when seeking to push the energy transition further (e.g., citizen engagement). Segmentation and clustering opens the door to the exchange of best practice, the pooling of investments and to the better assessment of the bankability of projects and the development of financing strategies (e.g. business cases, use of public procurement, of loans, etc.).

[95] Technical assistance can be offered through the use of EU instruments such as ELENA (DG ENER), JASPERS or JESSICA (DG REG). In order to increase the readability of the mechanisms for project promoters, some of these instruments (e.g. ELENA, JASPERS) have been channelled under the European Investment Advisory Hub, which acts as a single access point to the full range of advisory and technical assistance services.

[96] European Political Strategy Centre, April 2016, ec.europa.eu/epsc/publications/notes/sn11_en.htm#h3

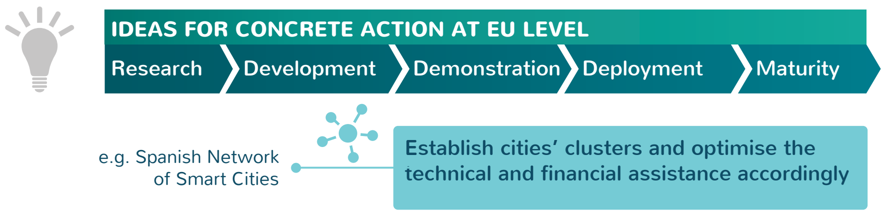
[97] See for instance the innovative approach by French regions to set up specialised companies (public and public-private entities known as Société de Tiers Financement (STF)) to provide a 'packaged' solution covering technical and financial assistance to homeowners for retrofitting. It will enable the STF to provide long-term funding to homeowners, currently not available in this form, and create an important leverage of public funds invested. The project is expected to support retrofitting of some 40,000 flats and houses. www.cpu.fr/wp-content/uploads/2015/06/O.-Debande-BEI-Plan-Juncker-Project-factsheet-FR-final.pdf

[98] According to the IIGCC, the finance available for energy efficiency-related projects can be constrained by procurement procedures and balance sheet restrictions under public accounting rules (IIGCC, 2015).

[99] E3G (2016), Rebooting Europe's Energy Leadership – Consumer-focused energy innovation is an opportunity for Europe

EXAMPLE 10: SPANISH NETWORK OF SMART CITIES

Since 2012, 49 City Councils in Spain have come together in a network called the Asociación Red Española de Ciudades Inteligentes (RECI)[100]. This network invites specific groups to work together on different city issues such as those relating to energy and the environment. The aim of this network is to share good practice in all these areas, and compare experiences and even tools such as open software, procedures or legislation. Policy-related issues are directly managed between the network representatives and Spanish ministries and public administrations



6.3.2 Key success factor #6: Reinforce data and knowledge sharing

Another issue that needs to be solved to scale the widespread deployment of smart district (or smart city) initiatives is how to identify, measure, access and the share the "right" data, such as traffics flows and energy demand, etc., at the local level.[101] Many energy-related innovations are linked to data, or are enabled by data collection technology and advanced data analysis. In order to facilitate new services and business processes that integrate energy, ICT and transport in districts, interoperable systems are essential, as are data security and privacy guarantees. The deployment of new energy services in buildings, mobility, districts or cities calls for linking the Digital Single Market and the Energy Union even more closely.

In the Energy Union Roadmap, the European Commission announced a new initiative on data analysis and intelligence, which will pool and make easily accessible all relevant knowledge in the Commission and Member States. However, at the regional or city level there is also the need to foster data sharing and to ensure privacy protection and cyber-security (see Example 11).[102]

[100] Source : Red Ciudades Inteligentes website, 2016

[101] As mentioned in Section 5.1, accessing data is also key to enabling cities to better map and tap their local innovative potential. This requires a thorough scanning of the available or missing relevant data for energy-related innovation at all levels (EU, national and local).

[102] As mentioned in Section 5.2, distributed network operators could play the role of a neutral market facilitator and enable cities to access all relevant data to better support the deployment of innovative energy projects on their territory.

EXAMPLE 11: ISSY-LES-MOULINEAUX'S OPEN DATA PLATFORM

The French city of Issy-les-Moulineaux has become a pioneer in the world of open data. Early in 2015, the city launched an open data platform to support the deployment of innovative projects. Despite all the efforts made at the city level to share available data, there are still missing components according to experts. In the area of mobility for example, private companies provide data on car sharing but the city has yet to come to an agreement with the regional public operator on the communication of real-time information of buses.[103]

Another way to accelerate systemic energy-related innovation at the city level is to **reinforce knowledge sharing between cities, industry and citizens** – especially around specific goals (e.g., how to accelerate clean mobility), to demonstrate solutions and business models that can be scaled up and replicated, and that could lead to measurable benefits in energy, resource efficiency and the environment. According to C40, a network of the world's megacities, 30% of all climate action has been delivered through city-to-city collaboration. Different networks, alliances and initiatives of cities and regions, such as C40, C100, CNCA, Compact of Mayors, the Covenant of Mayors for Climate and Energy, the Compact of States and Regions, Eurocities, Energy Cities, ICLEI, help share innovative and effective city-level climate action (see Topic Box D on Smart cities).[104]

6.4 Principle #4: Empower customers and citizens yet further

6.4.1 Key success factor #7: Foster customer-centric approaches

The end-user has a clear role to play in the adoption of energy-related innovation, in particular for new energy or mobility services. However, most energy consumers are currently not engaged in the energy transition, perceiving little to gain from engaging and having little confidence in market actors.

[103] Personal communication.
[104] See for instance www.c40.org/custom_pages/good_practice_guides

A prerequisite for the deployment of smart and energy efficient solutions is to **foster customer-centric approaches** by empowering consumers, for example with the establishment of a regulatory framework that allows demand-response and energy efficiency services, i.e., where the availability of information for consumers is guaranteed and a secure but non-discriminatory handling of data is in place. New business models, especially those that promote the efficient utilisation of energy by informed consumers, will emerge as a result. Such business models are being developed by companies such as Smart Impulse, C3 IoT (former C3 energy) or Enernoc, often by partnering with energy utilities to better inform consumers about their energy consumption. Efforts to deploy vehicle-to-grid solutions are also following this 'prosumer' approach (Example 12).

EXAMPLE 12: UK VEHICLE-TO GRID PROGRAMME

The UK is currently implementing its strategy to deploy vehicle-to-grid applications, with the ultimate aim to becoming a world leader in new battery technologies.[105] A Vehicle to Grid (V2G) system consists of a utility two-way charger and an energy management system that can also integrate off-grid and renewable power generation such as solar panels and wind turbines. Using this equipment, an EV owner equipped with the appropriate on-board device can connect to charge at low-demand, cheap tariff, periods, with an option to then use the electricity stored in the vehicle's battery at home when costs are higher, or even feed back to the grid with a net financial benefit.[106] Such an application is a clear example of a cross-sectoral/integrated innovation that is enabled by both buildings and vehicles becoming smarter and more user-oriented. While some remaining technical and economic barriers have yet to be overcome (e.g., battery lifetime and costs, and grid communication systems), owners of electric vehicles should be able in the near future to contribute to the balancing of the electricity grid while making money by exporting electricity.

Setting the right price signals and incentives is essential to foster the development of energy efficient behaviours and flexible energy consumption. The rollout of smart meters is a first step in this direction. However, to achieve more flexibility and energy efficiency requires more granularity and differentiation in tariffs, both in terms of geographical territories and at different times. For example, smart metering capabilities could be leveraged to offer more differentiated tariffs based on time. In France, for instance, in addition to the "heures pleines – heures creuses"[107] split, the smart meter Linky's four index could enable a "summer–winter" distinction.

[105] More details on the UK electric vehicles strategy are available in the final report from Element Energy Limited: www.element-energy.co.uk/wordpress/wp-content/uploads/2012/05/EVs-in-the-UK-and-ROI_final-report_10.12.10.pdf
[106] See for example: www.aston.ac.uk/news/releases/2016/february/aston-commissions-uks-first-electric-vehicle-to-grid-charging-system
[107] Equivalent to peak time / off-peak time

6.4.2 Key success factor #8: Mobilise citizens

Citizen engagement in the energy transition is key in creating the desire and buy-in for change. Where industrial revolutions occurred and were successful, the benefits were important to be disseminated to a wider group, but there was also resistance from those that were adversely affected. This is no different from today's energy transition. The energy transition, however, does not systematically bring direct value to the end-user. Indeed, new energy-related technologies do not necessarily provide additional services and are sometimes more expensive. A particular effort must therefore be made to stimulate consumer desire for solutions related to the energy transition.

Local leaders or organisations are the closest to consumers, and have a clear role in communicating and working with them. They are also the best placed to explain what the energy transition means for European citizens and their daily lives, and to involve them in the laying out the future vision for their community (see Example 13).

EXAMPLE 13: PARIS SMART CITY PROJECT

In France, Paris has chosen to make citizen participation a top priority of its Smart city project. One of the most notable examples is the introduction of a participatory budget, corresponding to 5% of the investment budget (i.e., €0.5 billion over the period 2014-2020). Over the first quarter of 2015, the city services have received more than 5,000 proposals from citizens.

6.5 Principle #5: Be more results-oriented and selective in nurturing energy innovation

Finite budgets need to be allocated to different technologies and solutions. In Europe, public funding is particularly important, especially at the early stage of energy innovation but also throughout the innovation cycle. It is essential to ensure an efficient and effective use of public funding. This can done through a combination of: (i) fostering collaboration and pooling resources, (ii) being results-oriented in attribution, consistency and follow-up of public support mechanisms, and evaluating the remaining gaps and barriers that prevent scaling of innovation.

6.5.1 Key success factor #9: Foster collaboration and pool resources

Deployment and RD&D support in member states are only weakly coordinated, which ultimately means that the deployment of new technologies such as renewables or low-carbon mobility solutions is achieved at significantly higher costs than if there were a more European approach. In some instances, such an approach could make the deployment of low-carbon technologies easier and more cost-efficient.[108] Different technologies developed in European member states are often competing to offer the same service, up until the moment when one (European or non-European technology) becomes the reference. Standards can emerge without regulation, although regulatory intervention can accelerate the process to help stakeholders realise the value of their R&I efforts and maximise socio-economic benefits (see Example 14).

EXAMPLE 14: THE CASE OF STANDARDS IN THE ELECTRIC VEHICLE MARKET

The development of electric vehicles (EV) is a good example of the importance of standardisation at the EU level. At the moment, there are a variety of options for the charging vehicles and there are limitations in the cross-border use of electrically chargeable vehicles due to specific national requirements and lack of EU standards. However this will change as greater harmonisation is implemented. Europe has decided by 2017 to standardise the connectors used for the charging of electric vehicles. Running up to this decision, various plug designs and regional standards had emerged in Europe and in other large geographies (e.g., Chademo in Japan is also used in Europe for the Nissan Leaf and the Renault Zoé, and by Tesla in the US). Carmakers from different geographies all tried to promote their own design, until the European Union selected the German version of the Combo plug. While fierce competition may have stimulated innovation, experts regret that standardisation did not occur sooner.

Europe can also facilitate cross-sectoral and cross-country collaboration to ensure the efficient support of the most promising energy-related innovations and rapid deployment at EU or international level. In particular, more resources could be pooled in the demonstration phase to support large-scale demonstration projects and in the deployment phase to support European exports, for example. Just as companies often build consortiums to seize new opportunities in their domestic markets or abroad (e.g., Schneider and Capgemini or Cofely Ineo and Sinovia competing against IBM and Accenture

[108] Brugel, for instance puts forward the idea of "more Europe", in particular when it comes to RD&D and deployment (Zachmann, 2015).

to develop the new City Operating System of Barcelona), cross-country collaboration could scale Europe's leadership.

Finally, more dialogue could be encouraged at the early stages of innovation between R&D stakeholders, business teams and possibly end-users, in order to take the market into account as soon as possible in the innovation cycle. Dialogue and cross-sectoral collaboration could be enabled through so-called innovation hubs (See Example 15).

EXAMPLE 15: URBAN INNOVATION HUB – THE MARS DISCOVERY DISTRICT

Innovation hubs are a way to foster innovation and cooperation between key players. The Mars Discovery District[109] in Toronto, Canada, is an example for how private companies and public authorities can promote the adoption of innovative energy technologies and leverage value from promising ideas into international markets. Its urban innovation hub has an Advanced Energy Center that works closely with energy utilities, start-ups, energy-related industries, and public authorities to identify high-priority and cost-effective solutions.

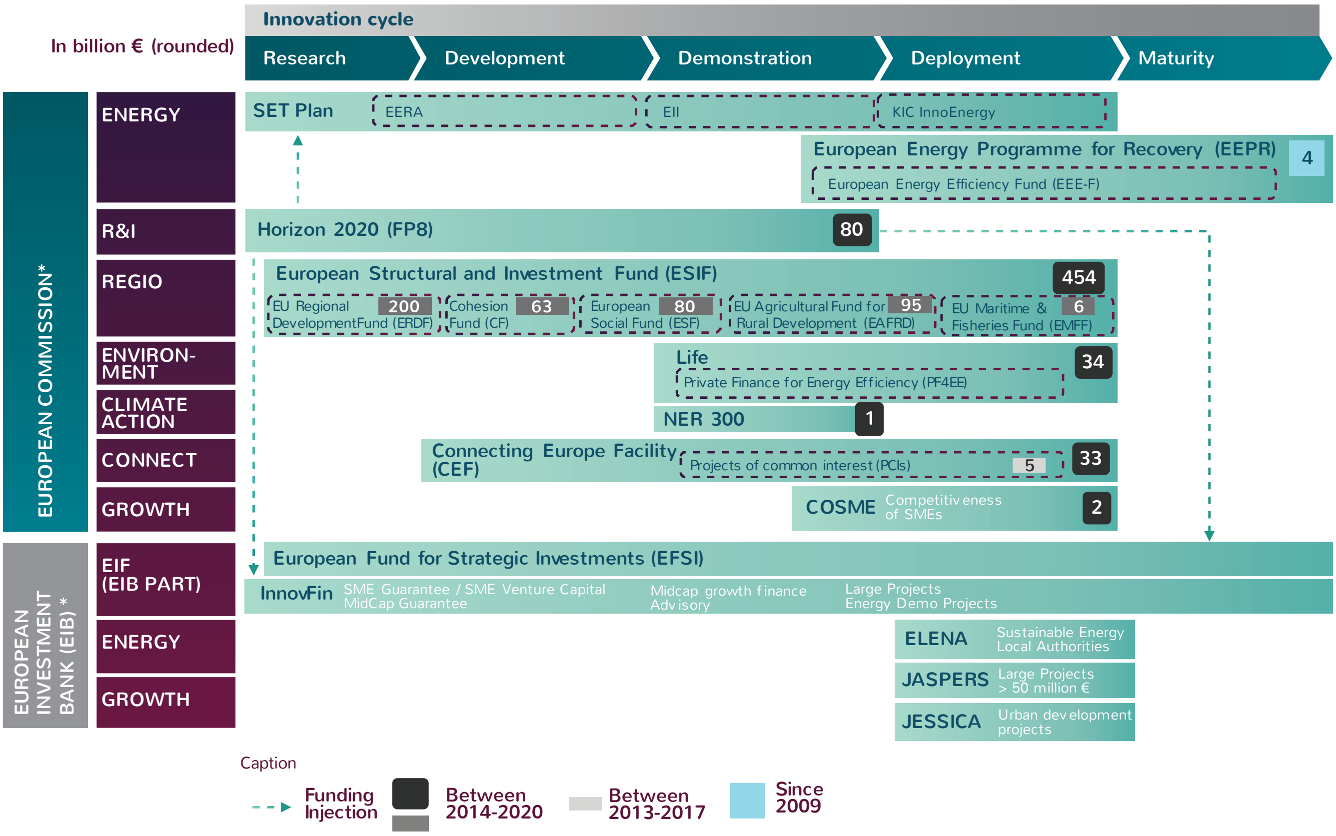
6.5.2 Key success factor #10: Generalise results-oriented approaches, ensure consistency of instruments, and use of metrics

In terms of technology support, it is also essential (I) to ensure **consistency of support mechanisms all along the innovation cycle**, (II) to **develop clear methodologies for the prioritisation of funding**, in accordance with the high-level objectives related to climate change and competitiveness (e.g., in terms of jobs, growth, exports), **and (III) to establish a transparent set of metrics and indicators** to assess whether projects are on track and/or to identify the need to adjust policies or instruments.

(i) Europe currently provides a large number of funding instruments along the entire innovation cycle, which are not always well articulated and sufficiently visible (see Figure 28). Mapping and communicating about existing funding instruments (and associated rules and mechanisms) along the innovation cycle could potentially help unlock specific investments (especially between low and high Technology Readiness Levels (TRLs) and ensure consistency between allocation criteria (e.g., job creation potential).

[109] https://www.marsdd.com/

Figure 28: European innovation instruments are used throughout the innovation cycle (tentative)[110]



Notes: non exhaustive list of energy-related innovation instruments, currently existing at European level (excl. nuclear).
Acronyms: SET: Strategic Energy Technology. EERA: European Energy Research Alliance. EII: European Industrial Initiatives. KIC: Knowledge & Innovation Community. NER: New Entrants' Reserve. COSME: Competitiveness of Enterprises and Small and Medium-sized Enterprises. ELENA: European Local Energy Assistance. JASPERS: Joint Assistance to Support Projects in European Regions. JESSICA: Joint European Support for Sustainable Investment in City Areas

(ii) Public funding could also be allocated and prioritised on the basis that innovation and deployment projects meet end-user demand and/or create value for and in Europe (e.g., in terms of jobs, growth, exports). For Horizon 2020, for example, a prioritisation methodology could be implemented to reinforce criteria for the expected outputs.

In that sense, the ARPA-E approach in the United States offers a pointer (see Example 15 and the Topic Box C on ARPA-E). Its motto *"if it works, will it matter?"* implies that from the beginning of the process, the impact of the technology's adoption and use is at the heart

[110] Source: Capgemini Consulting based on available information collected on the websites of the DG's of European Commission and EIB. Note: EIB can also be involved in the instruments related to the European Commission, but in a different role (as a financial authority).

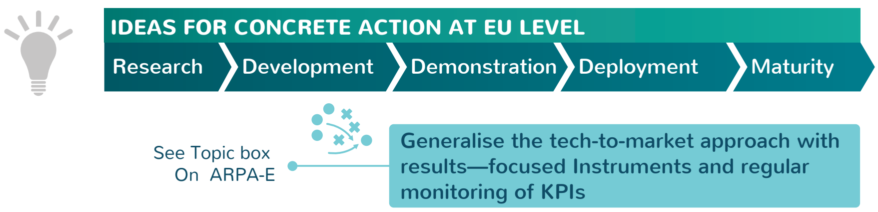
of the funding decision. In Europe, KIC InnoEnergy (which has a relatively higher budget than ARPA-E[111]) and other funding instruments have started to adopt this perspective, with a strong focus put on the business plan of candidates. However, an end-to-end approach throughout the innovation cycle still seems to be missing, especially when it comes to connecting technology and non-technological energy innovation.

EXAMPLE 16: THE US ADVANCED RESEARCH PROJECTS AGENCY-ENERGY (ARPA-E)

The US ARPA-E agency has taken a results-oriented approach and allocates its funding on the basis of a project's potential to radically improve US economic prosperity, national security and environmental wellbeing. ARPA-E focuses on transformational energy projects that can meaningfully progress with a small investment over a defined period of time, and adopts a milestone-based approach. ARPA-E acts like high-risk venture capital since it invests in early-stage innovations. The ARPA-E approach can be summed up in one catchphrase: **"If it works... will it matter?"** In other words, from the beginning of the process, the technology's final impact, in terms of adoption and usage, is at the heart of the funding decision. Questions such as what does it do? What problem does it solve? Who will buy it? What is the adoption process, and what are the barriers? are fundamental to the funding process. In addition to providing funds, ARPA-E has set up the 'Technology to Market Advisor' that helps to:

- Drive innovation project teams towards commercialisation by tracking progress with a milestone-based approach;
- Support project teams with the skills and knowledge to align the technology with market needs, including product hypothesis and economic analysis; and
- Engage third party financiers to support the continuity of technology development in the market, through technology showcasing, networking sessions, regular reports to potential investors and strategic partners, and financing agreements.

(III) Ensuring effectiveness also implies defining a transparent set of metrics to properly account for and assess progress in relation to stated objectives (e.g., jobs, growth or exports) for projects that receive public support. The Integrated SET (Strategic Energy Technology) plan has taken a step in this direction with the establishment of strategic targets on cost reductions and performance improvements in an endeavour to maintain global leadership in the sectors that receive support (namely for offshore wind, concentrated solar power, and smart cities and communities). Yet a lack of available data and metrics hinders a thorough monitoring of all dimensions of the innovation process and the assessment of the social economic co-benefits that the innovations provide.



[111] In 2014, the ARPA-E budget was $280 million (up from $180 million in 2011) compared with €300 million for KIC InnoEnergy (up from €211 million in 2011).

Evaluation of the efficiency of investments in energy-related research and innovation will not be sufficient, however, if it does not lead to concrete action. An evaluation process that requires an assessment of remaining gaps or inconsistencies, e.g., a lack of supportive policy/political environment, other market factors or developments not previously anticipated, can help achieve to detect specific barriers or anticipate market rules adaptations.[112]

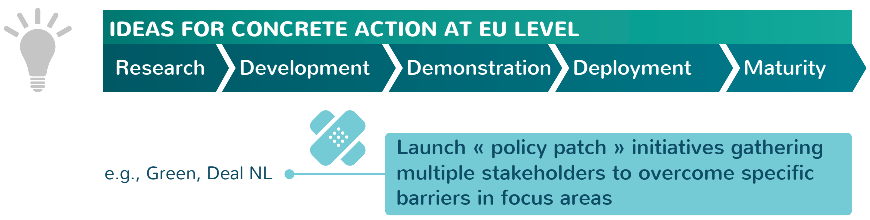
Cross-sectoral and multilateral approaches are often needed to overcome specific barriers that result from the systemic nature of most energy issues.

EXAMPLE 17: THE DUTCH APPROACH – GREEN DEALS AND ENERGIESPRONG

In the Netherlands, public authorities have played a key role in facilitating energy projects by involving multiple stakeholders. The Green Deals have enabled the removal of barriers to sustainable initiatives by bringing together companies, local and regional governments and interest groups to discuss existing barriers. This has enabled sustainable initiatives to get off the ground and to accelerate.

Similarly, Energiesprong, and in particular its Stroomversnelling programme, was created with the ambitious objective of delivering 111,000 energy-neutral houses by the end of the decade. A crucial dimension to the success of Energiesprong has been that it has brought together an ecosystem of stakeholders from across the value chain, including the social bank WSW, housing associations and market-leading manufacturers of energy efficient refurbishments. This has proven key to altering the underlying market conditions that prevented the widespread energy efficient refurbishment of the domestic housing stock, by matching new sources of supply and demand.

Establishing multi-stakeholder initiatives similar to those in place in the Netherlands (Example 17) at the European level could help overcome barriers to systemic innovation, especially if they focus on specific energy-related areas such as buildings, districts and mobility. Convening various relevant backgrounds (public authorities at EU, national and local level, companies and interest groups) could help develop actionable solution frameworks that address identified barriers to the deployment of systemic energy-related innovation.



[112] Barriers might result from regulatory overlaps that create inconsistencies. For example, some banks in France are entitled to collect Energy Efficiency Certificates when they finance energy efficiency building refurbishments. In such a case, banks must respect stringent and evolving regulatory requirements, both from the banking sector and from the energy side. However, it is difficult and sometime even impossible to meet all the requirements of the loan and the Energy Efficiency Certificates collection processes.

7. CONCLUDING THOUGHTS

This report has been developed with the aim of providing evidence-based analysis to inform the debate on what an integrated, forward-looking research, innovation and competitiveness strategy for the European Energy Union should seek to prioritise and achieve.

With ambitious domestic targets and the pioneering of new instruments to decarbonise its economy, Europe's policy framework has undeniably played an important role in paving the way towards a global clean energy transition. European policies have been successful in initiating energy-related innovations such as in large renewable technologies (e.g. onshore wind). At the same time, it has failed so far to industrialise deployment of other promising innovations, such as CCS or hydrogen storage, where other economies and their companies have either already succeeded, or are better positioned to reap the benefits than Europe is.

We find that, in several energy-related areas, Europe has a deployment deficit, and it struggles to bring to market promising innovations. Amid the innovation process, Europe struggles to industrialise promising energy-related demonstration projects. Some innovation areas are caught in the so-called 'valley of death' in Europe, while their large-scale deployment is more advanced in other geographies (e.g. power storage).

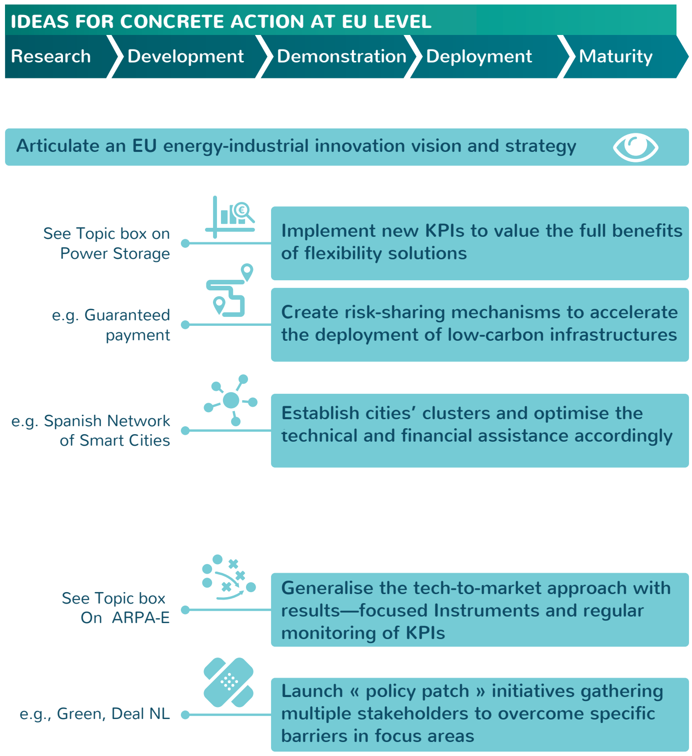
Our analysis shows that, without a comprehensive and operational strategy for research, innovation and competitiveness, bringing together supply, demand and regulatory aspects, the EU risks losing its comparative advantage to Asian and American competitors. This applies both to innovation supply and deployment taking place in Europe. This is already the case with some specific technologies such as solar PV. The EU faces similar risks in other areas such as in battery storage, and electric, hybrid and hydrogen mobility. The forthcoming European research, Innovation and Competitiveness Integrated strategy (EURICS) is an important milestone to redefine Europe's competitiveness and innovation strategy, and to align all the pieces of the puzzle.

There is therefore no room for complacency and much room for improvement, in particular to exploit investments made early in the innovation cycle (i.e. research and innovation). But Europe's starting position is a relatively strong one. It has structural strengths that it can build on to do this, including the size of the European market, the skills of its workforce and its research institutes.

Policy-makers therefore have key choices available to them to enable the EU to scale its energy innovations and reap the associated social and economic benefits, as well as achieve the core Energy Union objectives in relation to security, affordability and decarbonisation. This report offers five guiding principles, ten key success factors and a range of concrete ideas are set out that could be at the core of this new approach (see Figure 29), and give coherence and strength to an important new strategy for both the Energy Union, and Europe's wider growth, jobs and competitiveness agenda.

Figure 29: Key findings and suggestions along the innovation cycle

5 GUIDING PRINCIPLES	10 KEY SUCCESS FACTORS
1. PROVIDE CLARITY ON THE LONG TERM DIRECTION	1. Enable long term choices at local level and ensure their consistency at EU level 2. Set integrated energy-industrial priorities
2. DESIGN THE MARKET TO BETTER PULL ENERGY INNOVATIONS ACROSS THE 'VALLEY OF DEATH' AND TO SCALE	3. Adapt regulation and value the benefits of low-carbon technologies and energy efficient innovative solutions 4. Mitigate financial risks
3. ACCELERATE THE EMPOWERMENT OF LOCAL AND REGIONAL AUTHORITIES	5. Provide local and regional authorities the right technical, regulatory or financial assistance 6. Reinforce data and knowledge sharing
4. EMPOWER CUSTOMERS & CITIZENS FURTHER YET	7. Foster customer-centric approaches 8. Mobilise citizens
5. ENCOURAGE MORE EFFICIENCY IN NURTURING ENERGY INNOVATION	9. Foster collaboration and pool resources 10. Generalise results-oriented approaches, ensure consistency of instruments, and use of metrics



In sum, this report confirms the need for an integrated approach to the research, innovation and competitiveness agenda of the Energy Union. In listening to the full spectrum of relevant stakeholders, and learning from failures as well as successes, it offers a realistic but positive assessment of the current situation. It confirms the opportunity that this agenda presents for the EU to demonstrate that leadership on climate change can not only be successfully married to the achievement of its energy security, energy affordability and environmental sustainability goals, but should also be at the centre of its industrial economic strategy. With the right innovation-enabling policy framework and strong related signals to investors, the Energy Union can ensure that the EU is the world leader in renewables. In the context of a fast-changing and competitive global environment, it can also deliver strongly on the wider jobs, growth and competitiveness agenda that is at the top of the Commission's priorities.

8. TOPIC BOXES

8.1 Topic Box A: Bioenergy, lessons learned from the Swedish experience

1. Within a 30-year timespan, bioenergy has become Sweden's primary energy source [113]

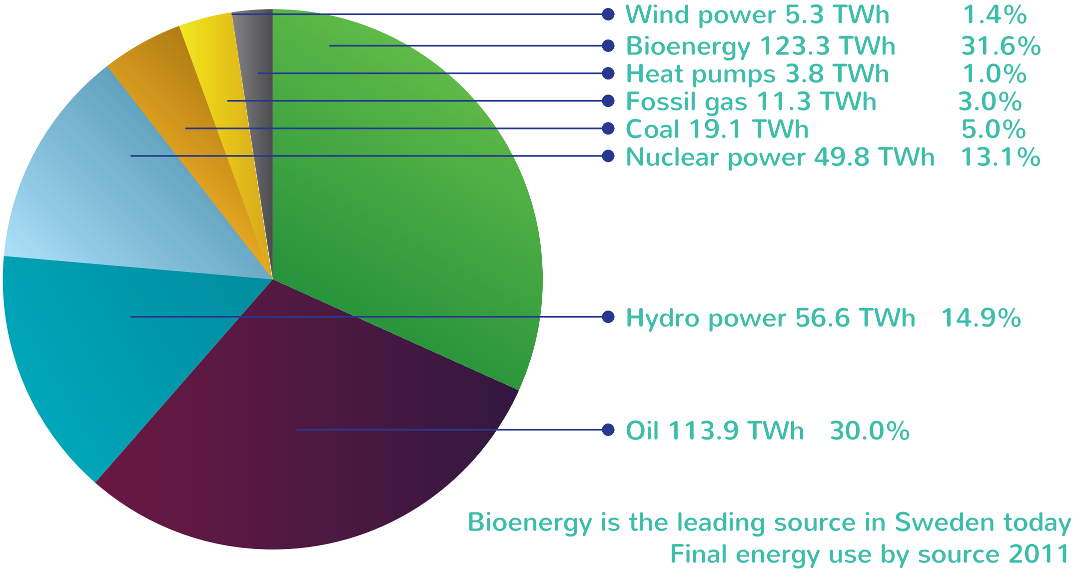
The remarkable growth of Sweden's bioenergy sector is an emblematic global renewable success story. From home and district heating, to bioelectricity and biofuels (1st and 2nd generation) from biomass, bioenergy has expanded throughout the Swedish energy mix.

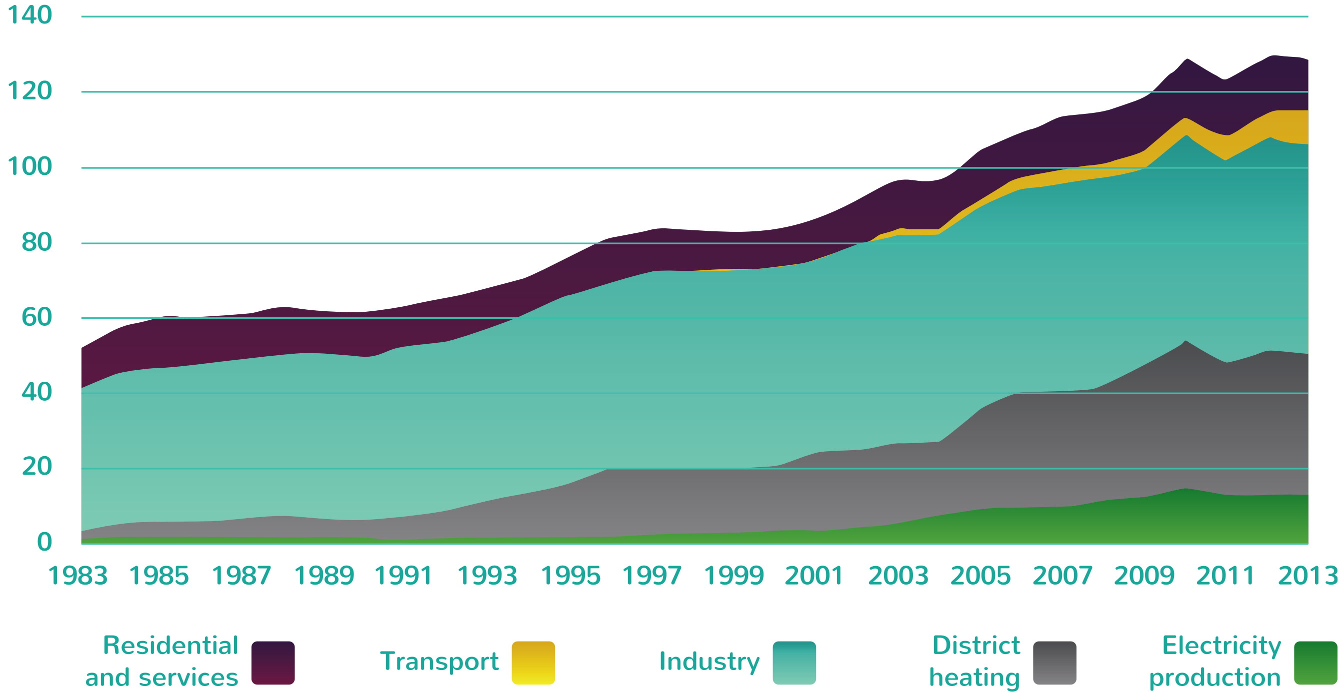
The share of bioenergy in the country's total final energy consumption has more than tripled between 1970 and 2014 (from 40 TWh/year to approximately 140 TWh/year in 2014). In 2009, bioenergy surpassed oil as Sweden's leading energy source. It is mainly used for heating but also electricity generation and transport (see Figure 29).

In terms of job creation, bioenergy jobs represent more than 69% (32,800 jobs in 2015) of total renewable energy sector employment in Sweden (with 84% in solid biomass, 15% in biofuels and 1% in biogas). In comparison, bioenergy jobs accounted for only 39% of renewable energy employment in Germany for the same year.

[113] While the Swedish bioenergy example is used to illustrate the potential for rapidly scaling up a renewable sector, it should be noted that the latest science shows that bioenergy strategies should be developed with caution. There are widespread concerns that unconstrained use of bioenergy could lead to significant climate impacts as a result of land-use change and carbon debt. In many pathways, these impacts are sufficient to make bioenergy use incompatible with the 2 degrees objective.

Figure 30: Swedish Energy Mix in 2011 & Distribution of bioenergy consumption by sector





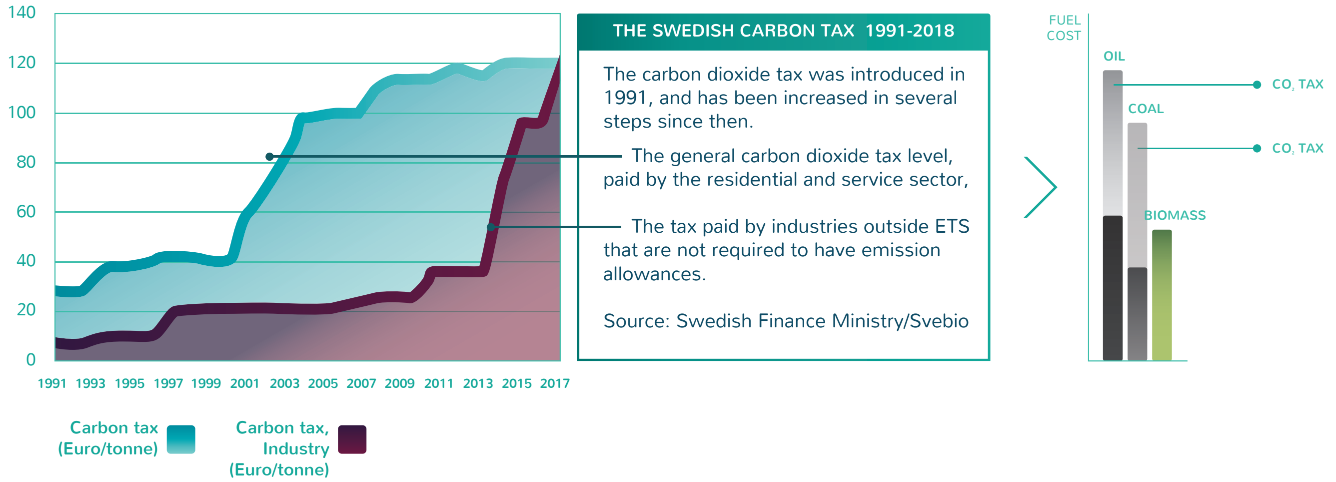
Source: Svebio based on statistics form Swedish Energy Authority

2. A visionary set of market pull instruments, including a strong carbon price signal, are driving fossil fuels out of the market

Beyond its unique set of natural and cultural factors – more forests than any other EU country, a strong tradition of using wood, a highly developed wood industry – Sweden's bioenergy boom is mostly attributable to the broad, constant and consistent policy support it benefited from. Starting in the late 1980s, a series of incentives were put in place, including three decisive 'market-pull' instruments, each with impacts on different sectors: (1) the Swedish carbon dioxide tax (introduced in 1991, impacting heating oil), (2) green electricity certificates (2003 – bio-electricity) and (3) tax exemptions for biofuels.

Of these incentives, the Swedish carbon tax had the most profound impact. Two levels of CO_2 taxation have been chosen for heating fuels: at a high level for households and the service sector (€29/t in 1991; €125/t in 2014 – the red curve on the figure below) and lower for sectors subject to international competition and the risk of carbon leakage (€7/t in 1991; €37/t in 2014 – the green curve). This tax has directly improved the competitiveness of renewable energy for end users, and has made fossil fuels less competitive in comparison (See Figure 30).

Figure 31: Evolution of the Swedish carbon tax



At a relatively fast rate, fossil fuels were driven out of the heating market, both in heat plants and in residential boilers. The transformation in district heating was significant: at the end of the 1970s heating oil accounted for 90% of the fuel used by district heating plants; by 2010, the share of fossil oil was only 2%, while biomass represented 70%. Many industries also switched from oil to biomass.

3. Substantial socio-economic benefits have been achieved, resulting in job creation and an improved trade balance

The Swedish biomass sector generated substantial socio-economic benefits, starting with the creation of up to 40,000 jobs spread throughout the country, including the most rural communities. Another key benefit has been the reduction in oil imports, adding up to an estimated savings of €4.5 billion/year.

The bioenergy boom has also generated significant environmental benefits, with higher protection and development of the country's bio-resources. Indeed, as of 1994, Sweden developed an innovative forestry policy, under which the respective goals for forest production and the environment are given equal weight. Consequently, during the 1990s, the volume of wood in Sweden's forests increased by around 20 million square meters. Similarly, forest productivity increased by approximately 21% between 1990 and 2008, exceeding 20 cubic meters (solid) per man-day.

4. Drawing from the Swedish experience, how can Europe duplicate these success factors for the wider development of highly competitive industries?

If Sweden's bioenergy revolution is partly thanks to natural advantages that other countries may not have, it nonetheless holds valuable lessons in how public policy can have efficient and substantial impacts. The sector developed thanks to strong, stable, and consistent political support over the years, with clear choices from the start. This translated into a set of market influencers, which created the right conditions for bioenergy to become the most competitive energy source in the entire energy ecosystem.

Specifically, the carbon tax has been the major driving force behind bioenergy's rapid growth. The price of carbon allowances in the EU ETS, at slightly above 5€/t in early 2016, are only a fifth of the level of Sweden's carbon tax in 1991, and 20 times lower than it is today. In Europe's market (which also cover Swedish companies), carbon emitters currently bear limited responsibilities for the negative externalities of their emissions. Sweden shows that establishing stronger accounting of these externalities through carbon-based market-pull instruments encourages alternatives in heat, electricity and fuels, while generating revenues, which can be re-invested in the low-carbon economy. Furthermore, the EU is the largest energy importer in the world, with 53% of its energy imported, on which it spends around €400 billion/year (˜2.2% of Europe's total GDP).

In this context, how can Europe ensure a stronger CO_2 price signal in the near future? While it raises a number of challenges, such as the impact on its industrial competitiveness, Sweden's example demonstrates a high degree of social, economic and environmental benefits, and suggests a path towards the decarbonisation of sectors that are not covered by the EU ETS.

8.2 Topic Box B: How did Denmark succeed in the wind industry?

1. Denmark has become a world leader in wind energy

Today Denmark is the wind power leader in Europe, with more than 40% of its electricity consumption met with wind energy. The Danish government has adopted a plan to increase the share of electricity production from wind to 50% by 2020, and to 100% in 2050.

Wind energy also represents 74.1% of total renewable energy employment in Denmark, providing almost 27,500 jobs. More than 200 Danish companies are involved in the wind industry. Together they constitute a unique supply chain including metal processers, sensor and controlling system manufacturers, and platform and foundation fabricators. They are linked by several collaborations involving academic institutions, the wind industry association and research centres, which help to develop products and support the industry. Danish companies annually invest €600 million in energy research, which represents 12% of all private research investment.

In addition to a considerable economic dynamism in the domestic market, the country exports its expertise all over the world. Indeed, Danish industrial leaders, such as Vestas Wind Systems, are recognised internationally. In 1986, the company decided to focus its product portfolio, which originally included household appliances and agricultural equipment, exclusively on wind energy. Nowadays, the group is the world's leading manufacturer of wind turbines, with a global market share of 13.2%. Vestas has already installed more than 56,000 turbines in 66 countries, which generate more than 90 million MWh of energy per year.

2. National public authorities have played a key role in the development of the Danish wind industry by providing stable market conditions, and by establishing large-scale demonstration programmes.

This global leadership position in offshore wind has three central explanations.

First, the country set out a consistent and long-term vision. In 1973, 90% of Denmark's energy consumption came from imported oil. The first oil shock initiated a re-evaluation of Denmark's energy strategy and, as a result, the government established long-term policies to promote renewable energy sources (RES).

Since 1978, the wind industry has benefited from a series of political decisions that have provided stable and transparent plans for the implementation of RES, investment in RES R&D from 1978 to 1989, financial support for RES through feed-in tariffs (1984-2000), and a carbon tax (since 1992). Rather than providing subsidies to turbine manufacturers, the Danish government focused on creating adequate market conditions. A particular regulatory focus has also been placed on the quality and safety of turbines. This resulted in the creation of a demand-based industry, enabling competition between manufacturers and ensuring quality.

Secondly, large-scale demonstration programmes have been established. For instance, in October 2012, the National Test Centre for Large Wind Turbines opened at Østerild. It is the largest and most advanced centre for full-scale turbine testing in the world. This was a key success factor for the Danish wind industry, which enabled it to remain one step ahead of overseas competition. It also attracted other European companies such as Siemens, which has established its own test centre in Denmark.

3. A unique cooperative model has enabled Denmark's citizens to play an active role in the wind industry development.

Citizens have played a major role in the development of onshore wind in Denmark. Some legal requirements unique to Denmark have helped private local investors co-finance new onshore wind turbines. But the greatest contribution of citizens comes from local cooperatives.

In fact, local cooperatives have largely contributed to the success of the technology, notably by financing 83% of all wind turbines in Denmark. Over 100,000 Danish families belong to such local wind cooperatives. Over their lifetimes, wind turbines provide stable, long-term investment returns.

Three main lessons can be drawn from Denmark's successful deployment of a renewable energy technology. Long-term policy has created favourable market conditions. Large-scale demonstration programmes improved the technology and attracted companies. Lastly, citizens have played a major role in deployment, in particular thanks to distinct regulations.

8.3 Topic Box C: ARPA-E: bridging the gap between demonstration and deployment

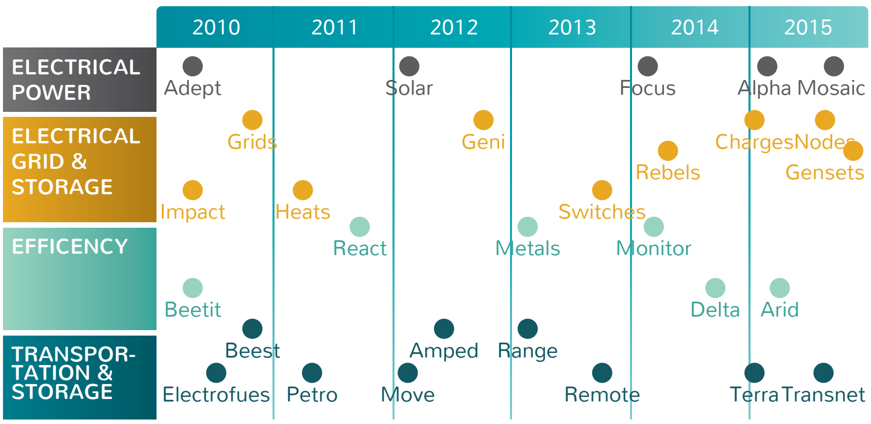
A public consultation conducted by the Commission in support of the Energy Technologies and Innovation Communication found strong demand for the integration of activities along the innovation chain[114], and suggested putting more emphasis on overcoming the 'valley of death' between the demonstration and commercialisation phases of the innovation cycle.

The approach developed by ARPA-E (Advanced Research Projects Agency-Energy) in the US offers an interesting example of how this can be done, and in particular draws out four elements that could be of interest to Europe. It emphasises:

- Integrating market impact criteria soon after project selection, even for upstream innovation;
- Following a project's results with a milestone-based approach;
- Bridging the gap between demonstration and deployment by fostering close collaboration with private financiers; and
- Including former private senior executives and scientists in the budget choices.

ARPA-E was established as a new agency within the US Department of Energy (DoE) in 2007. ARPA-E focuses on transformational energy projects that can meaningfully progress with a small investment over a defined period of time. ARPA-E acts like high-risk venture capital, since it invests in early-stage innovations.

Figure 32: ARPA-E Portfolio Approach



[114] European Commission, Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation, 2015

The agency has a focused programme portfolio strategy based on four main innovation areas: electrical power; electrical grid and storage; efficiency; and transportation and storage. Complementing its focused programmes, ARPA-E also has open programmes to support the development of potentially disruptive new technologies across the full spectrum of energy applications. These two types of programmes enable ARPA-E to keep a certain focus on pre-determined areas while maintaining flexibility and openness to unexpected innovations.

ARPA-E's approach can be summed up in one catchphrase: **"If it works... will it matter?".** That is, from the beginning of the process, the final impact of the technology on usage and adoption is at the heart of the funding decision. Crucial questions asked include: What does it do? What problem does it solve? Who will buy it? What is the adoption process, and what are the barriers?

In addition to providing funds, ARPA-E has set up the "Technology to Market Advisor" who helps to:

- Drive innovation project teams towards commercialisation by tracking progress with a milestone-based approach;
- Support project teams with skills and knowledge to align the technology with market needs, including product hypothesis, and economic analysis; and
- Engage third-party financiers to support the continuity of technology development in the market through technology showcasing, networking sessions, regular reports to potential investors and strategic partners, and financing agreements.

To date, ARPA-E has invested approximately $1.3 billion across more than 475 projects, through 30 focused programmes and three open funding solicitations. In 2014 alone, ARPA-E funded 362 start-ups. The leverage factor sometimes exceeded six times, with some 34 projects attracting more than $850 million from the private sector, based on $135 million of ARPA-E funds. Over its short lifetime, 30 new companies have been established and seven products with commercial sales have been created.

Earlier in 2016, ARPA-E announced that 45 of its projects have secured more than $1.25 billion in private sector follow-on funding. [115]

[115] arpa-e.energy.gov/sites/default/files/documents/files/2016_Summit_Press_Release_Addendum_FINAL.pdf

8.4 Topic Box D: How cities and regions can stimulate energy-related innovation

Cities and regions were brought into the spotlight in Paris at the climate talks, setting the tone for ambitious action. Indeed, local and subnational governments have long been pioneers of action on climate change, often setting a higher level of ambition than their national counterparts.

Cities such as Copenhagen, Melbourne, or Seattle, and also smaller municipalities like Turku in Finland, have set themselves the goal of becoming carbon-neutral by 2050 at the latest. There are numerous other examples where city mayors have taken decisive, innovative and effective climate action.

Cities consume more than two-thirds of the world's energy and account for more than 80% of global greenhouse gas emissions.[116] With continued urban population growth[117], it is vitally important to accelerate the deployment of cities' sustainable energy initiatives and find ways to replicate best practice in cities of all sizes.

1. Europe is a fertile area for cities' low-carbon solutions

Copenhagen, Stockholm, and Oslo were among the ten first global cities[118] announcing ahead of the Paris talks that they had achieved compliance with ambitious climate action plans of the Compact of Mayors, a global coalition of city leaders dedicated to reducing their GHG emissions. Their goal is to make urban communities more resilient to climate change. Their achievement builds on years of local efforts to mitigate climate change.

Although there is no commonly agreed definition of a smart city[119], they have typically launched pilot projects or have existing services in at least one of the six areas usually considered as smart: mobility, environment, governance, economy, people and social living. According to the Arcadis Sustainable Cities Index rankings, 12 of the top 20 cities identified as being more advanced in their environmental performance are European.[120]In

[116]C40 Cities Climate Leadership Group
[117] In 2014, the urban population accounted for 54% of the total global population, up from 34% in 1960, and continues to grow (WHO - Global Health Observatory (GHO) data).
[118] Buenos Aires, Cape Town, Copenhagen, Melbourne, New York, Oslo, Rio de Janeiro, San Francisco, Stockholm, Sydney and Washington, DC.
[119] A smart city could be defined as connected, responsible and sustainable. The European Commission describes a smart city as a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses.
[120] Arcadis (2015) Sustainable Cities Index 2015

addition to environmental and health benefits, smart city initiatives are expected to deliver economic advantages such as job creation, the optimisation of public financial resources, and increased economic productivity, although they can be hard to evaluate. For example, in the mobility sector, the European Partnership on jobs in green and healthy transport estimated in 2014 that up to 76,600 cycling jobs could be created if selected major European cities achieved the same cycling modal share as the city of Copenhagen.[121]

European companies in sectors including equipment manufacturing, utilities and technology are also involved in the world's largest smart city initiatives, in New York, Mexico City, Rio de Janeiro and Singapore, selling European know-how in power and automation technologies. For example, a Europe-based leading global energy equipment provider has been selected to work with New York's energy utility to make the power grid in Lower Manhattan more resistant to flooding-related outages.

2. Urban districts' evolving needs are fostering energy-related innovation

Many innovative energy solutions have emerged or been tested at city or district level. These include energy efficiency initiatives, electricity, heating and cooling supply systems, integration of renewables in the built environment. They are being integrated with transport systems, smart construction and urban planning solutions, waste and water treatment, as well as ICT solutions for the urban environment.

"Smart cities will be designed from the ground up through innovative technology pilots that will grow when ecosystems are born and data is shared. Policies don't have to define the whole system"

Perry Stoneman,
Utilities Global Sector Leader,
Capgemini

Research and innovation around urban issues has for long been supported within Europe. In particular, energy-related innovation projects at the district or city level have been specifically invited to participate in the Societal Challenges of the H2020 Research & Innovation Framework Programme.[122]

Cities such as Barcelona have created urban labs to foster innovation and facilitate the use of public spaces to test innovative projects in a real environment. The city is particularly famous for its Super Blocks project, which approaches urban development in a transversal way that simultaneously promotes energy self-sufficiency, sustainable mobility, public space revitalisation, biodiversity and urban green areas, as well as social cohesion and citizen engagement with the goal of reducing the city's ecological footprint and improving citizens' quality of life. As a result of a long-term policy, urban planning innovation and the mobilisation of citizens and local companies, the city now emits fewer than three tons per capita of CO2 equivalent emissions, which is very low compared to cities of the same size, such as Atlanta (12 tons).

[121] PJGHT, an initiative from the Transport Health and Environment Pan-European Programme Publication "Unlocking new opportunities: Jobs in green and healthy transport", April 2014

[122] Namely Challenge 6 – Inclusive, innovative and reflective societies, under the item 6.1.4: 'The promotion of sustainable and inclusive environments through innovative spatial and urban planning and design.' This item complements other R&I activities on urban issues, especially from the Societal Challenge 3 – Secure, clean and efficient energy and the Societal Challenge 4 – Smart, green and integrated transport

3. Lessons learned from past and present initiatives show that there are a few prerequisites in order to scale the deployment of sustainable energy solutions in urban territories

City governments could help accelerate the deployment of energy-related innovation, as they have regulatory authority over public procurement and land use, and often own or have a stake in local energy utilities. Five key success factors seems common to sustainable urban initiatives:

Smart and energy efficient cities have emerged thanks to visionary local public leaders, with citizen-focused, long-term, consistent, and integrated policies.

A long-term, ambitious and stable vision is essential to create confidence and attract private investments.

Cities that have succeeded in implementing energy-related innovation have ensured the mobilisation and strong involvement of citizens and local companies

- Making energy transition possible will require popular support.
- All public authorities have a key role to play in raising awareness and demonstrating a commitment to mobilising citizens and requiring private companies to make ambitious commitments.

Cities needs to take the lead and facilitate the orchestration of complex, enlarged ecosystems

Cities have a central role to play leading the implementation of innovative ecosystems.

Collaboration with other cities can make a significant difference to the scale and speed of climate action.

- According to C40, a network of the world's megacities, 30% of all climate actions have been delivered through city-to-city collaboration.
- Different cities and regions' networks and alliances, such as C40, C100, CNCA, Compact of Mayors, the Covenant of Mayors, the Compact of States and Regions, Eurocities, Energycities and ICLEI, help to share examples of innovative and effective climate action.

- Cities have a lot of common barriers to energy innovation. Examples include public procurement approaches (such as entry barriers for start-ups), a lack of understanding of end-users' evolving needs, the complexity of the decision-making process, a lack of integrated infrastructure and land-use planning, and out-dated regulation.

Innovative, agile and flexible, local regulation offers new sustainable business opportunities and boosts local small and medium-sized companies.

Public procurement rules can be adapted to favour the deployment of new ideas. The city of Barcelona has taken a particularly innovative approach to its tender specifications. Rather than specifying its needs, it chose to put forward six problems to fix (such as reducing bike theft) and communicated them in metro stations. Applicants were allowed to suggest products, new services, regulatory changes or any other ways to fix the problem.

In conclusion, cities have a potentially critical role to play in bridging the deployment gap identified earlier in this paper. Initiatives underway by the Commission and national and local governments across the EU can play a key role. But such initiatives need to be strengthened with an integrative, deployment-focused approach.

8.5 Topic Box E: Power storage lessons from California and the US East Coast

1. Power storage deployment is lagging in Europe

Europe has developed more than 100 demonstration projects for power storage. However, other than pumped hydro storage, which currently represents over 50 MW of installed capacity in Europe, the deployment of storage technologies is lagging in Europe. This is in part due to the fact that not all of the benefits of power storage such as flexibility or responsiveness are currently monetised because regulation has not yet enabled this.

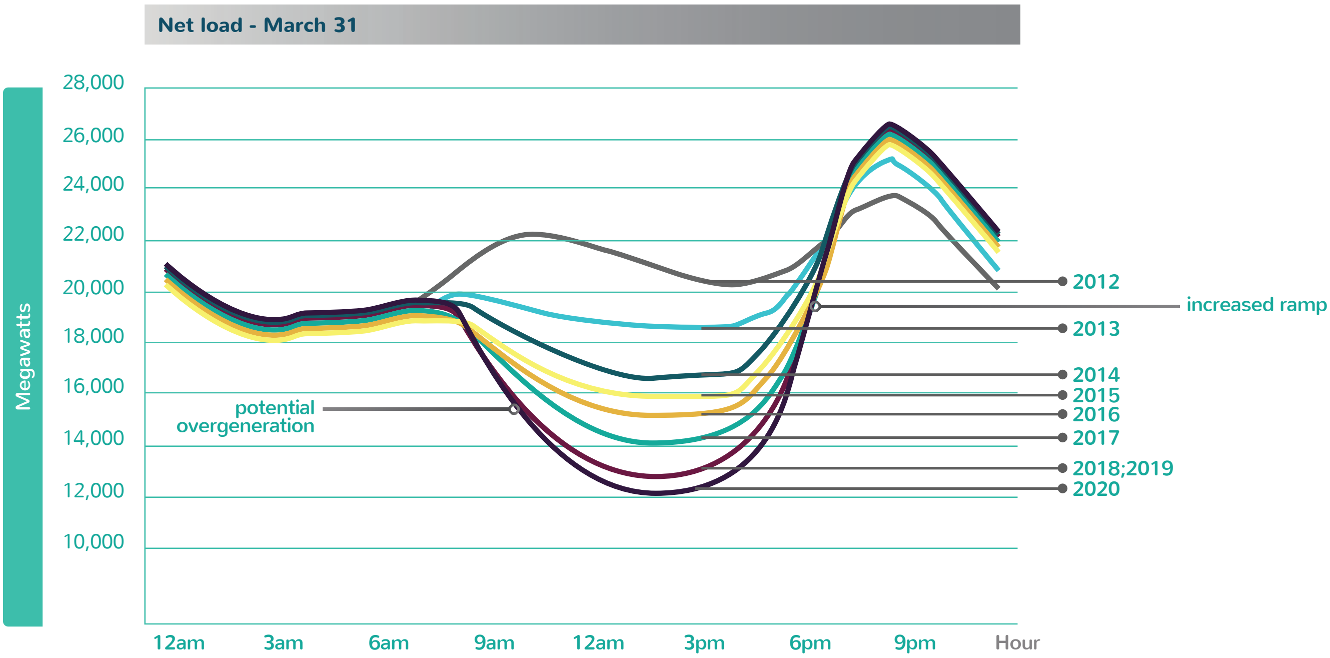
Other countries have implemented innovative approaches that have resulted in the deployment of power storage. In particular, two examples from the United States provide interesting lessons for Europe. In the first, long-term power storage targets, achieved thanks to cooperation between the regulator, system operator, and utilities, bring stability for market participants. The second example suggests a rethinking of the mechanisms used to determine compensation in given markets, and in particular the KPIs used. This latter approach has already led to the development of over 200 MW of storage capacity.[123]

2. California has provided long-term visibility and targets for storage deployment

California was exposed to the so-called 'duck curve' (see the shape of the curve in the figure below). On a daily basis, the net load (load minus PV production) was fell into a deep hole around 2pm (when PV production was maximal), before quickly rising, with a very stiff ramp, to the daily peak (matching a load peak and near zero PV production). The threat of blackouts called for flexibility in terms of demand response, generation and storage.

[123] As a comparison, 200 MW is equivalent to the power of 100 average onshore wind turbines (2 MW).

Figure 33: Duck curve issue – Net load over a day in March[124]



California was able to align the system operator (California ISO), the regulator (California Public Utilities Commission) and the three investor-owned utilities – Southern California Edison, Pacific Gas & Electric (PG&E), and San Diego Gas & Electric – to support the energy storage bill AB2514, which was introduced in 2010. This regulation set long-term power storage targets and requires in particular that 1325 MW be installed by 2025 by the three investor-owned utilities. There is no prerequisite on the technologies to be used. However, diversity is required in terms of connection level (household level, distribution grid level and transmission grid level).

The first rounds of energy storage procurement were launched in 2014, with PG&E seeking 74 MW (without specifying technology type) and receiving 5000 MW of applications. In this model, storage projects are installed by the regulated utilities, which is repaid through electricity rates. According to local stakeholders, many local Californian players other than utilities companies have benefited from this deployment, mainly from offering project development, asset maintenance and finance.

[124] Greentechmedia

3. PJM has developed new compensation mechanisms

A different approach was developed in the US Northeast (Pennsylvania, New Jersey, and Maryland - PJM), focusing on the use of energy storage for ancillary services, frequency regulation in particular.[125] More than 200 MW of storage has already been installed, and the goal is to reach 300 to 400 MW.

Storage technologies have been proven to react quickly to frequency regulation signals[126], much more quickly than the assets traditionally used to provide this service, mainly thermal power generators.

However, with a compensation scheme based on the total available capacity rather than on the ability to quickly follow a signal, storage technologies were not remunerated for the additional value they brought to the system.

The federal regulator, FERC, together with the local system operator, PJM, decided to let the regulation evolve and to implement a Regulation D (for Dynamic), which provides for new compensation for frequency regulation. This compensation is based on an innovative indicator called 'mileage', which basically accounts for the ability to quickly follow regulation command signals.[127]

To draw a parallel, the introduction of mileage values an externality, in this case the responsiveness of power storage, equivalent to pricing CO2 emissions, which values the externality related to the climate impact of power generators. This evolution has been sufficient to compensate storage assets, leading to their development without public subsidies. In this case, the evolution of a technical regulation and the introduction of a new KPI (mileage) have enabled the development of storage, bringing value to the system as a whole.

4. Lessons for Europe

The Californian case shows the relevance of an approach based on cooperation between different stakeholders. Together, they determined a long-term framework, providing consistency over time for market participants. However, this market is taking off slowly, most likely because the targets are still distant.

From the detail-oriented approach in the PJM case, Europe could retain one idea: look for new KPIs to value storage according to the benefits it provides. This approach does not have to be restricted to frequency regulation and could be generalised to other markets: indeed, the market potential for residential battery storage could be much higher in the long term. Such a technically detailed approach has been very efficient in generating short-term opportunities and optimisation, but may be lacking in the long-term vision it provides to market stakeholders.

[125] In electrical grid operation, the alternating current frequency must be held within tight tolerance bounds. Different methods available for "frequency regulation" include generator inertia, adding and subtracting generation assets and dedicated demand response and electricity storage. (Source: Energy Storage Association)
[126] Instructions sent by the system operator to frequency regulation operators to indicate them the adequate bhavior (ex: increase generation, reduce generation, increase consumption, etc.)
[127] Mileage is defined as the movement requested by the regulation control signal.

8.6 Topic Box F: Power Distribution: from network operators to system orchestrators

1. A new context pushes for the evolution of DSOs' business model and role

Given the new systemic challenges and opportunities brought by the energy transition, distribution system operators (DSOs) need to evolve. Besides the need for energy efficiency that should affect all types of DSOs, these context changes are particularly significant for power DSOs. Indeed, the growth of wind and solar capacity causes generation to become intermittent, while new patterns and loads rise on the consumption side, with for example self-consumption from household renewables, and the role of electric vehicles as electricity storage devices. This requires the development of flexibility tools: industrial demand response, residential and commercial demand response, flexibility in the use of fossil fuel-fired assets, network strengthening, storage and smart charging, as well as a better knowledge and operation of the networks, near real-time, thanks to smarter grids.

A DSO's business model does not lend itself to such an evolution, since it is traditionally based on network infrastructure development and capital investment compensation. How to adapt their business model, in order for them to select[128] the best solutions from the community viewpoint, and not focus on solely on network development and related capital investment? And, more generally, what should be the role of a DSO in the new energy context?

2. These two questions are already being discussed around the world

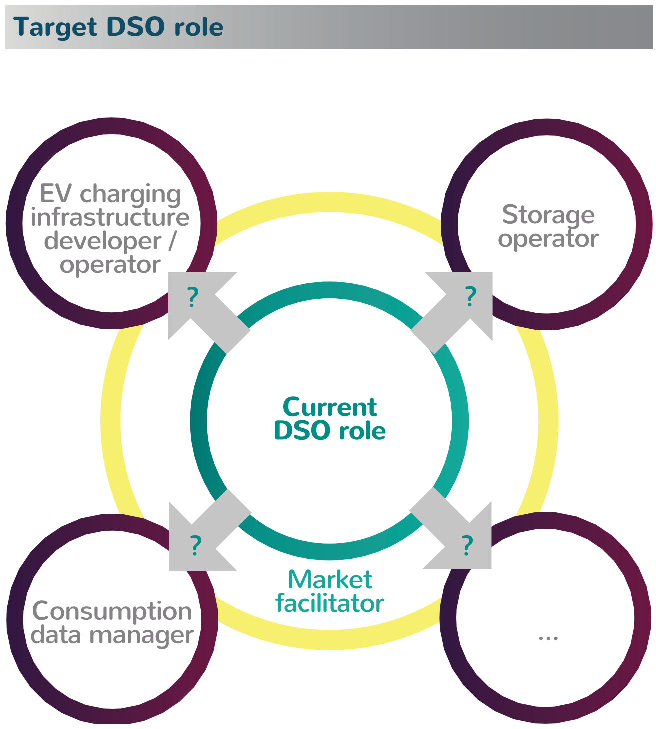
As the European Commission argues, "*regulatory incentives should encourage a network operator to earn revenue in ways that are not linked to additional sales, but are rather based on efficiency gains and lower peak investment needs, i.e., moving from a 'volume-based' business model to a 'quality- and efficiency-based model.'*"[129]

The State of New York has been one of the first jurisdictions in the world to envision the future role of a DSO, described as a 'Distributed System Platform Provider' (DSPP). The DSPP uses its modernised distribution system to create a flexible platform for new

[128] or enable the selection by a third party
[129] European Commission, Smart grids: from innovation to deployment, COM(2011)202, 12 April 2011

energy products and services. It uses markets, tariffs and operational systems to enable behind-the-meter resource providers to monetise products and services. It provides real-time information flows among market participants and supports demand-side markets and technology innovation. It functions as the aggregator of aggregators.[130] The DSO thus becomes a system orchestrator.

Figure 34: Evolution of the current DSO role and associated 'grey areas'



3. The DSO role should be redefined as a market facilitator

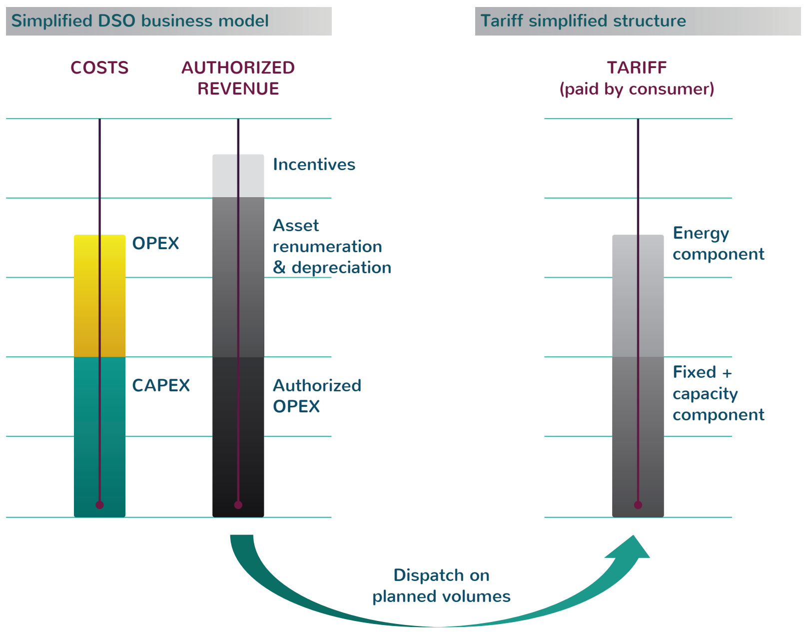
In this way, the target role of DSOs should be redefined. It is admittedly difficult to come to a single European-wide definition. Indeed, the variety of views across Europe for the need to respect unbundling principles and prevent DSOs from running non-regulated business leads to numerous 'grey areas' for DSO activities, with various directions taken by European countries. Examples include electric vehicle charging infrastructure, storage and smart metering data management (see Figure 34). In Ireland, for example, the DSO is allowed to use R&D funds to develop charging infrastructure; in Sweden, the decision has been made

[130] Adapted from NYS department of public service, Reforming the energy vision, CASE 14-M-0101, 24 April 2014

to let this market develop by itself. In the UK, small batteries can be part of the distribution network, whereas in Germany, storage should be a liberalised activity. Nevertheless, DSOs should be considered market facilitators, much as transmission system operators already are. Indeed, they are at the crossroads in terms of the need for and use of flexibility tools, and they should be allowed to play their role in this regard: they should be permitted to co-build flexibility mechanisms and markets so they can understand and anticipate their impacts on the grid.

DSOs should also be incentivised to enable flexibility provision and use by other stakeholders. DSOs themselves may be allowed to use flexibility, for instance by buying it through the market, although the use of such tools should be carefully framed, in order not to jeopardise DSOs' neutrality as market facilitators. This market facilitation role may include working as a data hub (e.g. in Belgium, the DSO is the single data hub for smart metering). Having such a facilitator will participate to acknowledging and developing aggregator business models[131] and fostering demand response development. Aggregators could indeed act as intermediates between producers, consumers and markets, in particular if a more complex version of the tariff structure is to come.

Figure 35: Simplified DSO business model



[131] Aggregators (of generation, consumption and possibly storage) provide flexibility that could be exchanged on markets facilitated by DSOs.

4. DSO business models must evolve to foster flexibility, energy efficiency, and innovation.[132]

A DSO's business model is based on two main dimensions: grid tariff design on the one hand and authorised revenues and associated incentives on the other hand.

First, tariffs are the signals sent to the consumer, producer, or prosumer, and must be refined. As reflected in the vast variety of tariff structures in Europe[133], there is no single response to the tariffs question.

Nevertheless, experts identify possible leads to better leverage this tool as a price-signal. What appears necessary is that there are both capacity and energy components in the tariff structure, with a sufficient weight given to the capacity component[143] that reflects the sizing of the network.[135] Having a sufficient capacity component matches the need from new consumption models such as self-consumption or demand response, and enables the DSO to foster energy-efficient behaviours with a light impact on revenues. Then, more flexibility requires more granularity in the tariffs, both geographically and temporally. From a geographical standpoint, there is a need for more territorially distinguished tariffs. Indeed, on low voltage grids, the peak has a strong local dimension, e.g., on weekends for residential pools. A solution could be to activate a signal integrating a local governance component on medium-voltage and low-voltage grids, without jeopardising the system consistence at a wider scale. In France, a tariff with mobile peak pricing based on a local signal is under discussion.[136] From a temporal standpoint, smart metering capabilities could be leveraged to have more differentiated tariffs at different times of the day. Tariffs should indeed be as time-differentiated as possible to foster energy and system efficiency. In France for example, on top of the "heures pleines – heures creuses"[137] split, a "summer–winter" distinction is being considered. This is possible thanks to the use of the Linky smart meter.

Secondly, another component of the DSO business model relates to the authorised revenue, i.e., the revenue that the regulator allows the operator to collect.[138] Here, the link

[132] Read also Keay-Bright, S. (2016). Electric Cars, the Smart Grid and the Energy Union. Montpelier, VT: The Regulatory Assistance Project. http://www.raponline.org/ document/download/id/8112
[133] Tariff structure is generally based on two major components: one depending on the network capacity (capacity component), and a second related to the energy (throughput) (energy component). E.g., the Netherlands has no energy component for residential customers whereas the UK has a relatively high energy component. A third component often exists, based on fixed costs; but fixed costs do not encourage energy efficiency or flexibility; they should be limited to the incremental costs of a consumer.
[134] This must be carefully designed though. Some designs should be avoided, such as a capacity limit that prevents high consumption in times when renewable energy is in surplus (as is happening in Germany). Also, care should be taken regarding application to small consumers, as many consumers will share the final transformer.
[135] Networks are designed to be able to convey to each consumer the maximal power flow it needs (even though this maximum is only reached a few times a year, because the actual energy consumption varies over time). This maximum is reflected in the capacity component.
[136] TURPE: Tarif d'Utilisation des Réseaux Publics d'Electricité (French power networks tariff)
[137] Equivalent to peak time / off-peak time
[138] Read also Lazar, J. and Gonzalez, W. (2015). Smart Rate Design for a Smart Future. Montpelier, VT: Regulatory Assistance Project. Available at: http://www.raponline.org/document/download/id/7680

between revenues and volume of energy sold needs to be broken, as energy efficiency reduces energy sales. Besides, DSOs must be incentivised to choose the appropriate mix of capital and operating expenditures, as "innovative investment related to smart grids is mostly in services and technology ... [from] operating expenditure rather than capital expenditure."[139] This can be achieved through mechanisms putting revenue caps on 'Totex'[140] , as implemented in Germany and Spain for example. Furthermore, DSOs need incentives to implement innovation, in order not to confine it to the laboratory but rather to take the plunge with implementing change. If possible, these incentives should be separated from main revenues to encourage risk taking. The British regulator, Ofgem, in its RIIO[141] model, is implementing an innovation stimulus composed of three instruments: Network Innovation Competition (to finance 90% of large, innovative, environment-friendly projects), Network Innovation Allowance (finance 90% of small innovative projects), and an Innovation Roll-out Mechanism that adjusts authorised revenue to cover the costs of small environment-friendly projects. Moreover, integrating output-based incentives in authorised revenues encourages the development of certain behaviours by the DSO. This is also applied by Ofgem in its 'Output Incentive', which rewards the DSO if it manages to reach predefined goals.[142]

[139] CEER, The future role of DSOs, 2015
[140] Totex = Capex + Opex. According to CEER, "regulatory schemes that do not differentiate between Capex and Opex, i.e. "Totex" approaches, may be more effective. A Totex approach allows the DSO to adjust investment strategies to the targets specified by the regulators in terms of cost efficiency and outputs."
[141] Revenues = Incentives + Innovation + Outputs
[142] Read also Keay-Bright, S. (2016). Electric Cars, the Smart Grid and the Energy Union. Montpelier, VT: The Regulatory Assistance Project. http://www.raponline.org/ document/download/id/8112

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APPENDIX

Appendix 1: Acknowledgements

I24c wishes to thank all the experts that contributed to the project.

Interviews and workshops were organised to gather essential input to this study. Participants from various sectors and geographies offered valuable insights, feedback and data for this analysis. Many experts from outside i24c provided input, commented on the underlying analytical work and/or reviewed the report. Their comments and suggestions were of great value. They include:

Interviewed experts and business leaders

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Olivier	Baud	EnergyPool
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Richard	Blundell	Rotman School of Management of Toronto
Cedric	Christensen	California Energy Storage Alliance
Gilles	du Crest	Microsoft
Bertrand	Deprez	Schneider Electric
Giles	Dickson	EWEA
Ron	Dizy	MaRS DD
Fabio	Ferrari	Symbio FuelCell
Bertrand	Fillon	CEA
Pierre-Etienne	Franc	Air Liquide
Virginia	Fuller	Enernoc
Jean-Michel	Guéry	Bouygues Energy Services
Jérome	Guillet	Green Giraffe
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Catrin	Jung-Draschil	Vattenfall Wind

Andrei	Klochko	Airthium
Anders	Kofoed-Wiuff	Ea Energy Analyses
Anne	Lange	Mentis
Jakob	Lau Holst	Danish Wind Industry Association
Colette	Lewiner	Capgemini
James P.	Mc Dougall	Younicos
Gustav	Melin	AEBIOM
Arne	Mogren	European Climate Foundation
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Thomas	Sanchez	CDC
Laurent	Schmitt	Alstom/GE
Perry	Stoneman	Capgemini
Frauke	Thies	Smart Energy Demand
Isle	Treurnicht	MaRs DD

Workshop participants

- Workshop 1: "How to scale up cleantech market adoption and value creation for and in Europe", March 15 in Brussels

First name	Surname	Organisation
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Frank	Eulitz	Siemens
Bertrand	Fillon	CEA
Pierre-Etienne	Franc	Air Liquide
Arcadio	Gutiérrez-Zapico	Civil Engineering Foundation; Spanish Energy Club
Marianne	Haug	Oxford University; University of Hohenheim, Stuttgart
Chris	Malins	ICCT
Luis	Munuera	IEA
Martin	Porter	I24c
Christoph	Wolff	European Climate Foundation

- Workshop 2: "How to scale up the deployment of smart and energy efficient initiatives in European urban districts", March 22 in Brussels

First name	Surname	Organisation
Rebecca	Collyer	ECF
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Regis	Hourdouillie	Ericsson
Sarah	Keay Bright	RAP
Anne	Lange	Mentis
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Sami Andoura, Saïd El Khadraoui, Christian Linder, Gerd Schonwalder, Dimitrios Sofianopoulos, Mark van Stiphout, Manuel Szapiro, Piotr Tulej, Philippe Tulkens (European Commission); Sarah Keay-Bright (RAP); Matthias Buck, Barbara Praetorius and Philipp Litz (AgoraEnergiewende); Arne Mogren (Global Utmaning); Manon Dufour and Jonathan Gaventa (E3G); Paul Verhoef (European Space Agency); David Donnerer and Claire Roumet (Energycities).

Reviewers

The authors wish to thank the reviewers for their careful reading and constructive criticism of the text, in particular:
Gustav Melin (AEBIOM / Svebio) on the Topic Box A: Bioenergy, lessons learned from the Swedish experience.

Michael Salomon (Cleanhorizon) and Christoph Wolf (ECF) on the Topic Box E: Lessons learned from Power Storage developments in California and the US East Coast (Pennsylvania, New Jersey, and Maryland).

Sarah Keay-Bright (RAP) for the Topic Box F: Power Distribution: from network operators to system orchestrators.

Survey participants

A two-month online survey was also launched by i24c and Capgemini Consulting in January 2016 with the aim to collect the views of industry experts and business leaders on energy-related innovation in Europe.

73 respondents participated in the survey. Approximately 80% of the respondents are top management executive, from various sectors and organizations, and mainly from Western Europe.

Main sectors represented

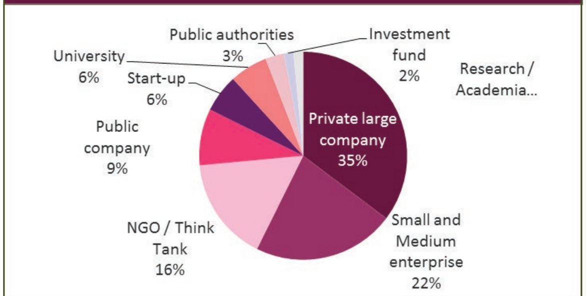
Power industry	Energy Services	Buldings & Construction	IT companies	Oil & Gas	Transports	Others
38 %	15 %	8.5 %	8.5 %	5.6 %	5.6 %	15.5 %

Innovation Areas represented

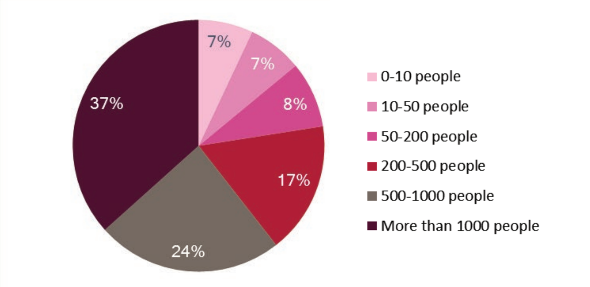
Multisector	Smart Grids Networks	Bulding Energy Efficiency	Solar Photovoltaic	Smart Mobility	Flexibility Demand Response
22 %	13 %	10 %	10 %	8 %	4 %

Others	21%
Energy Storage & Hydrogen	4%
Wind (onshore/offshore)	4%
Carbon capture/storage	1%
Smart cities/Districts	1%
Nuclear	1%

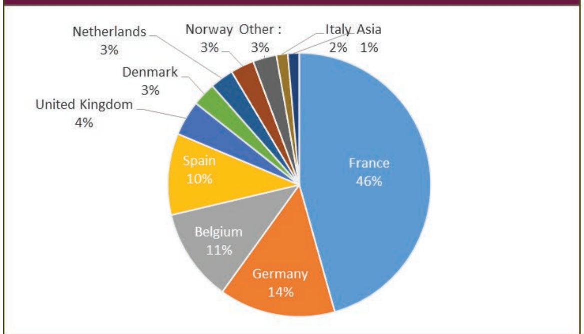
Type of organisation



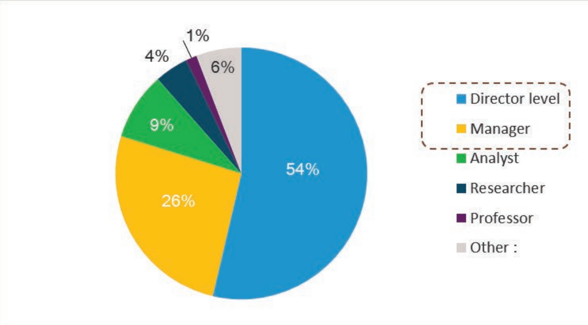
Size of organisation



Country



Participant Profile



APPENDIX 2: FACT & FIGURES FOR SELECTED ENERGY-RELATED INNOVATION AREAS

	Ability to innovate	Ability to support the competitiveness of European industries and to generate value for Europe
Wind Power	TOP 10 inventors (in # of patents)[143] **1. Wobben Aloys (EU)** **2. Vestas Wind Sys AS (EU)** 3. Gen Electric (USA) **4. Repower System AG (EU)** **5. Nordex Energy Gmbh (EU)** **6. Siemens AG (EU)** 7. State Grid Corp China (China) **8. Wobben Properties Gmbh (EU)** 9. Mitsubishi Heavy Ind Ltd (Japan) **10. Repower System SE (EU)**	TOP 5 global champions (2015)[144] 1. Goldwin (China) **2. Vestas (EU)** 3. GE (USA) **4. Siemens (EU)** **5. 5.Gamesa (EU)** Number of jobs linked to wind energy in the world (2013-2014)[145] - World: 1,027,000 1. China: 502,000 **2. Europe: 320,000** 3. USA: 73,000 Installed capacity of renewable energies in key regions, 2013-2014 (MW)[146] (wind onshore) - World: 369,602 (360,841) **1. Europe: 130,594 (122,558)** 2. China: 115,432 (114,763) 3. USA: 64,770 (64,770)
Solar PV	TOP 10 inventors (in # of patents)[147] 1. Canon KK (Japan) **2. CEA (EU)** 3. Du Pont (USA) 4. Sanyo Electric Co (Japan) 5. IBM (USA) 6. Sharp KK (Japan) 7. Gen Electric (USA) **8. Saint Gobain (EU)** 9. Konarka Technologies Inc (Japan) 10. Hitachi Chemical Co Ltd (Japan)	Number of jobs linked to Solar PV energy in the world (2013-2014)[148] - World: 2,495,000 1. China: 1,641,000 2. USA: 174,000 **3. Europe: 164,000** Installed capacity of renewable energies in key regions, 2013-2014 (MW)[149] - World: 175 304 **1. Europe: 88,726** 2. China: 28,050 3. USA: 18,280

Biomass		Number of jobs related to biomass energy in 2013-2014[150] - World: 822,000 **1. Europe: 343,000** 2. China: 241,000 3. USA: 152,000 Installed Power Capacity in 2013-2014 (MW)[151] - World: 80,227 **1. Europe: 24,864** 2. USA: 10,912 3. China: 9,480
Electric vehicles	State R&D Funding for Electric Vehicles (M€)[152] 1. China: 7,684 **2. Germany: 1,025** **3. France: 925** 4. Japan: 171 5. South Korea: 105 6. USA: 47 TOP 5 Ranking of EV Market Penetration worldwide (2014)[153] Country: Number of Ev in 2014 (EV Market Penetration) **1. Norway: 34 814 (13%)** **2. Netherlands: 32 077 (4%)** 3. USA: 289 716 (1.5 %) **4. France: 34 349 (1%)** **5. UK: 11 964 (1%)**	TOP 10 global manufacturers, H1 2015 (in # of EV car sales)[154] 1. Nissan (27,084) 2. Tesla (21,552) 3. BYD (20,409) 4. Mitsubishi (19,393) 5. **VW (15,402)** 6. **BMW (13,127)** 7. **Renault (12,256)** 8. Ford (9,719) 9. Zotye (9,263) 10. Chevrolet (8,192) EV Supply side [155]: **1. Germany** 2. Japan **3. France** 4. USA
Hydrogen mobility	Ratio of patents (rounded)[156] 1. Europe (28%) 2. Japan (22%) 3. China (20%) 4. USA (15%) 5. South Korea (8%) Ratio of R&D expenditure (rounded)[157] 1. Europe (42%) 2. USA (30%) 3. China (21%) 4. Japan (20%)	Models in production in 2015[158]: - Honda FCX Clarity (Japan) - Toyota Mirai (Japan) - Hyundai Tucson Fuel Cell (South Korea)

Carbon capture and storage (CCS)	Top 5 worldwide in CCS terms of patents[159] 1. Alstom Technology Ltd (EU) 2. Calera Corp (USA) 3. Gen Electric (USA) 4. Exxonmobil Res Eng Co (USA) 5. Lanzatech New Zealand (New Zealand) Number of large CCS demo projects[160] - North America: 10 - Europe: 2 - Rest of the world: 3 Number and ratio of patents by country[161] - Europe 19% - USA 21% - China 21% - Japan 10% - South Korea 4%	
Electrochemical Electromechanical Storage	Number of Electrochemical & Electromechanical projects (2015)[162] 1. North America: 432 2. Europe: 200 3. Asia: 163	
Smart Distribution Grids	Overall Investments in Smart Distribution Grids (M€)[163] - USA (2007-2012): 7 347 - China (up to 2010): 6 917 - Europe (up to 2011): 1 734	Smart grid demo projects worldwide[164] 1. Asia (220) 2. Europe (200) 3. USA (130) Average size of demo projects[165] 1. USA 56M€ 2. China: 30 M€ 3. Europe: 8,5 M€

Energy-efficient buildings	Horizon 2020 – Energy Challenge R&D (2014-2020) - 390M€ in Energy Efficiency (17% of the Energy R&D budget)[166]	Employment Factor (labour intensity of energy activities) in Jobs/GWh saved[167] - OECD Europe: 0.23 jobs/GWh net direct - US: 0.17 jobs/GWh net direct and indirect Energy efficiency activity 2010 jobs[168] - By EU28 Member State: 929,000 jobs (including 443,000 jobs energy saving building materials) - - In the US, 2010: 817 080 jobs (including 161,896 jobs energy saving building materials) Global buildings final energy consumption, 118 EJ (2012) (rounded)[169] 1. North America: 21 EJ 2. EU 28: 18 EJ 3. China: 18 EJ
Smart Districts	Top 10 of Sustainable Cities (Environmental indicators-Planet).[170]: 1. Frankfurt (EU) 2. Berlin (EU) 3. Copenhagen (EU) 4. Madrid (EU) 5. Rotterdam (EU) 6. Amsterdam (EU) 7. Singapore (Asia) 8. Rome (EU) 9. Toronto (North America) 10. Birmingham (EU) Horizon 2020 – Energy Challenge R&D (2014-2020) - 332M€ in Energy Efficiency (14% of the Energy R&D budget)[171]	

[143] Insight-E (2015) Exploring the strengths and weaknesses of European innovation capacity within the Strategic Energy Technologies (SET) Plan
[144] Bloomberg (2015) China's Goldwind Knocks GE From Top Wind Market Spot
[145] IRENA (2015) Renewable Energy and Jobs, Annual Review 2015
[146] IRENA (2015) Renewable Energy and Jobs, Annual Review 2015
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[148] IRENA (2015) Renewable Energy and Jobs, Annual Review 2015
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[150] IRENA (2015) Renewable Energy and Jobs, Annual Review 2015
[151] IRENA (2015) Renewable Energy and Jobs, Annual Review 2015
[152] Roland Berger Study E-mobility Index 1st Quarter 2015
[153] IEA, 2015
[154] IEA, 2015
[155] Electric Vehicle Index' plots import/export data and sales figures from the world's largest automotive economies and generates a ranking of 'importance'. McKinsey Consulting, Ecomento
[156] Insight-E (2015) Exploring the strengths and weaknesses of European innovation capacity within the Strategic Energy Technologies (SET) Plan
[157] Insight-E (2015) Exploring the strengths and weaknesses of European innovation capacity within the Strategic Energy Technologies (SET) Plan
[158] McKinsey Study Electric vehicles in Europe: gearing up for a new phase?
[159] Insight-E (2015) Exploring the strengths and weaknesses of European innovation capacity within the Strategic Energy Technologies (SET) Plan
[160] Global CCS Institute 2015
[161] Insight-E (2015) Exploring the strengths and weaknesses of European innovation capacity within the Strategic Energy Technologies (SET) Plan
[162] Energy Storage Exchange (2016)
[163] GSGF 2012, IEA 2011, JRC 2011, smart grid.gov 2012, SGclearinghouse 2012,UFE 2010, Zpryme 2010, Zpryme 2011a, Zpryme 2012a, Zpryme 2012b and CC analysis
[164] GSGF 2012, IEA 2011, JRC 2011, smart grid.gov 2012, SGclearinghouse 2012,UFE 2010, Zpryme 2010, Zpryme 2011a, Zpryme 2012a, Zpryme 2012b and CC analysis
[165] GSGF 2012, IEA 2011, JRC 2011, smart grid.gov 2012, SGclearinghouse 2012,UFE 2010, Zpryme 2010, Zpryme 2011a, Zpryme 2012a, Zpryme 2012b and CC analysis
[166] Horizon 2020
[167]Assessing the Employment and Social Impact of Energy Efficiency, Cambridge Econometrics
[168]Assessing the Employment and Social Impact of Energy Efficiency, Cambridge Econometrics
[169] IEA (2015) Building Energy Use in China Transforming Construction and Influencing Consumption to 2050
[170] Arcadis (2015) Sustainable Cities Index 2015
[171] Horizon 2020

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