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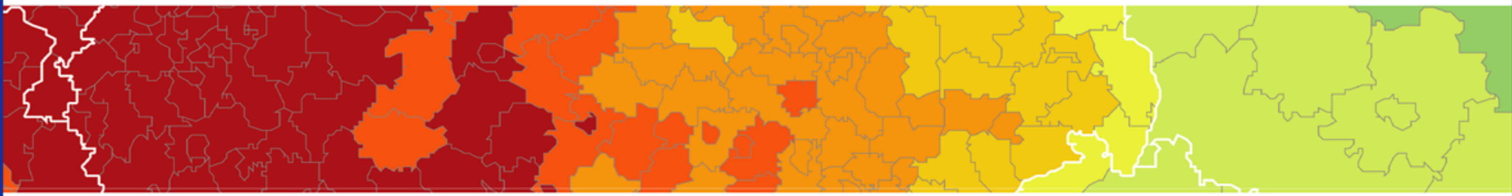
Inspire policy making by territorial evidence



Possible European Territorial Futures

Applied Research

Final Report
Volume E – 100% Renewable Energy

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Abbreviations

EC	European Commission
ESPON	European Territorial Observatory Network
EU	European Union
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GVA	Gross value added
NUTS	Nomenclature of Territorial Units for Statistics
PHP	Pumped hydroelectric storage
RES	Renewable energy source
SME	Small and medium-sized enterprise
UK	United Kingdom

1 Introduction

This report provides background information and nuanced considerations concerning territorial foresight for a European energy system that is fully based on renewables presented in Volume A of the Draft Final Report.

Following conceptual clarification in this chapter and an exploration of the narrative of the topic as defined by ESPON, chapter 2 summarises what the European territory would look like if it's energy system was based on a 100% renewables and what the effects on European territorial cohesion would be. It also includes reflections on how much this would support the territorial scenarios developed in the earlier ET2050 project.

Based on literature studies, two online surveys, two dedicated focus groups and one webinar, three main components have been identified to help understand the territorial dimension of a fully renewable European energy system. These are (a) regional renewable energy production and renewable energy potential, (b) regional energy consumption, and (c) regional transport and mobility patterns. These will be discussed in chapters 3 to 5. Building on document studies and the second focus group, key factors in each of the three components have been identified to illustrate the territorial dimension. The tools to evaluate exposure and sensitivity of regions to change (see the textbox below), developed within the ESPON territorial impact assessment, have been applied. Examples of possible future technologies and solutions are meant to illustrate the report and give a glimpse into the possible future energy generation.

Chapter 6 highlights that a European future supply that fully relies on renewable energy may look very different, depending on which component is put at the forefront. This is illustrated with the help of two scenarios.

Finally, chapter 7 sums up the results of the report and provides pointers for policy development.

- **Exposure**: taking the components of a fully renewable energy system as starting point, exposure is determined by asking the question: To what degree is a region/territory likely to be (positively or negatively) affected by the change?
- **Sensitivity** taking regional characteristics as starting point, sensitivity is determined by asking the question: To what degree will regional development be affected? What is the intensity of impacts due to specific characteristics?

2 The fully renewable energy future we wake up in

This chapter provides a summary of the territorial patterns of a transformation of the energy system to one that is fully based on renewables. Chapters 3 to 5 break down the territorial dimension into three main components – regional energy production and renewable energy potentials, regional energy consumption and regional transport and mobility patterns– by discussing their territorial exposures and sensitivities.

The assumption is that in the 2030s, Europe would have completed the transition to a fully renewable energy system. All primary energy production in Europe would come from renewable energy sources (sun, wind, flowing water, biological processes or geothermal heat flows) and the total energy consumed in Europe (private households, economic activity, including agriculture, forestry, fisheries, etc., and transport systems) will be renewable. Europe would increase its share of gross final energy consumption met with energy produced from renewable sources by a factor 6 within only 15 to 20 years. For this to be achieved, especially in view of the short time frame, signification changes on both the demand and supply-side of the current energy system would be required. This would have numerous (territorial) impacts.

Europe would not be a closed system, but there would be trade in renewable energy as well as imports of “grey fossil energy”, fossil energy embodied in imported manufactured goods and services. However, measures would be taken to achieve protection of the competitiveness of the (energy-intense) European economy, with a border tax adjustment on energy imports, including grey energy (to the extent possible under GATT).

Since all regions would have completed the transition to 100% renewable energy in the 2030s (at varying cost), it is assumed that across Europe policies incentivise energy saving and the deployment of additional renewable energy production capacities as well as better management of energy demand, inter alia, through dynamic pricing of electricity based on real time demand and supply, the abolition of direct and indirect subsidies on fossil fuels and renewables, the introduction of ecological tax and further integration of the European electricity market.

There is not expected to be any major change in the general framework conditions, but rather a continuation of current trends for the geopolitical situation, global/ European economic development, Europe’s demographic development (including immigration), and global climate policies.

2.1 Renewable energy generation

To keep up with energy demand in Europe, renewable energy production have to be further expanded across Europe, according to each region’s specific potential. The prevailing renewable energy technologies in Europe would be wind and solar (for power and heat production). But other technologies would also have a share of production in suitable locations. Hydropower would still be important, but there would be limited possibilities for additional capacity. Some hydropower plants would be built in areas with large untapped potential and inefficient small hydropower stations would be upgraded across Europe. Biofuels have been met with criticism due to their competition with food production and impact on water, other resources and biodiversity. They also play a dubious role regarding carbon balance, however they would play an important role in transport. Biomass for power production would largely disappear due to the low energy yield and, where possible, bioenergy, such as biogas would be produced from waste organic matter (manure, organic waste from households/ agriculture/ industry). For small-scale applications such as domestic heating and medium-size applications such as district heating systems, wood would continue to play an important role, in particular in densely wooded areas. The prevailing form of energy would be electricity and solid fuels (e.g. wood), gaseous fuels (e.g. biogas or compressed hydrogen) and liquid fuels (e.g. liquid hydrogen) would play a much smaller role.

The future energy supply has the potential to be much more decentralised and democratic, allowing citizens to have a direct stake in the transition to a cleaner energy supply through ownership of renewable energy installations, either private RES installations (e.g. through heat pumps, photovoltaic panels and solar thermal panels, biomass heating) on their property or by owning shares of energy cooperatives. Also district heating/ cooling solutions will be deployed widely. Nevertheless, for a full and seamless supply of renewable energy, large-scale generation facilities are still needed to ensure energy security as far as possible. The potential for individual and cooperative energy production as share of total renewable energy is below 10%, taking current shares as a baseline (Kampman et al., 2016).

Land availability would be a major limiting factor to renewable energy production, which is 10-1000 times more land-intense than energy production from fossil sources depending on the technology and local conditions[1]. While wind farms are partially compatible with other uses such as agriculture, or can be located offshore, biomass plantations, hydroelectric reservoirs and solar farms do not to allow double use, so in practice they monopolise the occupied (agricultural) land (Perrotti, 2015; Prados, 2010). This is further aggravated by the fact that an overcapacity of RES installations would be needed to ensure a permanent secure supply (Capellán-Pérez et al., 2017).

Overall, it is assumed that the supply with renewable energy would rely on existing technology, which would be improved, with more efficiency and much lower investment costs.

2.2 Reduction in energy consumption

Existing RES potential in Europe, even though not equally distributed, is deemed sufficient to keep up with demand when assuming a 100% RES supply and consumption, provided current consumption levels are reduced drastically. The reduction in energy consumption would be achieved through a mix of right policies and incentives, but mainly as a result of

[1] This assumption holds only true if the quarrying and surface extraction of coal and uranium are not considered. In the case of uranium, which is quarried mostly outside Europe

raising costs for energy, which should rise in the short and medium-term. High energy prices result mainly from the high cost of investments needed to install additional RES capacity in a very short time (15-20 years)[2]. In the long-run, however, if all direct and indirect subsidies for fossil fuels are abolished, energy prices will fall again as investments amortise. Since the production of wind and solar energy will be fully competitive, subsidies will be abolished.

There should be a significant reduction in energy consumption for industrial processes, buildings, households and transport. Industry, especially when energy makes up a significant proportion of production costs, would have put great efforts into optimising their processes to become more efficient and remain competitive. Energy-efficiency technologies would spread much quicker than today. Some of the most energy-intense sectors, such as steel and aluminium, cement and ceramics would, however, would lose competitiveness and are likely to move production to non-European countries–at least in the medium-term. The energy consumption of private households would also have to decrease significantly. On the one hand, rising energy costs would force people into using energy more carefully and would boost the purchase of energy-efficient appliances. On the other hand, a change in consumer habits would also be facilitated by making energy consumption more transparent and controllable, including through the use of smart meters and smart grids. However, part of the efficiency gain from using more efficient appliances would be eaten up by more energy-consuming activities and devices ("Jevons paradox" or "rebound effect"). New buildings would essentially be zero energy or even energy positive, however, they account for only a small proportion of the building stock. The rate existing building stock is retrofitted (currently 1%) would have to increase steeply, however, the demand for living space per capita would continue to increase, which would limit the reduction energy use in buildings.

The most dramatic change would have happened in transportation, where renewables currently account for only 1-10% of the energy used. There is an enormous investment backlog together with a lack of marketable technological innovation. Different transportation modes would face different adaptation challenges. Regarding motorised private transport, by 2030, vehicles with combustion engines would have been partly replaced by vehicles with alternative propulsion engines. Electric engines would be the dominating vehicle propulsion technology, while biofuels (biogas, bioethanol) would largely disappear for private motorised vehicles. Overall, public transportation would have a higher modal share than at present, especially in densely populated areas. Furthermore, flexible, on-demand mobility services (car sharing schemes, self-driving cars, etc.) would gain importance while private car ownership would decline, accompanied by a clear increase in bike or e-bike trips and walking.

For road freight, light vehicles would also change to electricity. Since existing battery densities are unsuitable for longer distances and heavy-duty road vehicles, biofuels and biogas would

[2] In the long-run, however, assuming that all (direct and indirect) subsidies for fossil fuels are abolished, energy prices will fall again once investments are starting to amortise.

be the only realistic options for these in the medium term. In the more distant future, hydrogen could become an alternative. The same is true for inland and maritime shipping, where, in the 2030s, biofuels and biogas would be the only feasible renewable alternative to heavy fuel oil currently used in shipping.

Railways would see a further wave of electrification and would have experienced a true renaissance, in particular for long-distance transport. The network of high-speed railway lines in Europe would be extended where possible, although by the 2030s there would not be enough time to considerably extend the network. Parts of the European rail network are already congested limiting the extent to which traffic can be shifted from road to rail.

Aviation would be faced with a huge challenge to adapt to the new situation and would, in the short and medium-term see drastic cost increases. Therefore, airlines would lose nearly all market share to other means of transport within Europe. Whether the future of aircraft propulsion would be electric, biofuels or hydrogen remains to be seen. Due to a steep cost increase for long-distance travel, at least temporarily, the amount of long-distance travel would plummet.

Overall, efficiency gains would be achieved both through a forced change in consumption patterns because of increased energy and mobility costs and through technological developments. Advances in energy-efficiency technology would play an important role in all spheres of life (housing, work, leisure, supply, education, transport and communication), however it is assumed that no new disruptive innovation would revolutionise our energy use.

2.3 Improved demand and supply management

One of the challenges of fully renewable energy systems is the intermittence of electricity production from sun and wind, so the variability of power output due to variations in production conditions. Europe's grid, in particular the Trans-European Electricity Network, would be further expanded and reinforced and would improve the balance of supply and demand. Currently, this process of interconnecting Europe's electricity grid is very slow and the current minimum interconnection target for 2030 is 15% of installed electricity production capacity, which is well below what the requirement to balance supply and demand at the European level (Wagner, 2014).

Smart grids would also make it possible to more accurately price and value distributed renewable energy production with the potential of turning energy consumers into potential suppliers and temporarily storing excess energy including in the batteries of electric cars. This would lead to a decrease in energy consumption[3]. In addition to reinforcing the European grid, many locations may have microgrids, that disconnect from the main grid for a period of time and operate autonomously from internal power sources. Furthermore, due to the

[3] The European Commission (2011) estimates that smart grids could reduce the annual primary energy consumption of the EU energy sector by almost 9% by 2020.

considerable variability in power output and the intermittence of many RES technologies, substantial redundant generation capacity would be needed as back-up and additional energy storage capacity, so existing technological solutions would be developed further and more widely deployed.

2.4 Summary of territorial impacts

Key aspects which imply changing territorial patterns and indications of how the patterns may differ in a fully renewable energy system are:

Regional **renewable energy production capacities** would have to be increased in all regions across Europe, but not all regions would have to undertake the same effort and not all regions would have the same possibilities as they have different starting positions regarding:

- regional and local RES potential, which determines how much renewable energy a region can produce domestically to meet its demand;
- regional energy self-sufficiency, so how much energy demand is met with endogenous energy sources and how much of these are renewable;
- existing energy production, distribution and storage infrastructure, and hence the need for additional capacity or replace existing infrastructure that becomes obsolete.

Wind power would be one of the cornerstones of Europe's energy supply. Areas with high potential and with significant installed onshore and offshore wind power capacity can be found around the North Sea; most notably in the UK and Ireland, Belgium and the Netherlands, Germany's North Sea coastal areas and Denmark as well as large parts of the Iberian Peninsula and the south of Italy. Regions with low techno-sustainable wind power potential and little installed wind power capacity are in the Alpine region and the foothills of the Alps (e.g. Northern Italy and large parts of Slovenia), Slovakia, Croatia and Hungary and large parts of Southeast Europe.

Solar power would gain in importance as a renewable energy source, mainly because of its high power density and potential. Regions with the highest unexploited techno-sustainable solar potential (in particular, with available land) and considerable installed capacity are in central Spain and, to a lesser extent due to land use constraints, the southern coastal regions of Spain, Italy, including the Italian islands Sicily and Sardinia and southwestern France. Regions with low techno-sustainable solar power potential and no significant installed capacity are in Scandinavia, most parts of the British Isles (except for the most south-western parts) and Poland.

While bioelectricity production would not be developed further, biofuels and biogas, in particular from non-food feedstocks, would play an important role as transport fuels. Areas with high bioenergy potential and significant production capacities are in France, Germany, Poland, Sweden, Finland, and Spain. Bulgaria, Greece, Cyprus, Croatia and Slovenia, the BENELUX, Denmark as well as Portugal and Ireland have low potential and low production of bioenergy.

Geothermal power would continue to play a minor role in Europe's energy supply, with the exception of Iceland. Areas with a high geothermal energy potential for geothermal district heating and significant installations are in Iceland, Italy (mainly Tuscany), France (the Paris Basin and the Aquitaine Basin in the southwest) and Eastern Hungary and selected regions in Germany. Heat stored in the ground would be harnessed by ground-source heat pumps all across Europe, but especially in moderate or cooler climates, whereas in warm climates air-source heat pumps would be more commonly installed.

Hydropower will continue to be important, especially for pumped storage. It currently accounts for around 15% of power generating capacity in Europe. However, areas with high and as yet unexploited potential for hydropower generation would experience conflicts between biodiversity protection and energy production. Areas with a high share of hydropower generation and high potential for further exploitation are in the Alps and Scandinavia, but also in South-West Oltenia in Romania. Regions with high potential, but a lower level of exploitation are in south-eastern Europe. For wave and tidal power, areas with a high potential and installed capacities coincide. These are Scottish coastal areas and the French Atlantic coast.

Regions that rely heavily on fossil or nuclear-based energy and/or have significant extraction of fossil fuels will feel the transformation strongly, especially if a significant share of the workforce is employed in mining and quarrying energy producing materials. For oil and gas, these are the coastal regions of Norway (in particular, Agder and Rogaland region and Vestlandet) and North-Eastern Scotland (UK). For coal, these are Slaskie, Silesia, Opolskie (Poland), Severozápad (Czech Republic), the Carpathian-Balkanian Basin (Bulgaria and Romania) and North-Eastern Scotland (UK).

The energy system transformation will require huge investments into Europe's energy infrastructure, which regions with low economic performance will find harder to mobilise. In particular, the energy grid would have to be expanded and reinforced and become smarter to better match supply and demand. Additional storage capacity is also needed. Furthermore, obsolete fossil-fuel and nuclear power infrastructure and production sites would have to be managed. All of this would require the huge investment, which regions with a limited economic performance would find hard to mobilise. Regions that are primarily affected by the need to extend their grid infrastructure, but which would find it hard to finance the necessary investment are two of the "electric peninsulas" in Europe. The Baltic States need to interconnect Finland, Sweden and Poland and reinforce the Polish internal grid and interconnections east and westward. The other is the Iberian Peninsula, where Spain and Portugal need to interconnect with each other and South Western Europe, in particular with France, to accommodate wind, hydro and solar. Furthermore, Central Eastern and South-Eastern Europe would need to reinforce the regional network for North-South and East-West power flows. Regions with a potential for additional pumped hydroelectrical storage are in mountainous regions with sufficient water; the Alps, Pyrenees, Scandes, the Scottish

Highlands and the Balkan Mountains and Rhodopes (Bulgaria). These would experience huge pressure on the remaining intact water ecosystems.

Europe's energy consumption would have to decrease substantially to ensure that all European energy demand (for economic activity, transport and households) can be met by renewable energy.

Regions with a high per capita household energy consumption, in connection with low household disposable income, especially regions where households have to spend a significant amount of their income on energy, would be particularly vulnerable to energy price increases. The most vulnerable regions, due to high energy consumption for heating and electrical appliances and a high share of the population at risk of poverty are in Estonia and Latvia. Areas least affected are the Netherlands, northern and north-western France, some parts of Spain (Basque country, Navarra, Aragon, Cataluña) as they have low household energy demand, high GDP and a low share of the population at risk of poverty.

Regions with a highly energy-intense economy (mostly regions with significant manufacturing) would have to undergo major efficiency improvements and would face a loss of competitiveness and, ultimately, jobs. Most vulnerable economies are in old industrial regions with outdated industrial infrastructure. These are in Eastern Europe (the Czech Republic, Slovakia, Romania, Bulgaria, Poland, Hungary and Estonia). Somewhat less, but still heavily affected are Latvia, Lithuania and Slovenia, but also Finland. Areas with limited value added and employment in manufacturing and low energy-intensity are in Norway, Greece, Luxembourg, Malta, Cyprus, the British Isles and the Netherlands.

To curb the energy use per person-kilometre or tonne-kilometre for transport, the share of public transport would have to increase at the expense of private transport. Regions that already have an above average share of public transport and rail freight would be in a favourable position to transition to a stronger use of public transport and enhanced rail for freight and long-distance passenger transport. Since transport is also an important industry, which, in some regions, accounts for more than 15% of the regional GVA and employment, those regions would be heavily affected by the enormous change that the sector would undergo. Among the most vulnerable regions with a currently low share of public transport, high share of road freight transport and a high share of GVA generated in the transport sector are Norway (with the exception of Agder and Rogaland), the German regions of Cologne and Darmstadt, but also the greater London area and Highlands and Islands (UK), Latium and Campania, as well as the islands of Sardinia and Sicily (Italy) and the Northeast and West of Poland and the Warsaw region.

Under a fully renewable energy supply and consumption, transport costs would increase steeply, which would heavily impact current **transport and mobility patterns**.

Remote regions will experience a substantial loss in accessibility and, hence, attractiveness as places to live and do business. But also regions with strongly transport-dependent economies, that is in particular regions living on tourism, but also regions with an airport or port hub function and related logistics industry will be particularly negatively impacted. The most highly exposed regions are Mediterranean coastal areas in the Iberian Peninsula, Highlands and Islands (Scotland), Central Macedonia (Greece) and the Bulgarian Black Sea coastal region as well as Mediterranean islands. These regions have limited accessibility by rail and road, but are highly dependent on tourism and a number of ports.

Some regions would lose their transport hub function and the GVA (and employment) generated from it. The most highly exposed regions are coastal areas in the western part of the Iberian Peninsula and the most eastern and south-eastern parts of Europe as well as smaller islands, as these regions have low accessibility by rail and road, but high dependence on coastal tourism and a number of important ports. Regions in the core of Europe (most parts of Germany, Austria and Switzerland, north-eastern France and Northern Italy), with high accessibility and no major transport hubs would experience the least pressure to adapt.

2.5 Impact on territorial cohesion

Taking all these points together, the transition to a fully renewable European energy system implies dramatic changes for all parts of Europe. However, not all regions would be equally affected. Different energy systems as well as different socio-economic conditions influence the challenges they face in moving to a fully renewable energy system. How positive or negative the impact will be in a region or specific location also depends on how well the region manages the transition and takes advantage of the changes. For territorial cohesion in Europe, the factors that determine the exposure and sensitivity of regions in moving to a fully renewable European energy system often work in opposite directions. While some can reduce disparities in Europe, others are likely to reinforce them.

The most important pointers towards greater or less territorial cohesion under a fully renewable European energy system are:

- The enhanced exploitation of renewable energy potential generally implies **better use of endogenous, place-based development potential**. Biophysical renewable energy potential is, however, not equally distributed across Europe. Some regions have more renewable energy sources than others, often as a result of specific geographical and climatic features. However, since renewable energy generation generally requires significantly larger areas for producing the same amount of energy as comparable conventional fossil or nuclear power plants, rural areas with a low population density would be at an advantage. Densely populated areas, especially urban and metropolitan regions, but also many of the densely populated coastal areas in Europe, and areas where arable land is limited due to topography would most likely see increasing tensions over conflicting land uses.
- Regions with high renewable energy potential and sufficient available land may produce a surplus and become energy exporters. This could particularly **benefit small rural economies**. However, since much of the renewable energy would be generated in the

form of electricity, proximity to large power load centres (i.e. centres of consumption) is important to minimise distribution losses. That might **hamper the prospect for remote rural regions to export surplus electricity**.

- In general, **highly urbanised regions would shift their energy dependence from the global to the (extended domestic) rural hinterland for satisfying their energy needs.** This may either strengthen cooperation between cities and their rural hinterland or increase the dominance of cities over their hinterland.
- If all of Europe's energy demand and supply is to be met by renewable energy, investments in energy infrastructure, i.e. energy production, transformation, storage and distribution infrastructure, would have to be ramped up. The ability to finance investments in additional energy production capacities and energy infrastructure and, hence, regional value creation, is linked to a region's economic performance and wealth. In other words, in the new situation, **current economic disparities in Europe may persist**. However, even though all European regions would require additional investment in energy infrastructure, those that can already cover a significant share of their final energy demand with domestic renewable energy resources would find it easier to finance additional investment and retain value creation in the region. For example, the Baltic States that already meet 24-39% of their gross domestic energy consumption with renewable energy would be in a much better situation than say Hungary, which has a much lower RES share (9.5%), but similar GDP per capita.
- What might also persist under the new situation is the **concentration of population, infrastructure and industry in and around Europe's metropolises** and in the urban corridor stretching from Northern Italy to Northwest England, **the so-called "blue banana"**. These have the highest net transfer capacity levels and highest grid densities as well as the best infrastructure connections and they generally have the highest (green) economic and innovation performance (**together with the north of Germany, Denmark and Southern Scandinavia**). This performance would provide them with new economic opportunities in the development of energy-efficient technology and appliances.
- Regions in which households have a **high disposable income** can afford to buy more energy-efficient appliances and, hence, would be able to maintain a similar lifestyle under the new circumstances. However, many of these regions have the highest per capita energy consumption, thus they would be faced with considerable pressure to change their current lifestyle. This forced adaptation may be seen as a substantial loss in quality of life and meet strong public resentment. On the other hand, rising energy costs may **throw a large part of the population in less developed regions into energy poverty**, especially in central and northern Europe where heating demand in winter is high.
- The future **energy supply has the potential to be much more decentralised and more democratic**, allowing citizens to have a direct stake in the transition to a cleaner

energy supply. This can be through ownership of renewable energy installations, either by private RES installations on their property or through shares of energy cooperatives. Energy self-production would, however, mainly benefit house owners outside central-city locations as there is limited available space and too much shade in urban areas.

- On the other hand, **cities and densely populated areas would gain from having the critical mass needed to provide accessible and high-quality public services** (e.g. district heating solutions and public transportation). This would help decarbonise utilities and maintain a high quality of life. Flexible, on-demand mobility services such as car sharing schemes and self-driving cars, can also be more easily implemented in densely populated areas. Even though individual passenger transport would still play a role (i.e. electric or hydrogen cars and motorbikes), cost increases would enhance the shift to shared modes of transport also in rural areas, but they would be much cheaper to implement in areas with a large population pool.
- Since air transport would nearly disappear and, where possible, be replaced by trains and most (heavy) freight transport would be shifted from road to rail (and partly to ship), regions and cities with good accessibility by rail and a dense rail network would be in a favourable position and would attract businesses and people. Overall, there would be a reinforced **tendency for people, particularly of working age, and businesses to move to highly urbanised, well-connected parts of Europe** in the centre of the continent and around major urban centres.
- Peripheral areas, far from bigger centres, would be greatly disadvantaged by the increased cost of transportation. The current **trend of aging and depopulation in less accessible regions may accelerate**. Regions whose economies are strongly transport-dependent, e.g. remote tourism regions would also be heavily affected.
- However, **central locations would also be affected if they have an important airport or port hub function and a related logistics industry** around it. Since the transport sector is an important industry in Europe, accounting for more than 15% of GVA and employment in some regions, these regions would see parts of their economic base erode as the European transport sector undergoes a complete restructuring and freight transport decreases significantly due to the steep increase in transport costs. Strongly affected regions are European capital regions such as greater London, Paris, Brussels, Athens, Bratislava, Warsaw and Prague regions, but also other regions that have an important transport industry.
- In general, Europe's trade structure would be shaken as freight transport becomes much more expensive and air transport uneconomical. The transport sector would react both by exchanging the old fleet with electric trucks and much more energy-efficient trucks/ships powered by biofuels and by shifting from road to rail. Producers would reduce the weight of transported goods, where possible. There would be more local suppliers and fewer intermediaries, production plants, especially new additive manufacturing facilities would be moved closer to end customers and, ultimately, the

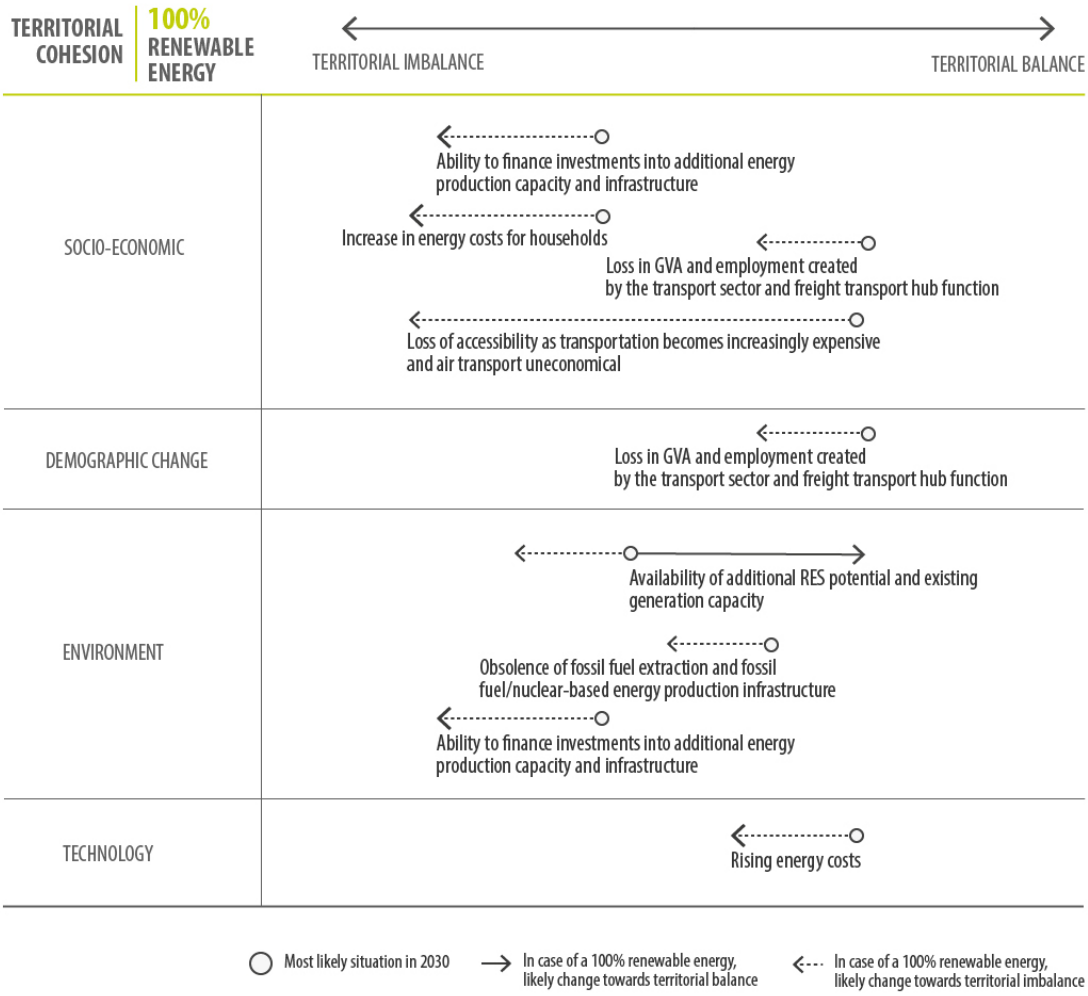
demand for certain products would decrease and transport volumes decrease significantly. Exactly how the new origin-destination pattern of goods flows would affect each region is hard to predict, but in all probability, **regions that are far from major centres of production would be heavily affected**.

- Also affected would be regions with heavy and energy-intense industries as the most energy-intense sectors (e.g. steel and aluminium, cement and ceramics) are likely to lose competitiveness and move production to non-European countries, at least in the medium-term. Some old industrial regions in Eastern Europe have not yet completed the process of industrial restructuring and modernisation, **reinforcing Europe’s east-west divide**. Often these are also regions with a significant production of fossil based energy and industries related to this (e.g. refineries, coal mines, gas/ oil extraction, major hubs for energy imports).

To conclude, since the magnitude of territorial impacts is subject to uncertainty, it is also unclear whether greater cohesion would prevail over greater disparities. While the focus on energy production from endogenous renewable sources is likely to strengthen rural and peripheral areas, the radical changes in transport and mobility would clearly have a negative impact on those areas, and would reinforce urbanisation and centralisation tendencies.

To stimulate further thinking, the below figure presents an attempt to summarise in what way a fully renewable energy might change the expected territorial outlook presented in Volume B. The figure illustrates the results with regard to the single factors used in the analysis and main topics for describing the current territorial situation of Europe and future outlook presented (see volume B). The arrows indicate whether a fully renewable energy is expected to give a push towards more territorial imbalance or balance at European level.

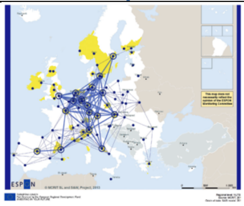
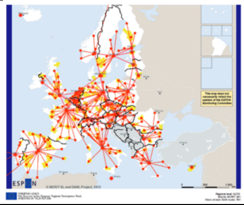
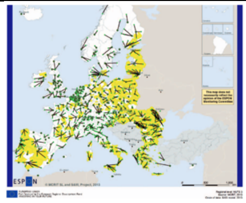
Figure 2.1 Fully renewable energy impacting on tomorrow's territorial patterns



Source: ESPON Futures project team

Another way of looking at territorial cohesion has been proposed by the ESPON ET2050 project, which essentially defines three policy scenarios. These scenarios focus on polycentricity at three different geographic scales based on networks of (a) major global or European metropolis, (b) urban areas of national or transnational importance, so-called secondary cities, and (c) cities of regional importance. The following table summarises impacts on large metropoles, secondary cities as well as rural and less developed regions.

Table 2.1 Impact on global metropolitan areas, cities and regions

	Focus on large metropoles	Focus on secondary city networks	Focus on small cities and less developed regions
			
Regional renewable energy potential and existing production capacities			
Availability of additional RES potential and existing generation capacity	↓↓ Lack of available land for RES generation in cities and potential land use conflicts in densely populated areas	O No specific impact	↑↑ Better use of endo-genous development potential, especially in rural and coastal areas with available land
Ability to finance investments into additional energy production capacity and infrastructure	↑↑ If the transition is financed largely by large utility companies and multinationals	↑ If the transition is financed largely by national and regional (public) utility companies	↑↑ If the transition is largely financed by citizens and citizen cooperatives
Obsolescence of fossil fuel extraction and fossil fuel/ nuclear-based energy production	O No specific impact	↓* Need to manage obsolete infrastructure *only in selected regions	↓ Loss in GVA and employment related to the extraction of energy material *only in selected regions
Need for additional energy infrastructure investment	↑ Highest grid densities and net transfer capacities	O No specific impact	↑ Possibility to become autarkic and indepen-dent from national grid. *Also possible lack of inter-connecting grid to export surplus renewable electricity
Regional energy consumption			
Increase in energy costs for households	↑↑ Large cities and densely populated areas will gain from having the critical mass needed to provide accessible and high-quality public services	↑ Medium-size cities will also gain, although to a lesser extent	↓↓ Remote rural areas may experience accelerated emigration
Loss of accessibility as transportation becomes expensive and air transport uneconomical	↑↑ Major urban centres with good rail connections will attract businesses and people	↑ Regional centres with good accessibility will experience a further inflow of people at the expense of the rural hinterland	↓↓ Regions that are far from major production centres will become increasingly inaccessible
Regional transport and mobility patterns			
Loss in GVA and employment created by the transport sector and freight transport hub function	↓↓ Major urban centres with an important airport or port hub function and related logistics industry	↓ Regional centres will only be affected if they have an important transport industry	↓ Rural area will only be affected if they have an important transport industry

↑↑ Strong developments in support of scenario
↑ Development in support of scenario
O Neutral with regard to this scenario
↓ Developments counteracting scenario
↓↓ Strong developments counteracting scenario

3 Component – Regional energy production and renewable energy potential

Regions have different starting points regarding:

- regional/ local RES potential, which determines how much renewable energy a region can produce to meet its demand;
- domestic energy production, i.e. how much energy demand is currently met with endogenous energy sources and how much of these are renewable;
- existing energy infrastructure for production, distribution and storage, and hence the need to either increase capacity or deal with existing infrastructure that becomes obsolete.

3.1 Why this component is important

In transitioning to a 100% renewable energy system, all regions will have to deploy additional RES capacity, however, not all regions have the same potential. Regional renewable energy potential is strongly based on biophysical conditions such as local wind speeds, solar irradiation and geothermal heat gradients. There are several limits to exploiting the full existing biophysical potential. These include the degree to which exploitation is technically feasible and cost-effective with existing RES technology (given a region's topography and remoteness), the level of social acceptance of increased RES production in the region and its competition with other land uses. This is expressed as the techno-sustainable potential.

Renewable energy production generally requires larger areas for producing the same amount of energy as a comparable caloric power plants and therefore land use conflicts are highly likely, particularly in densely populated (i.e. urbanised) areas, as well as areas where arable land is limited, such as mountainous areas. Regions with high techno-sustainable RES potential may produce surplus of renewable energy and become energy exporters, which means the creation of a new economic base and additional jobs.

Already today, regions make use of their renewable energy potential, albeit to varying degrees. Regions with a high share of renewable energy production, in particular in relation to regional demand, will find themselves in a better position than regions with a low share of domestic renewable energy production. The latter will have to mobilise huge investments in a short time or become increasingly dependent on imports from other regions (within or outside Europe).

Regions with a significant production of fossil (coal, oil, natural gas) or nuclear-based energy, as well as regions that have fossil fuel related industry, such as refineries, coal mines, gas or oil extraction, or major hubs for energy imports, will experience an erosion of parts of their economic base. In addition to production infrastructure, distribution and storage related infrastructure is important for bringing energy to the end user and managing the energy flow. This will include dealing with the intermittence and seasonality of production. Infrastructure for the production, storage and distribution of additional renewable energy, a large part of which will be in the form of electricity, will require space.

The increased share of renewables will require an increase in the capacity of interconnectors in Europe and new techniques to enable non-dissipative long-distance transportation of huge quantities of electricity. Grid infrastructure will have to be extended and enhanced. Furthermore, some infrastructure will become obsolete, in particular that related to oil and nuclear power (e.g. oil pipelines, oil storage tanks, nuclear power plants, etc.), while the gas grid (or parts of it) might be used to store renewable electricity in the form of gas. The dismantling of unused infrastructure will have to be managed or other uses found. To accommodate the high level of intermittence related to wind and solar energy, electricity systems will have to become more flexible, so they can balance generation and consumption.

That will require additional temporary energy storage when it is abundant and recovery later in the form of electricity or heat. While a number of possible large-scale storage technologies exist[4], there is none that can currently compete with well-established pumped hydroelectric storage for long-term and large-scale applications is compressed air storage (European Commission, 2014). However, its current level of deployment is very low. The extent to which other technologies would be sufficiently mature and cost-efficient to be deployable on a larger scale is uncertain.

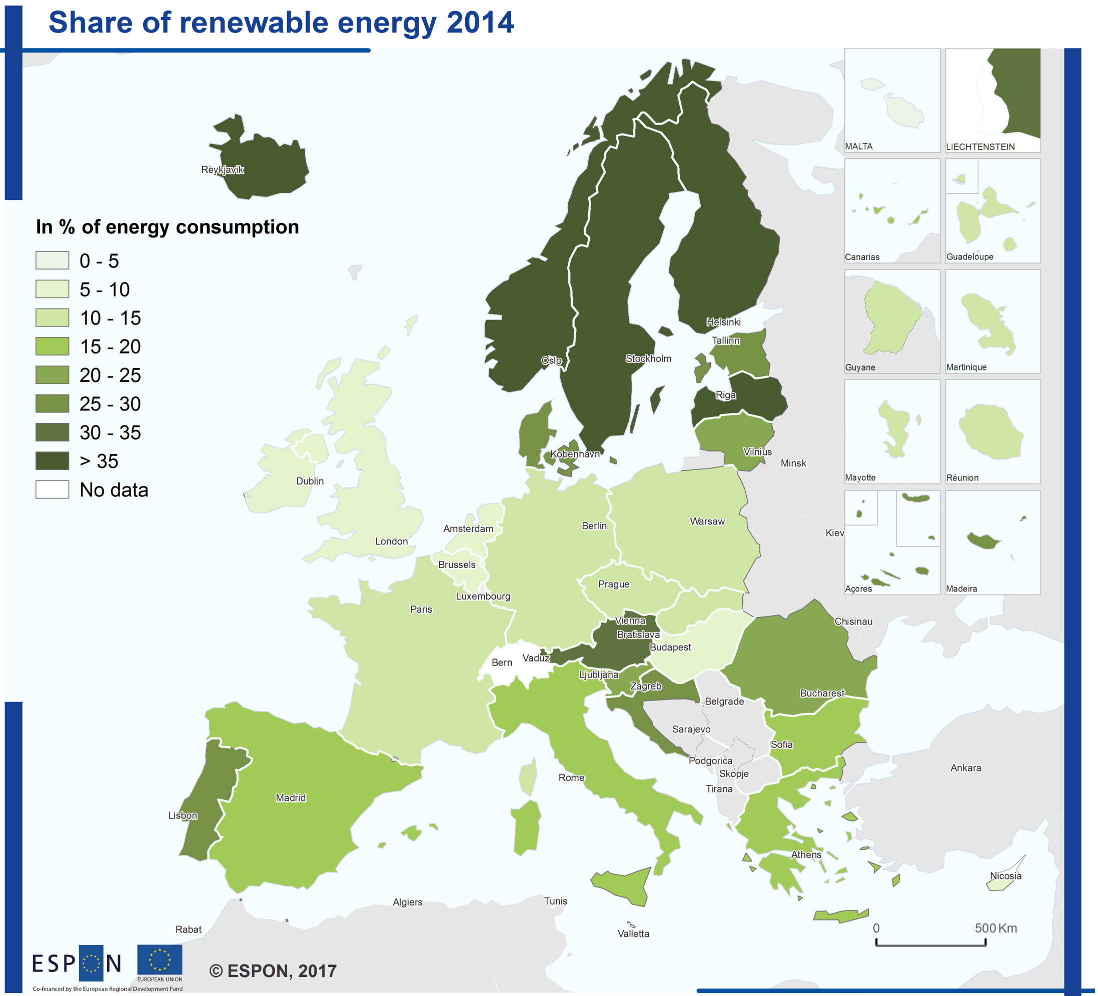
3.2 Territories exposed and their sensitivities

Regional renewable energy production capacity will have to increase in all regions of Europe, but not all regions will require the same effort and not all regions will have the same opportunities.

For all renewable energy sources, the most positively affected regions are those with high techno-sustainable RES potential as they will see new opportunities from the transition to a fully renewable energy system. The closer production centres are to large power load centres (i.e. centres of consumption), the more favourable the conditions for exporting surplus energy. Since much of the renewable energy will be generated in the form of electricity, proximity is particularly important to minimise distribution losses.

[4] Existing large-scale storage technologies include pumped hydroelectric storage, compressed air energy storage, hydrogen-based energy storage (converting power into gas), secondary (rechargeable) batteries, flywheels, thermal storage, and gas storage (European Commission, 2014).

Map 3.1 Share of renewable energy 2014



Regional level: NUTS 0 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: Eurostat (online data code: t2020_31), 2014
CC - UMS RIATE for administrative boundaries

The share of domestic renewable energy production in the EU currently ranges between 2% for Malta and 35.5% for Sweden. It is highest in Scandinavian countries (Norway, Sweden, Finland), Iceland, Latvia and Austria (>30%) and moderately high (>20%) in Portugal, Lithuania, Estonia, Croatia, Slovenia and Romania. Regions with a particularly low share of domestically produced renewable energy are the British Isles, the Benelux countries and Hungary. The most challenged regions will be those with a low share of domestic renewable energy production and significant extraction or production of fossil or nuclear-based energy. We will consider different renewable energy sources and technologies and how potential and current production is distributed across the EU.

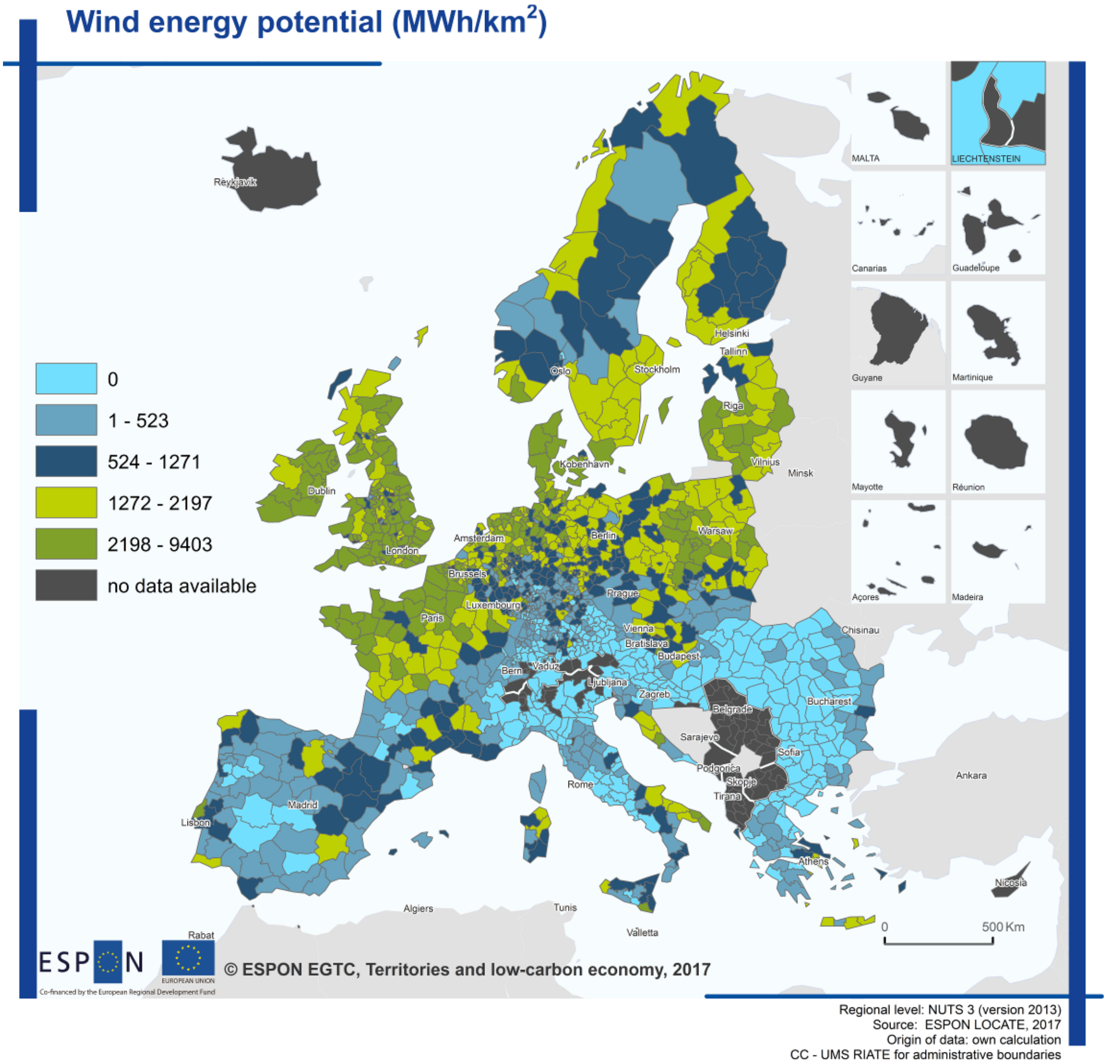
3.3 Wind power

Wind power is currently the second most important renewable energy technology in the EU, after bioenergy. It is a very mature technology that has already reached grid parity in favourable locations, with much potential that can still be tapped (in particular offshore).

3.3.1 Exposure

The theoretical wind energy potential, leaving aside environmental, social and economic constraints, is huge in Europe. For **onshore wind power**, the potential for wind energy strongly depends on average wind speeds and land availability for wind power installations. The highest techno-sustainable potential is around the North Sea and the Baltic Sea, but also along the Norwegian coast, in selected locations on the Iberian Peninsula, in the north and north-west and south-west of France, in Apulia, Italy, on the Dalmatian coast in Croatia, as well as on Crete. The lowest potential is in the Alps and the Balkans. High **offshore wind power** potential exists in the North Sea and Northern Seas, the west and the Mediterranean coast of France.

Map 3.2 Wind onshore energy potential in MWh/km²

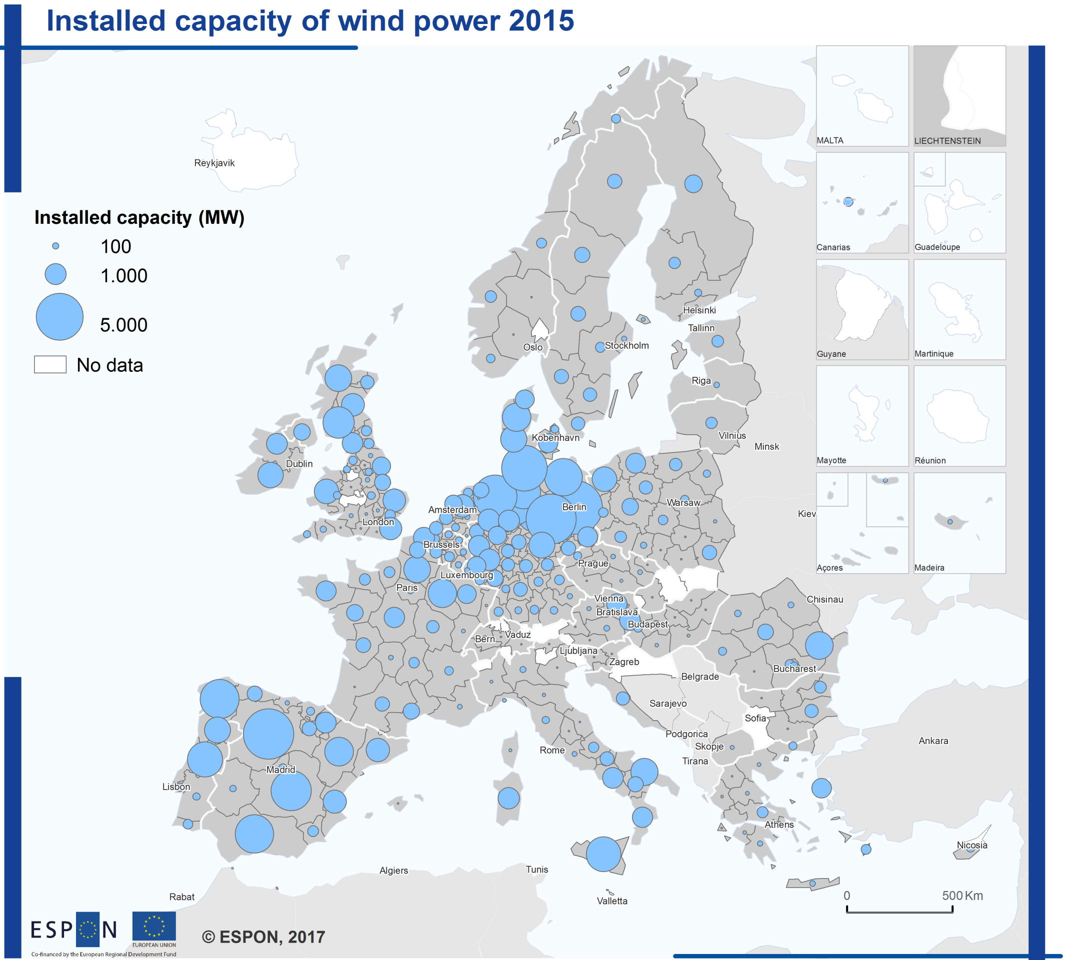


3.3.2 Sensitivity

For **onshore wind**, Germany and Spain are by far the biggest producers in the EU. Large installations can also be found in the north of Portugal, the northern and western part of the UK and Ireland, Netherlands and Belgium as well as parts of France (especially the north-east) the south of Italy and Sicily as well as the southeast of Romania. The exploitation rate (the share of potential actually exploited) is highest in Germany and Denmark and other selected regions, in particular in Belgium, Portugal and on the Mediterranean islands of Sardinia, Sicily and Corsica.

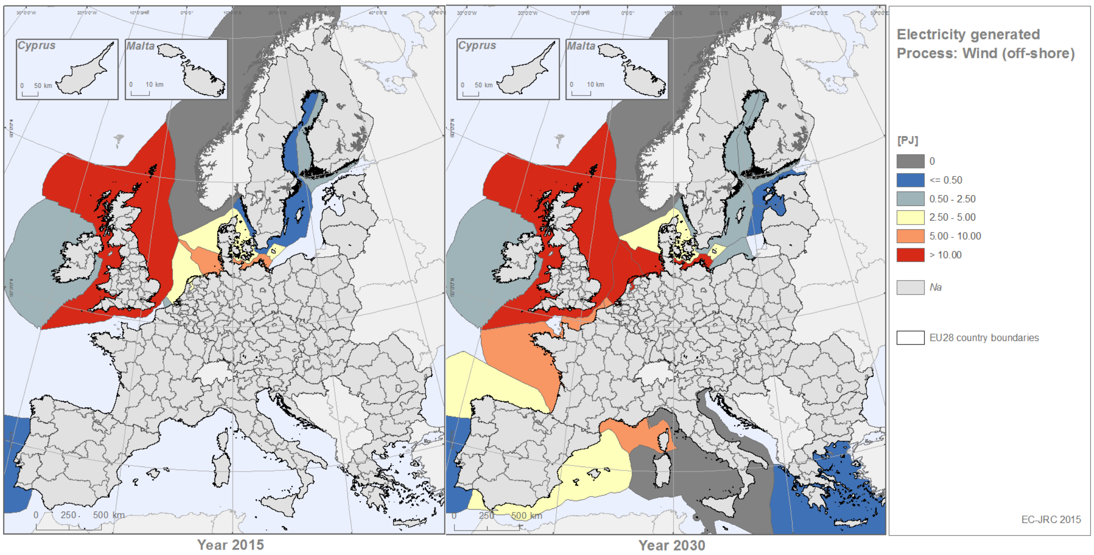
For **offshore wind power**, only a few Member States have a significant facilities, with the UK being by far the biggest producer, followed by Denmark. Most of the wind farms are currently installed in the North Sea and North-Western Seas, the West and the Mediterranean coast of France.

Map 3.3 *Wind onshore*



Regional level: NUTS 2 (version 2010)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: European Commission, JRC, EMHIRES dataset part 1, wind power generation, 2016
CC - UMS RIATE for administrative boundaries

Map 3.4 Electricity generated from off-shore wind, 2015 and 2030 (projection)



Source: Baranzelli et al., 2016

Example: Vertical wind turbines for home production, Spain

Vertical wind turbines for home production can feature eco-friendly, noiseless rotation and a small footprint. “The Kliux Geo 1800 is radically different,” say Kliux Energies CEO, Iñaki Eguizábal, “When most people think of a wind turbine, they imagine a white monster fan the size of a tall building that takes over a skyline, endangers wildlife, creates flicker and doesn’t let them sleep because of how noisy it is. The Kliux Geo 1800 is the exact opposite on every count.” Chief Technology Officer and inventor of the Kliux Geo 1800 technology, Juan José Eguizábal, explained the benefits of the company’s internationally patented design. “First, it’s noiseless and does not interfere with cable or over-the-air broadcast spectra. At just 33 feet high, it’s designed to eliminate flicker, while aesthetically integrating into any environment, and the air current created by the blade rotation creates a kind of safe zone, giving birds plenty of clearing space.”

3.3.3 Impact

- **High potential and high utilisation.** Areas with high potential and with significant installed onshore and offshore wind power capacity can be found around the North Sea; most notably in the UK and Ireland, Belgium and the Netherlands, Germany's North Sea coastal areas and Denmark as well as large parts of the Iberian Peninsula and the south of Italy.
- **Significant potential, but currently low exploitation.** Another group of regions, in particular around the Baltic Sea (the Baltic States, Southern Sweden and the coastal areas of Finland around the Gulf of Finland), in North/ Northwest and Southwest France, southern Norway and Sweden, Czech Republic and Central and North Poland have a high wind power potential, but currently a low level of deployment. These would need a surge in investment to unlock the potential.
- **Disadvantaged.** Regions with low techno-sustainable wind power potential and little installed wind power capacity are in the Alpine region and the foothills of the Alps (e.g. Northern Italy and large parts of Slovenia), Slovakia, Croatia and Hungary and the south-eastern parts of Europe (Greece, Romania, with the exception of the southeast, and Bulgaria).

3.4 Solar power

Solar power accounts for no more than 7% of the EU's renewable electricity generation. However, among renewables, it has the highest power density and biophysical potential. It is therefore thought to be, together with wind power, the corner stone of the EU's 100% renewable energy supply.

3.4.1 Exposure

The biophysical **solar energy potential** for thermal, photovoltaic and concentrated power using mirrors or lenses is based on local irradiation. This is, not surprisingly, higher in Southern Europe than in Northern Europe[5]. The highest potential is around the Mediterranean Sea, but also on the Iberian Peninsula and in the Balkans.

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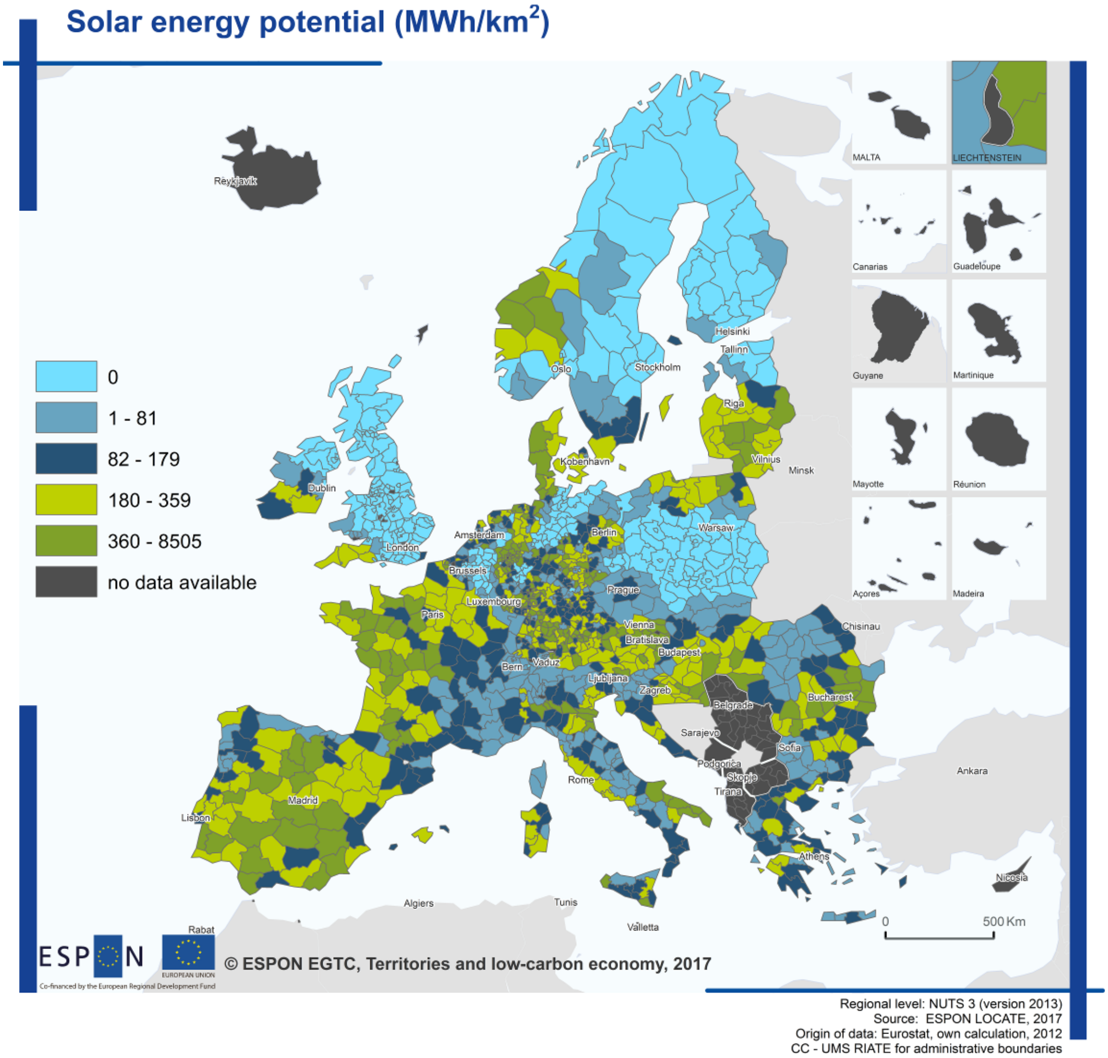
[5] http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_cmsaf_opt/PVGIS-EuropeSolarPotential.pdf

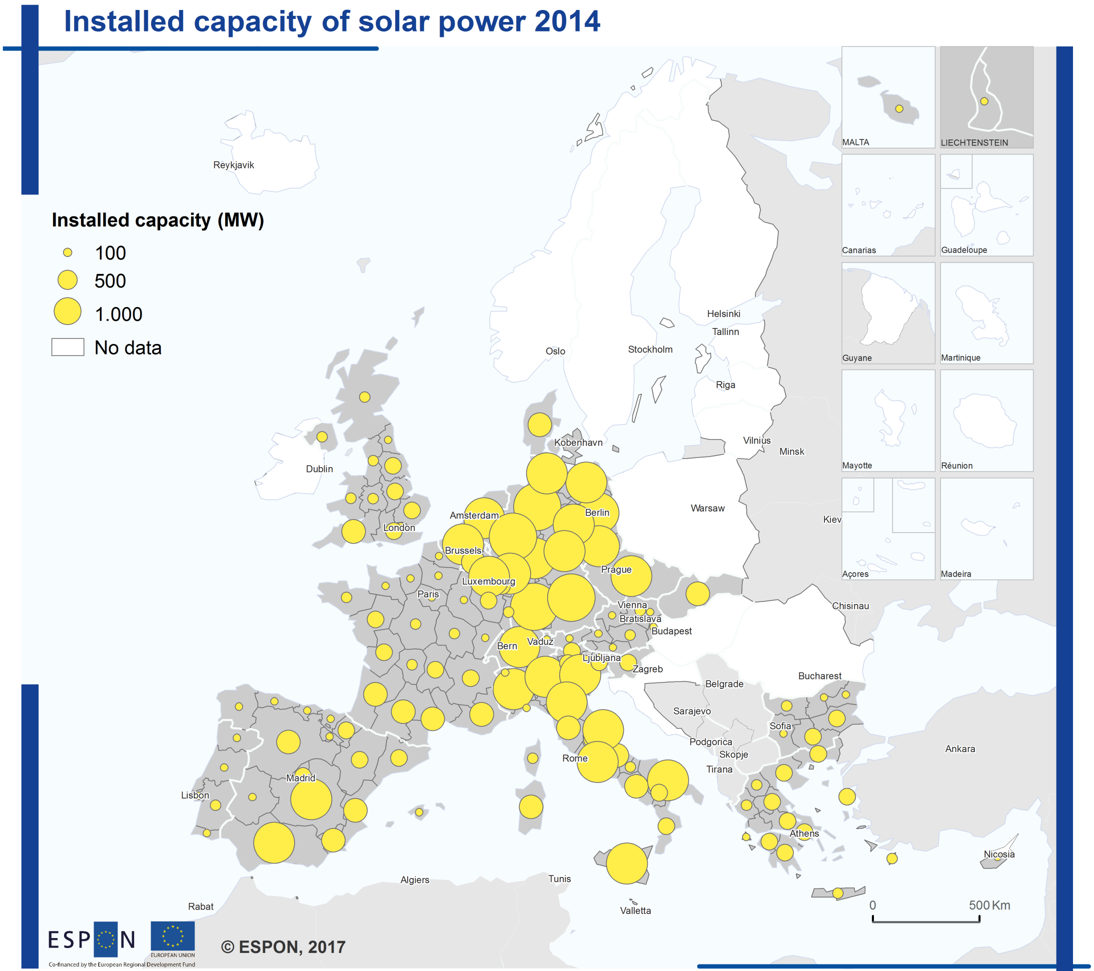
Map 3.5 Solar energy potential in MWh/km²



3.4.2 Sensitivity

When it comes to installed capacity, a differentiated picture emerges. Regions that stand out because of their installed solar power capacity are in Spain (Central and Southern Spain, in particular, Castilla y la Mancha, Andalusia), Germany and Italy (Northern Italy, Central Italy, and Puglia and Sardinia) mainly because they have specific policies to promote solar power installations.

Map 3.6 Installed capacity of solar power



Regional level: NL,CH,CZ,LI,LU,SI=NUTS 0/BE,DE,UK=NUTS 1/AT,BG,EL,ES,FR,IT,PT=NUTS 2 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: Solar Power Europe, 2015
CC - UMS RIATE for administrative boundaries

Example: The Les Mées solar farm, France

The Les Mées solar farm, in the rolling hills of La Colle des Mées plateau (Alpes-de-Haute-Provence), covers 200 hectares with 112,000 solar modules. This project, implemented by Siemens Energy on a turnkey basis, generates 100MW of clean energy, enough to power 12,000 typical French households.

This site is about 800 meters above sea level and has the best conditions for the production of photovoltaic solar energy in France. It enjoys plenty of sunshine with horizontal solar irradiation of 1550 kWh, and a high level of air purity that results in an energy yield that is 10 to 15% above average. The EUR 70 million investment included work to preserve the landscape with space for grazing and a system without a concrete foundation. The solar farm was designed to have very low environmental impact. The panels were installed without laying concrete foundations that would destroy the grass.

3.4.3 Impact

- **High potential and high utilisation.** Regions with the highest unexploited techno-sustainable solar potential (in particular, with available land) and considerable installed capacity are in central Spain and, to a lesser extent due to land use constraints, the southern coastal regions of Spain, Italy, including the Italian islands Sicily and Sardinia and southwestern France.
- **High potential, but low current utilisation.** Regions with a high techno-sustainable solar power potential, but low or somewhat lower current utilisation are in Greece, Romania, Bulgaria and Portugal. High utilisation, but relatively low potential regions are in Germany and Denmark.
- **Low potential and low utilisation.** Regions with low techno-sustainable solar power potential and no significant installed capacity are in Scandinavia, most parts of the British Isles (except for the most south-western parts) and Poland.

3.5 Energy from biomass

Despite its dubious reputation, bioenergy currently accounts for 80% of the renewable energy produced in the EU, or 8% of the gross inland consumption, with estimates suggesting that bioenergy could cover around 13% of the current energy demand in the EU. However, concerns regarding the sustainability of production from biomass, in particular its impact on resource consumption and greenhouse gas emissions, as well as the competition with food crops have dampened the production of bioenergy in Europe. When talking about bioenergy, a distinction should be made between different feedstock and conversion technologies. In general, energy-from-biomass makes use of the biodegradable part of products, waste and residue from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable part of industrial and municipal waste and can be converted into useable forms of energy such as heat, electricity or fuel (biogas, biodiesel or ethanol).

So-called second- and third-generation biofuels have no or low impact on climate change and indirect land use. First-generation biofuels are produced from cereal, oil and sugar crops, using established technology and are possibly in competition with food production. Second- or third-generation biofuels are produced by ‘advanced processes’ using non-food feedstocks such as waste, agricultural and forestry residue, energy crops such as grasses, short rotation coppice or algae. However, whether their development will be sufficiently advanced by the 2030s is unclear. While the assumption is that bioelectricity production will not be developed beyond existing capacity, biofuels and biogas, from non-food feedstocks, will play an important role as transport fuel.

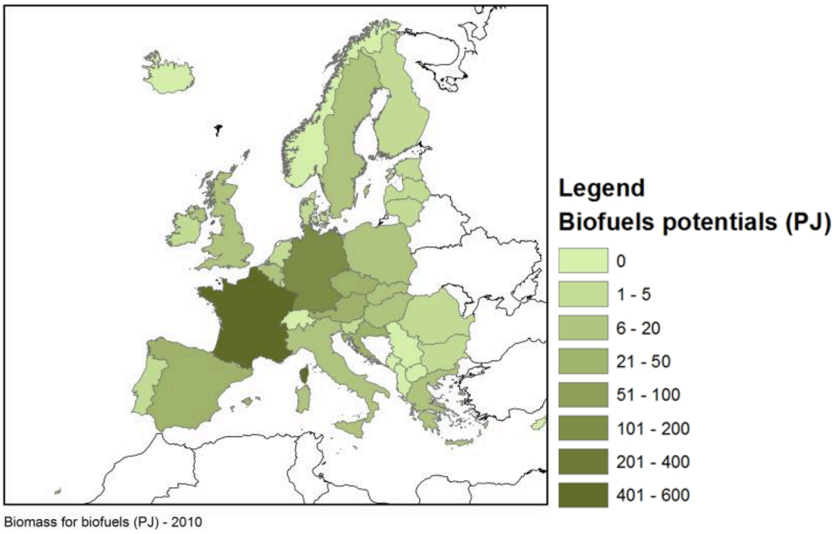
3.5.1 Exposure

The potential for energy production from biomass in Europe is big. It has been estimated that bioenergy could accounting for 13% of the EU's current total primary energy consumption[6].

The biomass production sectors relevant for renewable energy are agriculture (i.e. energy crops, manure, and primary, secondary, and solid agricultural residues), forestry (i.e. roundwood production and primary and secondary residues) and waste (i.e. primary residues coming from landscape care management, roadside verges and abandoned lands and tertiary residues from different industries and municipal solid waste). The currently most important feedstock is wood, which accounts for approximately 80% of the biomass used for renewable energy production. Depending on the feedstock, different parts of Europe have different potentials (Ruiz et al., 2015):

- The (projected) biofuels potential from agricultural biomass is particularly high in France, and Germany.
- The bioenergy potential from forestry is particularly high in France, Germany, Austria, Poland and Sweden.
- The bioenergy potential from waste is particularly high in France, Germany, Spain, Italy and the UK.

Map 3.7 Biofuels potential from agricultural biomass



Source: Ruiz et al., 2015

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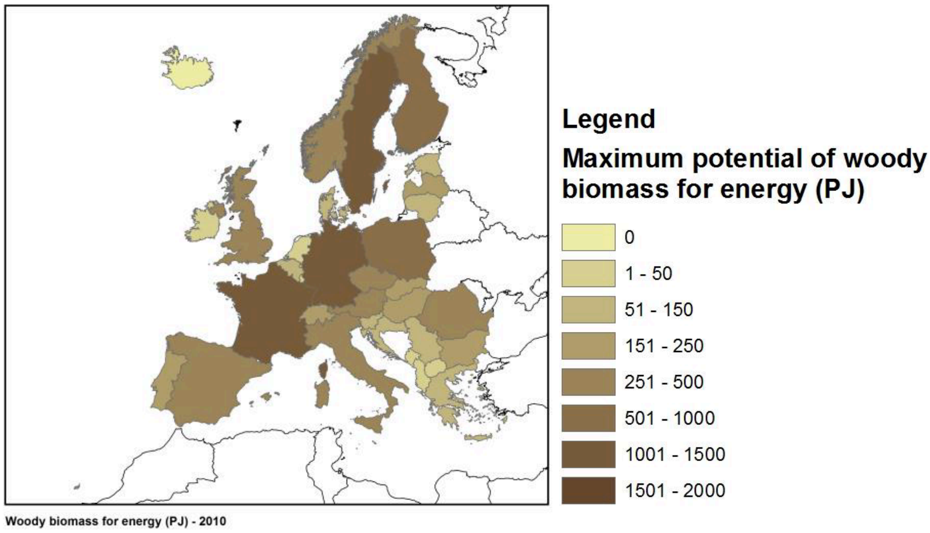
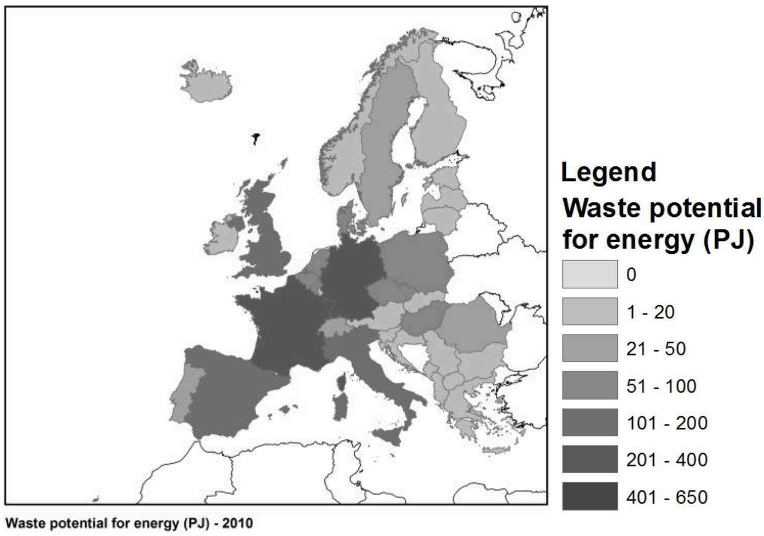
6 https://ec.europa.eu/agriculture/bioenergy/potential_en

Map 3.8 Bioenergy potential from forestry



Source: Ruiz et al., 2015

Map 3.9 Bioenergy potential from waste

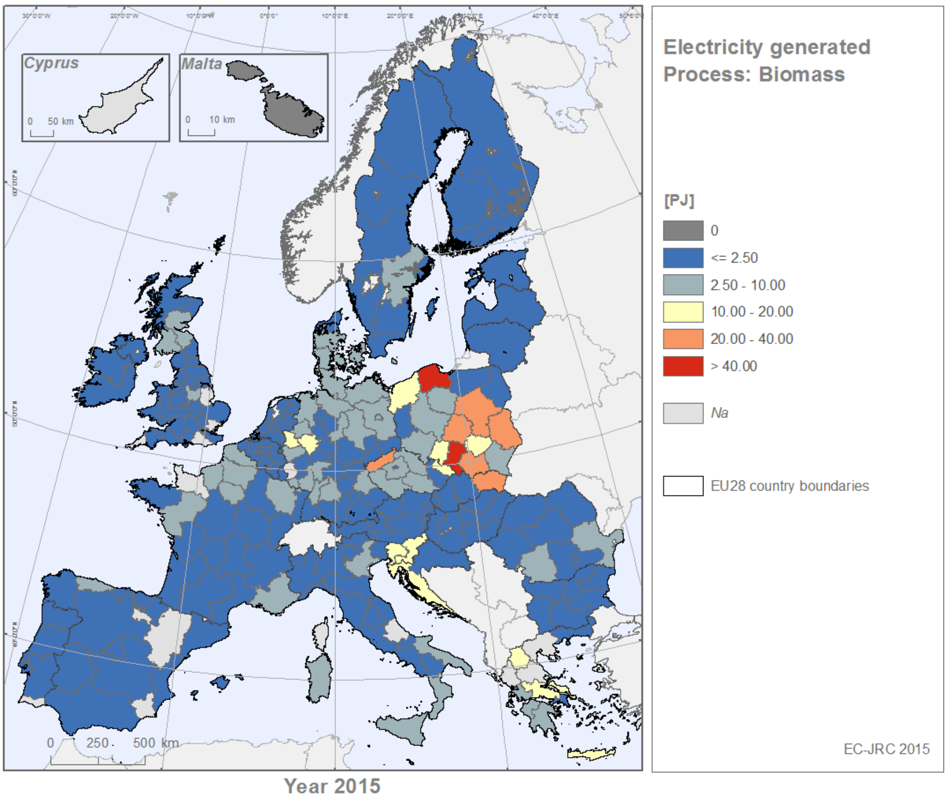


Source: Ruiz et al., 2015

3.5.2 Sensitivity

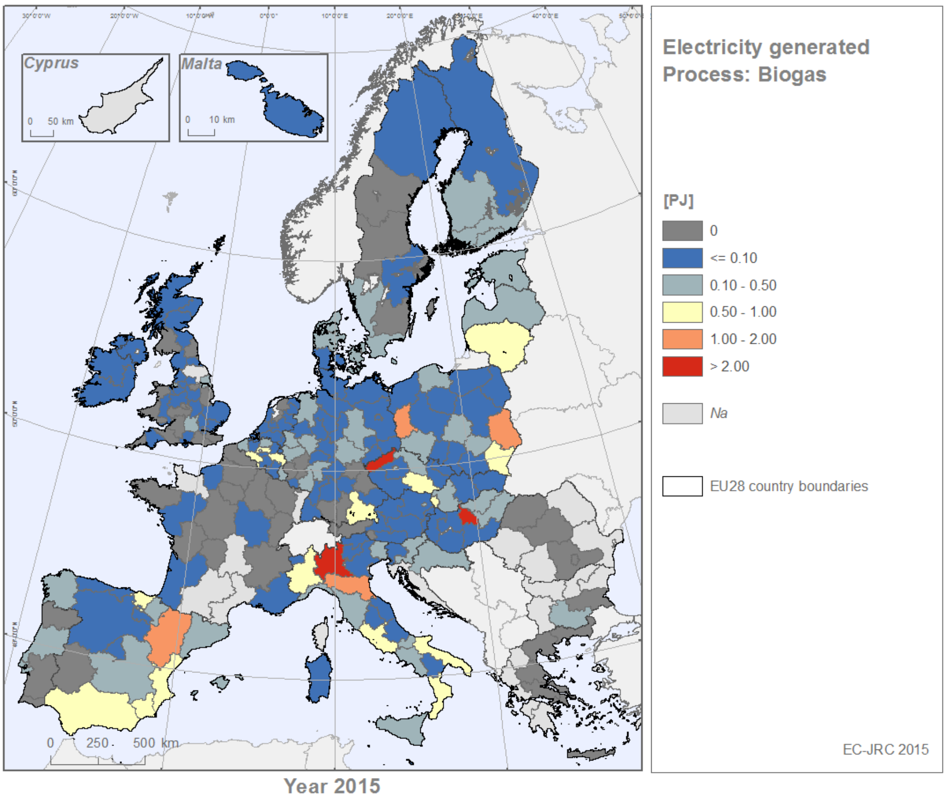
All European countries produce substantial **energy-from-biomass**. In the EU-27, biomass accounts for approximately for 95.7 Mtoe, of which only a small part is used for biofuels, 40 Mtoe is for heat and 48 Mtoe for electricity. The main producers of bioenergy in Europe are France, Sweden, Finland, Germany, Spain and Poland (in particular Pomorskie and Slaskie), but also Severozápad in the Czech Republic, Lombardia and Emilia-Romagna in Italy and Közép-Magyarország in Hungary. Little bioenergy is produced in the Baltic states, in Belgium and Bulgaria.

Map 3.10 Electricity from biomass in PJ



Source: Baranzelli et al., 2016

Map 3.11 Electricity from biogas in PJ



Source: Baranzelli et al., 2016

3.5.3 Impact

For bioenergy production from agricultural biomass, forestry and biodegradable wastes:

- **High potential and high utilisation.** Areas with high bioenergy potential and significant production capacities are in France, Germany, Poland, Sweden, Finland, and Spain.
- **High potential, but currently low utilisation.** Regions with significant potential, but lower levels of bioenergy production are especially the UK, but also the Czech Republic, Slovakia, Hungary, Romania. Austria, on the other hand, has
- **Low potential and low utilisation.** Bulgaria, Greece, Cyprus, Croatia and Slovenia, the BENELUX, Denmark as well as Portugal and Ireland have low potential and low production of bioenergy.

3.6 Geothermal energy

Geothermal energy is energy stored as heat below the earth's surface. In 2015, geothermal energy contributed to 3.1% of renewable energy in the EU-28 countries. Geothermal energy can be reclaimed in the form of electricity or in the form of heat. For geothermal energy to supply the energy for electricity generation, high temperatures are needed, which only exist in selected locations; typically, in fault-zones. Geothermal heat that can be either directly used for heating, such as in a district heating system, or for electricity production, the former being more widespread as it requires lower temperatures.

3.6.1 Exposure

Areas with high geothermal energy potential for district heating are in Iceland, Italy (mainly Tuscany), France (the Paris Basin and the Aquitaine Basin in the southwest, but mainly in overseas departments in the French West Indies and the Indian Ocean), in the Czech Republic and Eastern Hungary.

3.6.2 Sensitivity

Significant installations in Europe exist in Iceland, Italy (mainly Tuscany for power production), France (the Paris Basin and the Aquitaine Basin in the southwest, but mainly in overseas departments in the French West Indies and the Indian Ocean) Eastern Hungary and in Portugal (Azores Archipelago), but also in three German regions: Upper Rhine valley, the Southern German molasses basin (south and east of Munich) and the Northern German Basin[7] (European Commission, 2016).

3.6.3 Impact

- **High potential and high utilisation.** Areas with a high geothermal energy potential for geothermal district heating and significant installations are in Iceland, Italy (mainly Tuscany), France (the Paris Basin and the Aquitaine Basin in the southwest) and Eastern Hungary and selected regions in Germany.

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[7] http://www.geothermie.de/wissenswelt/geothermie/einstieg-in-die-geothermie.html

- **High potential, but currently low utilisation.** Regions with a geothermal potential, but currently low utilisation can be found in the Czech Republic, Spain, Denmark and Lithuania (as well as in the French Overseas Departments in the French West Indies and the Indian Ocean).
- **All other regions have no or low potential.**

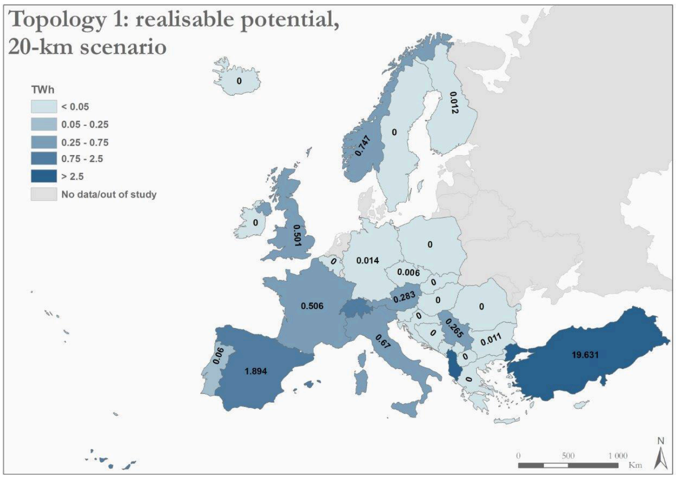
3.7 Hydropower (including wave and tidal power)

Hydropower is electrical energy derived from running or falling water generated in run-of-river hydropower stations and pumped storage hydropower plants. Wave and tidal power also belong to hydropower technology as both take advantage of the kinetic power in moving water.

3.7.1 Exposure

Hydropower accounts for around 15% of power generating capacity in Europe or around 45% of the installed renewable electricity capacity in the EU. This means that in terms of renewable energy generation it ranks clearly ahead of other renewable electricity generation technologies such as wind and solar power. Despite its importance for meeting Europe's electricity demand, further exploitation of Europe's hydropower potential is in contradiction with the EU's objective to maintain or even improve the environmental quality of Europe's waterbodies and is, therefore, a highly contested issue. Nevertheless, hydropower, especially pumped storage hydro power plants, occupy an important role in a fully renewable European energy system as energy storage. Areas with high and unexploited potential for hydropower generation will experience conflicts between biodiversity protection and energy production. These are in mountainous regions with sufficient water such as the Alps, Pyrenees, Scandes, Highlands, where hydropower already has a long tradition, but also mountainous regions in Southeast Europe where 60% of the economically viable hydropower potential is still unexploited, e.g. the Balkan Mountains and Rhodopes (Bulgaria). Estimates indicate that there is still untapped RES potential in the EU from new small-scale hydro power facilities (<10 MW) or from upgrading existing ones. Small hydro power generally has a lower impact on the environment and on river ecosystems. There also exists further potential for large hydropower (run-off river or pumped storage) stations producing more than 10 MW, however at much larger environmental costs. Map 3.12 shows the potential for additional pumped hydro power storage in Europe under the assumption that no additional pumped storage hydro power plants are built, but that sufficiently close existing reservoirs with adequate height difference are linked (Gimeno-Gutiérrez and Lacal-Arántegui, 2013). Such reservoirs, and hence, potentials are mainly in the Alps and in Scandinavia and the Pyrenees.

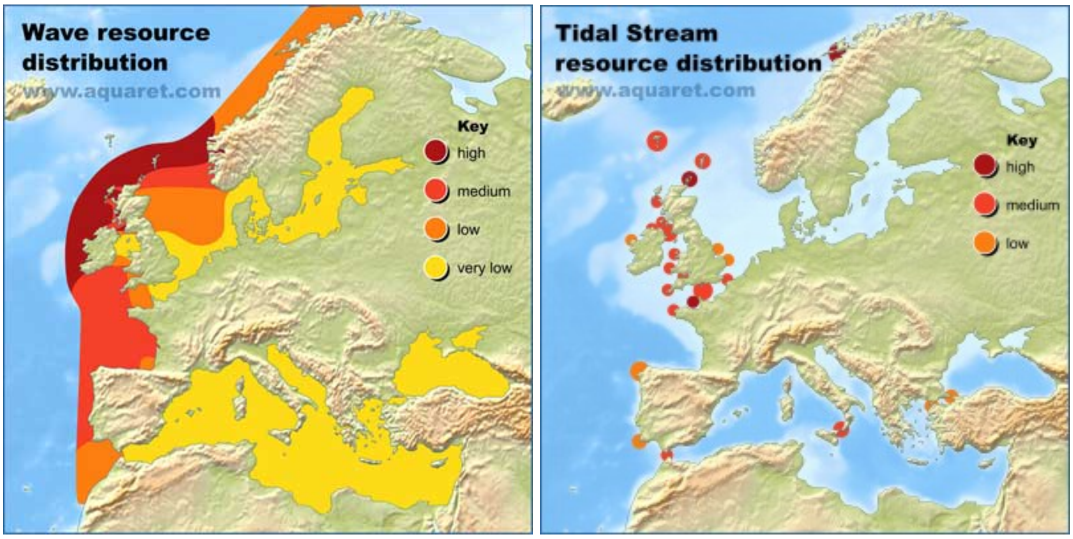
Map 3.12 Realisable additional pumped hydro power storage potential



Source: Gimeno-Gutiérrez and Lacal-Arántegui, 2013

Tidal and wave energy can only be economically exploited in a few locations. For wave energy, these are mainly along the Atlantic coast of Northern Ireland and Scotland, and the Atlantic coast of France and Spain. For tidal energy, the best locations are between the north-east tip of Scotland and the Orkney Islands and in Brittany (France). Nevertheless, for Europe's energy supply as a whole, tidal and wave power are almost negligible.

Figure 3.1 Tidal and wave resource distribution



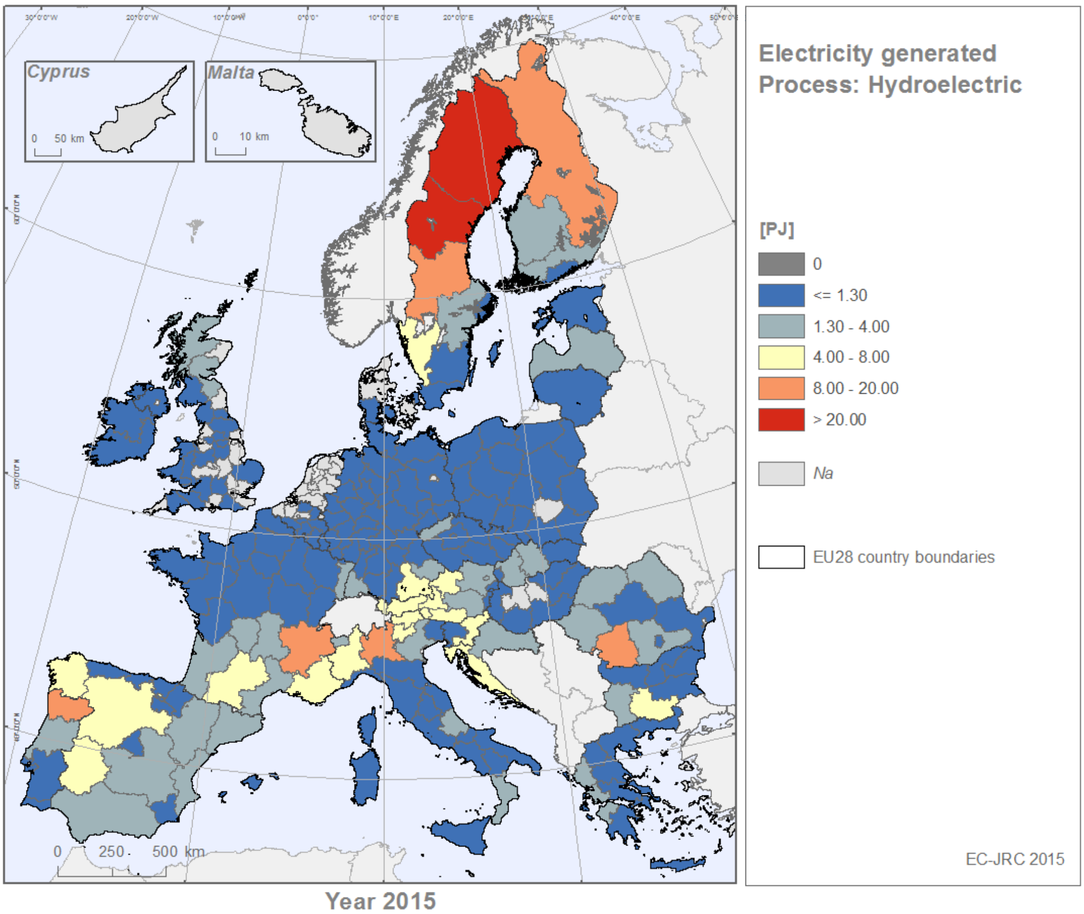
Source: http://maritimetidal.com

3.7.2 Sensitivity

In absolute terms, the main hydropower producers in Europe are (in descending order) France, Sweden, Italy, Austria, Spain, Germany, Romania and Finland. In terms of potential exploited, the countries with an exploitation rate higher than 66% are Austria, Germany, Finland, Italy and Latvia. For small-scale hydro power, the picture is different. The highest exploitation possibilities are in France and the Alpine basins. Some exploitation potential is in middle and eastern Europe as well as in Spain.

Wave and tidal power have and will have a very minor role in the energy supply of the EU. In 2015, this energy source contributed only 0.02% of the total electricity generated from renewable energy sources in the EU-28. The main tidal energy potential and the largest installations are in coastal areas of France and the UK. For wave power, significant installations only exist in the UK (Scotland) and one installation in Portugal.

Map 3.13 Electricity generated from hydroelectric, 2015 and 2030



Source: Baranzelli et al., 2016

3.7.3 Impact

For hydro power production, including tidal and wave power:

- **High potential and high utilisation.** Areas with a high share of hydropower generation and high potential for further exploitation are in the Alps and Scandinavia, but also in South-West Oltenia in Romania. For wave and tidal power, areas with high potential and installed capacity are mainly Scottish coastal areas and the French Atlantic coast.
- **High potential, but currently low utilisation.** Regions with high potential, but a less exploitation are in south-eastern Europe.
- **Low potential and low utilisation.** The rest of Europe.

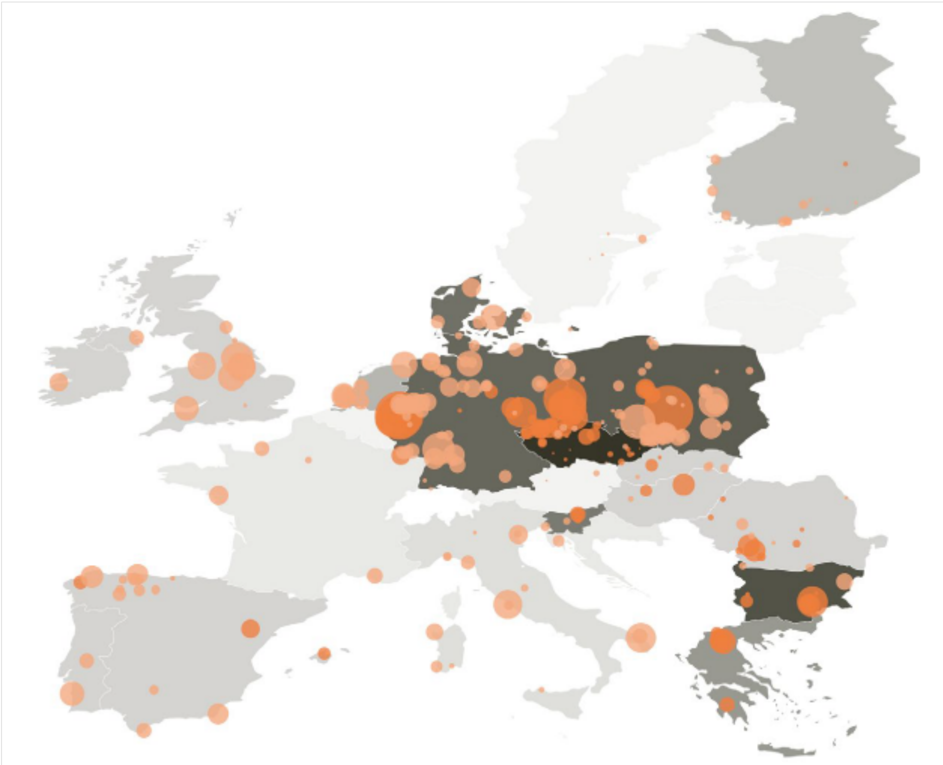
3.8 Regional production of fossil or nuclear-based energy

The EU's current energy supply is still heavily based on fossil fuels and nuclear energy. In 2014, around 16% of the EU's gross inland consumption was supplied from renewable sources, whereas 14% came from nuclear power and around 70% from fossil fuels (coal, petroleum and petroleum products and gas). Under the changed conditions for energy production, regions that rely heavily on fossil or nuclear-based energy or with significant extraction of fossil fuels will feel the transformation very strongly.

3.8.1 Exposure

Even though the EU is a net importer of fossil energy, it also has a few significant oil extraction areas and many smaller ones as well as a number of coal extraction sites.

Map 3.14 Location of coal power plants in the EU



Source: Rocha et al., 2017

For oil and gas extraction, mainly North Sea littoral regions are affected (Norway, the UK, Denmark, Netherlands, Germany) as well as Italy (Basilicata). Most of the production is offshore. Other smaller oil and/or gas-producing regions are in France, Poland, Hungary, Austria and Croatia, Romania (Carpathian and Sub Carpathian zone). Germany, Italy, France, the UK, Spain and the Netherlands also have large refinery capacity and would be hit by zero-fossil fuel energy supply in Europe. For coal, the main extraction sites in the EU are in Poland (Silesia), Germany (particularly in North Rhine-Westphalia, Saarland and Saxony), the Czech Republic (Chomutov fields in Northern Bohemia) and the UK (Yorkshire, Nottinghamshire and Scotland) and, to a lesser extent, in Greece (Western Macedonia), Bulgaria and Romania (in the Carpathian-Balkanian Basin, i.e. northern Bulgaria and in the Danubian lowlands and foothills of the Carpathian Mountains)[8].

3.8.2 Sensitivity

Regions with a significant share of people employed in mining and quarrying energy producing materials will particularly feel the negative impact of a shift towards renewables for Europe's energy. However, it is important to note that the share of employment is generally low and no European region exceeds 1%.

Regions that stick out as particularly vulnerable are the coastal regions of Norway, but especially the Agder and Rogaland region and Vestlandet, Severozápad (Czech Republic), Opolskie (Poland) and Vest, Sud-Vest Oltenia and Sud-Muntenia (Romania).

3.8.3 Impact

- **High vulnerability.** Regions with significant oil, gas or coal extraction paired with a significant share of people employed in mining and quarrying energy producing materials. For oil and gas, these are the coastal regions of Norway (in particular, Agder and Rogaland region and Vestlandet) and North-Eastern Scotland (UK). For coal, these are Slaskie, Silesia, Opolskie (Poland), Severozápad (Czech Republic), the Carpathian-Balkanian Basin (Bulgaria and Romania) and North-Eastern Scotland (UK).
- **Medium vulnerability.** Regions with significant oil or coal extraction, but a low share of people employed in mining and quarrying energy producing materials. Yorkshire and Nottinghamshire (UK), Northern Rhine-Westphalia, Saarland and Saxony (Germany) and Western Macedonia (Greece).
- **Low vulnerability.** The rest of Europe.

3.9 Regional energy infrastructure

Electricity grids will have to be to extended and reinforced to improve interconnectedness and smart grids need be installed across Europe. Moreover, 'electricity highways' will be needed that can accommodate surplus wind generation in and around the Northern and Baltic Seas and increasing renewable generation in the East and South of Europe and also North Africa, connecting these new generation hubs with major storage capacities in Nordic countries and the Alps and with the major consumption centres in Central Europe.

In the new reality, **fossil-fuel and nuclear power-based infrastructure** (e.g. caloric and nuclear power plants, LNG terminals, refineries, oil and gas pipelines) will become obsolete and will have to be managed.

Storage capacity in Europe is currently low and relies mainly on pumped hydroelectric storage (PHP). Currently, only about 5% of Europe's electrical generating capacity can be

[8] https://www.britannica.com/place/Europe/Economy#ref309533

stored in this way, about 45 GW. The realisable potential[9] for PHP storage in the EU is about 4 TWh (7-8% of EU current daily consumption), when only existing reservoirs with adequate height difference are considered that are close enough[10] to be linked by new equipment. When considering new reservoirs, which is highly contested for environmental reasons, the realisable potential increases to 33 TWh, or about 60% of EU daily consumption (Gimeno-Gutiérrez and Lacal-Arántegui, 2013).

3.9.1 Exposure

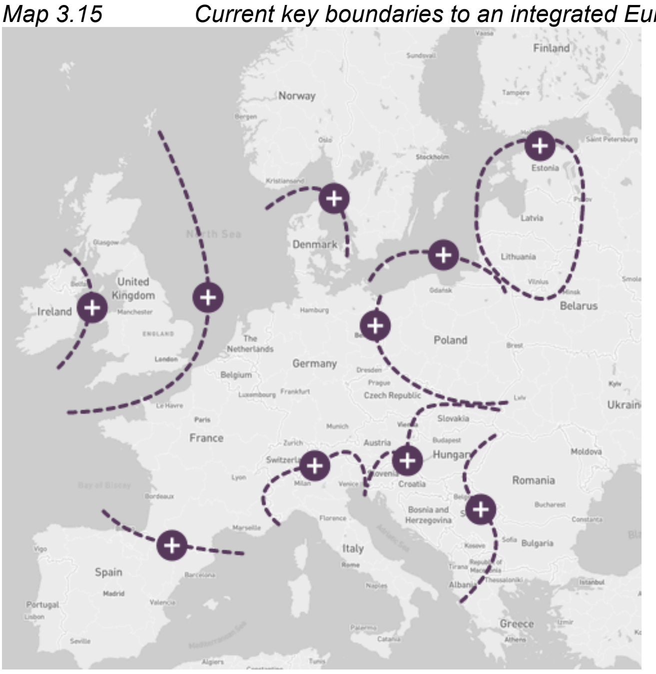
Particularly exposed regions are those with the highest need for additional infrastructure investment. Currently, the highest net transfer capacity and highest grid density areas are generally in the centre of the continent. This is the area between London and Milan, which has the highest population density and therefore higher consumption levels, as well as installed generation capacity. The European Network of Transmission System Operators for Electricity in its 10-year Network Development Plan (2014), defined priority corridors to make the grid ready to integrate renewables by 2030. They pinpointed about 100 spots on the European grid where bottlenecks exist or may develop without reinforcement. The most critical area of concern is the stronger interconnection to mainland Europe of the four "electric peninsulas": the Baltic States, Spain and Portugal, Ireland and Great Britain, as well as Italy. The main new electricity corridors required are:

- Connection of energy production capacity in the North Sea and North-Western Seas with consumption centres in Northern and Central Europe and hydro storage facilities in the Alpine region and in Nordic countries.
- Interconnections in South Western Europe to accommodate wind, hydro and solar, in particular between the Iberian Peninsula and France, and further with Central Europe.
- Connections in Central Eastern and South-Eastern Europe to strengthen the regional network for North-South and East-West power flows.
- Integration of the Baltic States into the European market through reinforcement of their internal networks and stronger interconnections with Finland, Sweden and Poland as well as reinforcement of the Polish internal grid and interconnections east and westward.

[9] Considering constraints by discounting potential sites close to centres of population, protected natural aras or transport infrastructure.

[10] A distance of max. 20 km is assumed.

Map 3.15 Current key boundaries to an integrated European electricity grid

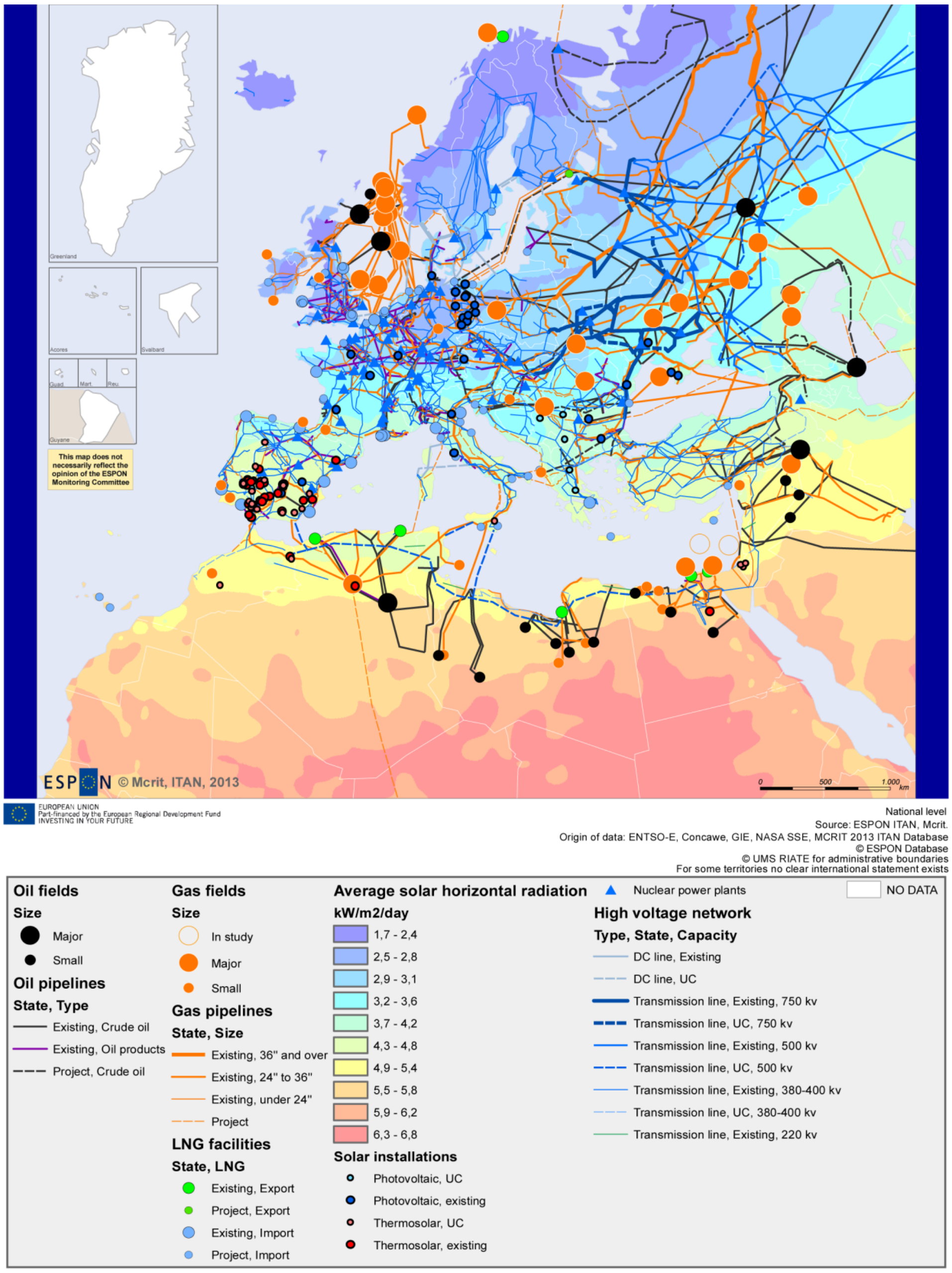


Source: http://tyndp.entsoe.eu/

Areas that will be affected by the **obsolescence of fossil-fuel and nuclear power-based infrastructure** and production sites are scattered across Europe (see). LNG facilities that will lose importance are mainly on the Mediterranean and North Sea, but also a few on the Baltic Sea (e.g. LNG terminal in Klaipeda/Lithuania). Regions that will have to deal with the management of obsolete nuclear power plants are mainly in the UK, France, Germany, Belgium, the Netherlands, Poland, the Czech Republic, Slovakia, Slovenia, Hungary, Spain, Sweden and Finland.

Concerning the need for **additional energy storage**, the main areas under pressure are those with considerable potential pumped hydroelectric storage, which are already considered in section 3.7 on hydropower.

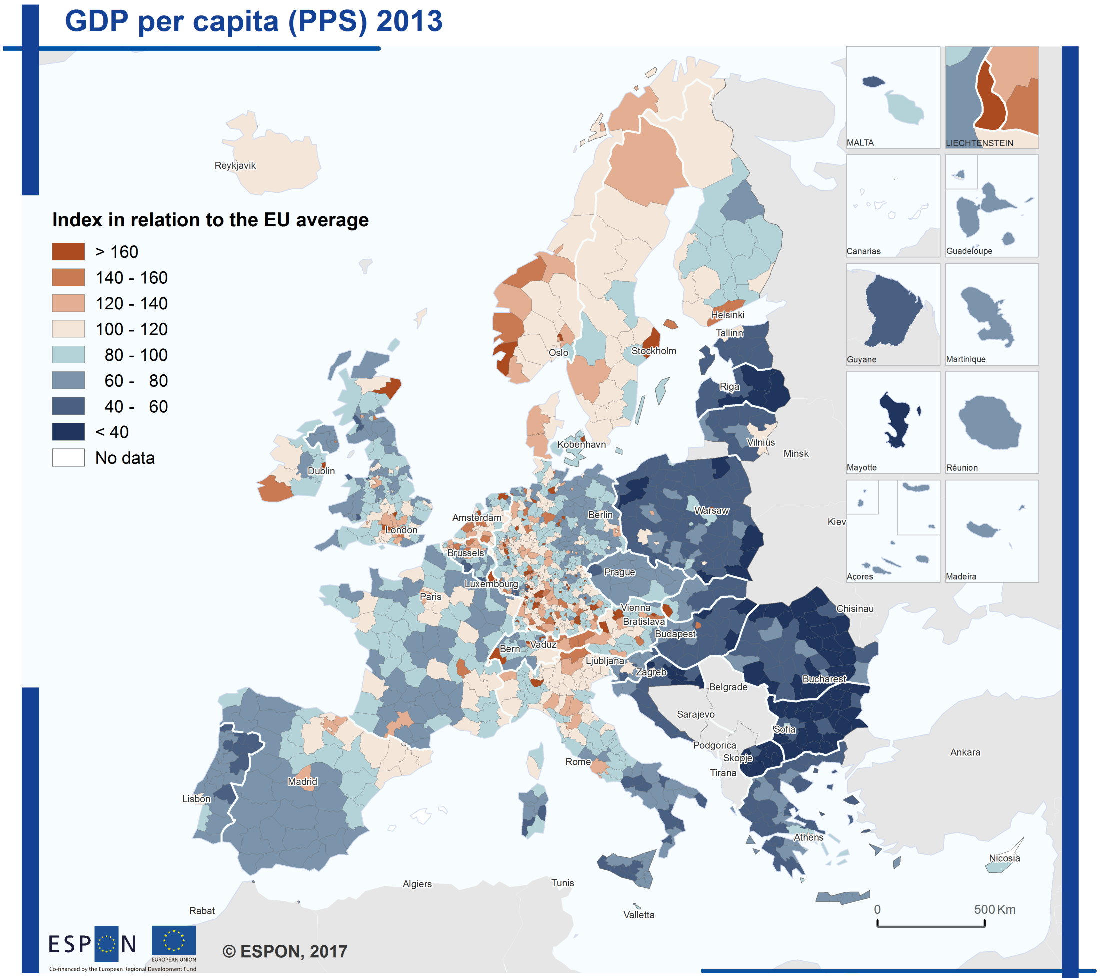
Map 3.16 Energy networks



3.9.2 Sensitivity

The transition to a fully renewable energy system will require large investment in additional RES capacities and related energy infrastructure in a very short time and will most likely raise energy prices, at least in the short and medium-term. Regions with strong economic performance will find it easier to finance investments. For them, the transition will present new opportunities for economic development, in particular in regions that can become renewable energy exporters, i.e. mainly rural regions with a high RES potential.

Map 3.17 GDP per capita (PPS) in 2013



Regional level: NUTS 3 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: Eurostat (online data code: nama_10r_3gdp), 2013
CC - UMS RIATE for administrative boundaries

Regions with GDP per capita (in purchasing power) above the EU-28 average are mainly the European capital regions (Madrid, Paris, London and surroundings, Dublin, Copenhagen, Amsterdam, Rome, Oslo, Stockholm, Helsinki), but also large parts of Central (the south and west of Germany, Austria, Switzerland and Northern Italy), the BENELUX and Northern Europe (Jutland and South Denmark, Norway, West Sweden and Upper Norrland in Sweden, Southern Sweden and Lapland, Iceland, but also Southern and Eastern Ireland and North Eastern Scotland).

3.9.3 Impact

- **Under pressure.** Regions that are primarily affected by the need to extend their grid infrastructure, but will be challenged to finance the investment are two of the “electric peninsulas”; the Baltic States and the Iberian Peninsula. Furthermore, Central Eastern and South-Eastern Europe need to reinforce the regional network for North-South and East-West power flows.
- **Under pressure but with the potential to cope.** Regions that are considerably affected by the need to extend their grid infrastructure, but are more likely to be able to finance the necessary investments are Northwest and Central Europe (need to connect energy

production capacity in the North Sea and North-Western Seas with consumption centres in Northern and Central Europe and hydro storage facilities in the Alpine region; need to better interconnect Ireland with Great Britain) as well as Italy (need to better interconnect with the European grid).

- **Least affected.** Scandinavia will be little affected. Iceland will be self-sufficient and is not connected to the European grid.

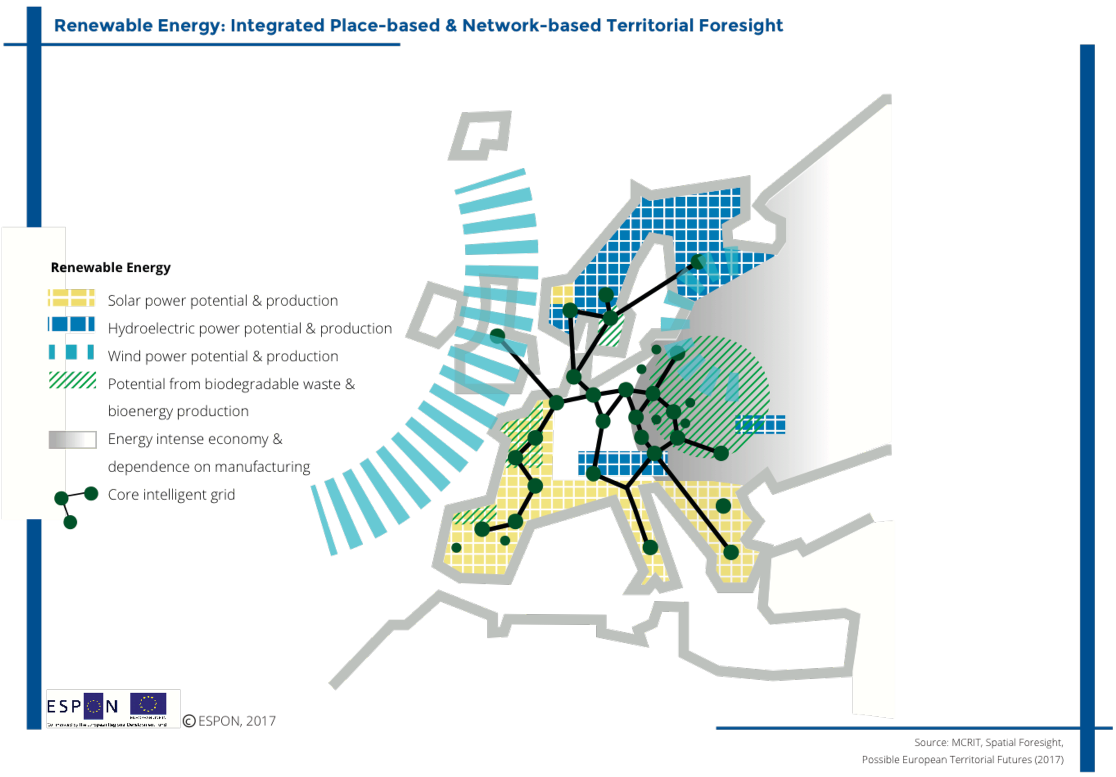
3.10 Conclusion on the territorial dimension of regional energy production and renewable energy potential

With an energy system based fully on renewables, regional renewable energy potentials and the RES production levels have a significant impact on region's ability to adapt to the new situation and even take advantage of it and, hence, on territorial development.

As discussed above, the exposure and sensitivity of regions regarding energy production and potentials varies. Some regions have a large RES potentials, and already today high levels of RES production, while others have only moderate potentials and little domestic RES production, while most regions are ranging in between.

Summarising the above sections, the map below shows territorial disparities and challenges that a fully renewable energy system may produce, due to differences in RES potentials and production levels. The map developed from sketches at the participatory workshop, enriched with the material presented above.

Map 3.18 Impact map



The following table summarises the territorial impacts of the additional regional RES production.

Table 3.1 Territorial impacts– RES potential and RES generation capacities

	Highly exposed and highly sensitive	Highly exposed but not so sensitive	Hardly exposed and hardly sensitive
Onshore and offshore wind power potential and production	Areas with high potential and with significant installed onshore and offshore wind power capacity can be found around the North Sea; most notably in the UK and Ireland, Belgium and the Netherlands, Germany's North Sea coastal areas and Denmark as well as large parts of the Iberian Peninsula and the south of Italy.	Another group of regions, in particular around the Baltic Sea (the Baltic States, Southern Sweden and the coastal areas of Finland around the Gulf of Finland), in North/ Northwest and Southwest France, southern Norway and Sweden, Czech Republic and Central and North Poland have a high wind power potential, but currently a low level of deployment. These would need a surge in investment to unlock the potential.	Regions with low techno-sustainable wind power potential and little installed wind power capacity are in the Alpine region and the foothills of the Alps (e.g. Northern Italy and large parts of Slovenia), Slovakia, Croatia and Hungary and the south-eastern parts of Europe (Greece, Romania, with the exception of the southeast, and Bulgaria).
Solar power potential and production	Regions with the highest unexploited techno-sustainable solar potential (in particular, with available land) and considerable installed capacity are in central Spain and, to a lesser extent due to land use constraints, in the southern coastal regions of Spain, Italy, including the Italian islands Sicily and Sardinia and southwestern France.	Regions with a high techno-sustainable solar power potential, but low or somewhat lower current utilisation are in Greece, Romania, Bulgaria and Portugal. High utilisation, but relatively low potential regions are in Germany and Denmark.	Low potential and low utilisation. Regions with low techno-sustainable solar power potential and no significant installed capacity are in Scandinavia, most parts of the British Isles (except for the most south-western parts) and Poland.
Potential for and production of bioenergy	High potential and high utilisation. Areas with high bioenergy potential and significant production capacities are in France, Germany, Poland, Sweden, Finland, and Spain.	High potential, but currently low utilisation. Regions with significant potential, but lower levels of bioenergy production are especially the UK, but also the Czech Republic, Slovakia, Hungary, Romania.	Low potential and low utilisation. Bulgaria, Greece, Cyprus, Croatia and Slovenia, the BENELUX, Denmark as well as Portugal and Ireland have low potential and low production of bioenergy.
Hydropower potential and production, including tidal and wave power	Areas with a high share of hydropower generation and high potential for further exploitation are in the Alps and Scandinavia, but also in South-West Oltenia in Romania. For wave and tidal power, areas with high potential and installed capacity are mainly Scottish coastal areas and the French Atlantic coast.	Regions with high potential, but a lower level of exploitation are in south-eastern Europe.	The rest of Europe.
Geothermal	Areas with a high geothermal energy	Regions with a geothermal potential, but	All other regions with low or no potential.

power	potential for geothermal district heating and significant installations are in Iceland, Italy (mainly Tuscany), France (the Paris Basin and the Aquitaine Basin in the southwest) and Eastern Hungary and selected regions in Germany.	currently low utilisation can be found in the Czech Republic, Spain, Denmark and Lithuania (as well as in the French Overseas Departments in the French West Indies and the Indian Ocean).	
Fossil and nuclear energy production	Regions with significant oil, gas or coal extraction paired with a significant share of people employed in mining and quarrying energy producing materials. For oil and gas, these are the coastal regions of Norway (in particular, Agder and Rogaland region and Vestlandet) and North-Eastern Scotland (UK). For coal, these are Slaskie, Silesia, Opolskie (Poland), Severozápad (Czech Republic), the Carpathian-Balkanian Basin (Bulgaria and Romania) and North-Eastern Scotland (UK).	Regions with significant oil or coal extraction, but a low share of people employed in mining and quarrying energy producing materials. Yorkshire and Nottinghamshire (UK), Northern Bohemia (Czech Republic), Northern Rhine-Westphalia, Saarland and Saxony (Germany), Severozápad/ Silesia (Poland), Drenthe (Netherlands), the Carpathian-Balkanian Basin (Bulgaria and Romania) and Western Macedonia (Greece).	The rest of Europe.
Energy infrastructure for transportation and storage	Regions that need to extend their grid infrastructure, but will be challenged financing the investment are two of the “electric peninsulas”, i.e. the Baltic States and Poland and the Iberian Peninsula, as well as Central Eastern and South Eastern Europe (need to reinforce the regional network for North-South and East-West power flows).	Regions that are considerably affected by the need to extend their grid infrastructure, but are more likely to be able to finance the investments are Northwest and Central Europe as well as Italy.	Scandinavia will be little affected, Iceland will be self-sufficient and is not connected to the European grid.

4 Component – Regional energy consumption

Regions have differing levels of energy consumption. A basic distinction should be made between economic activity, transport and households (building energy is included under economic activity and households).

4.1 Why this component is important

A significant reduction in energy consumption for industrial processes, transport and households is a prerequisite for managing the transition to European energy supply and consumption that relies fully on renewable energy.

Regions differ in their energy use, both in absolute terms and when normalised by capita or GDP. Reducing the current levels of consumption, through technical measures and changes in behaviour, will be indispensable in all regions. Regions with particularly high consumption levels will have to make a particular effort. Due to the expected steep increase in energy costs, changes in energy consumption patterns will be indispensable. Estimates of the potential energy savings from measures to change behaviour range from 5 to 20% (European Environment Agency, 2013). These measures include awareness raising, by giving direct feedback on personal energy consumption using smart meters and dynamic pricing schemes where users actively change their consumption to save money. Economic actors will put a lot of effort into improving production processes to increase energy efficiency. Regions with a high use of public transport, little road freight transport and a high share of renewable energy in transportation will have to shoulder the least adaptation costs and efforts.

Regions with high energy use can generally expect considerable challenges in providing the required energy from renewable sources.

4.2 Territories exposed and their sensitivities

To meet demand with renewable energy will require a significant reduction in energy use, given the short time available to increase renewable energy production. Regions with high energy use in economic activities and transportation will probably face considerable challenges unless they are able to drastically reduce their consumption. A forced reduction will come with negative side-effects, such as the loss of economic competitiveness and corresponding loss of jobs, accessibility and mobility. Private households with high energy consumption will be faced with a high adaptation pressure and may experience a signification reduction in their current quality of life. However, people with more disposable income can afford more energy-efficient appliances and should be able to maintain a similar lifestyle. Regions which today have a high share of population at risk of poverty will be particularly vulnerable to energy price increases and are likely to see an increase in energy poverty.

4.3 Regional energy consumption of households

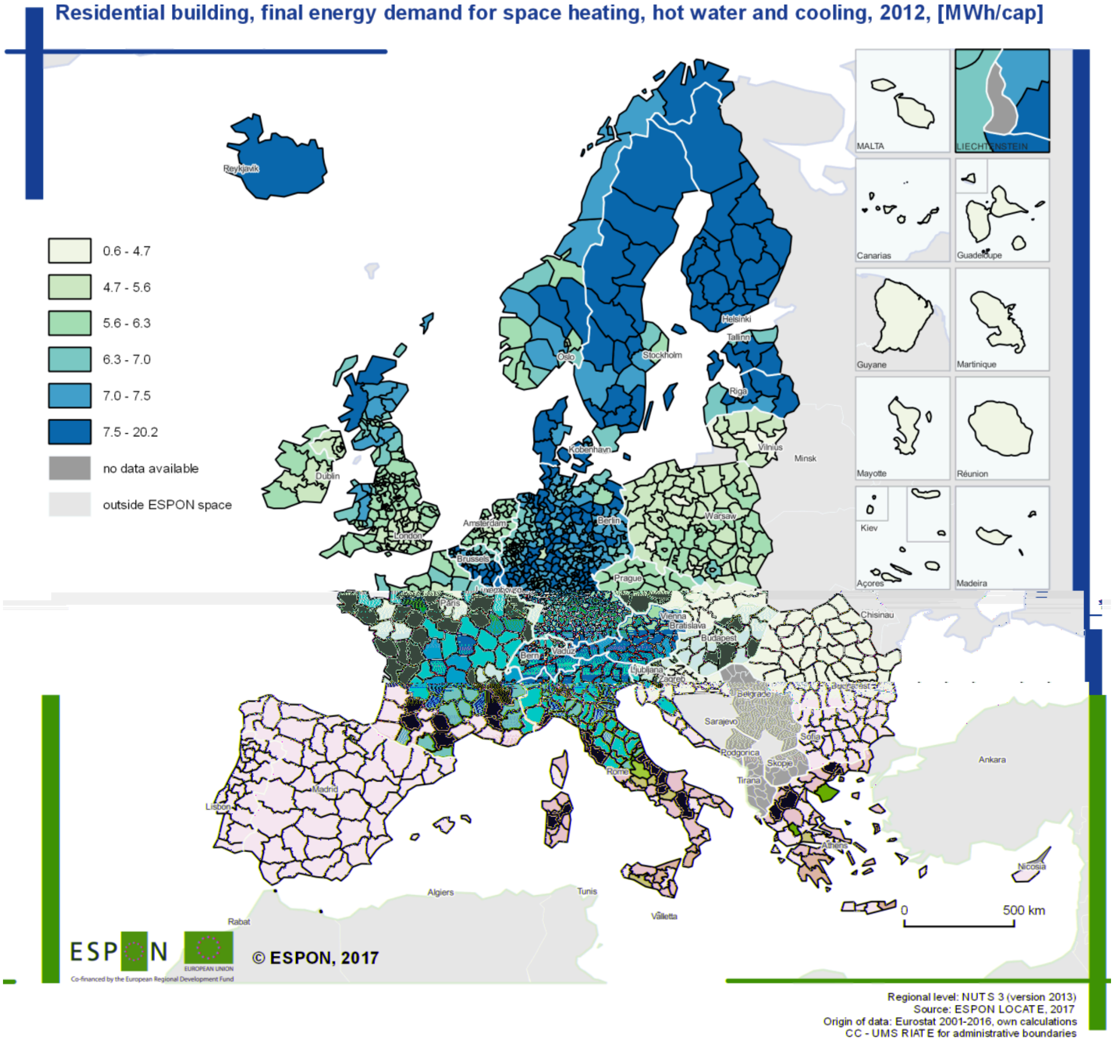
Households currently consume about one third of Europe’s energy, mainly for heating and running electrical appliances. Since energy prices are expected to increase (at least in the short run) as a result of high investment in additional renewable energy production capacity, this will affect households where energy makes up a significant share of household expenditure.

The influence of consumer behaviour on energy consumption is considerable, and the range of potential energy savings due to measures targeting behaviour is 5 – 20%, depending on the type and combination of interventions (European Environment Agency, 2013). Feedback on personal energy consumption can raise awareness among building owners so they can influence their energy bills. Such feedback can be, for example, from individual meters or heat cost allocators that measure individual consumption in multi-apartment buildings. Information on energy efficiency potential in a home, through instruments such as energy performance certificates, energy calculators or energy audits can assist energy management.

4.3.1 Exposure

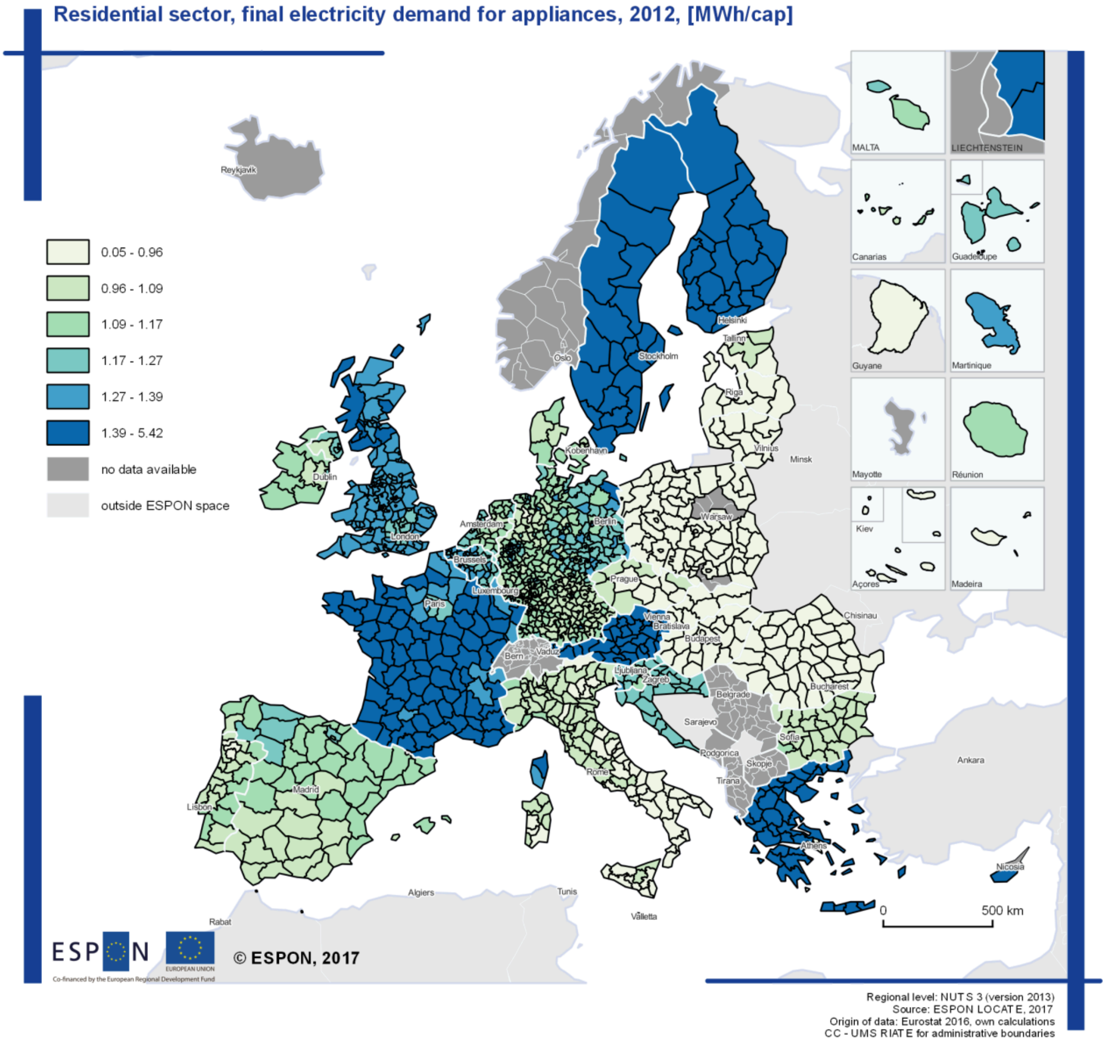
All territories will be affected by the need to curb the current level of household energy consumption. Regions with particularly high per capita consumption will be faced with greater adaptation pressure.

Map 4.1 Final energy demand for space heating, hot water and cooling



Heating, hot water and cooling accounts for most household energy consumption. It is particularly high in Northern Europe and Germany, Austria and Northern Italy. Regions with the highest energy use for heating and hot water are in Scandinavia (apart from Ager and Rogaland), Denmark, Estonia, Latvia, Scotland, most parts of Germany (except for parts of North Rhine Westphalia and Mecklenburg Vorpommern), Belgium and Luxembourg, central France, Austria and Northern Italy.

Map 4.2 Final energy demand for electrical appliances



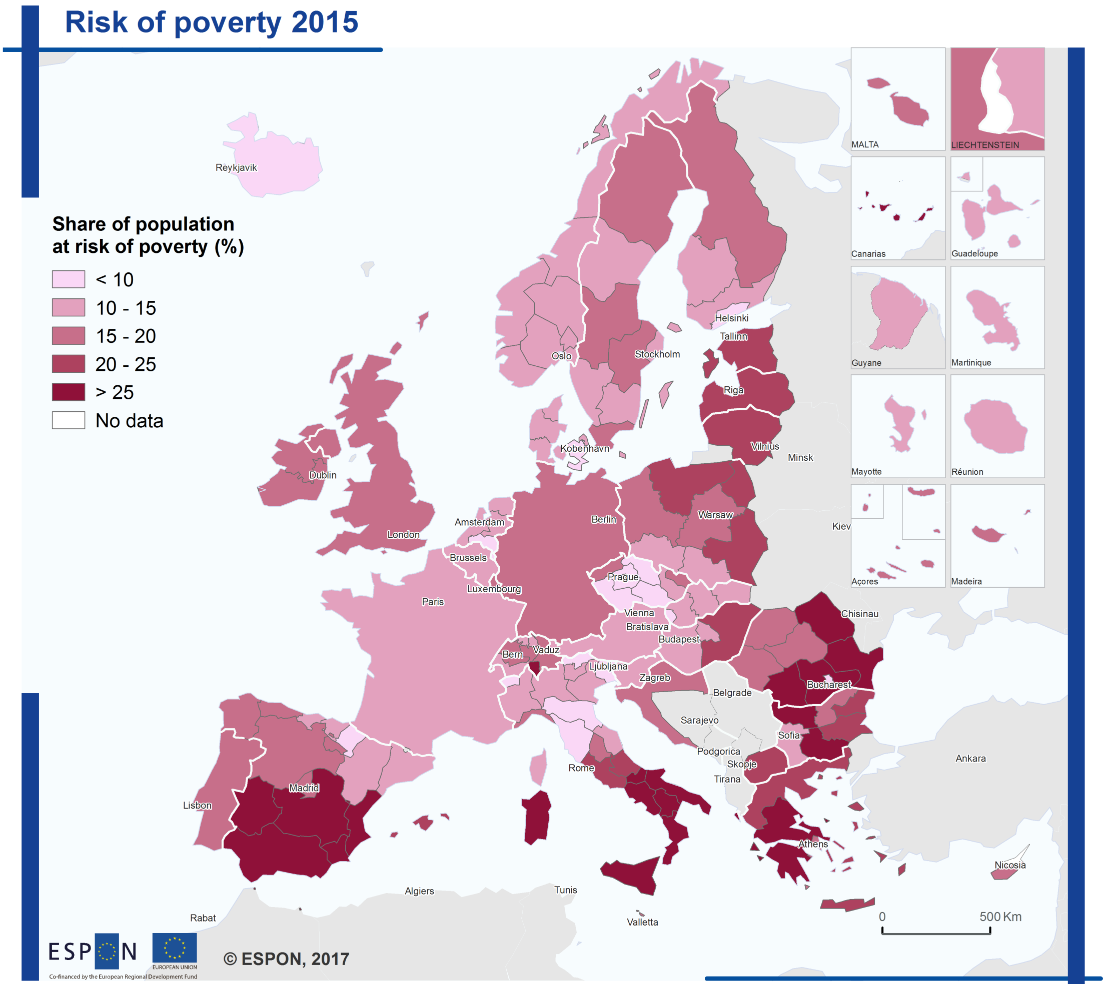
Energy demand for appliances and lighting in the residential and service sector is essentially attributed to household appliances such as stoves and washing machines, lighting and electricity-related heating devices. It is particularly high in France, the UK, Iceland, Norway, Sweden, Finland, Austria, Greece and parts of Eastern Germany (Saxony and Thuringia).

4.3.2 Sensitivity

Regions where households will be particularly affected are those where energy prices are expected to rise significantly due to high costs of transformation (e.g. areas with a low share of domestic RES production, in connection with moderate or low RES potential) and where the per capita household energy use is high. However, in affluent regions where people have more disposable income, the population can afford more energy-efficient appliances and can maintain a similar lifestyle. Poorer regions, where households have to spend a significant amount of their income on energy will be particularly vulnerable to price increases. They will experience a rise in energy poverty and, as a secondary effect, increased social inequality.

Currently, regions with the highest share of population at risk of poverty are in South and Southeast Europe, but also in the Baltic States. A similar picture emerges when looking at the current level of energy poverty in Europe. Countries where more than 10% of the population are unable to keep their home warm are Bulgaria, Lithuania, Greece, Cyprus, Italy, Latvia, Malta, Romania and Spain[11].

Map 4.3 Risk of poverty 2015



Regional level: NUTS 2/PL,HU,EL,NL=NUTS 1/AT,BE,CY,DE,EE,FR,HR,LU,LT,LV,MK,MT,PT,SI,UK=NUTS 0 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: Eurostat (online data code: ilc_li41), 2015
CC - UMS RIATE for administrative boundaries

4.3.3 Impact

Regions with high per capita household energy consumption, combined with low household disposable income, in particular regions where households have to spend a significant amount of their income on energy, will be particularly vulnerable to energy price increases.

- **Under pressure.** The most vulnerable regions, with high energy consumption of households for heating and electrical appliances and a high share of population at risk of poverty are in Estonia and Latvia.
- **Under pressure but with the potential to cope.** Energy consumption of households is particularly high in Northern Europe (Norway, Sweden, Finland, Denmark, Northern Scotland) and Central Europe (Germany, Austria, Northern Italy, Switzerland,

[11] Share of total population unable to keep their home adequately warm – EU-SILC survey, national data (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_mdes01&lang=en)

southwestern France and Belgium). These regions also have a low share of population at risk of poverty. On the other hand, the share of population at risk of poverty is high in Southern Spain, Southern Italy, Greece, Bulgaria and Romania, however, energy consumption in these countries and regions is also low.

- **Least challenged.** Areas least affected are the Netherlands, northern and north-western France and some parts of Spain (Basque country, Navarra, Aragon, Cataluña) as they have low household energy demand and a low share of population at risk of poverty.

4.4 Regional energy consumption for economic activities

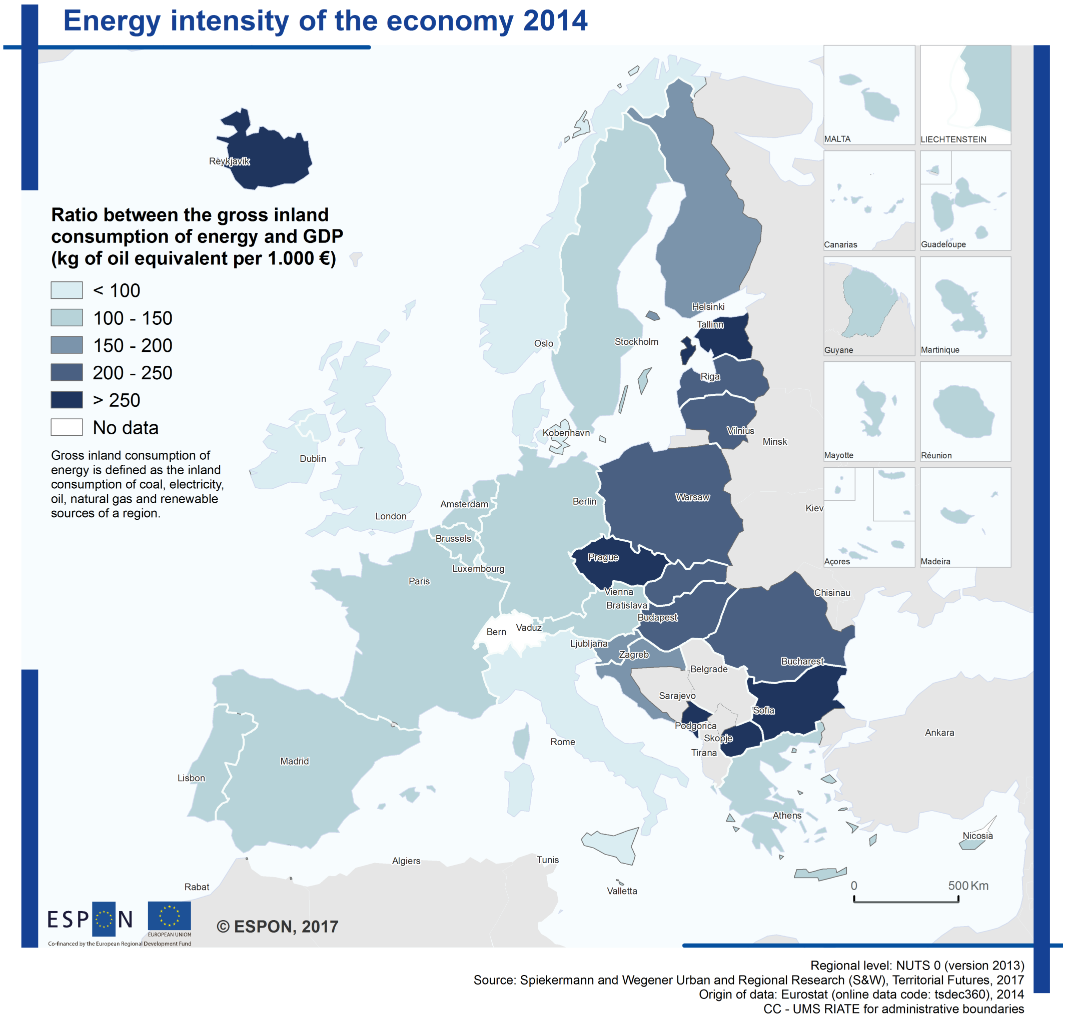
Regions with a very energy-intense economy and/ or strong reliance on fossil fuels will be faced with a huge transformation effort. Increased energy costs will result in lost competitiveness especially for businesses in sectors where energy costs are significant. Furthermore, due to increases in transport costs, export-oriented businesses far from their markets and/or where the transportation costs are significant will also experience a significant loss in competitiveness (see section 5).

4.4.1 Exposure

Energy-intensity of the economy describes the ratio between gross energy consumption and GDP, the energy-efficiency of a country's economic output. Regions with a highly energy-intense economy will have to undergo major efficiency improvements.

The most energy-intense regional economies are in the eastern part of Europe. However, they are also the regions with the biggest improvements in energy intensity over the past nine years, apart from Estonia, where energy consumption per GDP has stagnated. This was, however, not so much the result of efficiency improvements, but of changes in their economic structure. The lowest levels of energy intensity are in Norway, the British Isles, Denmark and Italy. The UK has also seen a big improvement in energy intensity.

Map 4.4 Energy intensity of the economy: gross energy consumption divided by GDP in 2014



4.4.2 Sensitivity

Currently, European industry consumes about 26% of total final energy, while the service, agriculture and fishery sectors together account for 15.6%. Highly energy intensive economies are mostly economies with a high share of national economic output and jobs provided by the manufacturing industry. Energy-intense, old industrialised areas will be the most vulnerable to increasing energy costs and the related loss in competitiveness.

High shares of manufacturing value added and employment can be found in the old industrial regions in Eastern Europe, in particular, the Czech Republic, Slovakia, Romania, Bulgaria, Poland, Hungary and Estonia, Latvia and Lithuania and Slovenia. But also Finland (iron ore, paper), Iceland (aluminium production), Germany (steel and cement in the Ruhr area) and Northern Italy as well as Sweden (northern Sweden, in particular Lapland), Belgium (Agglomeration Charleroi) and Austria (Upper Austria and Styria) have a significant share of GVA and employment in manufacturing.

Figure 4.1 *Value added and employment in manufacturing, Member States and Norway, 2006. Share in the non-financial business economy (%)*

(1) Malta, not available.
Source: Eurostat (ebd_all)

Source: http://ec.europa.eu/eurostat/web/products-statistics-in-focus/-/KS-SF-09-062

4.4.3 Impact

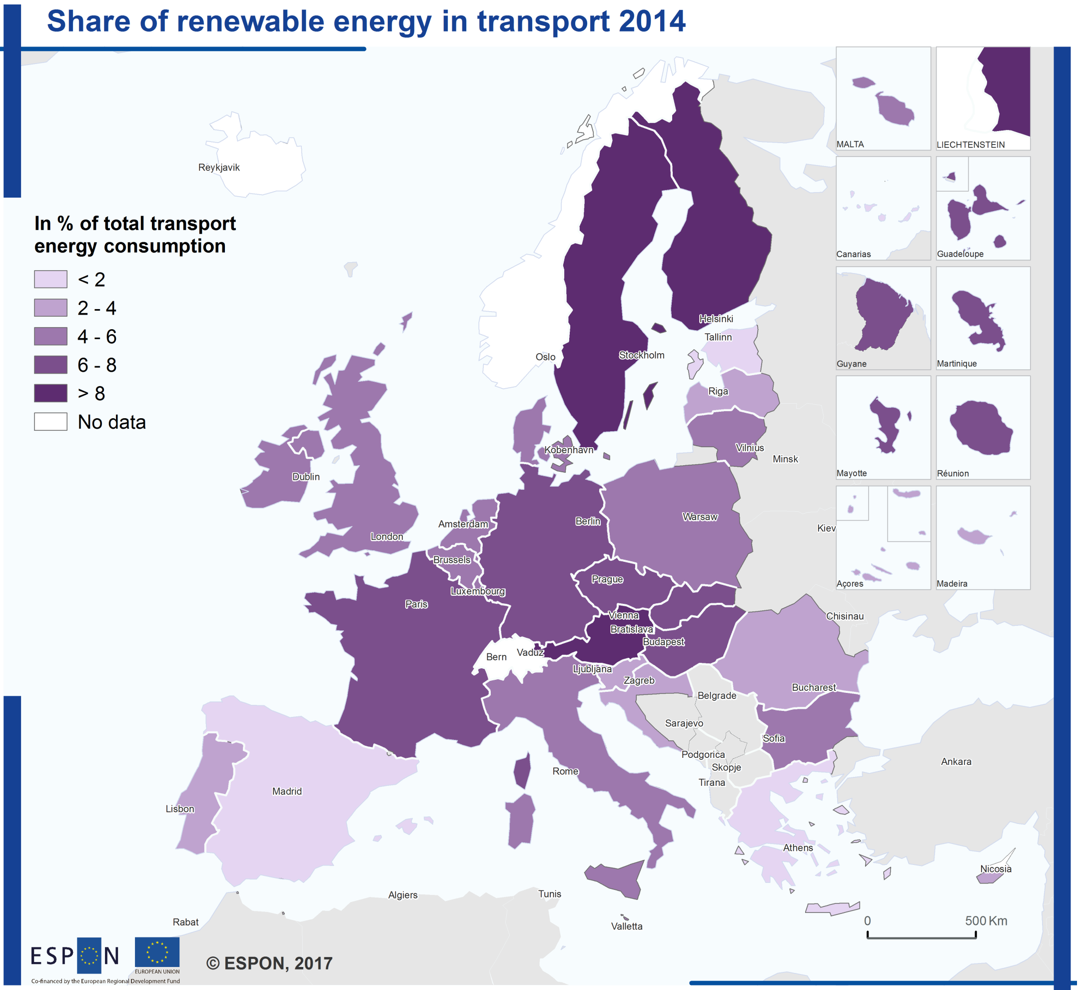
Regions with an energy-intense economy and a high share of the national economic output and jobs provided by manufacturing will be faced with a lot of pressure to modernise their economy or lose competitiveness.

- **Under pressure.** Most vulnerable economies are in old industrial regions in Eastern Europe often with outdated industrial infrastructure. These regions are in the Czech Republic, Slovakia, Romania, Bulgaria, Poland, Hungary and Estonia. Somewhat less, but still heavily affected are Latvia, Lithuania, Slovenia and Finland.
- **Under pressure, but with better chances to adapt.** Highly industrialised regions with an energy-intense economy are in Germany (the Ruhr area) and Northern Italy, but also to a lesser extent Sweden (northern Sweden, in particular Lapland), Belgium (Agglomeration Charleroi) and Austria (Upper Austria and Styria). The latter are also sensitive to an increase in energy costs, but have a much better starting position as they rely less on energy-intense industry.
- **Least challenged.** Limited value added and employment from manufacturing and low energy-intensity regions can be found in Norway, Greece, Luxembourg, Malta, Cyprus, the British Isles and the Netherlands.

4.5 Regional energy consumption for transport

Transport is responsible for around one third of Europe’s energy consumption. Furthermore, transportation relies heavily on fossil fuels, mainly in the form of petroleum products, while the current share of renewable energy is low.

Map 4.5 Share of renewable energy in transportation 2014



Regional level: NUTS 0 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: EEA, 2017
CC - UMS RIATE for administrative boundaries

To fully decarbonise transport, petroleum products will have to be substituted entirely by renewable energy. A number of alternatives exist (biogas, hydrogen for fuel cells, electricity), however, the fuel that will most likely take the place of oil is electricity (in the form of batteries or overhead lines). Biofuels are indispensable for transport, but are likely to meet public opposition due to sustainability concerns, limiting their use to certain sectors that cannot (easily) replace fossil fuels with electricity (e.g. aviation, maritime and inland shipping, heavy haulage trucks). Fuel cells might become increasingly important in the medium term when the technology is sufficiently mature, also because hydrogen will be used for storing surplus renewable energy. To curb energy use per person-kilometre, the share of public transport will have to increase, at the expense of private transport. Regions that already have a high share of public transport will find it easier to adapt. For freight transport, regions that already have an above average share of rail freight will find it easier to fully decarbonise the freight transport sector.

4.5.1 Exposure

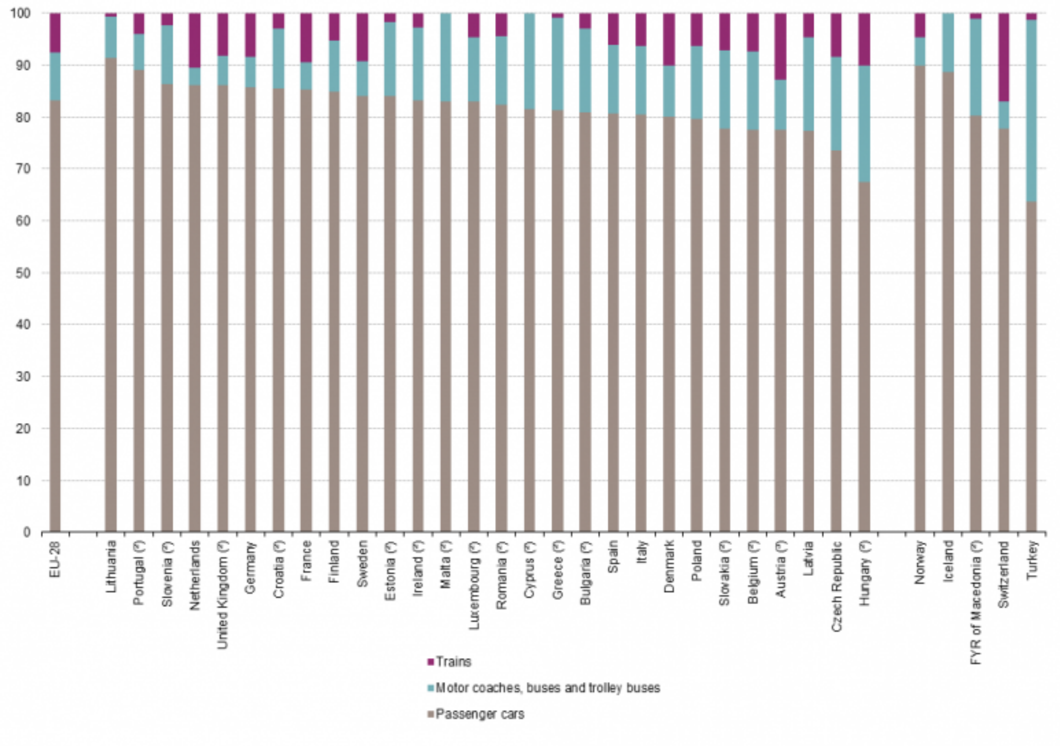
The use of public means of transport in the EU is currently low, but varies between countries. Most freight in the EU is carried by road. Regions that already have an above average share of public passenger and rail freight transport will be in a favourable position to transition to an enhanced role of rail for freight and long-distance passenger transport.

In the EU, cars currently accounted for about 83%, buses 9% and trains 8% of person-kilometres for passenger transport. Public transport accounts for less than 20% of all passenger transport and is particularly low in Lithuania, Portugal, Slovenia, the Netherlands, the UK, Germany, Croatia, France and Finland. Countries with a public transport share over 20% are Hungary, the Czech Republic, Latvia, Austria, Belgium, Slovakia, Poland and Denmark.

For inland freight in the EU, road transport carries around 75%, even though the share of rail has increased and from 2011 onwards has stabilised at around 18.5%. The share of inland waterways fluctuates between 6% and 7%[12]. The split of road, rail, maritime, inland waterways and air highlights that maritime transport is significant as it accounts for 33% of transport, while air freight only makes up 0.1% of total freight transport (measured in tonne-kilometres). The split at country level varies considerably and obviously depends on the availability of each mode (e.g. only 17 Member States have navigable inland waterways and Cyprus and Malta have no railways). The importance of rail transport in the Baltic States is evident (essentially linked to the transport of Russian energy products to Baltic Ports). Other countries with a 30-40% share of rail freight transport are Slovakia, Switzerland, Slovenia, Austria, Hungary, Romania, Sweden and Finland. Inland waterways are very important for freight transport in the Netherlands. High traffic on the Danube also explains the comparatively high share for inland waterways in Bulgaria and Romania (close to 30% in both countries).

[12] http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split

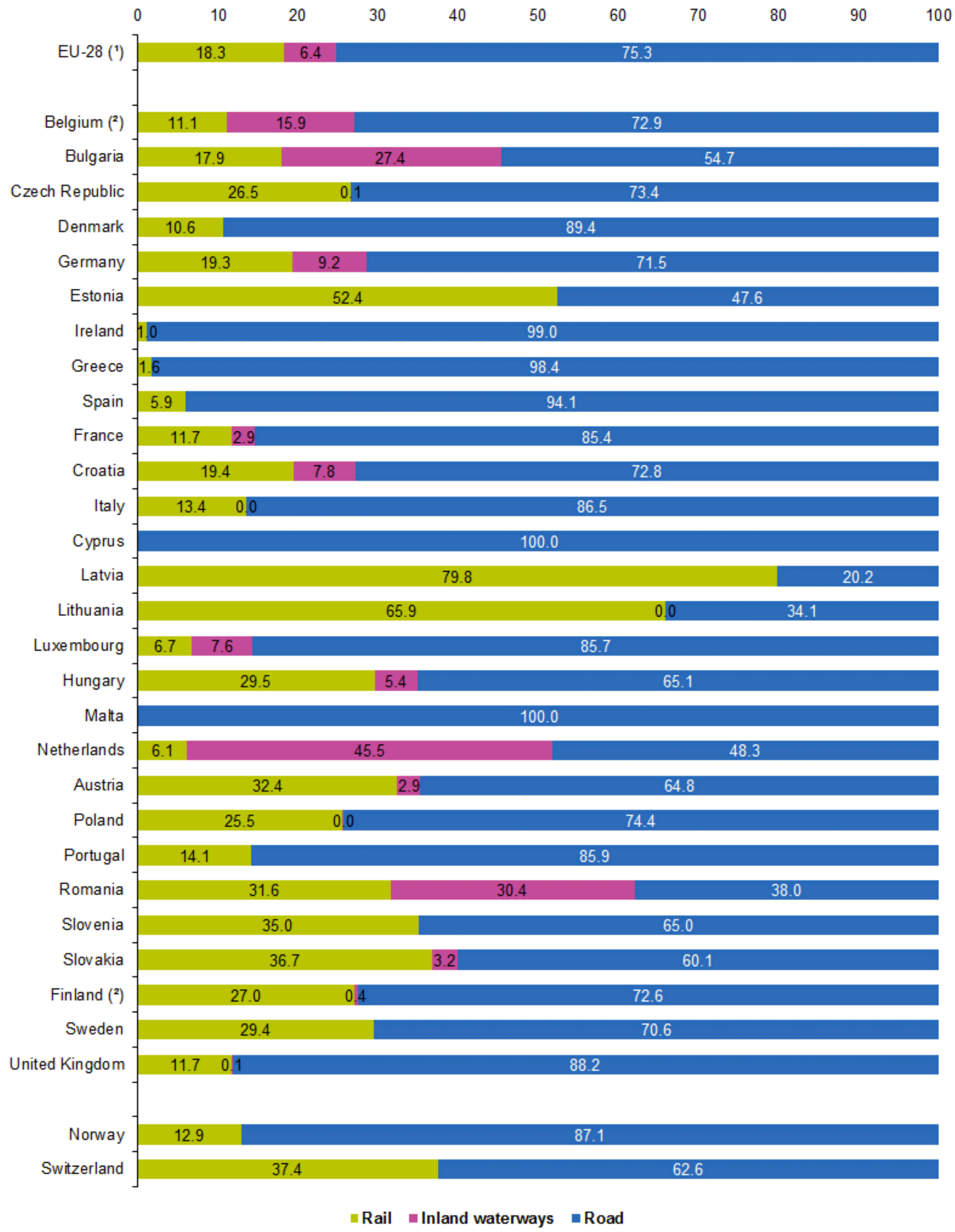
Figure 4.2 Modal split passenger transport



(¹) Excluding powered two-wheelers. Cyprus, Malta and Iceland: railways not applicable.
(²) Includes estimates or provisional data.
(³) The railway in Liechtenstein is owned and operated by the Austrian ÖBB and included in their statistics.
Source: Eurostat (online data code: tran_hv_psmod)

Source: http://ec.europa.eu/eurostat/en/web/products-statistical-books/-/KS-DK-16-001

Figure 4.3 *Inland freight transport*



(¹) EU-28 includes rail transport estimates for Belgium, inland waterways transport estimates for Finland and does not include road freight transport for Malta (negligible). Figures may not add up to 100% due to rounding.

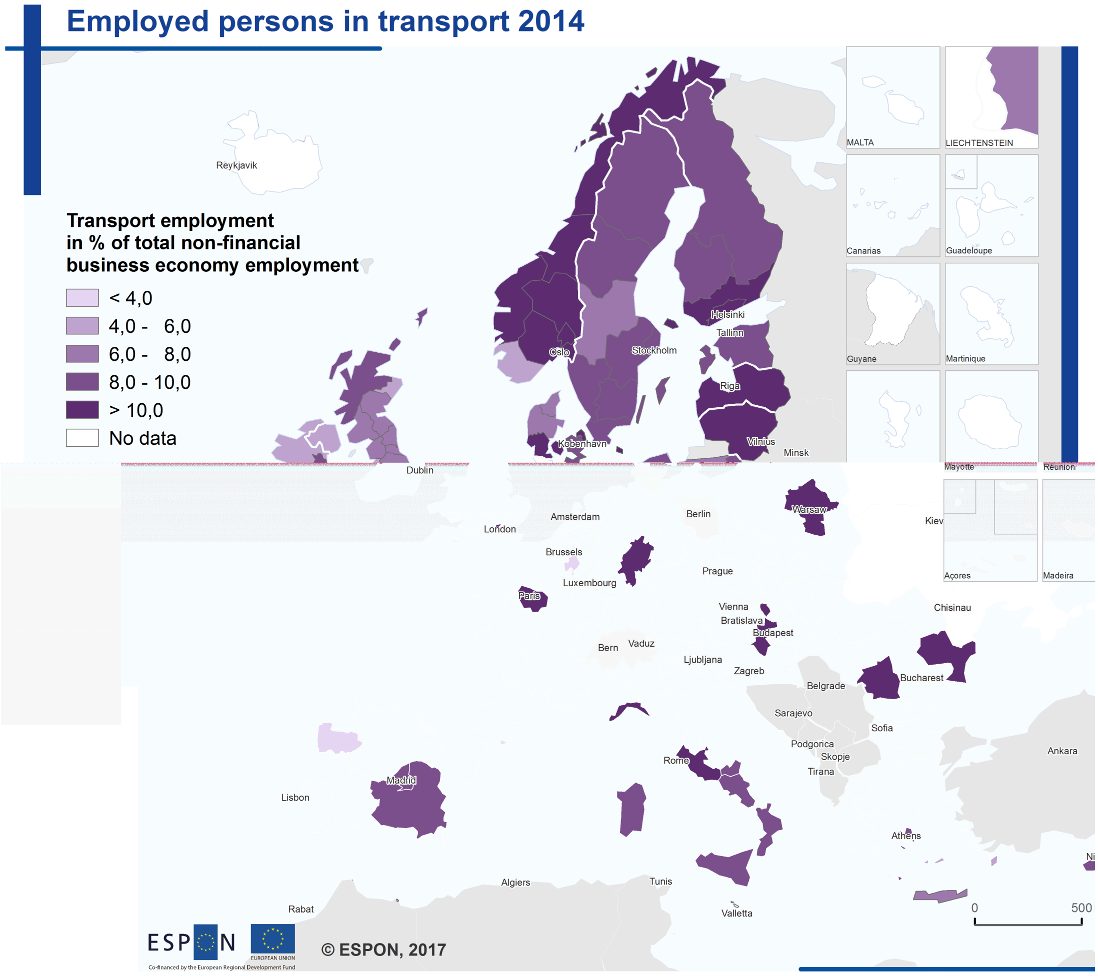
(²) Estimated values.

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split

4.5.2 Sensitivity

Transport is an important industry. In some regions, it accounts for more than 10% of the regional GVA. A complete restructuring of European transport and a significant reduction in freight transport due to a steep increase in costs will affect some regions heavily.

Map 4.6 GVA of transport and storage



Regional level: NUTS 2/DE=NUTS1 (vers
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futu
Origin of data: Eurostat (online data code: sbs_r_nuts06_
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European capital regions that will be heavily affected are the greater London area, Paris, Rome, Madrid, London, Warsaw, Bratislava, Copenhagen, Helsinki. On the other hand, selected regions and countries stick out as being strongly dependent on the transport industry. Examples are Norway (apart from Agder and Rogaland), Latvia and Lithuania, South West Oltenia and South-East Romania (Romania), Nyugat-Dunántúl (Hungary), Liguria (Italy) and the German regions of Cologne and Darmstadt.

4.5.3 Impact

Regions with a low use of public transport and a high share of road freight transport as well as a high share of regional GVA and employment generated in the transport sector will shoulder the biggest adaptation costs and efforts.

- **Under pressure.** Among the regions with a low share of public transport, a high share of road freight and a high share of GVA in the transport sector are Norway (with the exception of Agder and Rogaland), the German regions of Cologne and Darmstadt, but also the greater London area and the Highlands and Islands (UK), Latium and Campania as well as the islands of Sardinia and Sicily (Italy) and the Northeast and West of Poland and the Warsaw region.

- **Under pressure but with the potential to cope.** Regions that have a low share of public transport and a high share of road freight, that are moderately vulnerable in terms of GVA from the transport sector are the greater Madrid region (Spain), Cyprus and Greece, but also the South of Sweden and South of Finland and the Paris region, as well as Haute Normandie (France).
- **Least affected.** There are no regions in Europe with a high use of public transport, a low share of road freight and a low share of GVA generated in transport, thus, all regions will be hit to a high degree.

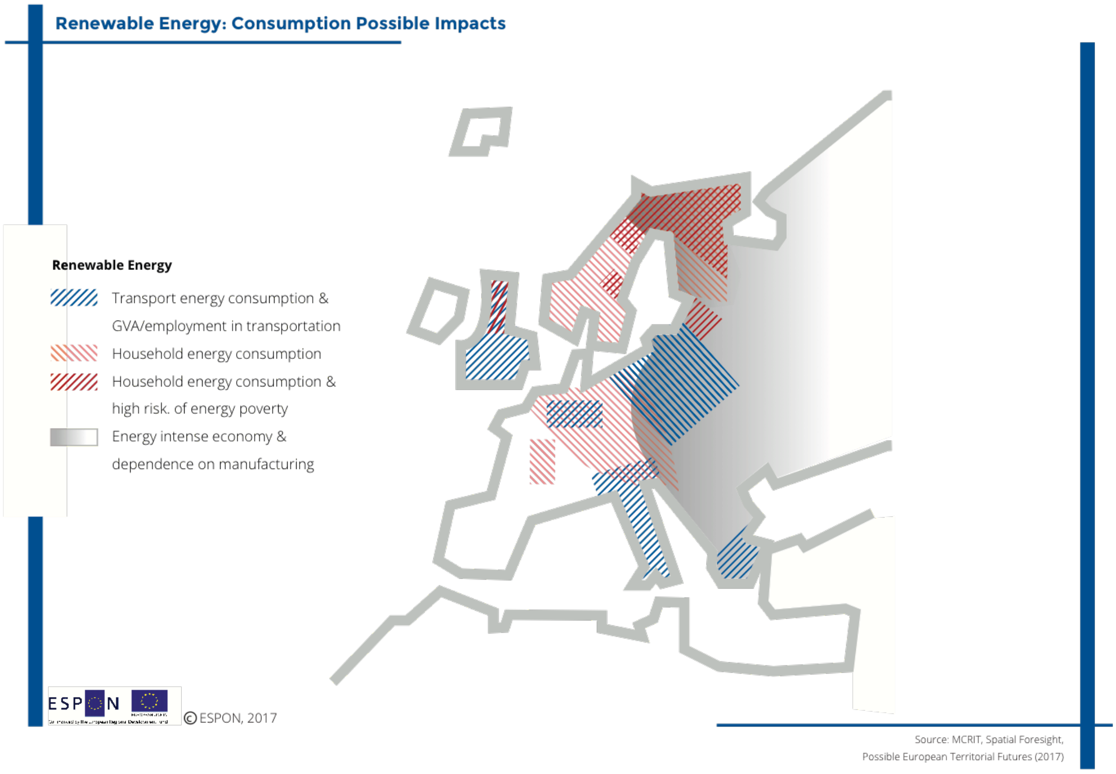
4.6 Conclusion on the territorial dimension of regional energy consumption

With an energy system based fully on renewables, regional energy consumption has a significant impact on the effort of regions to adapt to the new situation.

As discussed above, the exposure and sensitivity of regions regarding current energy consumption levels varies as some have a high household energy use, others a highly energy-intense economy and others an above-average energy use for transportation.

Summarising the above sections, the map below shows territorial disparities and challenges that a fully renewable energy system may produce, due to differences in regional energy consumption. The map developed from sketches at the participatory workshop, enriched with the material presented above.

Map 4.7 Impact map



The following table summarises the territorial impacts of the changing regional energy consumption patterns.

Table 4.1 Territorial impacts– Regional energy consumption

	Highly exposed and highly sensitive	**Highly exposed but not so sensitive**	**Less exposed and less sensitive**
Regional energy consumption of households	The most vulnerable regions, due to high household energy consumption for heating and electrical appliances and a high share of population at risk of poverty can be found in Estonia.	Energy consumption of households is particularly high in Northern (Norway, Sweden, Finland, Denmark, Northern Scotland) and Central Europe (Germany, Austria, Northern Italy, Switzerland, southwestern France and Belgium). These regions also have high purchasing power. The share of population at risk of poverty is high in Southern Spain, Southern Italy, Greece, Bulgaria and Romania, however, energy consumption in these countries/ regions is also low.	Areas least affected are the Netherlands, northern and north-western France, some parts of Spain (Basque country, Navarra, Aragon, Cataluña) as they have low household energy demands, but high GDP and a low share of population at risk of poverty.
Regional energy consumption for economic activities	Most vulnerable economies with often outdated industrial infrastructure are in the old industrial regions in Eastern Europe; the Czech Republic, Slovakia, Romania,	Somewhat less, but still heavily affected are Latvia and Lithuania and Slovenia, but also Finland. Highly industrialised energy-intense regions are in Germany (e.g. the Ruhr	Low value added and employment in manufacturing and low energy-intensity can be found in Norway, Greece, Luxembourg, Malta, Cyprus, the British Isles and the

	Bulgaria, Poland, Hungary and Estonia.	area) and Northern Italy but also Sweden (northern Sweden, in particular Lapland), Belgium (Agglomeration Charleroi) and Austria (Upper Austria and Styria). These are also sensitive to an increase in energy costs, but less energy-intense industry.	Netherlands.
Regional energy consumption for transportation	Among regions with a low share of public transport, a high share of road freight and a high share of GVA generated in the transport sector are Norway (with the exception of Agder and Rogaland), the German regions of Cologne and Darmstadt, but also the greater London area, the Highlands and Islands (UK), Latium and Campania as well as the islands of Sardinia and Sicily (Italy) and the Northeast and West of Poland and the Warsaw region.	Regions that have a low share of public transport and high share of road freight, but are moderately vulnerable in terms of GVA in the transport sector are the greater Madrid region (Spain), but also the South of Sweden and South of Finland and the Paris region as well as Haute Normandie (France).	There are no regions in Europe with a high use of public transport, a low share of road freight and a low share of GVA generated in transport, thus, all regions will be hit to a high degree.

5 Component – Regional transport and mobility patterns

Cheap transport is one of the backbones of Europe's economy and accounts for the increased mobility of Europe's population. In a fully renewable energy system, transport costs will increase steeply, which will heavily impact current transport and mobility patterns.

5.1 Why this component is important

In a Europe supplying all its energy demand from renewable energy, with a large shift towards electricity production, the transport sector will be faced with many transformation challenges. The vehicle fleet will have to be renewed, new infrastructure with fuelling stations for hydrogen and electricity will have to be developed and many current facilities require post-utilisation solutions, including dealing with contaminated soil. Long-distance passenger and freight traffic will undergo major changes. Alternatives to jet-fuel aircraft will not be sufficiently advanced to ensure the affordability of flying. Long-distance air transport will be replaced by trains where possible, benefitting regions with a good rail access. The transformation will hit both passenger and freight transport.

Passenger transport

European mobility patterns of the past were high with cheap transport and the removal of barriers to the free flow of people across borders. In well-connected regions this pattern will only be partly impacted by the "greening" of transportation. Even though individual passenger transport will still play a role (i.e. electric or hydrogen cars and motorbikes), the cost increase (at least in the short and medium-term) will enhance the shift to shared transport. Public transport and car sharing will gain importance, especially in densely populated areas, but also in rural regions. However, it will be much cheaper to implement in areas with a large population pool. Peripheral areas, with greater distance to larger centres, will be greatly disadvantaged by the increased costs of transportation. Depopulation of less accessible regions will accelerate.

Freight transport

Europe's current economic system is strongly based on the cheap transport of goods across the continent. This accounts for a high degree of internal EU trade and regional specialisation as well as a supply system based on just-in-time delivery to save on storage costs. Cheap fuel is also largely responsible for the fact that road freight predominates, plus the fact that it is the most flexible means of transport. In a 100% renewable energy system, freight costs are likely to increase sharply for two reasons: 1) haulers will have to renew their fleet and replace combustion engines with electricity, biofuel or hydrogen powered vehicles and 2) energy costs will generally increase sharply due to the high investment needed to realise full transition. This will disrupt current intra-European and international trade patterns.

Empirical data on the price sensitivity, or price elasticity, of road freight, expressed in tonne kilometres, indicates that it is sensitive to changes in fuel prices (De Jong et al., 2010)[13]. In a first step, with changes in fuel prices, hauliers will try to reduce fuel consumption by investing in more fuel-efficient trucks, implementing a more fuel-efficient way of driving and organising their transport more efficiently so they can reduce the number of vehicle kilometres needed to transport one tonne of cargo. If improvements in fuel and transport efficiency cannot fully compensate for the increase in fuel prices, hauliers will pass on the price increase to shippers. This will provide an incentive to reduce the number of tonne-kilometres shipped, e.g. by reducing the distance over which goods are transported, changing to other modes of transport, or passing on the price increase to end customers. Ultimately, transport volumes will decrease through lighter products, different suppliers (more local suppliers and fewer intermediaries), a different pattern of goods flows, producing closer to end customers and reduced demand for certain products. Not all product groups are equally sensitive to increased prices; among the most inelastic are agricultural products, minerals, building materials and metallurgical products.

Freight transport by air will become uneconomical, turning easily perishable foodstuff that is currently imported from outside Europe into luxury goods. Cargo transport by ship will also face considerable transformation. Even though marine and inland shipping can be considered energy-efficient, ships use cheap, heavy fuel oils as they are not bound by the same high emissions standards as land transport. The shipping sector is only slowly turning to alternative fuels. Renewable alternatives (e.g. biofuels such as biomethane and biomethanol, hydrogen fuel cells) are not yet widely used and are likely to be much more expensive.

Example: Solar-powered cargo ships

The Australian company Solar Sailor has signed a deal with the largest Chinese shipping line COSCO to fit their tankers with large solar-powered sails.

The sails are 30 meters long, covered with solar PV panels that will provide 5 percent of the ships' electricity and will harness enough wind to reduce fuel costs by 20 to 40%. The sails are controlled by a computer that angles them for maximum wind and solar efficiency. The company claims that the sails will pay for themselves within four years.

Shipping and air travel have been the hardest to conform to new efficiency demands. Planes and tankers require a lot of fuel, but the global economy depends on both, so the industries have been hard to regulate. Even the latest EU environmental standards included passes for shipping and airline companies. It is good to see a global company taking a dramatic step toward cleaner shipping.

[13] A 1% increase in fuel prices was estimated to lead to a 0.05 – 0.3% decrease in tonne kilometers, so it is inelastic.

5.2 Territories exposed and their sensitivities

The transformation to a 100% renewable energy system in Europe will come with a steep increase in transport costs and will make air transport uneconomical. This will affect all European regions. Regions with a high dependence on accessibility by air due to their remoteness will be particularly disadvantaged. This tendency will be reinforced in regions whose economies are strongly transport-dependent, e.g. remote tourism regions. Regions with an airport or port hub will be heavily affected as they will lose this function, which will also negatively impact the local logistics industry. By contrast, rail transport will gain importance for freight and long-distance passenger transport, so regions with rail good access will attract businesses and people.

5.3 Dependence on accessibility by different means of transportation

Regions that depend heavily on long-distance transport due to their remote location will experience a substantial loss in accessibility and, hence, attractiveness as a place to live and do business.

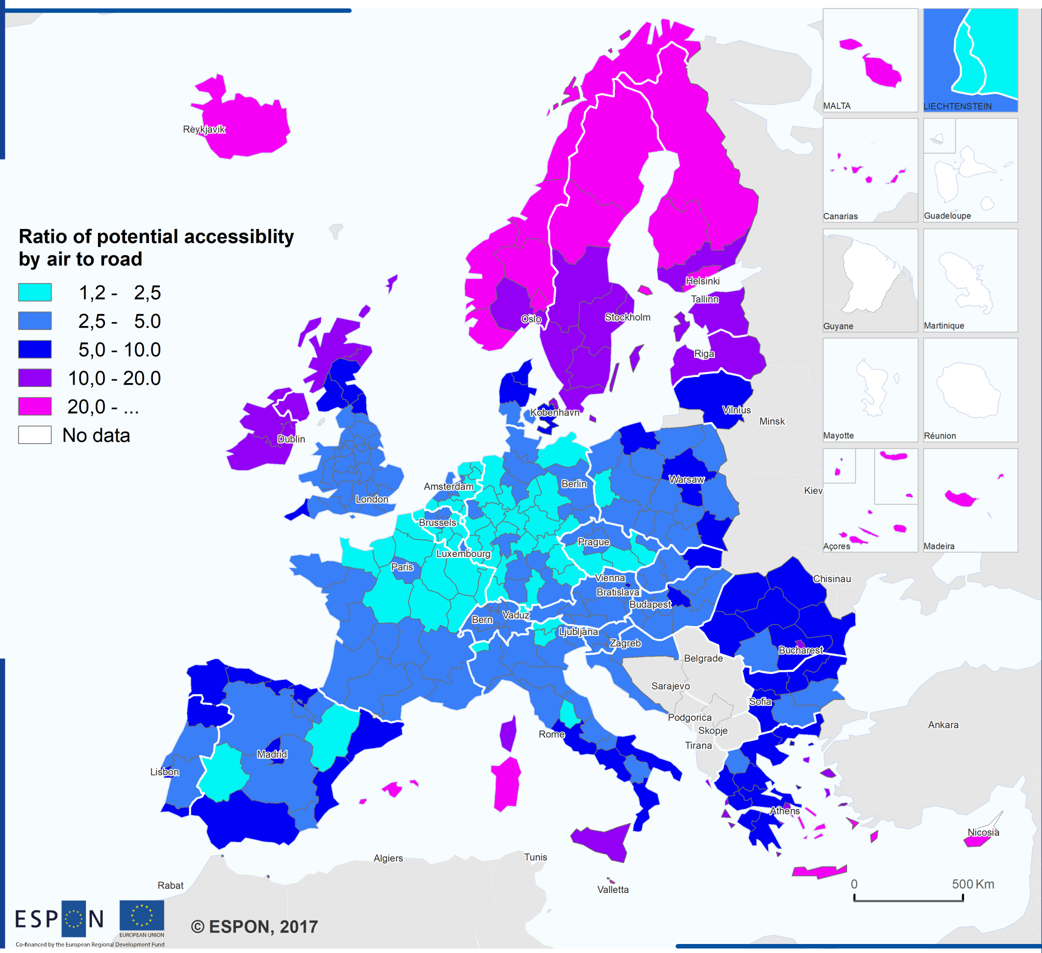
5.3.1 Exposure

Increased transport costs will affect all European regions. Regions with a high dependence on access by air due to their remoteness and distance will be particularly disadvantaged. By contrast, rail transport will gain importance for freight and long-distance passenger transport, so regions with good rail access will attract businesses and people. Overall, there will be a reinforced tendency of people and businesses to move to the highly urbanised parts of Europe and to a lesser extent to regional centres in all regions. Urban growth hubs will become the "power houses" of Europe and will attract the working age population, increasing the process of ageing peripheral regions. International firms, however, may decide to altogether move facilities to cities outside Europe.

When looking at the ratio of accessibility by air and road, regions in the European core (North and Northeast of France, BENELUX and most parts of Germany, Southern Czech Republic, selected regions in Northern Italy, i.e. South Tyrol, Trento, and Piedmont and Latio). The picture also correlates with the accessibility by rail and also with population distribution. The most air transport-dependent regions are can be found in Scandinavia, especially in the northern parts, Ireland and Northern Scotland, Iceland, the Baltic States, as well as most islands.

Map 5.1 Potential accessibility: dominance of air

Potential accessiblity: dominance of air



Regional level: NUTS 2 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: S&W Accessibility Model
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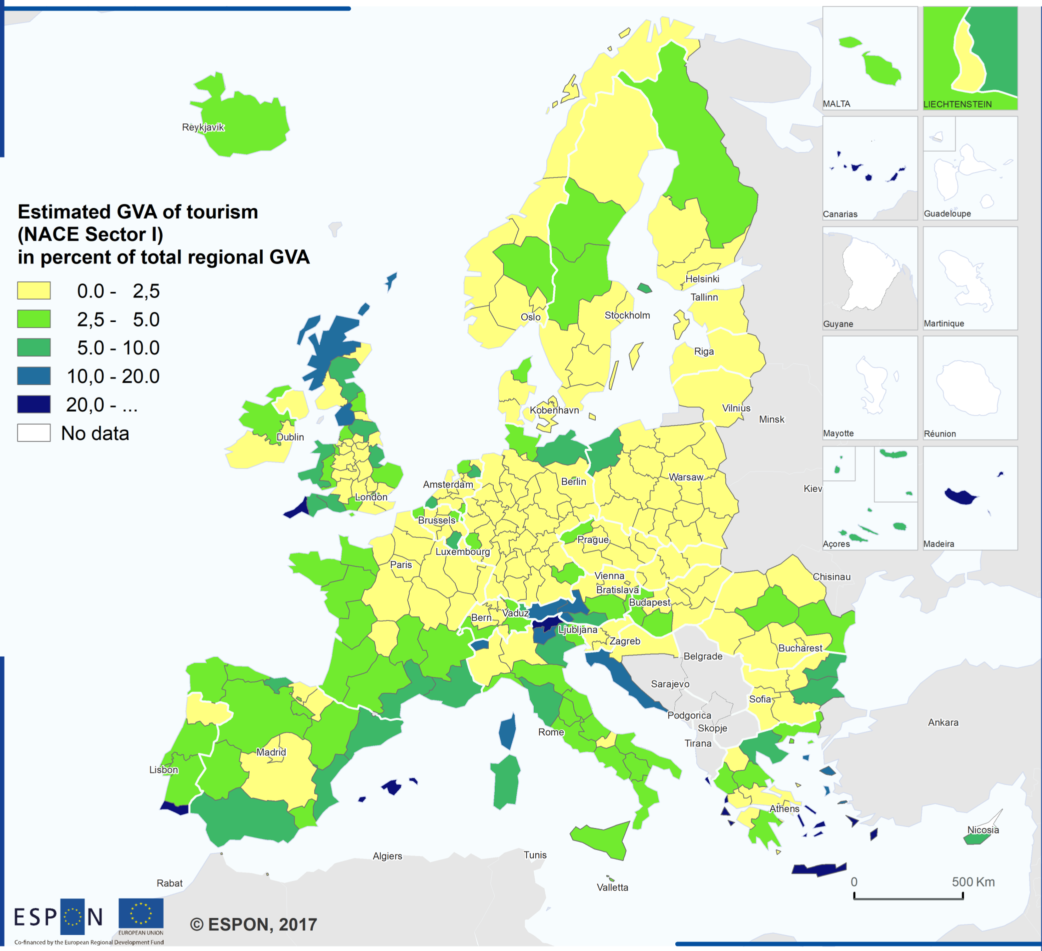
5.3.2 Sensitivity

Regions with strongly transport-dependent economies, such as remote and peripheral regions, will be particularly sensitive to reduced accessibility as a result of increased transport costs. This is particularly true for remote regions living on tourism, which will become much more local. Regions with an airport or port hub function will lose this function, which will also negatively impact the local logistics industry.

Regions in the periphery of Europe such as Greece, Southern Spain, Portugal, as well as islands, live on tourism and are highly dependent on good accessibility by air. Central tourist locations will gain while peripheral locations will lose. Regions with a strong dependence on GVA from the tourism sector are found in the Algarve (Portugal), Mediterranean coastal areas of Spain, Tuscany, Aosta Valley, South Tyrol and Trento and Veneto (Italy), Tyrol and Salzburg (Austria), Highlands and Islands, Cumbria and Cornwall (UK), the Croatian coast as well as most Mediterranean islands. However, several islands in (northern) Europe are already almost or completely energy-efficient (see example in info box 5).

Map 5.2 Estimated GVA share of tourism

Estimated GVA share of tourism



Regional level: NUTS 2 (version 2013)
Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: regionalised estimates based on Eurostat
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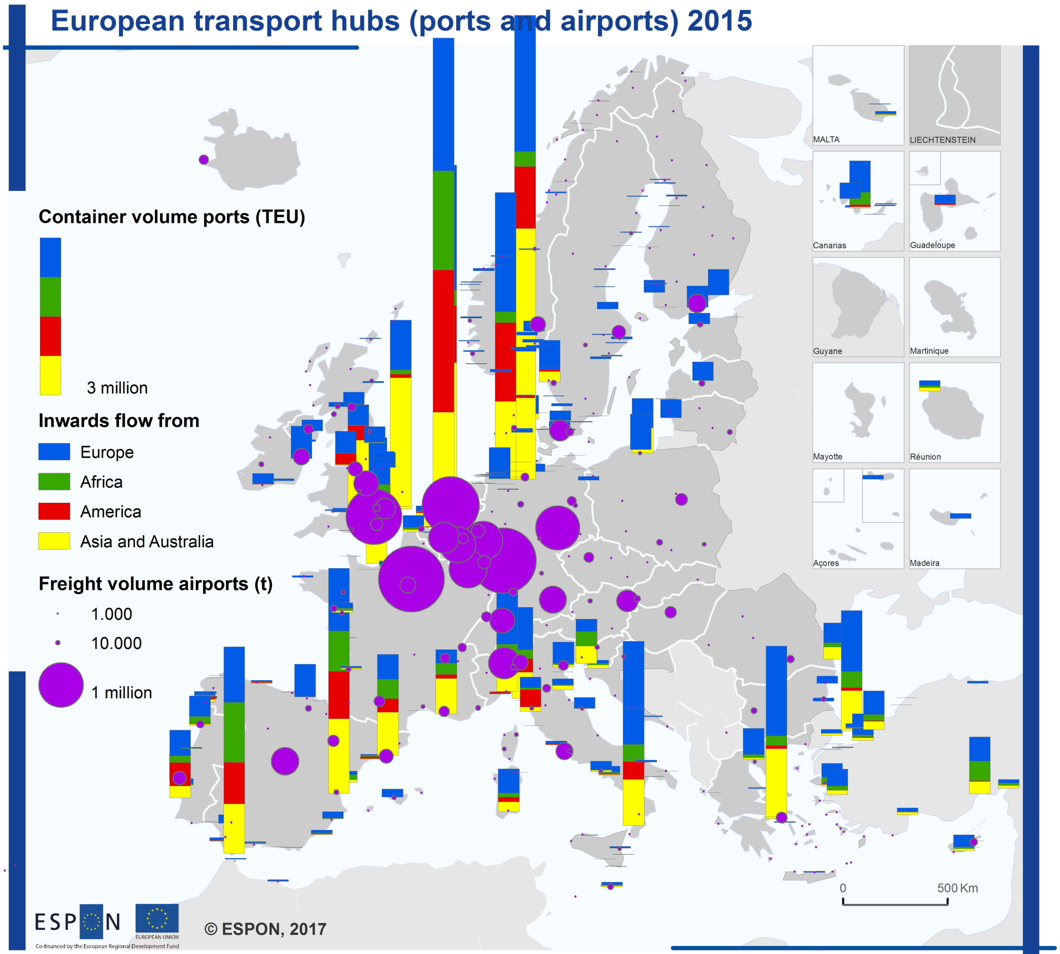
Example: Energy autarkic Isle of Wight, UK

The EcoIsland Initiative aims is to make the Isle of Wight self-sufficient with renewable energy sources by 2020. That includes at least 30 megawatts of renewable electricity. Renewable power technology to be adopted includes at least 1300 solar roofs, waste to energy, tidal, wind and geothermal power. The Isle of Wight's smart grid initiative aims to cut customer power bills by 50% with a combination of demand side management, battery energy storage and hydrogen storage.

Europe’s largest airport and port hubs for freight are in Northwest Europe (Benelux, Germany, UK and northern France). Other important ports are located on the Mediterranean Sea (Gibraltar, Valencia, Barcelona, Marseilles, Genova area, Reggio Calabria, Athens), the Atlantic coast (Lisbon and Porto), but also the Black Sea.

Map 5.3 European transport hubs (ports and airports) 2015



Source: Spiekermann and Wegener Urban and Regional Research (S&W), Territorial Futures, 2017
Origin of data: Eurostat (online data code: mar_go_qm_[year]), 2015, Eurostat (online data code: avia_gooa), 2015
©EuroGeographics Association for ports and airports
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5.3.3 Impact

Regions that depend heavily on long-distance transport due to their remote location will experience a substantial loss in accessibility and, hence, attractiveness as a place to live and do business.

- **Under pressure.** The most highly exposed regions are Mediterranean coastal areas in the Iberian Peninsula, Highlands and Islands (Scotland), Central Macedonia (Greece) and the Bulgarian Black Sea coastal region as well as Mediterranean islands. These regions have limited accessibility by rail and road, but are highly dependent on tourism and a number of ports.
- **Under pressure but with the potential to cope.** Regions with very good access by rail and road, and important airport hubs with high freight volume, will be able to replace a large part of the air transport with rail. These are often national and regional capital regions such as Paris, Brussels, Amsterdam; Berlin, Frankfurt, Munich and Milan, but also to some extent Vienna and Zurich. Regions with a low access and a low population density (Northern part of Scandinavia, the northern part of the British Isles, Iceland),

where air transport is not vital to the regional economy, will be severely challenged, but should cope with the new situation.

- **Least affected.** Regions in the core of Europe (most parts of Germany, France, Austria, Switzerland and Northern Italy), with high accessibility and no major transport hubs will experience the least pressure to adapt.

5.4 Conclusion on the territorial dimension of regional transport and mobility patterns

With an energy system based fully on renewables, regional transport and mobility patterns will be highly affected.

As discussed above, the exposure and sensitivity of regions to changing transport and mobility patterns varies. Some regions are highly dependent on affordable long-distance transport while others are particularly vulnerable due to a significant share of GVA and employment in the transport sector.

The following table summarises the territorial impacts of the changing regional transport and mobility patterns.

Table 5.1 Territorial impacts– Regional transport and mobility patterns

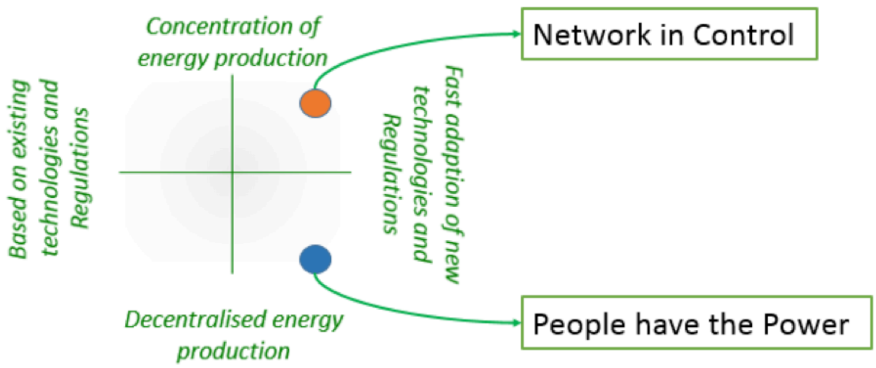
	Highly exposed and highly sensitive	Highly exposed but not so sensitive	Hardly exposed and hardly sensitive
Dependent on access by different means of transportation	The most highly exposed regions are Mediterranean coastal areas in the Iberian Peninsula, Highlands and Islands (Scotland), Central Macedonia (Greece) and the Bulgarian Black Sea coastal region as well as Mediterranean islands. These regions have limited accessibility by rail and road, but are highly dependent on tourism and a number of ports.	Regions with very good access by rail and road, and important airport hubs with high freight volume, will be able to replace a large part of the air transport with rail. These are often national and regional capital regions such as Paris, Brussels, Amsterdam; Berlin, Frankfurt, Munich and Milan, but also to some extent Vienna and Zurich. Regions with a low access and a low population density (Northern part of Scandinavia, the northern part of the British Isles, Iceland), where air transport is not vital to the regional economy, will be severely challenged, but should cope with the new situation.	Regions in the core of Europe (most parts of Germany, France, Austria, Switzerland and Northern Italy), with high accessibility and no major transport hubs will experience the least pressure to adapt.

6 Scenarios for extreme cases

The transition to an energy system that is fully based on renewables within the next 15 to 20 years will severely affect nearly all spheres of European life. Energy produced from renewable sources in the EU would have to increase six-fold[14]. For transport this implies increasing the share of renewables by the factor of 17, from 6% to 100%. Such targets cannot be achieved unless Europe drastically reduces its energy consumption, sacrificing some quality of life and economic competitiveness and energy security.

There is substantial uncertainty regarding a number of factors such as technological progress and the development of the European economy over the next two decades. Societal choices regarding additional RES production and operating the future grid are also subject to uncertainty. Possibilities range from a very technology-driven energy system transformation, with a focus on large-scale RES generation owned by large utility companies, to an bottom-up driven transformation that involves primarily a reduction of energy consumption and builds on small-scale, decentralised energy generation owned mainly by citizens and citizen cooperatives. The latter would allow citizens to have a direct stake in the transition to a cleaner energy supply through ownership of renewable energy installations whereas the former would benefit mainly large utility companies and their shareholders.

Figure 6.1 Localisation of RES in the ESPON scenario space



Source: ESPON Futures, 2017

In the following, two extreme scenarios regarding RES production and grid operation are presented and its impacts explored: one scenario where electricity production is concentrated and the distribution system hierarchical, and one where production is decentralised and consumers are at the centre of the energy system.

[14] The share of renewables in gross domestic consumption in the EU in 2014 was 16%.

Table 6.1 Two scenarios regarding renewable energy production and grid operation

	Network in Control	People have the Power
Alternative evolutions of the power sector	In 2030, policies that put the consumer at the centre of the energy system substantially fail. Some markets offer demand response options, but in large parts of the EU, individual consumers have few opportunities and incentives to actively participate in demand-side management. In this framework the share of distributed RES remains low and 100% of electricity production from RES is provided by big off-shore wind parks in North and West Europe, large PV and solar concentration plants, mainly in South Europe and (probably) North Africa. To cope with this, the National Regulating Authorities prioritise network investments to guarantee security of supply while Distribution System Operators (DSOs) remain the primary actors in the electricity market, with no or low competition. In collaboration with the Transmission System Operators (TSOs), they drive a smarter grid and invest in infrastructure upgrades and storage facilities.	Here the energy system faces a paradigm change. In 2030, smart grids and distributed electricity generation system have developed strongly thanks to the full interaction of all actors in the electricity network, including consumers and new businesses. Given this evolution, Distribution System Operators (DSOs) are neutral market facilitators, boosting the development of new services and enhancing demand response. Distributed RES contribute to 50-70% of European electricity demand, mainly through distributed RES generation, such as roof-top and vertical PV systems. The remaining electricity demand is still provided by off shore wind farms and large PV and solar concentration plants.
Technological and regulatory development	To balance the electricity distribution system, medium and high voltage grids have been widely equipped with ICT solutions improving grid management and control. In particular, to enhance interconnection capacity and ensure flexibility in the network, integrating a variable RES with reinforced grid infrastructure (including superconducting solutions) means data exchange and communication across countries result in electricity storage and trading. ICT devices and sensors are deployed in the grid at the low voltage level as well. However, their use is limited to the DSOs, to allow them to monitor the status of the grid and electricity consumption and supply. Advanced electronic meters have been installed in several Member States and an adequate ICT infrastructure has been developed, but the meters mainly provide automatic feedback to retailers and DSOs without actively involving consumers. Moreover there is widespread regional cooperation, thanks to "energy policy regions", as advocated by the European Network of Transmission of the System Operators (ENTSO-E, 2016). To ensure system security, additional storage would be installed and biogas power plants would serve as backup and balancing emergences. However, energy security could not be guaranteed at all times and frequent black outs would be the consequence.	To allow deep behavioural and economic changes, the distribution grid has evolved considerably. Fully digitalised infrastructure allows for multidirectional flows of electricity. An extensive ICT layer enables high interoperability of network operators and devices. There is complete and real-time interaction between all actors in the system. Sensors are widespread and data communication and ownership are well regulated. The security and reliability of the service is guaranteed by TSOs that cooperate through Regional Operational Centres, and with DSOs, to share all data for daily and long-term planning and for coordinating use of the distributed resources. To this end the functioning of the internal market in electricity and TSO/DSO cooperation is assured by the creation of an EU-DSO entity. In addition to the upgraded and smart main grid, micro-grids are deployed in many locations, with back-up connections to the local grid operators. Wherever and whenever this is convenient, micro-grids are used as an alternative to the electricity supply from grid operators. At the same time Member States have provided a regulatory framework that allows and incentivises DSOs to procure flexibility services from the main market actors (consumers, generators, aggregators,…) (Danish Energy

<table>
<tr><td></td><td></td><td>Association, 2016).

Since capacity reserve in this scenario is much more spread than in the other one the necessity to resort to backup power plants is much less critical. Nevertheless, blackouts may also happen under this scenario.</td></tr>
<tr><td>Impact on the engineering industry</td><td>The industries that primarily benefit from this scenario are provide products and services to the DSOs, since solutions are needed to balance the medium and high voltage grid. These developments result in strong support for the European wind power industry, which competes successfully in global markets. In parallel, the impact is highly relevant for industries producing large-scale storage facilities, which are needed to compensate for the lack of flexibility at the bottom level of the system. The impact is also high for sectors providing solutions for the digitalisation and automation of the grid. Business opportunities arise for ICT solutions to balance the system and to manage data and grid constraints, as the strengthened DSOs invest in this area to monitor and regulate electricity flows.</td><td>Given the pronounced changes in the system, new business opportunities arise in several sectors. The strongest impact is on producers of small-scale storage facilities, which are coupled to small RES power plants increasing the stability of micro-grids. The ICT industry benefits from investments in upgrades of the communication and data infrastructure to allow for full interoperability in the grid. The smart appliances industry also benefits considerably in this scenario, as these devices are needed to ease flexible electricity demand and production at residential level. Heat pumps improve competitiveness with traditional heating solutions thanks to additional income from participating Demand Response programmes. Business opportunities arise also in electricity trading, especially for independent aggregators. PV system developers will experience a great boost, especially for those able to provide innovative solutions, e.g. PV panels for windows and vertical surfaces.</td></tr>
<tr><td></td><td colspan="2">Network in Control and People have the Power</td></tr>
<tr><td>Final energy end uses</td><td colspan="2">Transport.

Light and medium duty vehicles mainly use electric motors. Moreover, the development of EVs, assured by low-cost and fast charging performance, provide additional storage capacity to balance electricity flow at the low voltage level. It is also diffuses the use of biomethane, especially in countries that have a long-standing tradition in using methane and could count on an effective gas distribution grid and refuelling stations.

Heavy duty vehicles use biodiesel produced by non-food crops.

By 2030, bio-jet is starting to be used by the aviation industry even if the high cost of this fuel would still limit its application.

Heating and cooling

RES district heating fed by biomass and biogas will be widespread in Central and Northern Europe while heat pumps and solar thermal plants provide the majority of heating demand in Southern Europe. In the “People have the Power” scenario, efficient management of heat and electricity (CHP, micro-CHP and heat pumps with heat storage systems) increase system flexibility allowing effective demand response schemes.

Cooling is assured by absorption devices, either recovering the waste low temperature from industry or biomass power stations, or by solar panels and electricity where required.

High temperature industry processes

Coking coal is still used in blast furnaces but the steel industry uses electricity for steel production (electric arc furnaces). The cement, glass and ceramic industries use biomass to feed their furnaces.</td></tr>
</table>

Main (grid-side) drawbacks of the two scenarios	As seen by the short description of this scenario, it entails notable investments in fixed capital assets with limited possibilities to make use of the reserve capacity offered by demand side flexibility. This scarce reserve of flexibility capacity may raise problems of grid stability and security that can be solved by curtailment interventions of RES energy production and/or use of backup fossil fuels (natural gas) power plants. Moreover, the investments required to upgrade the transmission and distribution network may give rise to high electricity tariffs, consequent problems of either social equality and energy poverty leading also to the establishment of isolated communities sourcing their own electricity consumption, thus worsening the capacity imbalance between supply and demand.	This scenario entails important structural changes in market and infrastructure, along with modifications in energy consumption, but initial investment required for the installation of the self-production facilities may be too high for economic vulnerable consumers. Moreover, at residential level, the poorest or culturally deprived households, having low or very low electricity consumption, can hardly be involved in DR programs. Finally, available space, specially roof-space, and visual impact can be limit small scale RES power plant deployment. Vertical PV systems may significantly increase the available space for this technology but technological and economic barriers still have to be overcome.

Source: ESPON Futures, 2017

7 Towards territorial cohesion?

In this final chapter the focus is on pointers for policies focusing on how to strengthen territorial cohesion in a European energy system that is fully based on renewables.

For this, we summarise the differences in territorial cohesion between a fully renewable European energy system and a business as usual European energy supply and consumption. We identify drivers for these differences and subsequently develop policy pointers to support territorial cohesion and counteract challenges.

7.1 Territorial cohesion today and tomorrow

As shown in volume B on the future of the European territory, a business as usual scenario for the territorial future of Europe points to considerable challenges for territorial cohesion, including:

- increasing polarisation of settlements;
- increasing concentration of economic activities;
- growing climate change and environmental concerns; but also
- technology and innovation that can make new regional stars.

Compared to this, a fully renewable European energy system gives a mixed picture regarding territorial cohesion in Europe. For example, while the focus on energy production from endogenous renewable energy sources is likely to strengthen rural and peripheral areas, the radical change of transport and mobility patterns will clearly negatively impact them, and will reinforce urbanisation and centralisation.

Examples of factors that point towards greater territorial cohesion:

- **Better use of endogenous, place-based development potentials (chapter):** The enhanced exploitation of renewable energy potential generally implies better use of endogenous, place-based development potential. Biophysical renewable energy potential is, however, not equally distributed across Europe. Some regions have more renewable energy sources than others, often as a result of specific geographical and climatic features. However, since renewable energy generation generally requires significantly larger areas for producing the same amount of energy as comparable conventional fossil or nuclear power plants, rural areas with a low population density would be at an advantage, possibly reducing existing economic disparities.
- **Rural and peripheral communities may become energy exporters**. Regions with high renewable energy potential and sufficient available land, often located at Europe's periphery, may produce a surplus and become energy exporters. This could particularly benefit small rural communities and provide them with an additional economic base.
- **Strengthened rural-urban relations.** Provided the Europe's renewable energy demand is largely supplied domestically, highly urbanised regions would shift their energy

dependence from the global to the (extended domestic) rural hinterland for satisfying their energy needs. This may strengthen cooperation between cities and their rural hinterland.

- **Positive effect on climate change and environmental concerns.** With a fully renewable energy system and a nearly complete abolishment of combustion, the concentration of pollutants (NOx, CO, SOx, soot in the form of small particles) as well as climate-active gases (CO_2) and the formation of ground-level ozone will decrease drastically. This improvement in air quality will increase the quality of life and have positive health effects and related health care costs. Furthermore, the drastic reduction in CO_2 emissions will also have positive effects on the global effort to limit climate change. All areas will benefit and will experience a big improvement in air quality and, hence, quality of life. Areas that have so far suffered from low air quality, e.g. densely populated areas, areas with heavy industry and insufficient treatment and filtering of exhaust gases, but also locations with frequent thermal inversion and reduced dilution of air pollutants, will be particularly positively affected.
- **Equitable distribution of the economic benefits.** The future energy supply has the potential to be much more decentralised and more democratic, allowing citizens to have a direct stake in the transition to a cleaner energy supply. This can be through ownership of renewable energy installations, either by private RES installations on their property or through shares of energy cooperatives. Energy self-production would, however, mainly benefit house owners outside central-city locations as there is limited available space and too much shade in urban areas.

Examples of factors that point towards greater territorial disparities:

- **Positive effect on regional value creation higher in wealthy regions.** The energy system transformation will require huge investments into additional energy production capacities and energy infrastructure. The ability to finance investments and, hence, regional value creation, is linked to a region's economic performance and wealth. Prosperous regions have hence better conditions to benefit economically, entrenching current economic disparities in Europe. Regions in which households have a high disposable income can afford to buy more energy-efficient appliances and, hence, would be able to maintain a similar lifestyle under the new circumstances. On the other hand, rising energy costs may throw a large part of the population in less developed regions into energy poverty, especially in central and northern Europe where heating demand in winter is high.
- **Concentration of population, infrastructure and industry in and around Europe's metropolises.** The large European conurbations have the highest net transfer capacity levels and highest grid densities as well as the best infrastructure connections and they generally have the highest (green) economic and innovation performance. This

performance would provide them with new economic opportunities in the development of energy-efficient technology and appliances.

- **Reduced accessibility and quality of public services in remote, rural areas.** Peripheral areas, far from bigger centres, would be greatly disadvantaged by the increased cost of transportation, which might accelerate aging and depopulation trends in less accessible regions. Regions whose economies are strongly transport-dependent, e.g. remote tourism regions would also be heavily affected. On the other hand, cities and densely populated areas would gain from having the critical mass needed to provide accessible and high-quality public services (e.g. district heating solutions and public transportation). Overall, there might be a reinforced tendency for people, particularly of working age, and businesses to move to highly urbanised, well-connected parts of Europe in the centre of the continent and around major urban centres.

Taking all these points together, a fully renewable energy system will imply radical changes for all parts of Europe and will also affect the European urban system and territorial balance. At a European level, regional disparities between highly urbanised and well-connected parts of Europe and rural, peripheral regions may be even enhanced, unless these regions are supported in taking better advantage of their RES potentials. In particular the role of providing energy infrastructure for the distribution and storage of renewable energy and the role of providing financing for the installation of addition RES production capacities should be underlined.

7.2 Drivers on the way from today to tomorrow

Transitioning to a fully renewable European energy system, and, at the same time, contributing as much as possible to territorial cohesion, requires both a political effort and will to push forward a process that was started with the European Union climate and energy package, societal change in terms of attitudes and consumer behaviour and new technological developments. Key drivers are:

- **Political will.** Most important for this paradigm shift is the political will to push forward the process of decarbonising our lives and economy, especially in the field of transportation where little progress has been made so far. Such a radical change cannot rely only on voluntary commitments, but requires a normative, and largely top-down approach. Politics are also required when it comes to cushioning the negative effects of the transformation on territorial cohesion.

- **Societal acceptance.** Even though a political commitment to the energy system transformation is paramount, having the population on board is equally indispensable. A reduction in consumption will require a change in consumer behaviour and cannot rely only on technical efficiency gains, which otherwise will be eaten up through the so-called rebound effect. Promoting and supporting citizen-energy has the potential to greatly enhance the acceptance of the measures as citizen will directly have a stake in the energy system transformation.

- **Technological solutions.** A third pillar that will both drive and enable the energy system transformation is technological progress. A wide range of technical innovations in the field of energy efficiency, renewable energy generation, energy storage, energy transmission, etc. exist, but have not yet reached market maturity. While existing technologies need to be more widely applied, new technical development have to be stepped up to speed up the transition to a fully renewable energy system.
- **Deployment speed.** Currently, a number of non-technological barriers that impede a wider renewable energy deployment such as administrative hurdles like planning delays and restrictions. Lack of coordination between different authorities and lack of experience of civil servants, long lead-times in obtaining authorizations, but also the sometimes inhomogeneous application of laws, and unclear administrative framework result in severe costs for obtaining permissions and consequently add to investor risks. Simplifying these procedures can give a considerable boost to RES deployment.

7.3 Pointers for territorial cohesion policies for tomorrow

To foster the positive and cushion the negative effects of this energy transition on territorial cohesion, policy-makers ought to consider that:

RES exporting rural and peripheral communities rely on a well-connected grid. A well connected grid is a prerequisite for rural and peripheral communities to be able to export surplus electricity and benefit economically from the energy transition. It has to connect Europe's new centres of renewable energy production, which are often in rural and peripheral areas, with Europe's centres of consumption, many of which are in central Europe. Since much of the additional renewable energy will be generated in the form of electricity, development of the electricity grid, which is currently being expanded and reinforced at a slow rate, has to keep up with the development of additional energy production capacity.

Deeper coordination of energy and land use planning is needed. The enhanced dependency of cities on rural areas to secure their energy supply ought to also lead to deeper coordination on energy and land use planning. Areas highly suitable for renewable energy production ought to be kept free from infrastructure or settlement development.

Citizen-energy increases the acceptance of a fully RES energy system. The energy transition will be very costly and not all regions will be able to raise funds to finance the investment and keep value creation in the region (Mühlenhoff, 2010). This might entrench the current disparate economic structure in Europe. However, since the future energy supply is likely to be more decentralised and small-scale, it also has the potential to be owned more by citizens. These ought to be encouraged and supported to have a direct stake in the transition to a cleaner energy supply through ownership of renewable energy installations. In this way, some economic benefits of transitioning will remain with the local population rather than with large utility companies and multinationals, increasing acceptance of the energy transition.

Urban areas benefit from proximity and critical mass. In spite of their limited potential for renewable energy generation, cities and urbanised areas, in particular large metropolitan areas in the central part of the continent (the “blue banana”), but also Europe’s northern conurbations and large conurbations on the Mediterranean Sea (“golden banana”), seem to be in a more favourable position than rural, peripheral areas. They can rely on proximity and critical mass as they have the population pool to provide accessible and high-quality public services such as district heating solutions, public transport and car sharing schemes when energy costs rise substantially. They are also generally better connected to both the transport network and the electricity grid. Furthermore, they often produce above average GDP and are centres of innovation, which should promote new economic opportunities in the development of new energy-efficient technologies and appliances. Peripheral areas, where the distance to bigger centres is large, will be greatly affected by increased transport costs, which may accelerate the current trend of depopulation. Thus, the value-added potential from becoming centres of renewable energy generation may not make up for other location disadvantages. If there is political and social consensus that peripheral, rural communities are to be maintained as liveable environments for people and businesses, targeted policies for rural areas are needed to actively make them fit for a 100% renewable future. These include policies for public service provision, public transport, in particular, rail infrastructure development, diversification of their economic structure of rural areas, etc.

Additional social protection measures to counter energy poverty are needed. Since the energy transition is likely to go hand in hand with a substantial rise in energy costs, the risk is that it throws a large part of the population in less developed regions into energy poverty. This would affect central and northern Europe where winter heating demand is high. Social protection measures are needed to avoid widening social disparities in Europe. Since all Europeans will experience a steep increase in energy costs, it is important to inform the population through awareness raising, open public debate, financial support for turning private homes into energy positive houses, etc. Otherwise this may be seen as a project for the elite when people have to radically change their lifestyle.

High freight transport costs favour local production. Increased freight transport costs will likely overturn Europe’s current trade structure and flow of goods. This should result in a new origin-destination pattern of goods flows with more local production of goods and fewer intermediaries as well as a reduced consumption of dispensable goods. While this is, in principle, a positive development towards sustainability, it is likely to also result in high job losses. Timely alternatives[15] to the current economic model based on perpetual growth and

[15] E.g. a post-capitalist ecological economy such as the bioregional approach (James and Cato, 2014).

related resource consumption have to be developed, accompanied by open public discussion and participation.

Alternatives to mass tourism must be developed. (Remote) tourism regions are advised to develop alternative concepts to mass tourism based on millions of vacationers flocking in during a few months of the year. Increased transport costs will make such a business model no longer viable.

Europe's economic competitiveness dependent on the reduction of its energy intensity. Also heavily affected will be industry, in particular energy-intense sectors. Even though the productivity of the European economy relative to its consumption of primary energy, its energy intensity, has decreased over the past two decades, there are still major savings to be tapped. These can include optimising individual components like engines, pumps or water cooling installations as well as integrated, step-wise optimisation of the whole production system. In particular Eastern European industry is often still outdated. As these regions are still catching up economically, a loss of industrial competitiveness would jeopardise the progress made so far. Many enterprises still fail to take advantage of energy-saving measures due to a lack of knowledge or capital to finance measures that pay off only after some years. So policies that support and encourage enterprises to better exploit energy saving potential would be a win-win approach.

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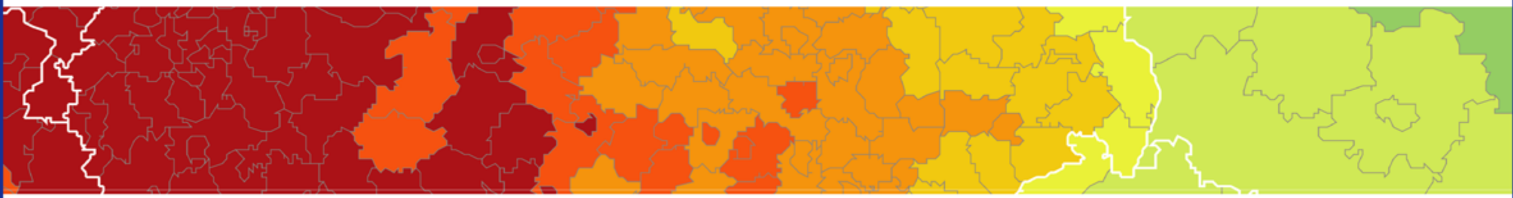

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