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Going local: empowering cities to lead EU decarbonisation

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Executive summary

Four trends are reshaping the European energy system: decarbonisation, digitalisation and, as a result of the two, decentralisation and convergence.

Based on strong public policies, decarbonisation is reshuffling the European energy mix, while innovation in digital technologies is enabling disruptive change in the way energy systems are operated. This enables the European energy system to become more decentralised with increasing interaction between services (electricity, heat, transport, data) that used to be largely separate.

In this new context, cities are the key arenas of decarbonisation. However, European Union (EU) energy and climate governance is based on top-down policies that are not complemented by a solid bottom-up system that ensures consistency of EU, national and local measures and incentivises decarbonisation at city level.

We propose better integration of top-down energy and climate policy mechanisms with new bottom-up incentives that aim to promote decarbonisation at city level. This mechanism can be set up in four steps.

- Step 1: understand a city's carbon footprint and create a baseline scenario. A participating city should start by carrying out an emissions inventory that would quantify the amount of greenhouse gases emitted from energy consumption on its territory during a specific year. This should identify the principal sources of emissions and therefore enable prioritisation of reduction measures.
- Step 2: understand a city's carbon handprint and create a reference scenario. With an emissions inventory in place, each city can identify the areas of its economy with the greatest decarbonisation potential, and can prioritise its decarbonisation policies accordingly.
- Step 3: create a city Climate Plan. The baseline and reference scenarios would form the basis of comprehensive city Climate Plans. To ensure consistency of national and municipal policies, Climate Plans could be developed as a sub-component of member state National Energy and Climate Plans.
- Step 4: track progress and allocate financial support. City progress reports on decarbonisation should be used by the EU to determine the eligibility of local governments for EU grants. Grants would be key to the success of this scheme. If EU money is given to a city to implement a project listed in its Climate Plan, it should be paid in in biennial tranches, conditional on positive progress reports.

A grant-based system would give the EU some control over the effective implementation of cities' decarbonisation projects. EU countries could use city progress reports to provide fiscal incentives to cities that implement in practice their Climate Plans. This premium system would make economic sense for member states considering that the better cities perform in terms of decarbonisation, the easier it will be to achieve national decarbonisation targets.

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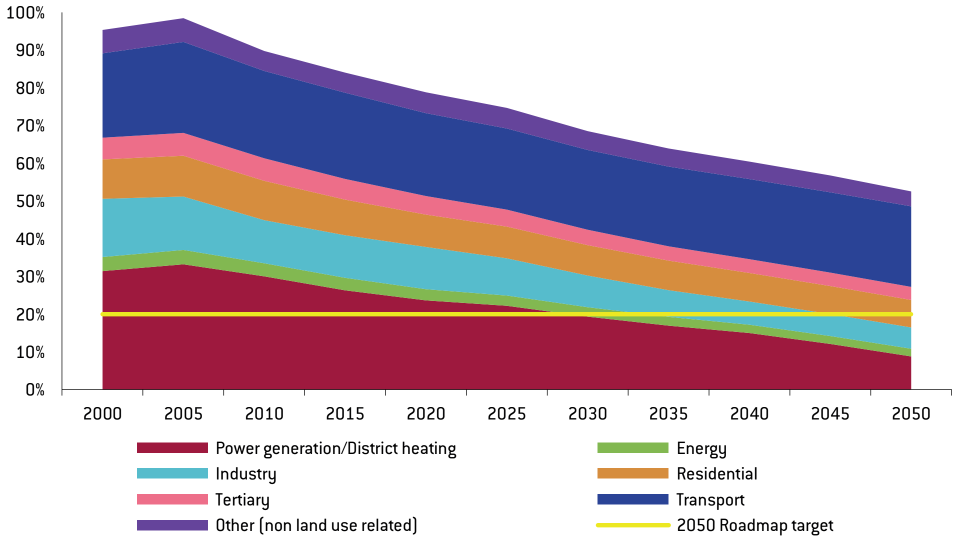
Decarbonisation and digitalisation are reshaping the EU energy system

The EU's energy and climate policy architecture has at its core an aim to deliver decarbonisation. On the basis of a long-term vision of reducing greenhouse-gas emissions by 80-95 percent by 2050 compared to 1990 (Figure 1), the EU adopted a binding 40 percent emissions reduction target percent to be achieved by 2030 compared to 1990. This target is also the basis of the EU's international commitment to the United Nations Framework Convention on Climate Change Paris Agreement[1].

Figure 1: EU greenhouse gas emissions reduction scenario under current policies: not yet in line with the 2050 target (1990=100%)



Source: Bruegel based on European Commission (2016).

Turning these targets into reality is challenging. It requires radical changes to Europe's power, heating and cooling, industry and transport sectors.

This task can become even more challenging if the global effort against global warming is further strengthened. The current EU 2050 decarbonisation trajectory is calibrated against the target of keeping the global temperature rise this century below 2 degrees Celsius compared to pre-industrial levels. This is also the central aim of the Paris Agreement. But the Paris Agreement also pledges to pursue efforts to limit the temperature increase to 1.5 degrees Celsius (a significantly safer defence line against the worst impacts of a changing climate) (United Nations, 2015).

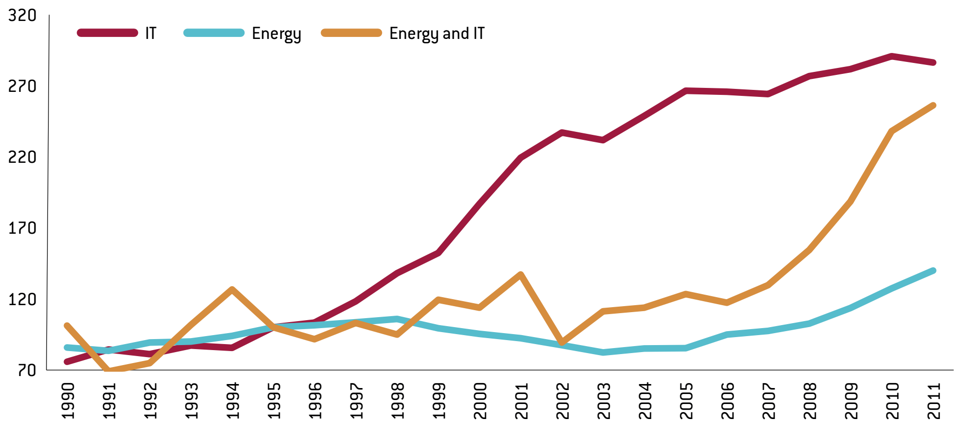
Digitalisation, by making the overall energy system smarter and more efficient, can be an important catalyst for decarbonisation. Digital technologies give consumers more control over their energy use and offer benefits from additional services. At the same time, suppliers can optimise their operations and develop new offers, and system operators can benefit from new tools to manage their grids more efficiently and to integrate an increasing amount of variable renewables into the system. Interaction between intelligent appliances, smart grids and home platforms – mediated by or on behalf of consumers – can usher in a new era with radically different consumption patterns centred on automation and remote controls.

From a technological perspective, energy is already going digital. The share of patents in

1 See Latvian Presidency of the Council of the European Union (2015).

which energy and IT co-occur has boomed since 2006, largely outpacing traditional patents in IT and energy taken individually (Figure 2).

Figure 2: Share of IT and energy tech in total patents, EU28, index=1995



Source: Bruegel based on PATSTAT (2014). Note: The graph shows the share of patents related to specific IPC codes among all PCT patents with at least one European inventor in a given year indexed in 1995. Share of patents in total patents, first priority application under the Patent Cooperation Treaty (PCT), classified with IPC codes H02 or G06 with at least one inventor from the EU28. The graph is based on international patent applications under the PCT retrieved from the PATSTAT database. Counts are derived using the priority date (first date of filing of a patent application) and the inventors' country of residence, where at least one inventor came from the EU28. The International Patent Classification system (IPC) is used to distinguish patents relevant to energy generation technology and IT. In particular, the classification codes H02 – 'Generation, Conversion, or Distribution of Electric Power' – and G06 – 'Computing; Calculating; Counting' – were taken into consideration. All inventions in the database are classified with at least one IPC code but classifications in multiple groups is common. In the latter case, the patent is counted in equal fractions towards each technology.

The EU energy system is decentralising and converging with other services

This rapid technological evolution means digitalisation is set to be a key enabler for the transformation of the European energy system, from the traditional static and centralised model, into a more dynamic and decentralised eco-system within which a wide range of players interact in a flexible system.

For instance, according to the International Energy Agency (2016e), since 2010 leading markets such as Europe have seen a cost reduction for decentralised-scale solar PV installations of 40-75 percent. This trend has allowed the increasing deployment of these small-scale installations. Germany illustrates this well: between 2012 and 2015, installations with a capacity below 10 megawatts (eg rooftop solar PV) grew by 3 percentage points and now represent 37 percent of the total power plant park in Germany. At this speed, small-scale installations will represent half of Germany's power plant park by 2030.

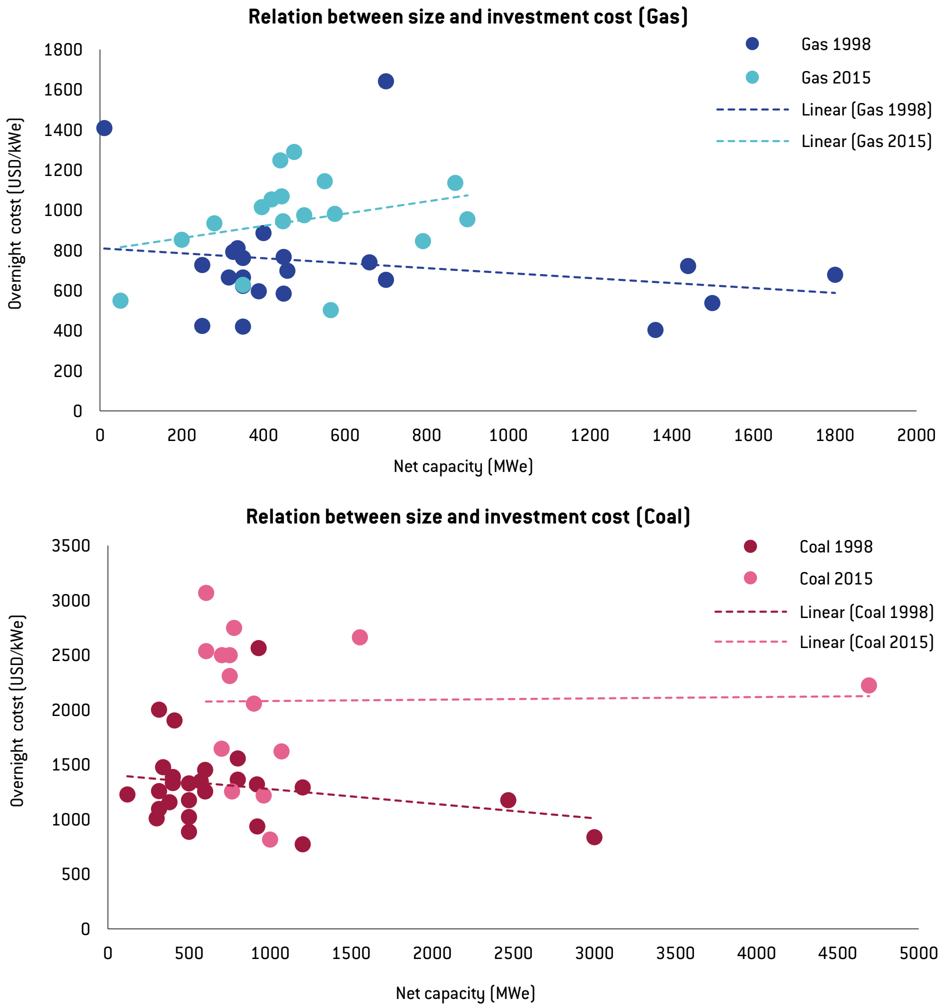
Also between 2012 and 2015, about 27,000 small-scale storage systems (eg domestic appliances combined with rooftop solar panels) with a total of 136 MWh of storage capacity were installed in Germany[2].

Trends in ownership of energy generation capacity also illustrate the progressive decentralisation of the European energy system. Private citizens and farmers in Germany now own almost half of the country's installed renewable energy capacity, while in Denmark, private individuals own 85 percent of the country's wind turbines (i24c, 2016). Scale efficiency (larger units are

2 See Frankfurt School-UNEP Centre/BNEF (2016) p39.

cheaper per kilowatt and/or more efficient than smaller units), which justified larger central plants in the past, has apparently become less important. In 1998, the investment cost for coal and gas plants decreased with size; this relationship is no longer visible (Figure 3, 2015 data).

Figure 3: Relationship between installation size and investment cost



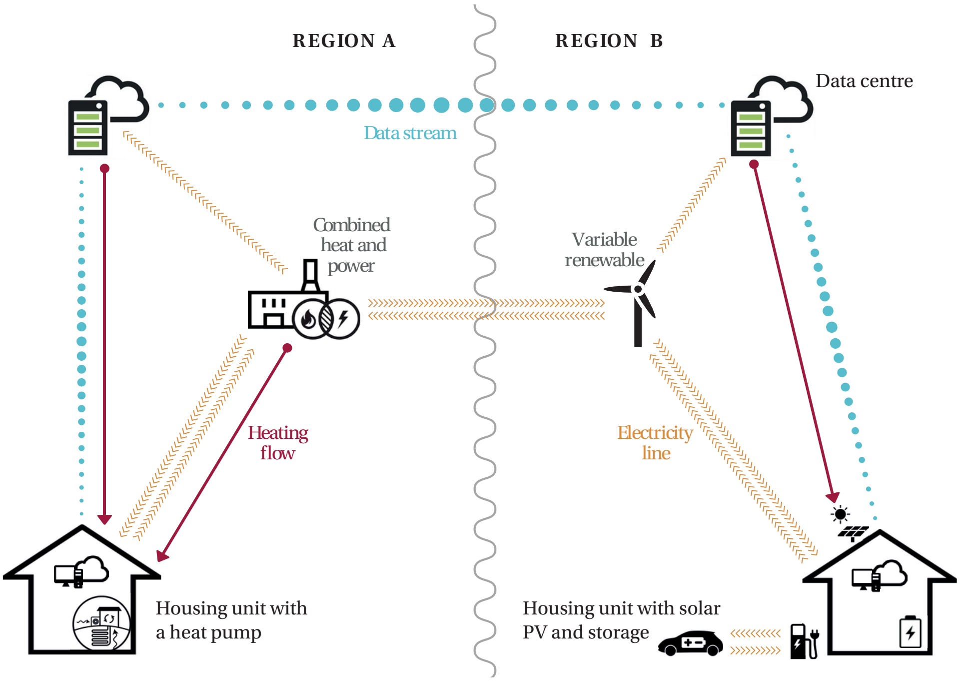
Source: Bruegel based on IEA Projected Cost of Electricity generation (1998 and 2015). Note: MWe = megawatt electric, or the electric output of a power plant in megawatts. kWe = kilowatt electric, or one thousand watts of electric capacity.

But decarbonisation and digitalisation do not just drive energy system decentralisation. They also drive convergence of services (electricity, heat, transport, data) that used to be largely separated. Figure 4 illustrates this how this works. Technological developments now enable households to not only consume electricity, heat, transport and data services, but also to provide them. Rooftop solar already produces significant amounts of electricity. Personal computers connected to services such as the start-up Idle Computing[3] can offer their computation power to others over the web. Vehicle sharing can be arranged through new peer-to-peer services such as getaround.com. Domestically produced heat might be fed back into heat networks. Furthermore, households can provide heat and electricity storage. This has been enabled by a number of innovations that allow smaller scale units (such as heat pumps, batteries, solar panels) to become almost as cost efficient as their large-scale counterparts (combined heat and power plants, pump storage, nuclear power plants). These developments reinforce the decentralisation of the energy system.

3 This start-up collects computation power into a grid and sells it to different sectors across the globe.

Potentially more disruptive, some technologies lead to a convergence of electricity, heating, transport and data. Figure 4 conveys this idea by looking at the relationship between two neighbouring regions. If, for example, the wind is not blowing in region B, it might not only be compensated for by increasing production from the combined heat and power plant in region A (which might be difficult when electricity transmission is congested), but also by a reduction in electricity consumption by region B's data centre. The consequent shortfall of computational power would then be replaced by increasing utilisation of the data centre in region A. The connection between data centres therefore substitutes to some extent for the electricity interconnection. In addition, household energy storage units and the batteries of electric vehicles might release electricity when needed. However, if the wind is blowing strongly, the combined heat and power plant might be surplus to requirements. Currently, if electricity is too cheap, the plant would just continue to work in heating mode. But new heating systems might become more bi-directional with households using not just some of the heat stored underground, but also using the heat-pump to transform some of the cheap electricity from wind into additional heat. Furthermore, the data centre might be increasingly used for the value of its by-produced excess heat.

Figure 4: Convergence of electricity, heating, transport and data



Source: Bruegel.

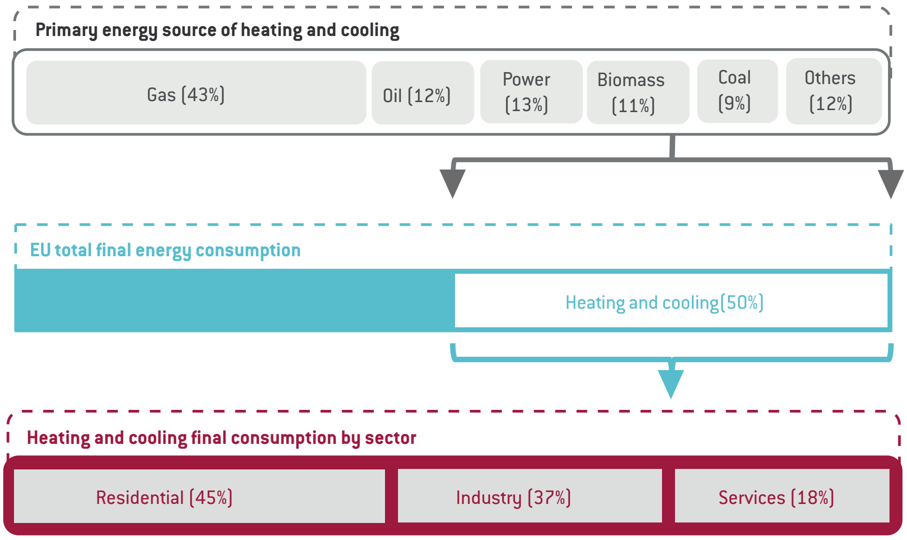
Cities are emerging as the key arenas of decarbonisation

With the energy system becoming more decentralised, and with the progressive convergence of electricity, heat and transport, cities will emerge as the key arenas for EU decarbonisation. In fact, certain decarbonisation options can be better, or only, implemented at city level, as the following examples illustrate.

Half of the energy consumed in the EU is devoted to the heating and cooling of buildings, industry and businesses (Figure 5). As heat/cold cannot be efficiently transported over long distances, it is produced and consumed locally. These markets will thus remain local.

Solutions such as district heating and cooling can contribute to the decarbonisation of the sector, particularly if based on clean fuels such as renewable electricity (through heat pumps), geothermal and solar thermal energy and waste heat from industry. The same logic applies to co-generation of heat and power, which can produce substantial energy and emissions reductions compared to separate generation. District heating and cooling systems can also store significant volumes of energy and thus might serve as a buffer enabling more energy production at local level from variable renewables.

Figure 5: The crucial role of heating and cooling in the EU energy system



Source: Bruegel based on European Commission (2016a).

Digitalisation offers an unprecedented opportunity to advance along this path (IEA, 2016a). For instance, with digital technology, buildings are evolving from being stand-alone energy-consuming units to becoming energy hubs that consume, produce, store and supply energy more flexibly than before (Building Performance Institute Europe, 2016). Buildings could progressively generate energy with on-site renewable systems (eg rooftop solar photovoltaic or solar thermal panels), provide storage for electric and thermal energy (IEA, 2016c), and deliver demand-response in an integrated manner, thanks also to smart meters, smart thermostats, lighting controls and other load-control technologies with smart end-use devices (IEA, 2015).

The deployment of these innovative solutions can be fostered by stronger coordination at local level, where synergies between the various sectors can be better exploited. Much of the challenge of integrating different sectors and parties relates to the standardisation of interfaces[4].

Defining these at European level will be a long and complex exercise – also because of the competing interests of different players. In the absence of top-down guidance, local standards might be more easily agreed based on local preconditions (such as existence of a district heating network or presence of a municipal utility), enabling efficient deployment of smart technology in line with local circumstances.

Transport is the EU's second most important contributor of greenhouse-gas emissions (European Environment Agency, 2016b). The sector still heavily relies on oil (94 percent; European Commission, 2016b), and is also the main source of air pollution. Road transport is the predominant contributor with passenger cars, trucks and buses generating more than 70 percent of the sector's emissions (Figure 6). As about 70 percent of Europeans live in cities, much of this activity happens at city level.

Decarbonising transportation will be a difficult challenge for Europe (European Environment Agency, 2016a), but cities can make a major contribution. For instance, use of public transport could increase substantially, as digital technologies can make public transport more accessible and integrated. Large-scale data analysis can help in optimising service frequency and density, making public transport more efficient and attractive to citizens. Walking and cycling – the cheapest, lowest-emission, most-accessible forms of mobility – can be promoted by creating/extending pedestrian zones, bike lanes and bike sharing systems in cities (European Commission, 2016b).

All these options require decisive action at city level.

BOX 1: EUROPE'S LOCAL CLIMATE ACTION FRONTRUNNER: COPENHAGEN

The need for local action in decarbonisation is exemplified by Copenhagen. In 2009, the city council adopted the 'CPH 2025 Climate Plan,' structured around the target of becoming carbon neutral by 2025. Since then, the city has rapidly evolved, significantly reducing CO2 emissions through changes in energy production, consumption and mobility.

For instance, the city: i) promoted a district heating system to which almost all households are now connected; ii) created a new district cooling system that uses harbour water, saving 70 percent of energy compared to traditional air-conditioning; iii) increased mobility through integrated transport and cycling solutions; iv) replaced high-pressure sodium lamps with highly efficient LEDs.

Governance-wise, this was only possible because of the high level of decentralisation of Denmark's public sector. With the public sector reform of 2007, municipalities grew larger and took over more responsibilities from the regional and the state levels.

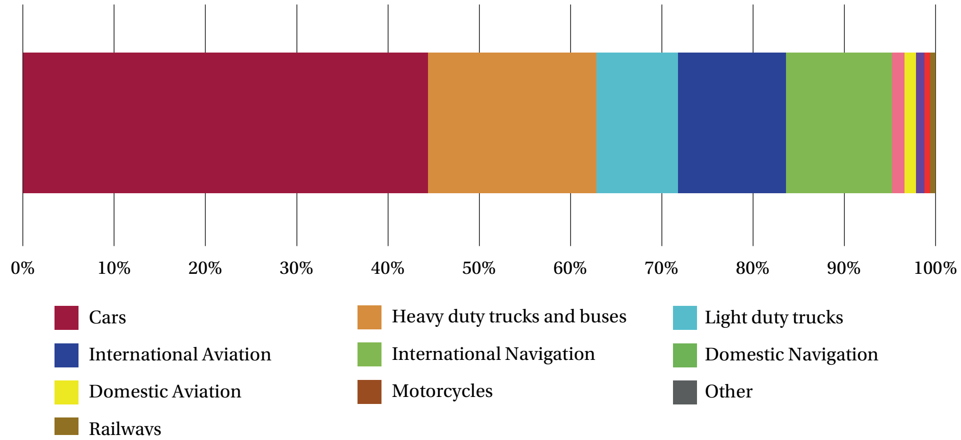
Specifically, municipalities became responsible for activities such as 'Technology and the environment,' covering environmental sector planning, preparation of regulations on construction, roads, transportation and waste management. The 2007 reforms also gave more fiscal power to local authorities, to allow them to meet the new responsibilities. As Katz and Noring (2016) point out, the establishment of publicly-owned corporations (eg the Greater Copenhagen Utility) and of innovative public-private partnerships has contributed to the success of the model.

Public investment in cities has always represented a significant share of government spending (Figure 7). In 2014, local government expenditures in the EU amounted to 11.3 percent of GDP and 23.5 percent of total public expenditure. Local public investment is responsi-

4 For example, which type of information is exchanged by which technology and based on which data protocol.

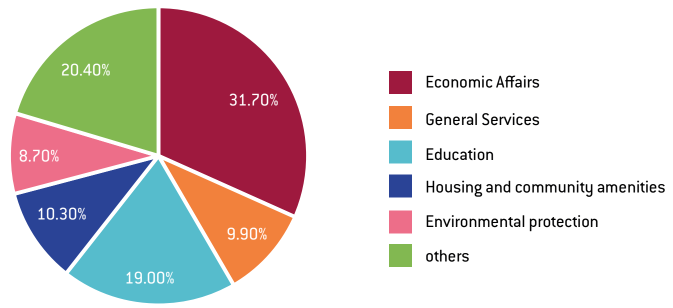
ble for 44 percent of total public investment (OECD, 2016). In many cities, network infrastructure – such as roads, tramway and suburban train lines, but also gas and electricity networks – is publicly owned. Even if this is not the case, local authorities can strongly influence the development of such infrastructure. At the same time, local public buildings represent a significant share of the total building stock[5]. However, local authorities do not respond to the same incentives as the private sector. Local authorities are typically elected for limited periods and voters might not put the right value on local greenhouse gas reductions, in particular because citizens of ambitious cities might bear the cost of decarbonisation without receiving a direct benefit. Thus, citizens might find it more convenient to equip local coal-fired heating plants with expensive scrubbers than to entirely redesign the district heating system. In addition, the budget constraints of local authorities are typically a consequence of complex intra-country transfer schemes. This – together with the short electoral cycles – implies that local authorities underinvest in infrastructure that pays off in the long term.

Figure 6: EU greenhouse-gas emissions from the transport sector by category (2014)



Source: Bruegel based on European Environment Agency database, accessed in November 2016.

Figure 7: EU local government investment by economic function (2013)



Source: Bruegel based on OECD (2016).

5 For example, around 17 percent and 35 percent respectively of the floor area in German and French non-residential buildings comprises hospitals and education institutions, according to www.buildingsdata.eu.

EU energy and climate governance also needs to be bottom-up

EU energy and climate policy is driven by the long-term vision of reducing greenhouse gas emissions by 80-95 percent by 2050 in comparison to 1990 levels. This vision is being pursued through intermediate steps: the 2020 Climate and Energy Package and the 2030 Climate and Energy Framework. Both of these include greenhouse gas emissions reduction targets (20 percent reduction by 2020 and 40 percent reduction by 2030), which are binding through the EU emissions trading system (ETS) and the related effort-sharing decision, which covers non-ETS parts of the economy. There are also targets for the increase in renewable energy (20 percent of total consumption by 2020; 27 percent by 2030) and of energy efficiency (20 percent saving by 2020 compared to baseline; 27 percent by 2030) (Figure 8).

However, while in the 2020 package renewable energy targets were binding at national level through the Renewable Energy Directive and the Energy Efficiency Directive set out binding measures to help the EU reach its energy efficiency target[6], in the 2030 Framework they are binding only at EU level. Formally, this is to allow greater flexibility to EU countries, in line with the provisions in Article 194(2) of the Treaty on the Functioning of the European Union (TFEU) on the issue of national control over the energy mix. However, EU states do not have a common vision on how EU energy markets should be organised. They therefore seek maximum flexibility in order to implement their national energy policies.

This situation raises questions about how the 2030 Framework, and therefore the longer-term 2050 vision, can concretely be implemented, and consequently brings the issue of governance into the spotlight. While the lack of strong EU policies allows member countries to continue with policies that fragment the internal energy market, the lack of binding national targets carries the risk that national efforts will not add up to the EU aggregate commitments. Only a solid governance structure can guarantee the achievement of the 2030 targets in the absence of binding obligations for member states. In particular, without a strong and reliable governance system, investor confidence might be undermined and the investments needed for decarbonisation postponed.

The European Commission's solution to this need for strong governance has been to ask member states to adopt national energy and climate plans (NECPs), with biennial progress reports on their implementation. These plans should outline the state of national energy systems, national climate policies and national policy frameworks for all five parts of the Energy Union (eg energy security, internal energy market, energy efficiency, climate action, research and innovation[7]). This system should enable timely assessment of progress and forecasts of the fulfilment of EU energy policy objectives and agreed climate and energy targets in each country (European Council, 2015). The introduction of the NECP system is predicted to foster the consistency of EU member state energy and climate measures, and ensure that the EU-wide 2030 targets on renewables and efficiency are actually reached.

In this context, local action for decarbonisation is incentivised in either direct and indirect ways, from the ETS for local fixed-source pollution to national implementation of EU directives that force local authorities to act (eg the Energy Efficiency Directive mandates renovation of public buildings). However, this system is still far from representing a consistent incentive structure for local authorities to conduct systemic decarbonisation. In this regard, it is important to outline that the only relevant platform established by the EU to engage cities

6 These targets substantially impacted the EU energy system. For example, the share of renewable energy in EU gross final energy consumption reached 15.3 percent in 2014 and thus the majority of member states are expected to meet their 2020 renewable energy targets.

7 See https://ec.europa.eu/priorities/energy-union-and-climate_en.

in the decarbonisation process, the EU Covenant of Mayors for Climate and Energy[8], is a voluntary system in which participation remains sporadic around Europe.

Covenant signatories promise to support implementation of the EU 40 percent greenhouse gas reduction target by 2030 and the adoption of a joint approach to climate change mitigation and adaptation. In order to translate their political commitment into practical measures and projects, Covenant signatories commit to submitting Sustainable Energy and Climate Action Plans (SECAP) outlining the steps they plan to take. Plans are monitored every two years to check implementation.

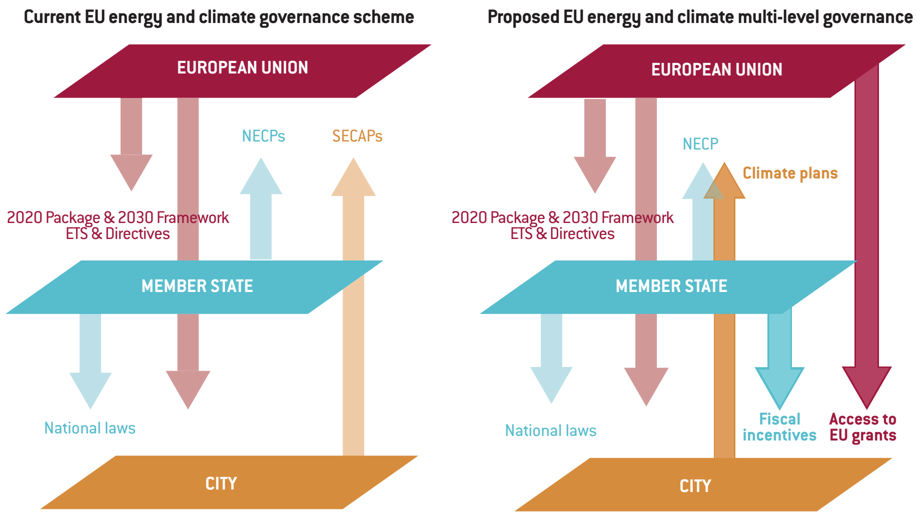
The concept behind this mechanism is good for several reasons: the engagement of local authorities that are otherwise not involved in the governance of decarbonisation, the sharing of best practices via a common platform, and the standardisation of local climate and energy policy plans to favour consistency with the overall national and EU policies. However, this theoretically sound system in practise has limits. The inconsistency is highlighted by the fact that the signatories of the Covenant in Sicily equal in number those in Germany, France, Portugal, Poland and the United Kingdom combined.

The two main reasons for the Covenant's lack of widespread impact are the isolation of the Covenant system within the broader EU energy and climate governance framework, and the lack of financial incentives for cities to participate and take measures within the system. The Covenant of Mayors SECAPs are not related to the NECPs that must be prepared by member states in the EU framework, and successful participation in the Covenant system does not give cities easier access to EU grants to implement SECAPs. In this context, the Covenant mainly represents a platform for the sharing of good practises.

In this context, we consider that in order to successfully pursue its decarbonisation pathway, the EU needs to further develop its energy and climate governance architecture, in particular to establish a solid basis for tapping into the local potential for decarbonisation. We propose a new voluntary scheme to better engage cities in the EU's decarbonisation effort. This system would be based on Climate Plans, which when implemented would be an eligibility criteria for cities to access EU funding and national-level fiscal incentives (Figure 8).

For the sake of simplicity, we consider that only cities with more than 20,000 inhabitants should participate in the system. Smaller towns could take part if they aggregate at provincial or regional level (according to the respective country's administrative structure). Considering that about 70 percent of European citizens live in cities, towns and suburbs, this system could potentially embrace about 365 million EU citizens.

Figure 8: Current vs. proposed EU energy and climate governance scheme



Source: Bruegel.

8 See http://www.covenantofmayors.eu/index_en.html.

A four-step proposal for engaging EU cities in decarbonisation

Step 1: understand a city's carbon footprint and create a baseline scenario

A participating city should start by carrying out an emissions inventory that would quantify the amount of greenhouse gases emitted from energy consumption on its territory during a specific year. This should identify the principal sources of emissions and therefore enable prioritisation of reduction measures.

The inventory would include data from all sectors that represent significant sources of emissions in the city: private and public buildings and transport. Data can be obtained from public authorities, energy market operators active on the city territory and, in the case for energy carriers which do not pass through a centralised grid, directly from energy consumers.

On the basis of this inventory, each city should forecast the development of its greenhouse gas emissions based on current policies over a defined period (eg up to 2030). This would be the baseline scenario.

Step 2: understand a city's carbon handprint and create a reference scenario

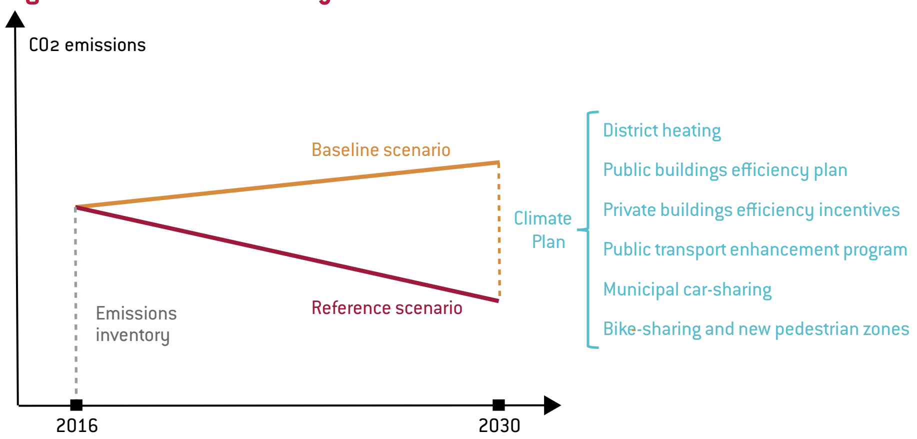
With an emissions inventory in place, each city can identify the areas of its economy with the greatest decarbonisation potential, and can prioritise its decarbonisation policies accordingly. Areas to be taken into consideration could include: i) built environment, including new buildings and refurbishment of existing buildings; ii) municipal infrastructure (district heating, public lighting, smart grids); iii) land use and urban planning; iv) decentralised renewable energy sources; and v) public and private transport policies and urban mobility. Cities should identify the most promising decarbonisation solutions, and calculate their emissions reduction potential over the defined period. On the basis of this exercise, a city should be able to put in place a future emissions reference scenario that would take into account new policies.

Step 3: create a city Climate Plan

The baseline and reference scenarios would form the basis of comprehensive city Climate Plans (Figure 9). To ensure consistency of national and municipal policies, Climate Plans could be developed as a sub-component of member state NECPs. This integration of local and national governance tools could simplify overall governance by use of a single template.

It is clear that the more effective cities are in achieving decarbonisation, the easier it will be for EU countries to achieve their decarbonisation targets, which are fixed at EU level. National governments therefore have a direct interest in supporting cities in this process.

Figure 9: the Climate Plan system



Source: Bruegel.

Step 4: track progress and allocate financial support

Each city should submit biennial progress reports on implementation of its Climate Plan to its national government. These documents should feed into to the overall progress reports that national governments must submit every two years to the European Commission in line with the Energy Union governance system. City progress reports should also be used by the EU to determine the eligibility of local governments for EU grants.

Through the European Investment Bank[9], the Structural Funds, the European Regional Development Fund, the Cohesion Fund, the LIFE Programme, the Connecting Europe Facility and several other initiatives, the EU already provides grants, loans and equity investments to cities. Taking progress against Climate Plan goals into consideration when allocating this money would incentivise cities to take decarbonisation seriously and make the most of the potential solutions at their disposal.

In particular, grants would be key to the success of this scheme. If EU money is given to a city to implement a project listed in its Climate Plan, it should be paid in in biennial tranches, conditional on positive progress reports. A negative progress report would result in a stopping of grant money. This system would mirror the methodology traditionally used for EU research funding. For multi-year research projects, the overall grant is not paid upfront, but in annual tranches unlocked only on the basis of a successful review of the previous year's activities.

A grant-based system would, in short, give the EU some leverage over cities and some control over the effective implementation of their decarbonisation projects. EU countries could use city progress reports to provide fiscal incentives to cities that implement in practice their Climate Plans. This premium system would make economic sense for member states considering that the better cities perform in decarbonisation, the easier it will be to achieve national decarbonisation targets. Furthermore, successful decarbonisation measures at city level could have macro-implications at the national level, as the next section will outline.

Beyond energy: the potential macro-implications of our proposal

An EU energy and climate multi-level governance framework with a new bottom-up policy component would improve the functioning of the energy system, and would also have wider positive implications in terms of energy security and affordability, environment, health care, job creation, economic growth and the relationship of citizens with the EU.

First, smarter cities can facilitate the functioning of national energy systems by helping grid operators to better plan and operate national power systems and, in turn, to increase the hosting capacity for renewable and decentralised energy technologies at lower cost[10]. Consequently, smarter cities can also contribute to energy security and affordability at both national and EU levels. Furthermore, reduced air pollution and traffic congestion should translate into lower costs for national healthcare systems, while increased job creation in local small and medium enterprises would have positive repercussions for the overall economy.

9 Notably via the JESSICA (Joint European Support for Sustainable Investment in City Areas) and ELENA ('European Local ENergy Assistance') programmes.

10 International Energy Agency (2016b).

References

Buildings Performance Institute Europe (2016) *Smart Buildings In A Decarbonised Energy System*, Brussels

Copenhagen City Council (2009) *CPH 2025 Climate Plan*, The Technical and Environmental Administration, City of Copenhagen

European Commission (2011) 'Communication from the Commission on A Roadmap for moving to a competitive low carbon economy in 2050', COM(2011) 112 final

European Commission (2016a) 'Commission Staff Working Document, Review of available information, Accompanying the document EU Strategy for Heating and Cooling', SWD(2016) 24 final

European Commission (2016b) 'Communication, A European Strategy for Low-Emission Mobility', SWD(2016) 244 final

European Council (2015) 'Council conclusions on the governance system of the Energy Union', Press release 869/15

European Environment Agency (2016a) 'Towards clean and smart mobility, Transport and environment in Europe', EEA Signals 2016

European Environment Agency (2016b) 'Annual European Union greenhouse gas inventory 1990–2014 and inventory report 2016, Submission to the UNFCCC Secretariat', Report No 15/2016

Frankfurt School-UNEP Centre/BNEF (2016) Global Trends in Renewable Energy Investment 2016, Frankfurt am Main

International Energy Agency (1998) Projected Cost of Electricity generation, OECD/IEA 1998

International Energy Agency (2015a) Projected Cost of Electricity generation, OECD/IEA 2015

International Energy Agency (2015b) Energy Technology Perspectives 2015 Report OECD/IEA 2015

International Energy Agency (2016a) Tracking Clean Energy Progress 2016, IEA Input to the Clean Energy Ministerial, Report OECD/EIA 2016

International Energy Agency (2016b) System Integration of Renewables: Implications for Electricity Security, Report to the G7, Report OECD/IEA 2016

International Energy Agency (2016c) Technology Roadmap, Energy storage, Report OECD/IEA 2014

International Energy Agency (2016d) *Global EV Outlook 2016, Beyond one million electric cars*, Report OECD/IEA 2016

International Energy Agency (2016e) *World Energy Outlook 2016*, OECD/IEA 2016

i24c (2016) *Scaling Up Innovation in the Energy Union to Meet New Climate, Competitiveness and Societal Goals. Scoping the Future in Light of the Past*, Brussels

Latvian Presidency of the Council of the European Union (2015) *Intended Nationally Determined Contribution of the EU and its Member States*, Riga

OECD (2016) *Subnational Governments in OECD Countries: Key Data 2016 Edition*, Paris

Katz, B. and L. Noring (2016) 'Why Copenhagen Works', Brookings Institution, available at https://www.brookings.edu/research/why-copenhagen-works/

United Nations (2015) *Paris Agreement*, available online at: www.unfccc.int

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