European Commission

European **Political** **Strategy** Centre

10 TRENDS

RESHAPING CLIMATE AND ENERGY

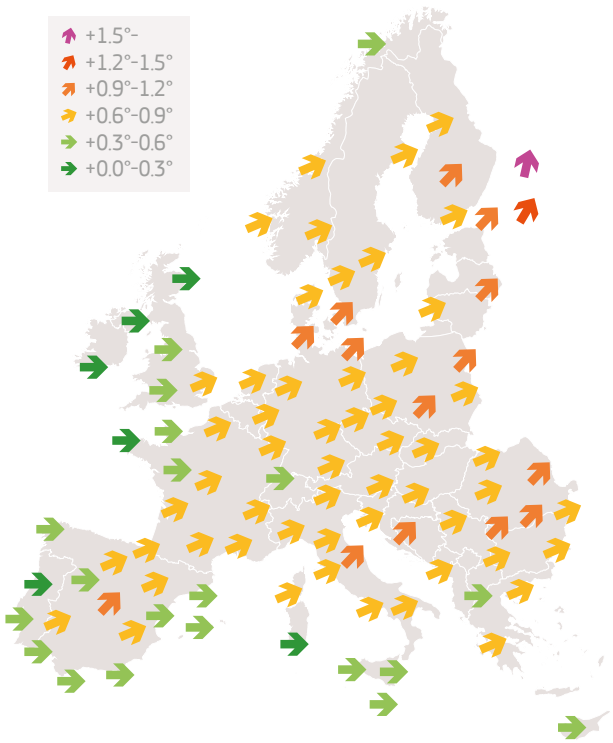
TREND 1

FROM DISTANT THREAT TO HERE AND NOW

The once remote-seeming dangers of climate change are already a reality – also in Europe

- Initially seen as a distant, next-generation problem full of uncertainties, climate change is now an observable phenomenon.
- **Global warming has already reached 1°C above preindustrial levels and is increasing at approximately 0.2°C per decade**.[1]
- **Weather-related disasters** – from hurricanes and wildfires wiping out forests and towns, to typhoons and heavy floods, or severe droughts and extreme heatwaves – **are already proliferating around the globe** forcing countries to develop expensive climate adaptation strategies, next to climate mitigation ones. Worldwide weather-climate disasters caused a record-breaking loss of **290 billion euro** in 2017, and are set to increase significantly with higher temperatures.[2]
- The damage is not limited to other continents: During the summer of 2018, climate-related catastrophes struck across Europe, including in Sweden, Greece, and Portugal, **taking hundreds of lives**. 2018 also saw large-scale crop losses of up to 50% in several parts of Europe due to droughts or late frost.[3]
- Climate-related disasters have begun causing alarming **peaks in numbers of displaced people** in recent years. As future climate impacts will be felt disproportionally strongly by populations in the developing world, this is likely to drive unprecedented migration flows (see the EPSC's *10 Trends Shaping Migration*).
- **Environmental degradation linked to traditional energy production and consumption patterns is also creating new health risks. Air pollution** – which already causes more than 400,000 Europeans to die prematurely each year[4] – is set to get worse as climate change further magnifies the effects of pollutants. Climate change is also expected to redraw the map of **mosquito-borne diseases** globally.[5]

European cities are already on average 1°C warmer than in the 20th century



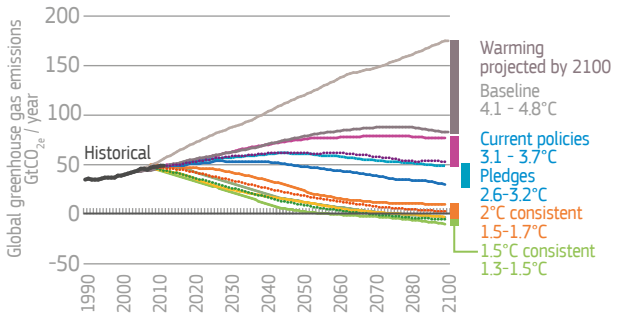
Source: European Data Journalism Network

- Unaddressed, global warming could cause severe ocean over-acidification by 2100, that could **not only kill off the entirety of coral reefs**, but also **cause fatal damage to all ecosystems relying on underwater plants** for food sources.[6]

INCONVENIENT TRUTH: DESPITE POTENTIALLY VAST COMMON BENEFITS, THE WORLD IS NOT ON TRACK TO LIMIT GLOBAL WARMING WELL BELOW 2°C

- The international community has already pledged to reduce greenhouse gas emissions in the past. While Europe has succeeded in diminishing its carbon footprint over the past 25 years, progress around much of the rest of the world has been limited, not least because the 1997 Kyoto Protocol did not bind emerging economies of the time, and the United States never ratified it.
- Since the renewal of global commitments to tackle climate change with the December 2015 Paris Agreement, **only sixteen countries out of the 197 signatories** have actually defined national climate action plans ambitious enough to meet their pledges.[7]
- The Intergovernmental Panel on Climate Change's latest report warns that the world has **just twelve years left** to fundamentally reshape its energy systems and economies, or it will suffer the worst effects of climate change for generations to come[8] as the global average temperature increase could reach 2°C soon after 2060 and continue rising afterwards. Conservative estimates[9] expect **the cost of climate-related damages to grow as climate action is delayed**, averaging around 120 billion euros per year in a 2°C scenario and 190 billion euros with 3°C.
- On the contrary, **avoiding damages from climate change, such as flooding, extreme events or health damage, would raise GDP at G20 level by 4.7% net** by 2050 compared to a 'no-action scenario.[10]

Emissions and expected warming based on pledges and current policies



Source: Climate Action Tracker

GROWING FRUSTRATION DRIVING LOCAL – AND LEGAL – ACTION

- Frustration with the 'top-down grand deal approach' and lack of action at national level continues to drive **new grassroots and local initiatives focusing on action on the ground**. One example of this is the C40 Global Leadership on Climate Change, a network of world cities committed to take action against climate change. This is opening new opportunities for actors that were not able to play more influential roles in climate change negotiations.[11]
- In parallel, **a new wave of strategic court cases is emerging, linking climate change to human rights, and aimed at holding governments and greenhouse gas emitters accountable for climate change** and pushing them to increase their action on climate change.[12]

TREND 2

A CHANGING ENERGY MIX

Renewables are growing fastest even as fossil fuels continue to dominate

- Buoyed by an ambitious policy and regulatory framework, as well as binding targets, **the EU continues to lead the penetration of renewables**, with renewable energy sources now representing at least **17%** of final energy consumption in Europe – on track towards the 2020 target of 20%.[13]
- This growth has enabled a **reduction in the overall share of fossil fuels** in the EU's gross energy consumption: from 81% in 1995 to **72.6% in 2016** – even though absolute figures remained constant. Renewables penetration rates in Europe are expected to accelerate further, reaching **32% by 2030**.[14]
- **At global level**, the share of renewables in total energy demand is limited to 10.4%, while fossil fuels have maintained a constant share of 81%.[15]
- Nonetheless, **global renewables penetration is expected to grow by one-fifth in the next five years**, reaching 12.4% in 2023. Much of this growth will be **driven by the power sector**, where a further 920 gigawatts of renewable capacity is expected to be installed by 2022 (compared to a total renewable capacity in the EU of 412 gigawatts in 2016). Most of this growth will take place in **China**, which **is expected to add more renewable power than the EU and US combined over the next 20 years**.[16]

FACTORS HOLDING BACK RENEWABLES GROWTH

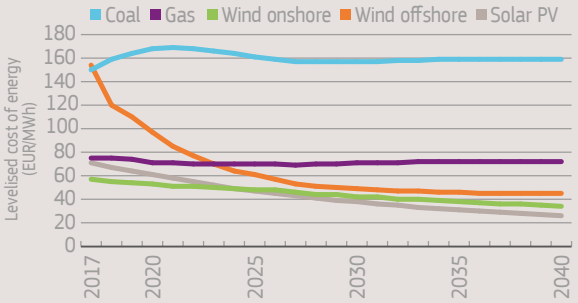
- The integration of additional renewables into the existing energy system is the main barrier to their large-scale deployment. While still in its infancy, **battery storage is happening and set to play a key part in the future of the renewable energy industry**, by enabling the storage of surplus energy that currently goes to waste.[17]
- Another key issue for further development is that **the renewables industry remains fragmented**. Many renewable energy firms are small, local, and often lack the capital to grow – even if **wind energy projects are growing in size**. A more radical change will be needed to make the industry capable of competing on the scale necessary to displace fossil fuels.[18]
- The growth in renewables is not without challenges in other areas, in particular the agricultural sector, as **competition for land use heats up, putting pressure on food prices**. The transition also puts stress on cities – traditionally built around fossil fuels – where **infrastructure and urban planning systems are struggling to keep up**.[19]

BREAKING EVEN

Stronger growth in renewable energy is buoyed by the fact that both solar and wind power are becoming significantly more competitive. **Costs of solar have fallen by 70% since 2010**.[20]

Grid parity for wind power, i.e. the moment when these technologies can compete without subsidies, is imminent – or already happening in some countries, like Germany.

Renewables now cheaper than fossil fuel in Germany

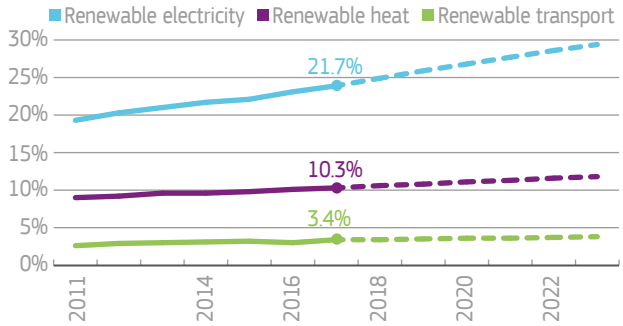


Source: Joint Research Centre, based on Bloomberg New Energy Finance

NOT ALL SECTORS ARE CONTRIBUTING EQUALLY

The power sector has the highest rate of renewables penetration (24%), while **renewable penetration in transport is still as low as 3.4% and stagnating**, as the sector remains dominated by oil products. Up till now, only 4 million electric vehicles have been sold worldwide – although sales are expected to take off, hitting 41 million (or 35% of new light duty vehicle sales) by 2040.[21] Electric vehicles are however only as clean as the power mix that fuels them.

Share of renewable energy by sector, worldwide, 2011 - 2023

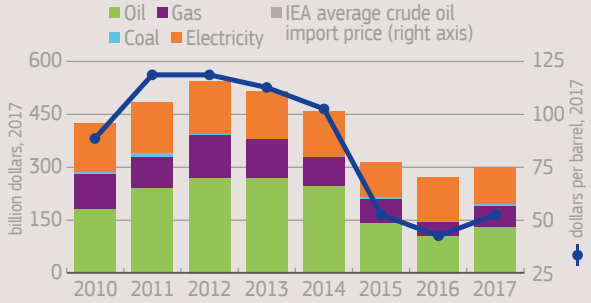


Source: International Energy Agency, Organisation for Economic Cooperation and Development

INCONVENIENT TRUTH: THE WORLD IS STILL MASSIVELY SUBSIDISING FOSSIL FUEL CONSUMPTION

Although diminishing, the world still allocates tens of billions in fossil fuel subsidies each year. In Europe, some 112 billion euro are estimated to have been allocated annually to the production and consumption of fossil fuels between 2014 and 2016.[22]

Value of global fossil fuel consumption subsidies worldwide



Source: International Energy Agency

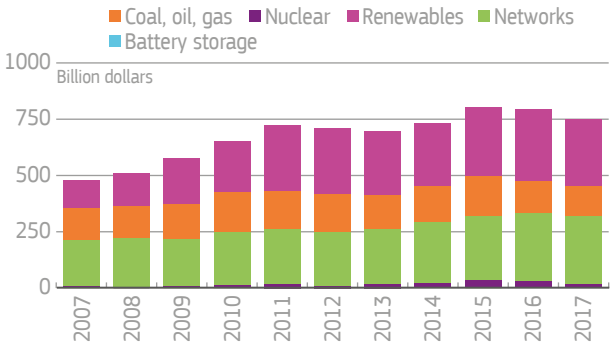
TREND 3

AS BUSINESS SHIFTS FINANCIAL MARKETS FOLLOW SUIT

Clean technologies are opening up major new opportunities for industry and investors, even if capital markets are slower to align with the climate economy

- Not so long ago, sustainability was little more than a side-note in the corporate social responsibility chapter of businesses' annual reports. Investments were driven by public sector incentives and financing, while the private sector viewed climate investment as a burden rather than an opportunity.
- **Today, private firms are exploring and applying climate-oriented business models, often with the strong conviction that these will be good for the bottom line**. Of course, public finance continues to play a key role, in particular to crowd in private funding and help carry riskier projects.
- **Global markets for climate-friendly businesses and technologies have already grown to close to one trillion euro annually**. The European battery market alone is projected to be worth 250 billion euro per year by 2025.[23] This trend is expected to accelerate, driven by strong growth in emerging economies. A mere 21 emerging market economies are thought to hold over 23 trillion euro in climate-smart investment opportunities through 2030.[24]
- The opportunities for the **African continent** – which is a natural fit for renewable energies given the available resources there, and where some 650 million people still do not have access to electricity – are also immense.

Clean energy investments have largely overtaken fossil fuels



Source: International Energy Agency

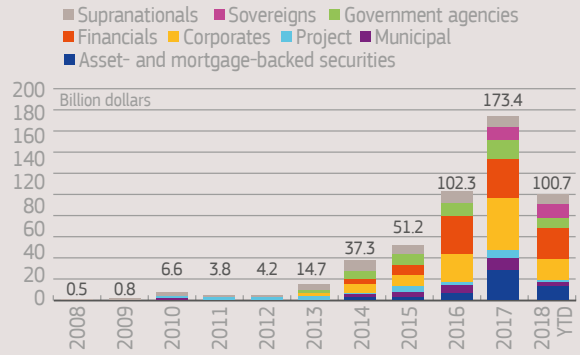
- **Low-carbon technologies are also becoming a major trade commodity**, with the EU benefiting from significant positive trade balances. During the period 2012-2015, EU exports of clean energy technologies reached 71 billion euro, exceeding imports by 11 billion euro.[25]

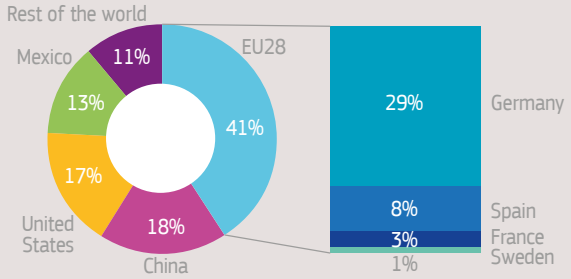
INCONVENIENT TRUTH: THE FINANCIAL SECTOR STILL HASN'T MADE THE PARADIGM SHIFT TO SUSTAINABILITY

- As sustainable business models and projects become more profitable, **investors and bankers are gradually backing the shift** towards more climate-friendly investments.
- **Innovative investment tools are gaining traction: the green bond market in particular has seen rapid growth**. First issued in 2007, by the European Investment Bank, green bond issuance reached 151 billion euro in 2017, so that these assets now constitute a large chunk of financing for clean energy investment.
- Nonetheless, **green bonds still only represent a tiny fraction (less than 1%) of the overall bond market**.[26] These, and other forms of green financing, such as green loans or green securitisation, continue to be **held back by a lack of common definitions and standards** and an insufficient integration of longer-term climate risks in investment decisions. The EU is currently leading the charge to address these issue at European and global level.
- **Large institutional actors – insurance companies, pension funds and sovereign wealth funds – have been particularly slow to change course**, despite their significant exposure to longer-term climate risk and growing regulatory pressure.[27]
- **Recent high-profile divestments from carbon-intensive sectors could signal much larger-scale shifts in the near future**. France's AXA pioneered divesting from the coal sector in 2015, and since then, most of the EU's leading insurance companies have pulled out of coal investments.[28]
- Many major global investors have also joined forces in the 'Climate Action 100+ group', calling for improved climate change governance, emissions reductions and greater transparency on climate risks.

Green bonds explode but remain marginal to the global economy

The EU accounted for 41% of all green bonds issued globally in the first half of 2018. Corporate and financial sector investments are expanding fast





Source: Bloomberg New Energy Finance

TREND 4

BENEFITS SPREADING UNEVENLY

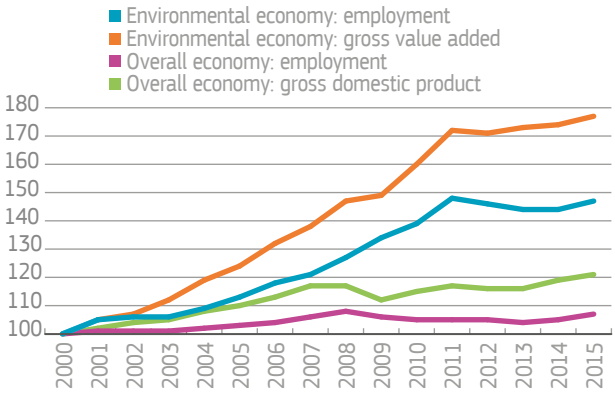
Environmental economy growing fast – but not for everyone

- The **clean economy has been growing considerably faster** than the overall economy over the past fifteen years in the EU – both in terms of value added and jobs.[29]
- The total number of **people employed in the renewable energy industry worldwide** (including large hydropower) **surpassed 10 million** for the first time in 2017.[30] In the EU, the number of renewable energy jobs reached 1.4 million in 2017[31] and is expected to increase, with the creation of up to 1.5 million net jobs by 2030.[32]
- On the other hand, many **traditional, fossil fuel-based industries are struggling**: While the fossil fuel sector provided jobs for 30 million people globally in 2017, it is set to lose 8.6 million jobs by 2050.[33]
- Carmakers will also be affected as the switch to electric cars risks making one in four jobs in the production workforce redundant.[34] Jobs in the 'garage next door' could also suffer given that electric cars require fewer components and are easier to maintain than complex internal combustion engines.

RETRAINING AND LIFE-LONG LEARNING MORE IMPORTANT THAN EVER

- In most cases, new jobs created in the clean economy will be created for different skills profiles to those jobs that will become obsolete. In the automotive sector for instance, jobs are already shifting in favour of IT specialists, power electronics, and recycling and battery technologies.
- **Skillsets across Europe are trailing**. The renewable energy and clean tech industry is already facing shortages – whether in the wind sector, where there is a shortage of maintenance skills, or the solar photovoltaic industry, where manufacturing experts and installation technicians are lacking. Of course, many traditional skills will remain relevant, in particular in areas such as building retrofits and the construction of new public transport infrastructure.[35]

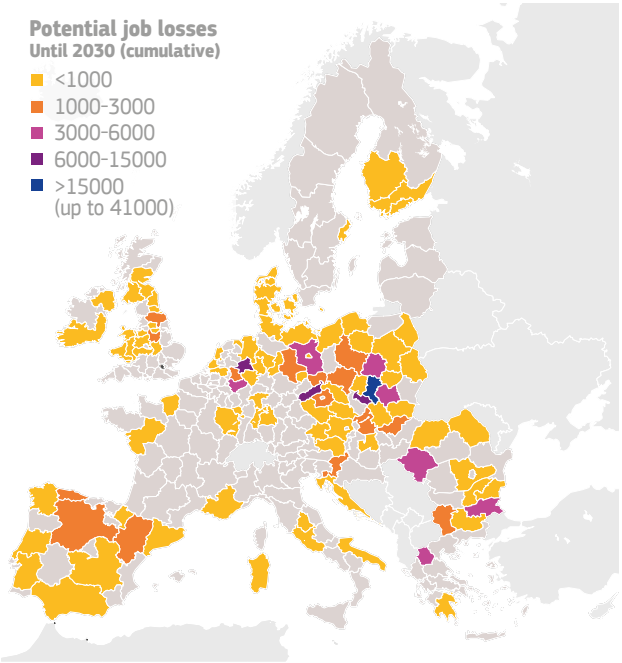
Environmental economy growing faster than overall economy



Source: Eurostat, European Commission

Carbon-intensive regions are most at risk

In 2015, there were 237,000 direct jobs in coal and lignite mining and power-plants – the majority of them in just a few regions. By 2030, it is estimated that around 160,000 of these may be lost.[36]



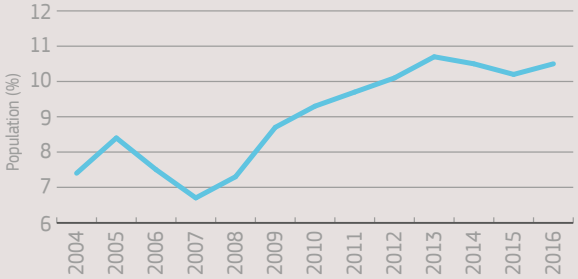
Source: Joint Research Centre

INCONVENIENT TRUTH: SOCIAL CONTESTATION GROWS AS LOWER INCOMES STRUGGLE WITH THE TRANSITION

- Despite the opportunities it presents, fighting climate change has not come without costs.
- There is a **growing discontent among consumers and taxpayers** as new regulatory frameworks and taxation policies supporting the clean economy transition cause hikes in fuel prices and constrain their mobility (e.g. as older, more polluting cars are banned from cities). The November 2018 'gilets jaunes' movement in France epitomises the growing social discontent and highlights the need for policies that not only champion the sustainable transition, but do so in a way that is **fair and manageable for lower-income groups**.

More Europeans unable to pay their utility bills in recent years

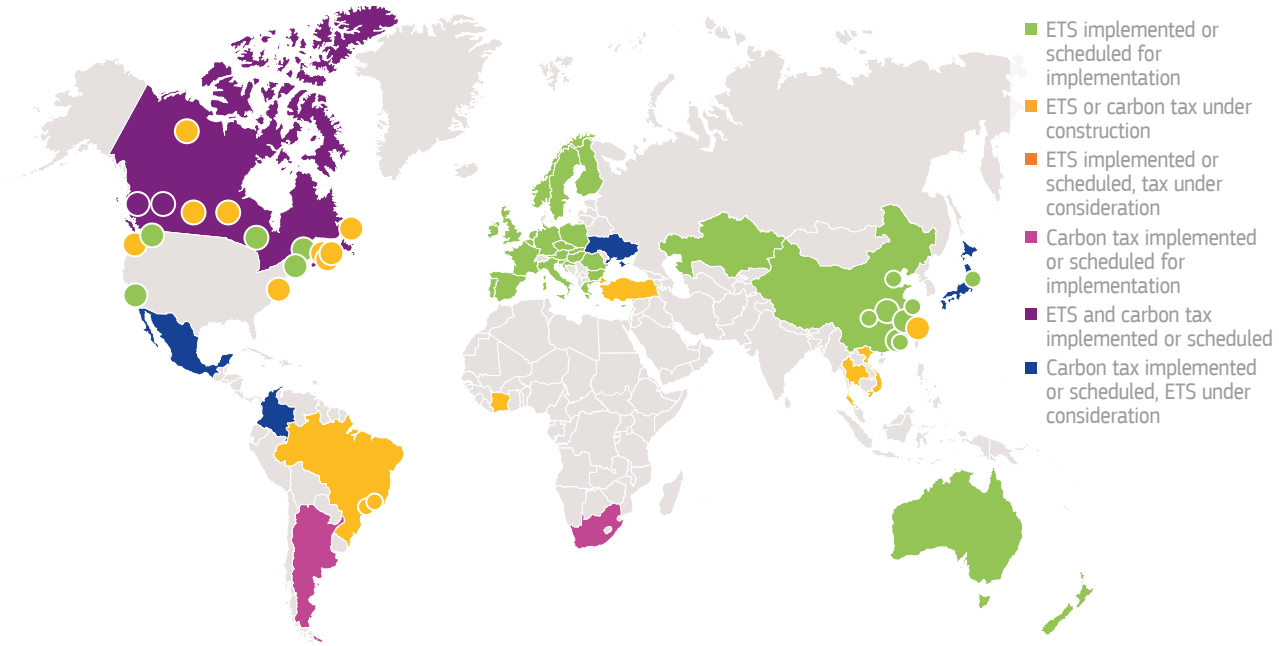
Share of population facing arrears on utility bills, 2004 - 2016



Source: Eurostat, Energy poverty indicator

- Stricter regulations in Europe compared to other parts of the world could result in carbon leakage, i.e. businesses transferring production outside Europe due to costs related to climate policies – leading to job losses, and potentially intensifying social unrest. There is however so far no solid evidence of carbon leakage.
- Creating a global level playing field is all the more urgent in this context, and requires both adapting the global trading framework (and World Trade Organisation rules) and reaching a global price for carbon. Currently there are 53 carbon pricing initiatives implemented or scheduled for implementation worldwide.[37]

Carbon pricing initiatives cover roughly 20% of global greenhouse gas emissions



Note: ETS = Emissions Trading Scheme

Source: https://carbonpricingdashboard.worldbank.org/

TREND 5

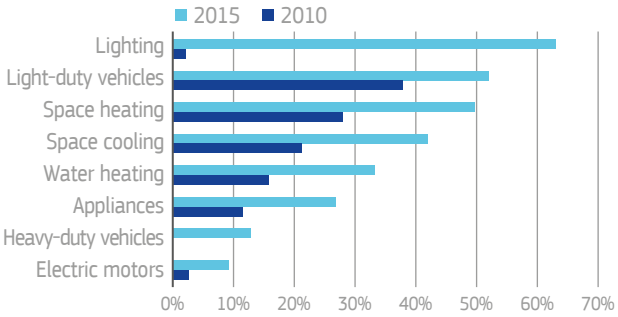
ENERGY DEMAND TRANSFORMED AS RESPONSIBLE CONSUMERISM KICKS IN

Energy efficiency has become the world's 'hidden fuel'

- The growing world economy will require more energy, but **consumption is expected to grow less quickly than in the past** – at 1.3% per year over 2015-2035 compared with 2.2% per year in 1995-2015.[38]
- This is because **energy intensity** (energy usage in relation to gross domestic product) **improvements are speeding up – leading also to improved carbon intensity.** In fact, Europe has already succeeded in decoupling economic growth and greenhouse gas emissions, with total emissions decreasing by 22% between 1990 and 2017, even as the EU's combined GDP grew by 57.5%.[39]
- The acceleration of energy efficiency improvements largely reflect a **shift in policymaking from supply-side issues to the demand side**. Today, a third of the world's energy consumption is covered by mandatory standards and regulations, compared with just 11% in 2000.[40]
- Energy efficiency solutions also bring everyday economic benefits, which are all the more important for people living in precarious conditions or exposed to energy poverty.
- A global leader on energy efficiency, **the EU is nearing its target of improving energy efficiency by 20% by 2020 – although recent years have seen a resurgence in energy consumption levels**.

A third of the world's energy consumption now covered by mandatory standards

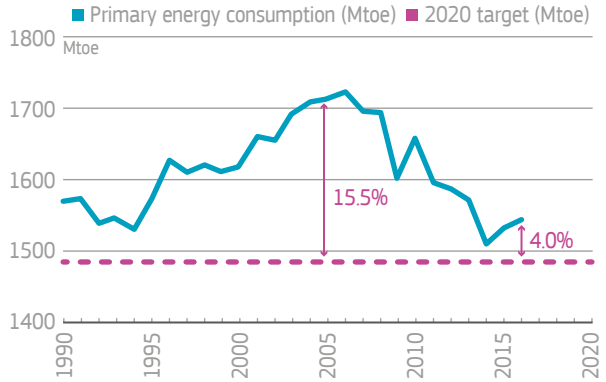
Share of global end-use energy consumption covered by mandatory energy efficiency policies, 2000 and 2015



Source: International Energy Agency

Recent years see setback in EU energy efficiency progress

Primary energy consumption (million tonne equivalents) in the EU 28 2020



Source: Eurostat

THE ECONOMY IS GOING CIRCULAR

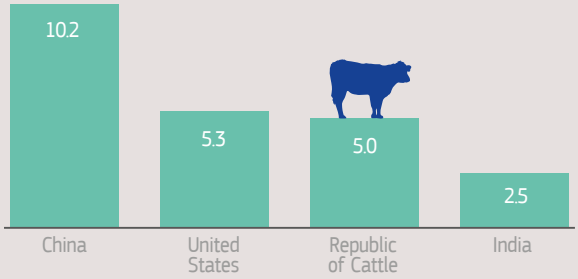
- The shift towards more circular and sustainable modes of production and consumption is driving a shift towards greater energy efficiency and a smaller carbon footprint.
- In a circular economy, raw materials are re-used and recycled; and new materials needed for the energy transition are produced more efficiently and sustainably. In turn, products are designed to be reusable, or to be easily repaired or dissassembled, to facilitate remanufacturing and recycling. **As a result, energy, raw material and labour costs per product are declining.**
- Wastes and biomass are gradually replacing crude oil in industrial processes. In the cement industry, for instance, the share of fossil wastes and biomass has gone from almost nothing in 1990 to 28% and 14.8% respectively in 2015.[41] The gradual integration of hydrogen produced from renewable electricity as an industrial feedstock provides even more scope for circular economy growth.

INCONVENIENT TRUTH: TECHNOLOGICAL PROGRESS WILL NOT RELIEVE CONSUMERS OF THEIR RESPONSIBILITY TO MAKE SUSTAINABLE CHOICES

- To date, reductions in energy consumption remain primarily driven by energy efficiency improvements, rather than by changes in consumption patterns.[42] In fact, the relationship between consumer behaviour and energy efficiency and cost is complex and can even be inversely proportionate – for example, fuel-efficiency improvements in cars have also resulted in drivers being more inclined to increase the distances they travel or to switch to larger vehicles.[43]
- Furthermore, even as some parts of the population are reducing consumption, the global population is growing fast and will require greater shifts in how society consumes. For instance, the share of European consumers avoiding red meat and beef stood at 13% in 2016.[44] Yet this trend stands in stark contrast to the growing appetite for meat and other more resource-intensive food products amongst the rising middle class of emerging economies like China[45] or India.[46]

If cattle were a country, they would rank third in greenhouse gas emissions

Gigatonnes of CO2 emissions per year (CO2 equivalent for cattle)



Source: UNFCCC, European Commission, UNFAO

TREND 6

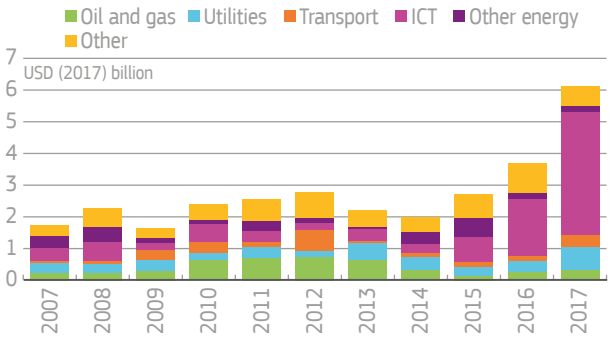
DIGITAL DRIVING AN ENERGY REVOLUTION

But like in other sectors, the digitalisation of critical energy infrastructure does not come without risks

- The energy sector started integrating digital technologies as early as the 1970s to make grid management and operation more efficient. Today, **the pace of digitalisation in the energy system is accelerating**.[47]
- In 2016, **global investment in digital electricity infrastructure** such as smart grids – which use digital technologies to enable two-way communication between utility providers and customers – amounted to 40 billion euro. This was almost 40% higher than investment in gas-fired power generation worldwide (30 billion euro).[48]
- **Energy tech start-ups are popping up** the world over, attracting some 5 billion euro in 2017 in corporate venture capital and growth equity.[49] Importantly, since 2015 this increase has been driven by IT companies, rather than energy, transport or utility companies. **The growing involvement of digital platforms** is driving the development of new services and apps that serve to optimise society's energy consumption, cut costs and reduce carbon footprint.
- As such, **digitalisation is giving rise to a new generation of empowered consumers**, able to control their energy consumption in real time – e.g. shifting demand to times of cheaper prices.
- By leveraging advanced analytics, digital assets such as smart meters and micro-grids not only enable **smarter energy management**, but also the integration of **predictive capabilities** to address asset malfunctions.[50]

IT companies ramping up energy investments

Corporate investments in new energy technology companies, by sector of investing company



Source: International Energy Agency, World Energy Investment 2018

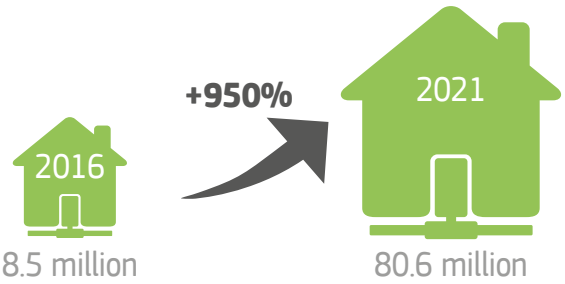
- Digitally-enabled technologies are also transforming the very nature of modern energy demand, as seen with the sharp growth in '**mobility as a service**', as car-sharing and ride-hailing apps grow in popularity.
- The expansion of the **Internet of Things (IoT), as well as the integration of new technologies, such as big data and even Artificial Intelligence, will further amplify this digitalisation trend**. For instance, the electricity generation industry, as well as oil and gas exploration and production companies are already making use of '*digital twins*' – virtual copies of power plants and other industrial assets for predictive maintenance and training simulations.

CYBER RESILIENCE IS THE KEYWORD IN A WORLD OF DIGITAL ENERGY

- In past years, several **major cyberattacks have targeted energy companies – whether for economic espionage, blackmail, vulnerability mapping or sabotage**.
- To date, such state-sponsored cyberattacks have mostly been used to test the waters and see how affected governments and organisations would react. The manipulation of the Ukrainian power grid in 2015, for instance, came across as primarily designed to signal and demonstrate an ability to disrupt.[51] But **in the future, such attempts could serve more destructive – or indeed political – purposes** (e.g. attacks on nuclear power plants; or the triggering of major blackouts days before pivotal elections).
- **Both power plants and the growing number of individual installations are at risk**: Cyber security researchers have demonstrated that hackers need physical control over just one turbine to take over the operation of (or indeed paralyse) an entire wind farm.[52]
- The strong interconnection of energy systems across Europe and well beyond EU Member States mean that the **cascading effects** of such attacks could be significant. Unlike other IT systems, control systems in the energy sector cannot be easily shut down, and an outage of an energy sector in a region might easily spill over to other sectors or regions.[53]
- Finally, a more widespread use of digital technologies not only raises cybersecurity concerns, but also raises questions relating to data privacy and information protection, with risks of uncontrolled use of customer data.[54]

The number of smart homes in the EU is expected to increase tenfold by 2021

Smart homes* in the European Union



*Homes which use digitally controlled lighting, heating, ventilation, air conditioning, security, as well as home appliances

Source: European Commission

INCONVENIENT TRUTH: NEW TECHNOLOGIES ALSO CREATE NEW ENERGY DEMAND

- Data centres worldwide consumed the equivalent of about 1% of total global electricity demand in 2014.[55]
- The growth of energy-intensive digital uses, such as big data and AI could see this share rise in the future.
- Inefficient networked standby could waste the equivalent to the current annual electricity consumption of France and the United Kingdom combined in 2025.[56]

TREND 7

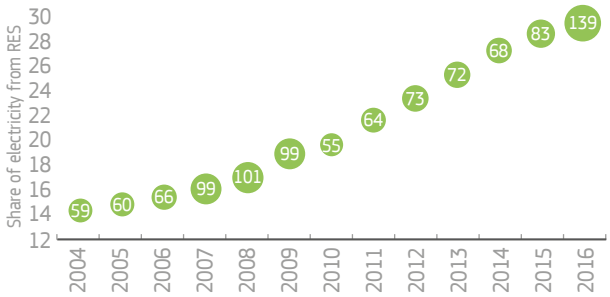
ELECTRIFICATION RHYMES WITH DEMOCRATISATION - AS WELL AS FRAGMENTATION

Electrification, renewables and digitalisation are giving rise to a new generation of small producers; but it's not without challenges

- The rapid global deployment of renewable technologies – solar in particular – means that **millions of consumers around the world are now able to produce their own electricity** – from rooftop solar panels, for example.
- While most coal, gas and nuclear power plants are owned by big utilities, **the ownership structure for renewables is more diverse**. This is partly because individual renewable installations tend to be much smaller. While a typical European nuclear power plant has a capacity of around 2,000 megawatts, and coal power plants have an average capacity of 700 to 1,000 megawatts, the average solar energy project size in Europe in 2015 was 3-8 megawatts.[57]
- **This allows more investors to enter the energy sector**, creating a more competitive energy market.

Renewables revolution brings drop in electricity market concentration

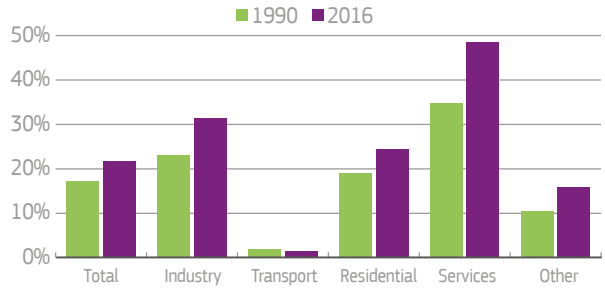
Number of generating companies representing at least 95% of national electricity generation in EU28 in relation to share of renewable electricity



Source: Joint Research Centre, Eurostat

Electricity finds growing applications in industry, heating and in services

Share of electrical energy on final energy consumption, sectorial breakdown



Source: Eurostat

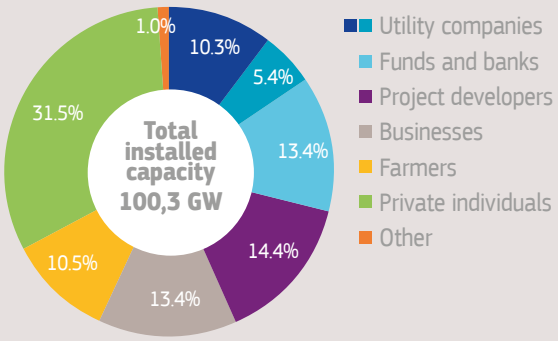
POWER TO THE CONSUMERS

- **New technologies mean that consumers can now not only produce their own energy, but also sell any surplus back to the grid**. These energy 'prosumers' (producer-consumers) are increasingly able to participate in wholesale energy markets through technologies like virtual power plants.[58]
- Estimates suggest that, by 2030, energy communities could own some 17% of installed wind capacity and 21% of solar.[59] By 2050, almost half of all EU households – around 113 million – could be involved in producing renewable energy.[60] Currently however, Europe's 3,000 or so energy communities are limited to just a few countries – around 75% of them being located in Austria, Germany and Denmark.[61]

German citizens own roughly one third of the country's renewable electricity capacity

Farmers own another 10.5% while the four dominant utility companies (when considering coal, gas and nuclear markets) – i.e. RWE, Eon, Vattenfall Germany, EnBW, only own 5.4% of renewable production.

Share of renewable energy production by type of owner (2016)



Source: German Agency for Renewable Energy (2018)

INCONVENIENT TRUTH: OPERATORS AND REGULATORS NOT YET READY FOR A DECENTRALISED POWER SYSTEM?

- Current distribution systems and **regulatory frameworks were primarily designed for a centrally-controlled reality**, in which power flowed one way and market participants were large corporations. **Domestic renewable production is revolutionising this paradigm**.[62]
- System operators are finding it increasingly difficult to integrate the **growing diversity of electric supply** into existing grids, as well as to balance it with demand. At the same time, the **proliferation of off-the-grid assets** make regulatory control all the more difficult.
- In a decentralised context, the question of **security of supply** is also being transformed, making it necessary for governments to invest in 'safety nets', such as capacity mechanisms. The challenge will then be to close them once they are not necessary anymore.
- But **decentralisation also comes with new business opportunities**: the aggregation of distributed energy resources is one of the few areas of the digital economy where innovative European firms are expanding in the United States – and not the other way around.[63]

A NEW ROLE FOR BLOCKCHAIN?

- Blockchain can help facilitate the transition to a decentralised energy system, by providing a secure and transparent transaction environment for **independent energy trading platforms**.
- As a result, blockchain energy startups are multiplying and, in 2017, they raised more than **265 million euro** for blockchain technology applications in the energy sector.[64]

TREND 8

PIVOT EAST

As energy demand surges in Asia, it is also driving innovation

- Driven by rapid economic growth, **energy consumption is growing fastest in the Asia and Pacific regions**.[65]
- **China** already surpassed the United States as the world's largest crude oil importer in 2017[66] and the International Energy Agency projects that it will become the world's largest consumer of oil by the early 2030s.[67] China is also expected to account for more than a quarter of all the worldwide growth in gas consumption between 2015 and 2040.[68]
- China is also the world's largest greenhouse gas emitter, surpassing the combined carbon contribution of both the US and the EU. **The Asia Pacific region as a whole is now responsible for nearly 50% of global carbon dioxide emissions**.[69]
- This **rapid growth is also driving major investments in renewables and in energy efficiency**, as China and other countries in the region seek to keep their swelling energy bills under control and their citizens demand cleaner air. **China and India** are set to stand for almost **half (46%) of the projected growth in renewable energy markets** between 2015 and 2021.[70]
- **China has become the world's largest destination of investment in the energy sector**, standing for one-fifth of global energy investment in 2017.[71] Combined with an ambitious – sometimes aggressive – government-supported industrial strategy – this has enabled the country to rapidly transform itself into a **leading global centre for clean tech manufacturing.**
- It has already taken over the solar photovoltaic sector. It leads by far on electric vehicles sales.[72] And is set to dominate global battery cell manufacturing, feeding about 70% of the global Li-ion batteries market by 2020.[73]

Less than 15 years to take over the solar photovoltaic sector

Top 10 manufacturers of solar panels/cells, 2004 to 2018

	Production 2001	Production 2004	Production 2009	Production 2010	Production 2017-2018
1	Sharp	Sharp	First Solar	Suntech	Jinko Solar
2	Kyocera	Kyocera	Suntech	First Solar	Trina Solar
3	Shell solar	BP solar	Sharp	Yingli Solar	Canadian Solar
4	BP solar	Q-Cells	Q-Cells	JA Solar	JA Solar
5	Astropower	Mistubishi	Yingli	Sharp	Hanwha Q Cells
6	Sanyo	Shell Solar	JA Solar	Q-Cells	GCL-SI
7	Isofoton	Sanyo	Kyocera	Gintech	LONGi Solar
8	RWE Solar	Schott Solar	Trina Solar	Motech	Risen Energy
9	Mitsubishi	Isofoton	SunPower	Trina Solar	Shunfeng
9	Photowatt	10 Motech	10 Gintech	10 Kyocera	10 Yingli Green

In 2018

8 out of 10 Global manufacturers did not exist in 2010

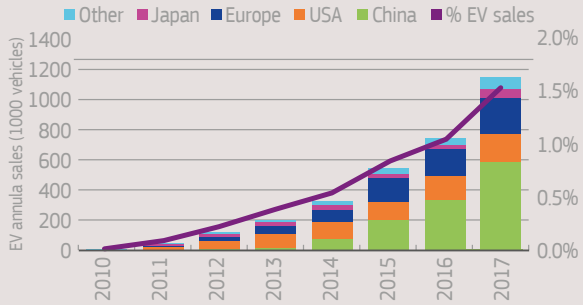
7 out of 10 Global manufacturers are Chinese companies

No 'Global' manufacturer of Solar Cells

Sources: Luxembourg Ministry of the Economy, Photon International, Joint Research Centre, PV-Tech.org

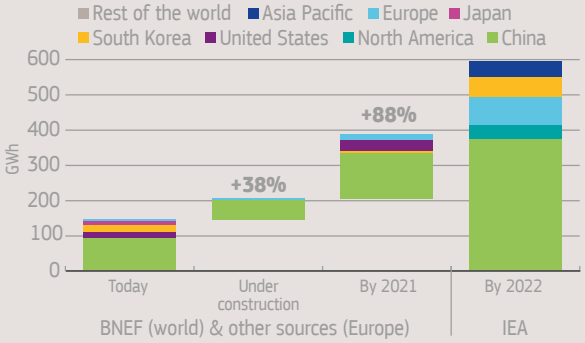
Half of the world's electric vehicle sales in China

Annual sales of electric vehicles.



Source: Joint Research Centre, Bloomberg New Energy Finance

China set to dominate global battery cell production



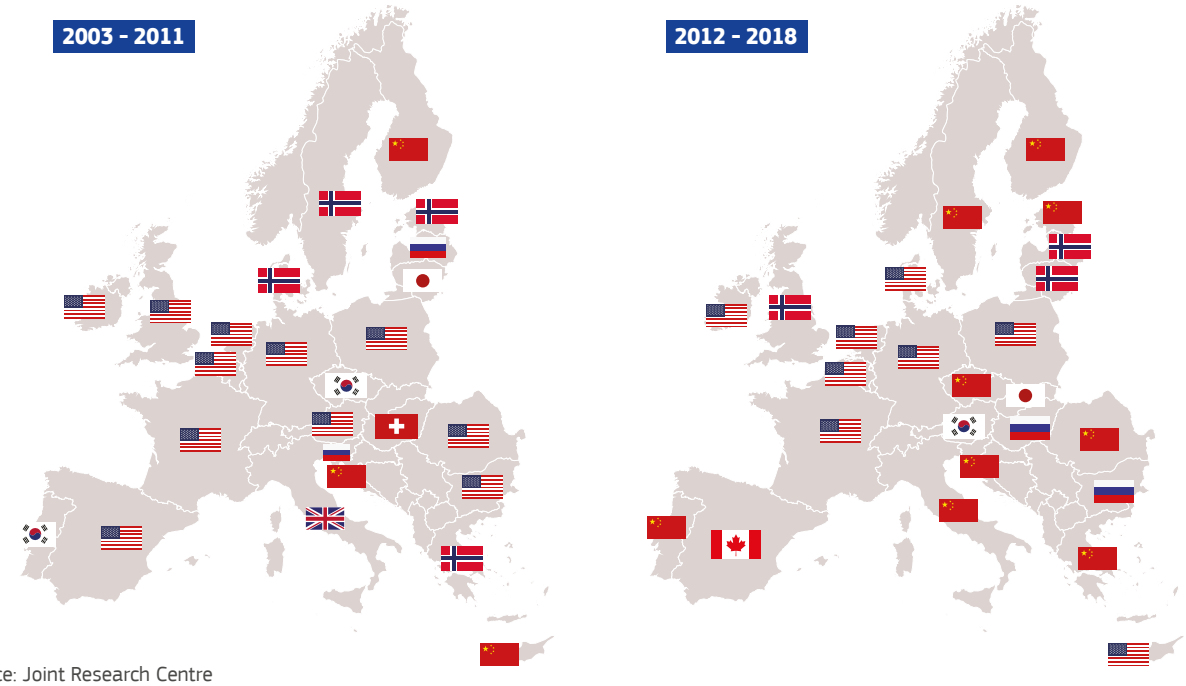
Source: Joint Research Centre (Compilation from various sources)

A SPRAWLING INFLUENCE

- **China is also investing massively in energy infrastructure and resources abroad**, namely through its Belt and Road initiative, as well as in Africa (although relative to Europe, its presence still remains limited).
- In Europe, Chinese foreign direct investment in the energy sector shows rapid growth after 2008, increasing from 155 million euro in 2010 to 3.7 billion euro in 2017, making **Europe the fastest-growing destination for Chinese brownfield foreign direct investment**. The EU accounted for 77% of the total Chinese stock during this period.[74]
- Chinese investments in the European energy sector reflect a commercial and political strategy to secure the position of state-owned energy companies. Chinese investors benefit from an investment-friendly environment and the undervaluation of assets resulting from the economic crisis. This contrasts with existing restrictions to inward foreign direct investment in energy companies in China.

Who controls critical infrastructure? Energy sector Foreign Direct Investment in the EU28

Largest source of investment per Member State



Source: Joint Research Centre

TREND 9

NEW SUPPLY RISKS EMERGING

...as energy value chains go global and the clean tech revolution increases reliance on new materials

- Security policies in the energy sector have traditionally evolved around **pipeline diplomacy and hard security issues** affecting the supply of oil and gas. While this will remain a concern in the medium term, the balance is shifting.
- On the one hand, the globalisation of gas markets and rising shares of liquefied natural gas mean **import sources can be diversified more easily**.
- On the other hand, the rise in renewable energy enables **a shift to local production**, helping to decrease import dependency. **However, this will take time and could be accompanied by new dependencies** that will need to be managed in Europe's external and trade relationships.
- Indeed, the large-scale production and deployment of batteries, wind turbines and other clean tech solutions will require uninterrupted supply of **specialised raw materials like rare earths and cobalt**[75] at low cost, most of which, however, are not produced in Europe but must be imported – in some cases from countries with less stable political regimes. In this context, trade partnerships are expected to play central role, as is the application of circular economy principals (recycling and reuse of materials and components).[76]

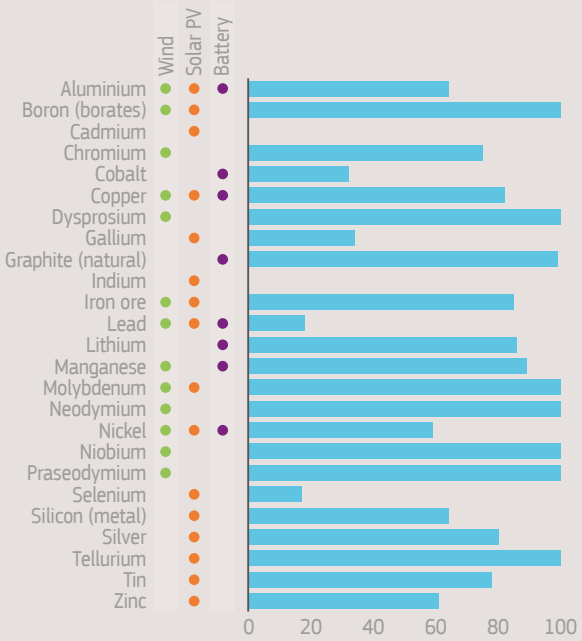
INCONVENIENT TRUTH: IN THE SHORT TERM OUR IMPORT DEPENDENCY WILL INCREASE, AND IN PARTICULAR OUR RELIANCE ON RUSSIA FOR FOSSIL FUELS

- **The EU's import dependency increased from 46.7% in 2000 to 53.6% in 2016**.[77] But thanks to better interconnections in Europe, Member States are now much better prepared to handle this situation. This trend is set to continue with the decline of the exploitation of gas and oil fields in Europe and the progressive phase-out of coal.
- Russia remains the EU's main supplier of oil, gas, coal and nuclear fuel – even if its energy sector has been affected by the EU-imposed sanctions regime.
- The switch of the United States from an energy importer to a net exporter will strengthen security of supply in Europe, notably through **increased liquefied natural gas supplies**. However, it could also leave Europe in a more exposed geopolitical position when it comes to global oil markets if the United States turn their back on the Middle East.

THE FUTURE OF EUROPEAN ENERGY ALSO RELIES ON IMPORTS

It's not just a question of raw materials: many of the intermediary components required to produce finished renewable energy projects will have to be sourced from China.[78]

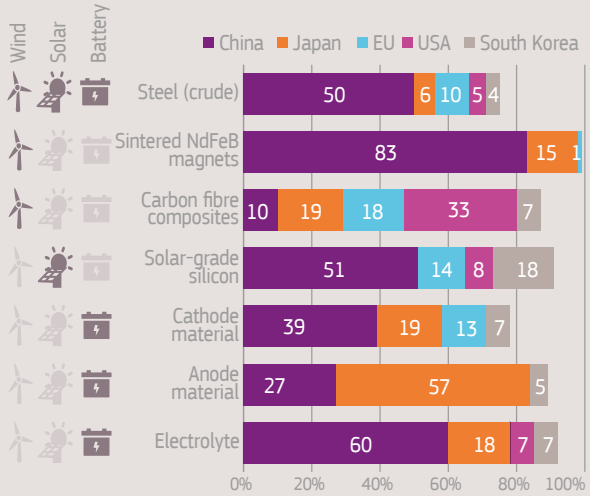
Import dependency for raw materials, as well as for selected materials used in wind, PV and battery technologies



Source: Joint Research Centre

EU competitiveness at stake as China leads on supply of most materials and components needed for renewables

Share of global production of different processed and finished materials used in wind turbines, solar photovoltaic panels and batteries, in % of total



Source: Joint Research Centre

NEW RISKS ON THE HORIZON? FORESIGHT AND ANTICIPATION GROW IN IMPORTANCE

- The combination of new and increasingly complex risks and threats, as well as the growing interaction between sectors and actors calls for **more anticipatory capabilities to facilitate political steering and enhance preparedness with respect to alternative future scenarios**.
- Yet, currently, the EU relies heavily on external foresight, planning and economic modelling capabilities, as well as on data and intelligence from the private energy sector, foreign government agencies or international organisations of which it is not a member.

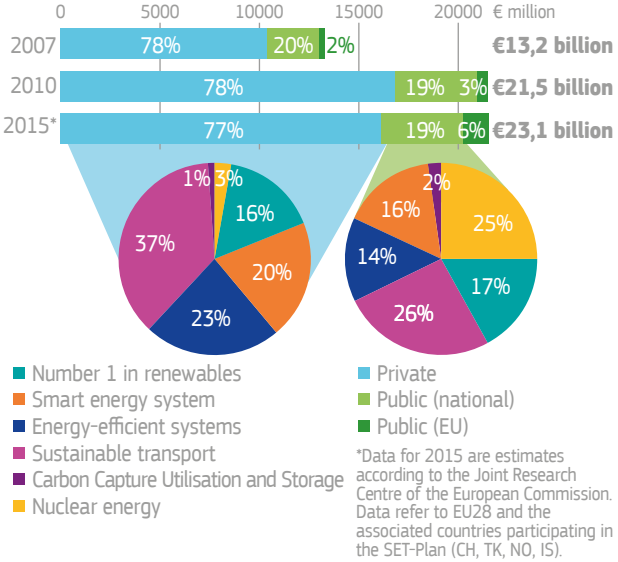
TREND 10

NET-ZERO EMISSIONS NO LONGER A MERE DREAM

Innovation is gradually delivering on the promising technologies needed to erase our carbon footprint

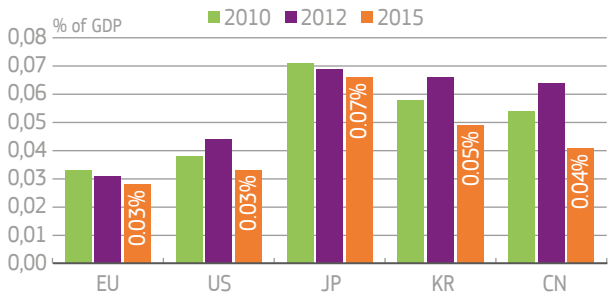
- Those renewable technologies that are already mature, like solar, hydropower or wind, are expected to enable the EU to cut its greenhouse gas emissions by up to 90% by 2050.[79]
- But in order to make the final step towards net-zero greenhouse gas emissions by 2050, **other innovative technologies will be needed**, such as artificial photosynthesis, carbon capture and storage and advanced manufacturing for energy-intensive industries, or precision farming and advanced biofuels.[80] Energy storage technologies and low-emission options for airplanes will also need to be further developed.
- **The private sector has been raising the game in recent years**, consistently accounting for more than 75% of EU investment in clean energy research and innovation, and increasing annual spending from some 10 billion euro to over 16 billion euro in the past decade.[81]
- Yet, despite its strong research base and its large public research budget for clean energy technologies (second largest after the United State), **the EU ranks last among major economies in terms of investments per GDP**.
- Furthermore, insufficient access to finance, in particular venture capital, combined with high capital costs and excessive red tape mean that **Europe all too often fails to bridge the gap from research to market**.
- Technological leadership is key as those who set the standards are also those who later control the markets. Yet, **the EU is at risk of losing the early-mover competitive advantage it has benefitted from thus far**. It lags behind Asian competitors in terms of numbers of low-carbon inventions – although it ranks second after Japan in numbers of high-value patent filings, i.e. inventions that seek protection in more than one country or market. This is also because China's innovations mainly target its internal market at the moment.[82]
- **Public funding will continue to play a key role** in steering private investments in the right direction and bridging the gap from labs to commercialisation.

Private research spending on the up in Europe



Source: Joint Research Centre

But the EU ranks last among major economies in terms of R&I investments as a share of GDP



Source: Joint Research Centre

Inconvenient truth: Despite growing investments, many key innovations remain elusive

Innovation progress of technology options in the energy transition, by sector.

Pace of innovation progress	Power generation	Industry	Transport	Buildings[83]
Mature / on track	• Hydropower • Solar photovoltaic • Onshore wind • Offshore wind • Smart grids • Battery storage • Energy efficiency in end uses	/	• Electric Vehicles	/
Lagging but viable	• Biopower • Geothermal • Interconnector capacity • Ultra-high-voltage direct current • Demand-side response • Concentrated solar power	• Carbon Capture and Storage in various production processes (gas ammonia, clinker substitutes, direct reduced iron-making) • Biomass supply at scale	• Conventional biofuels • Energy efficiency • Biomass supply at scale	• Zero-energy buildings • Energy renovation and existing stock • Clean cooking using renewables • Solar-assisted water/ space heating systems • Heat pumps
Not viable at current pace	• Carbon Capture and Storage for natural gas and biomass (BECCS)	• Direct reduced iron-making hydrogen • Carbon Capture and Storage for blast furnace iron-making • Biomass for chemicals and recycling • Hydrogen ammonia production • Material efficiency • CO2 transportation and storage infrastructure	• Hydrogen vehicles • Advanced biofuels • Railway infrastructure for modal shift	• District heating & cooling with renewables
Not currently available	• Various negative emission technologies • New materials for advanced battery storage	• Solar thermal aluminium smelting • Direct conversion of CO2 to fuels and materials	• Solar passenger cars • Electric aircraft	• Advanced lightweight materials for construction • New appliance technologies such as magnetic refrigerators; breakthrough materials for insulation; and advanced smart heating, cooling, and appliance use and control systems

Source: World Intellectual Property Organisation, Global Innovation Index 2018

CAN CARBON ITSELF BECOME A RESOURCE?

- A growing number of innovative industrial carbon capture and utilisation (CCU) processes are under demonstration. They use carbon dioxide as a resource to produce value added products such as chemical feedstocks, fuels or building materials, with the promise of achieving net-zero GHG emissions provided that they are powered by renewable energy.
- Carbon Capture and Storage (CCS) technologies promise the permanent and safe, large-scale storage of carbon dioxide in suitable underground locations. But the lack of any successful demonstration project, negative public perception, in particular for underground storage of carbon dioxide inland and regulatory constraints in many countries will also limit the large scale deployment of CCS in Europe.
- Key issues also remain unanswered regarding commercial viability and solutions will be needed to ensure that carbon capture and utilisation solutions can be fed by low-cost renewable energy and carbon dioxide captured from industrial facilities at minimum cost.[84]

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