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EUROPE'S CLEAN TECHNOLOGY INVESTMENT CHALLENGE

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Highlights

- Development and deployment of clean-energy technologies is crucial if climate targets are to be met cost-effectively. The European Union already has a plan that deals with these issues: the Strategic Energy Technology Plan, which has become central to the achievement of the EU's ambitions.
- In a period of constrained public finances, if governments want to leverage the necessary private innovation for clean-energy technologies, they will have to provide well-designed time-consistent policies, reducing commercial and financial risk through a combination of consistent carbon pricing, regulations and public funding, which will have to give a sizable and consistent push to early-stage clean-energy technologies, with a clear exit strategy.
- But first and foremost, governments should establish a sufficiently high and long-term predictable carbon price. The design of the EU emissions trading system and the distribution of carbon allowances should take into account more explicitly its power to leverage innovation. A move to a 30 percent EU emissions reduction target, which would involve a tighter emissions cap and fewer allowances being auctioned, would result in a higher carbon price and provide greater incentives for innovation.

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EUROPE'S CLEAN TECHNOLOGY INVESTMENT CHALLENGE

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THE EUROPEAN UNION'S ROADMAP for moving to a competitive low-carbon economy by 2050, which was published in March 2011, recognises the crucial part that will be played by the development and deployment of new technologies, and the importance of the competitiveness of EU clean energy technology companies on world markets, if climate change targets are to be met in a cost-effective manner. The EU already has a plan that deals with these issues: the **Strategic Energy Technology Plan**[1], which has become central to the achievement of the EU's ambitions.

However, the big question is where the money will come from to finance these clean technology investments. With constrained EU and member state public funding, leveraging private funding will be essential. But will the private sector be willing to allocate resources to Europe's clean energy projects? This Policy Contribution looks at where clean energy innovation is happening. Using new evidence on clean energy patenting, we demonstrate the multipolar character of the clean energy technology landscape, in which the EU faces strong competition, particularly from Asian countries. After relating clean energy patenting activities to government policies on carbon pricing and public funding, we conclude with a discussion on what is needed in order to drive forward private clean-energy technology investments in Europe.

1 EU CLIMATE POLICY: THE STATE OF PLAY

As re-emphasised in the March 2011 roadmap for moving to a competitive low-carbon economy[2], the EU has a long-term target of reducing its greenhouse gas (GHG) emissions by 80-95 percent by 2050. It put in place targets for 2020 in the 2009 climate and energy package[3]: renewable energy to make up 20 percent of the energy mix, and a 20 percent greenhouse gas reduction compared to 1990 (with the option to increase this to 30 percent). A mix of policy instruments has been designed to meet these targets, including an emissions trading system (ETS) and a set of regulatory measures on vehicle carbon dioxide emissions, energy efficiency and on sectors currently not covered by the ETS. The first phase of the ETS was criticised because of the oversupply of allowances and the distribution methodology (via grandfathering rather than auctioning). As a consequence, carbon prices have been volatile (see Aghion et al, 2009). The drop in the price in 2007 marked the end of the first phase of the ETS. This was due to the absence of bankability of ETS first phase allowances, which could not be carried over to later phases. In its second phase, the ETS was made more consistent and predictable. From 2013, an emissions cap will be set at EU level and cut each year to reach targets. The level of auctioning in the system is set to gradually increase and member states should use at least half of their auctioning revenues for measures to combat climate change. Since 2009, the carbon price has been much more stable, albeit at a low level of around €15 (Figure 1).

From the outset, the EU recognised the importance of research, technological development, innovation and the diffusion of new technologies for meeting its targets. It published the Strategic Energy Technology Plan (SET-Plan) in October 2009, to beef up the technology part of its energy and climate policy. The goal of the SET-Plan is to provide an all-encompassing technology roadmap, coordinating fragmented policies and

'The EU recognises the crucial part that will be played by the development of new technologies, and the importance of the competitiveness of EU clean energy companies on world markets, if climate change targets are to be met. The big question is where the money will come from.'

1. European Commission (2009) *Investing in the development of low carbon technologies (SET-Plan)*, COM (2009) 519 final, available at http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm.

2. European Commission (2011) *A roadmap for moving to a competitive low carbon economy in 2050*, COM (2011) 112 final, available at http://ec.europa.eu/clima/documentation/roadmap/docs/com_2011_112_en.pdf

3. Official Journal of the European Union, volume 52, L140, 5 June 2009.

Figure 1: EU ETS daily carbon prices

Source: Datastream (BlueNext).

programmes, and organising energy research efforts across Europe, in partnership with the private sector and directed towards a clear set of technology targets. The SET-Plan (see Box 1) envisions raising the total public and private investment in low-carbon energy technologies by an additional amount of €50 billion over the next decade.

BOX 1: EUROPE'S STRATEGIC ENERGY TECHNOLOGY (SET) PLAN

The SET-Plan's objective is to accelerate the development of low-carbon energy in six sectors: wind, solar (both concentrated solar and photovoltaic), smart grids, bio-energy, nuclear fission, and carbon capture and storage.

In each sector, a European Industrial Initiative (EII) is set up. These initiatives, to be led by industry, are large-scale programmes bringing together companies, the research community, member states and the European Commission in risk-sharing public-private partnerships. In addition there is also a Smart Cities Initiative and the European Energy Research Alliance, which aim to coordinate and accelerate research into, and development of, new generations of low-carbon technologies.

Since the completion of the EU climate and energy package plan in 2009, a number of events have had an impact, not least the economic and financial crisis. The full force of the economic crisis had a significant downward impact on emissions in the short term. Carbon prices fell in early 2009 from €25 to €8 before slightly recovering (see Figure 1).

At the same time, the crisis has spurred governments to kick-start their efforts to build a greener economy through their economic recovery packages. At the EU level, €4 billion is being spent as part of the European Economic Recovery Plan. This money is being directed to energy infrastructure projects, offshore wind electricity generation and demonstration of carbon capture and storage.

The crisis increased the attractiveness of higher target scenarios. As part of the climate and energy package, the EU committed itself to increase its 2020 emissions reduction to 30 percent if the conditions are right. In 2010, the Commission prepared an analysis of what practical policies would be required to implement a 30 percent reduction (European Commission, 2010). Stepping up to a higher target would now be less costly than before, thanks to the crisis. The Commission estimated that the additional cost for the EU of stepping up from 20 percent to 30 percent would be around €33 billion in 2020, bringing the total costs of a 30 percent target to 0.54 percent of GDP. This compares to 0.45 percent of GDP calculated before the crisis for achieving the 20 percent target.

In addition, it is hoped that a higher target would increase the carbon price, bringing it back to the level targeted pre-crisis of about €30 per tonne. This in turn should support innovation and technology deployment, and thus invigorate the SET-Plan.

Nevertheless, despite the reduced costs of the more ambitious target, the European Commission has chosen not to advocate a move to 30 percent, preferring to monitor the international context and "be ready to act whenever the conditions are right to take this decision". Sticking to its current targets, the Commission estimates in its 2050 roadmap an emissions reduction of 25 percent by 2020, on the way to an overall 80 percent reduction in domestic emissions by 2050.

In all its calculations, the Commission recognises that to realise these targets as cost effectively as possible, it needs the development of new low-carbon technologies, and favourable economic conditions for investment. It considers the implementation of the SET-Plan to be of "crucial importance". To keep the 20 percent target, and *a fortiori* any higher target, affordable, the scenarios employed by the Commission rely heavily on new technologies coming to market and being smoothly deployed. This faster innovation and deployment should preferably also give a competitive edge to European companies in key sectors, securing growth in the post-crisis economic environment, and creating the 1.5 million additional jobs as envisaged in the 2050 roadmap. In its Europe 2020 strategy, and accompanying Innovation Union and Resource Efficiency flagship plans[4], the EU has re-emphasised its aim of activating to a greater extent its innovative capacity for future sustainable growth and jobs. Green innovation has never been higher on the policy making agenda in Europe, crystallised in the SET-Plan.

But will the EU be able to activate its innovation potential for green growth? The following sections examine how the EU is performing on clean energy innovation, and assess what is needed to boost performance to the level needed in the long term.

2 CLEAN ENERGY INNOVATION IN THE EU

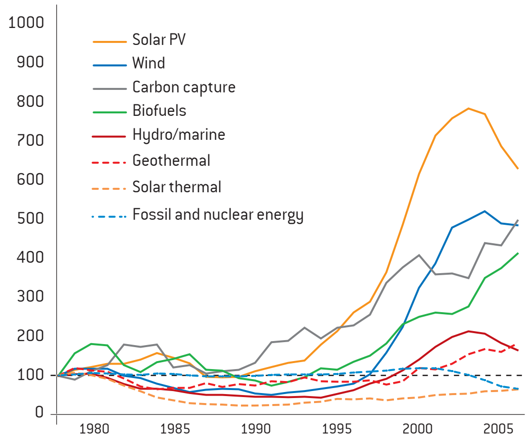
To assess how well the EU is doing in producing new clean-energy technologies, we use a recently developed and published categorisation of **green patents** provided by UNEP/EPO/ICTSD (2010). UNEP/EPO/ICTSD examines six main categories of clean energy technologies, which are either already commercially available or have strong prospects of commercialisation in the near-to-medium term. These are solar (both thermal and photovoltaic (PV)), wind, carbon capture and storage, hydro, geothermal, biofuels and integrated gasification combined cycle (IGCC)[5].

2.1 Clean-energy patenting trends

Overall, clean-energy technologies represent a very small share of total patents, less than 1 percent over the period (1988-2007), indicating that the creation of new clean technologies is still in its infancy. However clean-energy technology patents are increasing rapidly, albeit from a small base (Figure 2).

Until the mid-1990s, clean-energy technology patent growth rates were stagnant or even declining, certainly in relative terms, as overall patenting activity grew. But since the late 1990s, the trend has also been upwards for clean-energy technology patents. This upward trend holds particularly when compared to the traditional energy fields (fossil fuels and nuclear), which have been on a downward trend since 2000. When looking at individual clean-energy technologies, patenting rates in solar PV, wind and carbon capture have shown the most activity. Biofuels is a more recent growth story. IGCC and solar thermal and geothermal are not yet taking off, probably reflecting their still early stage of development.

Figure 2: Growth rates of patents for selected clean-energy technologies (1978 = 100)



Source: UNEP/EPO/ICTSD (2010). Note: patents are counted on the basis of claimed priorities (patent applications filed in other countries based on the first filed patent for a particular invention).

4. See European Commission (2010a), and: http://ec.europa.eu/resource-efficient-europe/index_en.htm and http://ec.europa.eu/research/innovation-union/index_en.cfm.

5. By looking at information from patents, we can only evaluate the capacity for creating new clean-energy technologies, not the adoption and diffusion of existing clean-energy technologies, which is arguably another important factor in reaching the EU's climate and energy targets cost efficiently. Patent data has the advantage of being widely available across countries, time and technologies. However, not all inventions are patented. In particular, inventions embedded in production processes and still far from the market might not show up in patent statistics. Data on R&D expenditures would be a better measure of activities in the early stage of technology development. Unfortunately, R&D statistics are not collected by area of technology. Green R&D expenditures can therefore not be assessed easily.

One cannot ignore the correlation between political decisions and the take-off of clean-energy technologies, as the upward trend started around 1997, when the Kyoto Protocol was signed.

2.2 Clean-energy patenting: who's who

If we look at the countries active in clean-energy patenting, **Japan** is the clearest positive outlier (Table 1). Japan holds about 30 percent of all clean-energy technology patents, but it is heavily concentrated on solar PV and is not particularly specialised in clean-energy technologies. **South Korea** is another major source country of clean-energy technology patents. South Korea is specialised and heavily concentrated on solar PV.

The **US**, despite its 16 percent share of world clean energy, is not specialised in clean-energy technologies and does not exhibit particular clean-energy technology specialisations.

In Europe, **Germany** is by far the most significant source of clean-energy technology patents, being somewhat specialised in these areas. Like the US, its patents reflect the development of a range of clean-energy technologies[6].

If the **EU** is counted as a homogeneous bloc, it would be the economy with the world's largest share of clean-energy technology patents, with a relatively broad-ranging clean-energy technology portfolio.

Although the BRIC countries are still small players in clean-energy technology patenting, they are growing rapidly. Of the BRIC countries, **China** is the most active. It has particularly strengthened its position in recent years, and has started to specialise in clean-energy patents. It is less concentrated on solar PV than Japan and Korea. Although China has leading manufacturers in the solar PV and wind technology sectors, these companies are less active in patenting.

Table 1: Who's who in clean-energy technology patenting?

	Size	Specialisation	Concentration
	Share of world clean-energy tech patents	RTA in clean-energy tech patents	Herfindahl across clean-energy tech technologies
Top six			
Japan	29.7%	0.99	0.72
US	15.9%	0.87	0.33
Germany	15.2%	1.05	0.28
Korea	5.6%	1.21	0.82
France	3.9%	0.7	0.26
UK	3.6%	0.98	0.28
EU	3.2%	1.01	0.25
BRICs			
China	0.9%	1.11	0.36
India	0.3%	1.44	0.45
Russia	0.2%	1.11	0.27
Brazil	0.2%	1.51	0.41

Source: Bruegel based on UNEP/EPO/ICTSD (2010). Note: Patents are counted on the basis of claimed priorities (patent applications filed in other countries based on the first filed patent for a particular invention). A Top 6 country has at least two percent of world clean-energy technology patents; together the Top 6 represent 74 percent of world clean-energy technology patents. RTA = share of the country in world clean-energy technology patents relative to the share of the country in total world patents; RTA > 1 measures specialisation in clean-energy technology patents; Herfindahl is the weighted sum of the share of each clean-energy technology in total country's clean-energy technology patents, with the weights being the share. The Herfindahl ratio varies between 0 (maximal dispersion) and 1 (perfect concentration).

The other BRIC countries are less important in terms of total clean-energy technology patenting, although they are specialising in clean-energy technologies. **Brazil** and **India** are concentrating on a small number of clean-energy technologies. Patentees from India show the highest activity in solar PV. The main patenting areas for Brazil are hydro/marine and biofuels. However, overall patenting activity is limited in these areas, compared to other countries. For example, China has more patents for biofuels and as many patents in hydro/marine as Brazil. This suggests that Brazilian companies are focused more on production than on developing new technologies.

Table 2 looks at each clean-energy technology separately. By far the most important in terms of patents is *solar PV*, which represented 57 percent of all clean-energy patents over the period 1988-2007. Solar PV patents are concentrated in a few countries, in particular Japan.

6. Some other EU countries are also specialised in environmental technologies (RTA>1, see note to Table 1), but are nevertheless small players (less than 2 percent of clean-energy technology patent share). These countries are Denmark (13.46), Portugal (4.93), Netherlands (1.19), Spain (1.14), Hungary (1.11) and Austria (1.05).

'In view of the pervasive environmental and knowledge externalities characterising clean-energy innovation, the private green-innovation machine cannot be expected to be effective on its own. It needs government intervention.'

Wind is the second most important clean-energy technology in terms of patents. But this sector is much less concentrated. Germany is the largest patenting country and specialises in wind technology, but there are many other European countries specialising in wind technology.

The strong solar PV and wind patenting activities suggest that these technologies can be considered as the more mature clean-energy technologies among those under consideration (Figure 2).

The big clean-energy patenting countries (Japan, Germany, US) are less dominant in *geo* and *solar thermal*, *hydro* and *biofuels*. Many countries are active and specialising in these technologies.

Carbon capture and storage (CCS) is a sector with a high level of concentration. In this sector the US is a strong and specialised player, although several European countries also specialise in CCS, including France and the United Kingdom. The share of CCS patents in total clean-energy patents is low, reflecting the still early stage of CCS technological development.

If taken as an integrated bloc, the EU would specialise in all clean-energy technologies excluding solar PV. The EU is particularly specialised in geo and solar thermal, and, though to a lesser extent, biofuels, hydro/marine and wind. It is only marginally specialising in CCS[7].

Overall, Table 2 and Figure 2 both show that with the exception of solar PV and CCS, the patenting of clean-energy technologies is spread across a number of quite geographically dispersed countries. Different countries tend to specialise in different clean-energy technologies. Concentration is still low, especially for the newer, emerging technologies, such as biofuels, hydro and geothermal. In contrast, for the more mature clean technologies, concentration is high, especially in solar PV where Asia holds a dominant position.

3. THE ROLE OF PUBLIC POLICY

In view of the pervasive environmental and knowledge externalities characterising clean-energy innovation, the private green-innovation machine cannot be expected to be effective on its own. It

Table 2: A multipolar clean technology space? (1998-2007)

	Share of technology in total clean-energy technology patents	Share of largest country C1	Share of top 3 countries C3 (2)	Concentration (Herfindahl)	Countries with specialisation technology (1)
Solar PV	57	44 (JP)	69	24	JP, KR, TW
Wind	14	29 (GE)	52	12	DE, UK, NL, CA, DK (!), ES, NO, SE, EU
Hydro	12	20 (US)	44	9	US, UK, IT, CA, CH, ES, AT, SE, NO, AU, EU
Solar thermal	10	27 (GE)	47	10	DE, IT, NL, CA, CH, ES, AT, AU, IL, EU
Biofuels	5	18.5 (US)	52	10	DE, FR, UK, IT, NL, CA, CH, CN, AT, FI, BE, EU
CCS	4	32.5 (US)	61	16	US, FR, UK, NL, CA, NO, EU
Geothermal	2	18 (US)	44	8	DE, IT, NL, CA, CH, CN, AT, SE, NO, FI, IL, HU, EU
All clean-energy technologies	100	30 (JP)	61	14	DE, KR, NL, TW, DK, ES, CN, EU

Source: Bruegel on basis of UNEP/EPO/ICTSD (2010). Notes: (1) only countries with at least 1 percent of world patents in technology; specialisation if RTA >1; (2) although relative positions vary across technologies, the top 3 countries are always Japan, the US and Germany.

7. The values for the RTA index (see notes to Table 1), reflecting the EU's specialisation pattern, are 1.80 (geothermal), 1.70 (solar thermal), 1.39 (biofuels), 1.35 (hydro/marine), 1.23 (wind), 1.05 (CCS), 0.62 (solar PV).

needs government intervention. The patterns in patenting clearly suggest the importance of this. The kick-start in clean-energy patenting in 1997 coincided with the Kyoto Protocol (Figure 1). Johnstone et al (2010) confirm using econometric analysis that policies indeed have a significant impact on the green patenting activity in a country. National policies such as feed-in tariffs, renewable energy credits, carbon taxes and R&D subsidies are found to significantly affect innovators, although the strength of the effects varies across technologies, instruments and countries. For example, Germany has seen a dip in wind patenting despite the existence of feed-in tariffs. Policies therefore are no straightforward panacea for stimulating green innovation.

Aghion, Hemous and Veugelers (2009) discussed how government intervention should be designed in order to effectively turn on the private green-innovation machine. In particular, their analysis strongly supports the case for a portfolio of instruments including, simultaneously, carbon prices, R&D subsidies and regulation. In tandem with a sufficiently high and long-term time-consistent carbon price, R&D support for clean technologies is needed. Public R&D support is especially crucial for clean technologies that are still in the early stages of development, neutralising the installed-base advantage of the older, dirtier technologies. At the same time Aghion et al (2009) argue that governments should have an exit strategy for public R&D support, once private sector efforts in clean-energy technology have been sufficiently leveraged.

So, are governments deploying the right effective policies for stimulating private green innovation? Aghion et al (2009) examined in detail the record of green government policies for innovation, both in terms of carbon pricing and clean-energy R&D subsidies. With low, volatile and fragmented levels of carbon pricing and subsidies, they concluded that there is still some distance to go before ideal policy support is realised.

For the technologies included in the EU's SET-Plan, the European Commission's Joint Research Centre has tried to assess the amounts currently being invested in these technologies in the EU, both by the public sector and the private sector (Table 3).

Of the total public R&D budgets, 25 percent is spent at the EU level, indicating the importance of the EU level for clean-technology public funding. Most of the public budget goes to nuclear. Nuclear also has the highest ratio of public-to-private investment.

For non-nuclear energy, *hydrogen and fuel cells* and *PV* are the main recipients of public R&D funds in the EU. They also have the highest ratio of public-to-private investment. CCS, closely followed by *biofuels, smart grids* and *wind* have the lowest ratio of public-to-private investment. The relative position of the EU in public funding is highest in *CCS* and *hydrogen and fuel cells*. These also happen to be the two clean-energy technologies in which the EU is the least strong in terms of patenting.

As PV is among the most mature technologies in the clean-energy set, its still high share of public funding is surprising. Equally surprising is the high share of private funding in CCS, although it is still an early stage technology.

SETIS-JRC[8] also estimated the total amount of R&D investment needed to finance the roadmaps published by the various European Industrial Ini-

Table 3: R&D funding for clean-energy technologies in the EU

Technology area	Share in total public R&D	Share of EU in total public R&D funding	Share of private in total R&D funding
Hydrogen and fuel cells	0.13	0.29	0.61
Photovoltaics (PV)	0.085	0.17	0.58
Wind	0.05	0.12	0.76
Biofuels	0.04	0.17	0.775
CCS	0.03	0.3	0.81
Smart grids	0.03	0.23	0.777
Solar (CSP)	0.02	0.13	0.58
Nuclear fission	0.37	0.16	0.43
Nuclear fusion*	0.25	0.42	0
TOTAL	100% (=€476m)	0.25	0.53

Source: EC-JRC (2010). Note: * Nuclear fusion, although a technology closely related to SET priority technologies, is not included in the SET-Plan.

8. Strategic Energy Technology Information System (SETIS): http://setis.ec.europa.eu

tiatives established under the SET-Plan (see Box 1). CCS and solar will soak up most of the required money, respectively 28 percent and 22 percent. For CCS, 2007 investment levels only cover 13 percent of the required annual investment; for solar, this is 18 percent (EC-JRC, 2010).

4 BUILDING MOMENTUM

Although EU countries have started to become active patentees in specific clean-energy technologies, the EU cannot be considered as a fore-runner in clean-energy patenting. Clean-energy patenting is a multipolar activity, with Asian countries in particular – Japan, Korea and increasingly China – being active players, particularly in the more mature clean-energy technologies. Low, uncoordinated and too-volatile carbon prices, as well as low, uncoordinated public funding for clean-energy investments in the past – too much of the stop-and-go type – correlate with this below-potential clean-energy innovation capacity in the EU.

But this might be changing. To meet its EU2020 goals, the EU explicitly aims to activate its clean-energy innovative potential. And in its 2050 low-carbon roadmap, the Commission argued that full implementation of the SET-Plan “is indispensable”. Will this policy attention invigorate the private green innovation machine in Europe?

Beyond stating ambitious targets in policy roadmaps, the big question is where the funding will come from to finance these plans. To kick off the first SET-Plan industry initiative, on CCS in 2009, the Commission tapped €1.05 billion in EU crisis funds. Beyond this, concrete funding for the ambitious SET plan still has to materialise. The ETS will generate auction revenues, especially from 2013, which can be reinvested at national level in the development of more efficient and lower-cost clean technologies. The allocation of the revenues is determined by the member states, but at least 50 percent should be used for climate-change related activities, including in developing countries. A stock of 300 million EU allowances, set aside from the ETS new entrants reserve, will be used to support carbon capture and storage and innovative renewables. These allowances will be made available via member states to fund demonstration projects selected on the basis of criteria defined at EU level.

For the five other industrial initiatives which did not receive EU crisis funds, the private sector is expected to bear most of the financial burden, especially given the crippling budget deficits of many European governments. That puts an even greater burden on policy-makers to ensure that the public-private model is attractive for industry. Will the private sector and their financiers be willing to initiate and (co-) fund clean-technology projects in Europe? Because most private clean-energy companies are active globally, this will require Europe to be an attractive location for such investments compared to Asia and the US.

5 TOWARDS A EUROPEAN PRIVATE GREEN INNOVATION MACHINE ON FULL SPEED

If governments want to leverage the necessary private innovation for clean-energy technologies, they will have to provide well-designed, time-consistent policies, reducing commercial and financial risk through a combination of consistent carbon pricing, regulations and public funding. With current heavily constrained public budgets, it is all the more important that this public funding is allocated as cost effectively as possible.

This implies that public funding for clean-energy R&D will have to give a sizable and consistent push to early stage clean-energy technologies, with a clear exit strategy as soon as the private innovation forces have been sufficiently activated.

But beyond efficiently targeting and timing public budgets, governments should first and foremost establish a sufficiently high and durably predictable carbon price. A well-functioning carbon

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market is essential for driving low-carbon investments and achieving global mitigation objectives in a cost-efficient manner, particularly for investments in development, demonstration and deployment of later-stage technologies.

For the EU, this is perhaps the biggest threat to its SET-Plan: the lack of a sufficiently high carbon price. To this end, a greater effort should be devoted to harmonising EU member state carbon taxes. At the same time, the design of the ETS and the distribution of carbon allowances should take into account more explicitly its power to leverage innovation. The longer-term predictability of the system has been improved, leaving a more stable carbon price, but still at low levels. A move to a 30 percent emissions reduction target, which would involve a tighter emissions cap and fewer allowances being auctioned, would result in a higher carbon price and thus provide greater incentives for innovation.

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