EU Climate Change Policy: mobilizing innovation?

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VERY, VERY PRELIMINARY
Still work in progress

The paper first describes the world of Climate Change policies after Copenhagen and during the crisis. It focuses on EU climate change policies, analyzing the implications of its low and high-end pledge of resp 20 and 30% GHG emission reductions. As the cost-effectiveness of these targets, particularly the high-end one, requires the development and deployment of new technologies, and the competitiveness of EU firms in green technologies, the paper next takes a look at the performance of the private green innovation machine and whether or not governments have succeeded in leveraging this machine.

1. The implications of Copenhagen

The main outcome of the Copenhagen Climate Change Conference in December 2009 was an agreement among a representative group of 29 Heads of State and Government on the "Copenhagen Accord". It requested developed countries to put forward their emission reduction targets, and invited developing countries to put forward their actions, by 31 January 2010. It also provided the basis for regular monitoring, reporting and verification of those actions.

By the summer of 2010, 125 parties had officially associated themselves to the Copenhagen Accord and required to be listed in its chapeau. These countries represent more than 80% of global GHG emissions. The EU and its Member States are included in this list of countries. Next to an unconditional pledge of -20% against 1990 levels that is already translated into binding legislation through the Climate and Energy Package (CEP), the EU has a conditional pledge of -30% against 1990 levels by 2020 in the context of a sufficiently ambitious international agreement,

Table 1: REGION PLEDGE (base year)

	LOW	HIGH
EU	-20% (1990)	-30% (1990)
US	-17% (2005)	-17% (2005)

Japan	-25% (1990)	-25% (1990)

China
China has pledged to lower the carbon intensity of its GDP by 40% to 45% with respect to 2005 by 2020. In addition it intends to increase the non-fossil fuel share of primary energy consumption to 15%.

These are voluntary measures but reference is made to the principles and conditions of Art 4.7 of the UNFCCC. It is unclear to what extent China sees this as a condition. Assessing the stringency of the carbon intensity objective is very difficult. Substantial uncertainties remain on the accounting of the indicator. Much will depend on expected GDP growth. High GDP growth typically goes together with faster restructuring and productivity growth, as such making the achievement of the objective easier but also leads to higher absolute emissions. Baseline projections for China vary considerably. Some model projections estimate the pledge as binding, particularly the high-end pledge, others estimate it as baseline or below. (IEA, WEO 2009). Similar uncertainties exist for the measurement of the non-fossil fuel objective, which actually is a nuclear & renewable energy objective.

Overall it is difficult to assess the real ambition level of the Chinese pledge. While disagreement exists on the low end pledge, most models indicate that certainly the high end pledge is significant.

South Korea
South Korea, as a non-Annex I country, has pledged a 30% emissions reduction target by 2020 relative to a “business as usual” baseline, implying a 4% cut from the 2005 level. The pledge does not seem to have explicit conditions attached. It is not legally binding.
The target is going to be achieved mainly through energy efficiency programmes (voluntary agreements to encourage energy efficiency in the business sectors and energy efficiency programs for electronics & appliances), increased use of renewable energy, with a target of increasing the share of renewables to 30% by 2050. Nuclear energy’s share of electricity generation is targeted to increase to 41% in 2030. A Five-Year-Plan for Green Growth (2009-2013) has been launched, committing spending 2% of GDP financed almost exclusively by the central government budget.

2. EU CC policy post-Copenhagen and during the economic crisis

Since the Climate and Energy Package (CEP) was adopted in early 2008 (including -20% GHG and 20% Renewables target by 2020) there have been important changes. The economic crisis has reduced short-term growth rates. At the same time the average level of energy prices is significantly higher. Both elements have led and will lead to lower greenhouse gas emissions than projected by the 2007 baseline.

But already in 2007, before the crisis started, emissions had reduced to -8% compared to 1990 and in 2008, a year which still recorded positive but smaller GDP growth for the EU, emissions had decreased to -10% compared to 1990 (Delbeke (2010)). But the full force of the economic crisis in 2009 had a significant impact on emissions in the short term, with estimates putting the emission reduction in 2009 at around -14% compared to 1990 levels.

Not only the economic crisis and higher energy prices but also measures to reduce emissions such as the CO_2 and Cars Regulation and the further implementation of energy efficiency regulations, have reduced emissions in the non-ETS sectors. For example, ten Member States are projected to meet their non-ETS target already in baseline.

Also ETS carbon price projections had to be adjusted. Carbon prices fell early 2009 from Euro 25 to Euro 8 and then slightly recovered. Furthermore, there were unexpectedly significant levels of banking, giving little incentives to reduce emissions further after 2012, and still a large amount of unused international credits and banked allowances in the system up to 2020.

Emissions are expected to rebound when GDP growth rates recover to pre-crisis values, but overall GDP levels by 2020 are projected to remain lower than expected before the crisis. This together with the continued impact of higher than expected energy prices, the decrease in investments in the years around the economic downturn due to a higher risk premium, the implementation of newly adopted energy efficiency measures and the price signal in the ETS to be compliant with the ETS target result in emission projections in baseline to -14% in 2020 compared to 1990. This is significantly lower than for the 2007 baseline, which projected GHG emissions in 2020 only to be 1.5% below 1990 levels (EU COM (2010)).

An approximation of the costs of full implementation of the Climate and Energy Package puts the estimated costs in the context of the new 2009 baseline framework at €48 billion in 2020, or 0.3% of GDP. This is a reduction of costs per GDP between 30% and 50%. (EU COM (2010)). 2010 projections for 2020 estimate GHG emissions to be -19% below 2005 (compared to -13% with 2008 projections). In the 2010 projections for 2020, the ETS price estimate has been reduced to Euro 16.5/allowance (2008 prices), down from Euro 30/allowance (2005 prices) in the 2008 projections for 2020 (J.Delbeke (2010))

In the reference scenario with policies in line with the commitments under the Climate and Energy Package, the EU is now estimated to reach the -20% GHG reduction targets of the Climate and Energy Package internally without a need for significant amount of international credits both in the ETS and non-ETS.

3. Green stimulus packages

The crisis has spurred governments to kick-start efforts towards a greener economy through their economic recovery packages. The stimulus measures put in place include among others public investments in green infrastructure, including public transport, low-carbon energy production, smart electricity grids, clean energy related R&D… These measures aim to combine short term economic signals, job creation, and long term sustainable growth.

In addition to national programmes, the EU is spending, as part of the European Economic Recovery Plan €4 billion on energy infrastructure projects, off-shore wind electricity generation and demonstration of carbon capture and storage. In addition, €1.5 billion were freed up in the Community budget for three technology development initiatives, two of them focusing on clean technologies for cars and construction. Moreover, 300 million allowances have been earmarked in the EU ETS for supporting demonstration activities in innovative renewable technologies and carbon capture and storage.

In addition to national and EC funding, the European Investment Bank (EIB), in a response to the financial crisis and as set out in the European Economic Recovery Plan, has increased its lending target in the energy field to €9.5bn in 2009 and €10.25bn in 2010.

There is no overall official estimate for the green share or volume of all recovery programmes available. And in some countries, the crisis has forced government to cut back on green subsidies (eg Germany and Spain). Nevertheless, a study by UNEP/NEF estimates the combined stimulus programmes related to sustainable energy from five major EU countries and at EU level at $26 billion in total (UNEP (2009)).

Stimulus packages outside the EU

Many stimulus packages around the world contain important green elements. According to UNEP/NEF (2009), seven of the major non-EU economies included significantly higher stimulus measures for sustainable energy. These energy-related green stimuli account for around 6% of the total recovery packages announced – but the countries vary significantly in the clarity of their measures.

In the **US**, the clean energy investment part of the American Recovery and Re-investment Act includes funds for smart grids, energy efficiency in buildings, R&D on energy storge and investments in Carbon Capture and Storage. For more on the US, see Cline (2010)).

South Korea dedicates the highest share of its stimulus package to green growth measures, sometimes estimated as going beyond 80%. According to UNEP South Korea's package devotes with 20% the highest share of all major economies to sustainable energy. Late 2009, it presented its five year green growth investment programme to spend an additional $60 billion over five years to cut carbon dependency. The Government forecasts the creation of up to 1.8 million jobs by 2020. The high level of spending is due the inclusion of large construction projects, a.o. a high-speed train system and dams construction in the “Four Major Rivers Restoration Project” . Although the Korean government is contemplating a cap-and-trade system, it is currently still weak on establishing a carbon price through taxes or other means.

China's stimulus package includes the largest green investment programme in absolute terms. A considerable part of the $586 billion package relates to green investments, mainly in rail transport, grid improvements, energy efficiency, and waste and waste water treatment. The clean energy part is estimated by UNEP (2009) to be approximately $67 billion.

4. EU CC policy beyond 20%

As part of the Climate and Energy Package, the EU has committed itself to move to a 30% target by 2020 if the conditions are right. The Commission is currently preparing an analysis of what practical policies would be required to implement such a 30% reduction.

The main motivation for investigating the 30% target does not come so much from a more ambitious international environment to reduce GHG. Stepping up to a 30% target would now be less costly to realize than before, thanks to the crisis. Preliminary EC estimates suggest that the extra cost would be 0.22% of GDP in 2020, lower than estimated before (EC-COM (2010)).

A cost-effective split of the -30% target between ETS and non-ETS, would imply for the former to move from -21% to -34% below 2005 emissions, while for the latter from -10% to -16%.

Options in the non-ETS to accelerate include first and foremost technological options (eg product standards and energy efficiency measures), but also energy taxes and the leverage of Cohesion and CAP funds. Options in the ETS include tightening of targets by auctioning fewer allowances. This would have the added benefit of leading to higher carbon prices which is expected to stimulate more strongly innovation.

In any case, in order to keep the costs of reaching targets affordable, the 20% target and a fortiori the 30% target, scenarios rely heavily on new technologies coming to market and being smoothly deployed. Preferably, this faster innovation and deployment should also create a competitive edge for European companies in key sectors of the future, thus securing growth and jobs in the EU.

But will the EU be able to activate its innovation potential for green growth? First, we take stock of the current innovation activities. Next, we will detail the outlook for the future.

5. Assessing the current performance of the private green innovation machine

We need the innovation machine to work for climate change on 3 levels:

- Diffusion of commercially viable green technologies;
- Demonstration, development and scaling up near-commercial technologies in the pipeline;
- Basic and Applied Research for new breakthrough green innovations.

We use mostly information on applications for **green patents** to assess the capacity of the innovation machine to generate new green technologies. [1] [2]

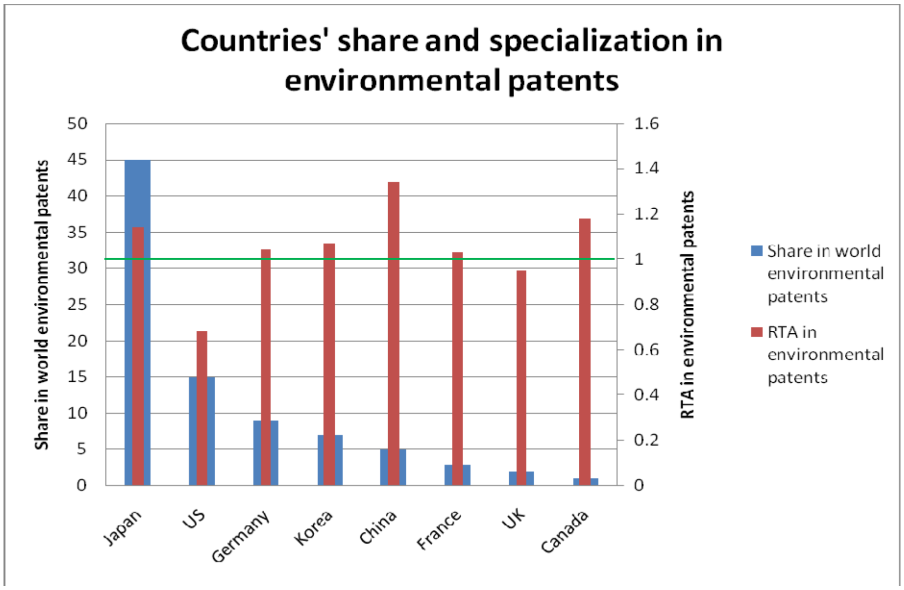
Data from the World Intellectual Property Organisation (WIPO, 2008) reveals that **only 1.5%** of all PCT patent applications are to be found in "environmental technologies" (world average 2001-2005). This is a staggering low number. The **growth rate** in patent applications provides a more hopeful picture. The Average Annual Growth Rate (AAGR) for patents in environmental technologies in the period 2004-2008 was 11.6% . Although substantial, this is nevertheless still less than other technologies such as Computer Technology (14%) and other emerging technologies such as Nano-technologies (20%).

If we look at which countries are active in patenting Environmental Technologies, **Japan** is the clearest positive outlier (Graph 1). Not only does Japan hold 45% of all environmental patents, it is also specialized in environmental patents. Also Korea and China are specializing in environmental patents.

Graph 1

[1] With regard to technologies, a multitude of labels exist ranging from 'environmentally friendly', 'green', 'clean', 'eco-friendly'. We will try to stick as closely as possible to the definitions used by the various sources reported; else we will use the label of "green".

[2] A few caveats before we discuss the numbers: (i) Not all inventions may be patented. Particularly those inventions still far from the market may not yet show up in patent statistics. (ii) There is as yet, no international standard to classify patents as "green", with EPO, WIPO, OECD each using their own classification.



Source: Aghion, Veugelers & Hemous (2009), *A cold start for the green innovation machine*, Bruegel Policy Contribution

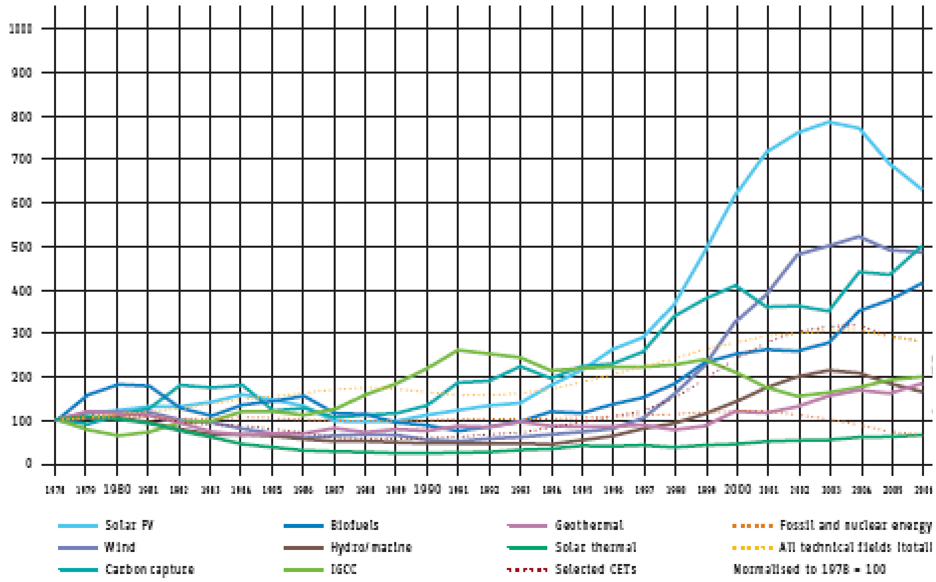
Note: On the basis of WIPO 2008, PCT applications in environmental technologies (2001-2005 average); RTA= share of the country in world environmental patents relative to the share of the country in total world patents; RTA > 1 measures specialization in environmental patents;

The US, despite its 15% share of world "green patents", is least specialized in Environmental Technologies. In Europe, Germany is by far the largest country for environmental patents, being somewhat specialized in environmental technology. [3].

A closer look at the trends in the various subfields of green technology is provided by UNEP/EPO/ICTSD (2010). UNEP/EPO/ICTSD examine 6 main categories of renewable energy technologies which are either already commercially available or have strong prospects of commercialization in the near-to-medium term. These are solar (both thermal and PV), wind, carbon capture and storage, hydro, geothermal, biofuels and integrated gasification combined cycle (IGCC). These technologies are loosely labeled as CET (Clean Energy Technologies).

Graph 2: Growth rates of patents for selected CET

[3] Also some other countries are specialized in environmental technologies (RTA>1), but are nevertheless small players (<1% of environ patent share): Spain 1.14; Brazil 1.28; Norway 1.95; Poland 2.42; India is absent both in size and specialization (RTA=0.67))



<u>Source</u>: UNEP/EPO/ICTSD, 2010, Patents and clean energy: bridging the gap between evidence and policy;
<u>Note</u>: 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)

Until the mid-1990s, CET patents have stagnated and even declined, certainly in relative terms as overall patenting activities continued to grow. But since the late nineties, also CET patents have trended upwards. Particularly when compared to the traditional energy fields (fossil fuels and nuclear) which have trended down since 2000. When looking at individual CET 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 & geo thermal are not yet kicking off, probably reflecting their still premature stage of development.

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

Table 1 zooms in on who's who in the various clean energy technologies. By far the most important CET in terms of patents is *Solar PV*, which represented over the period 88-07 57% of all CET patents (in turn representing 0.68% of all patents). Solar PV is a technology that is concentrated in a few countries. Especially Japan is a dominant and specialized player in Solar PV patents. *Wind* is the second largest CET technology in terms of patents. But in this sector concentration is much lower. Germany holds the largest position and is specialized in wind, but there are many other European countries specializing in wind technology. The strong patenting activities in solar PV and wind suggest that these technologies are extensively used in the market. *Geo & solar thermal*, *hydro* and *biofuels* all have lower dominant positions of the big 3, with many countries specializing. The only other concentrated sector is *CCS*. In this sector the US is a strong and specialized player, although also several European players are specializing in CCS as well, including FR and UK. The share of CCS patents in total CET patents is low, reflecting the still early stage of technology development for CCS. Overall Table 1 shows that with the exception of Solar PV and CCS, most CETs have a quite dispersed, multipolar, pattern of countries positions in patenting.

Table 1: A multipolar clean technology space?

1988-2007	**Share of technology in total CET patents**	**Share of largest country C1**	**Share of top 3 countries C3 (2)**	**Her find ahl**	**Countries with RTA in technology (1)**
Solar PV	57	44 (JP)	69	24	JP, KR, TW
Solar Thermal	10	27 (GE)	47	10	DE, IT, NL, CA, CH, ES, AT, AU, IL
Wind	14	29 (GE)	52	12	DE, UK, NL, CA, DK (!), ES, NO, SE
GeoThermal	2	18 (US)	44	8	DE, IT, NL, CA, CH, CN, AT, SE, NO, FI, IL, HU
Hydro	12	20 (US)	44	9	US,UK, IT, CA, CH, ES, AT, SE, NO, AU
Biofuels	5	18.5 (US)	52	10	US, DE, FR, UK, IT, NL, CA, CH, CN, AT, FI, BE
CCS	4	32.5 (US)	61	16	US, FR, UK, NL, CA, NO
All CET	**100**	**30 (JP)**	**61**	**14**	**DE, KR, NL, TW, DK, ES, CN(3)**

Source: Own calculations on basis of UNEP/EPO/ICTSD, 2010;
Notes: (1) Only countries with at least 1% of world patents in technology; (2) although relative positions vary across technologies, the top 3 countries are always JP, US, GE; (3) If taken as one aggregate, the EU would hold a RTA in all CETs excl Solar PV

Next to patent statistics, the performance of the private innovation machine can also be assessed through statistics on **R&D expenditures**. R&D data 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. The OECD, which is the reference source for R&D expenditures, only reports R&D statistics by sector of performance, not by technology.

A pivotal business sector for greenhouse gas emissions is **Electricity Generation and Distribution** (**EGD**) [4],[5]. The EGD sector is remarkably inactive in **R&D**. It represents

[4] This includes all types, also thermal and nuclear.
[5] A caveat: not all R&D and innovation activities by firms in this sector will have to be related to climate change.

less than 1% of total World R&D Expenditures by the Business Sector[6]. And even more alarming are the negative growth rates. Rather than on the rise, the low R&D activities have even gone down over time[7].

The R&D scoreboard [8] latest data for 2008 confirm the weak R&D picture for the Electricity sector. For the EU, the "Electricity sector" has 21 companies in the list of Top EU1000 R&D spenders. These companies have an average R&D-to-sales ratio of only 0.6% in 2007. Of these 21 companies, only 2 (French) companies make it in the 100 largest R&D spenders in the EU (Areva, EdF). In the non-EU Top1000R&D scoreboard, there are 11 companies (of which none are from the US), with an average R&D-to-sales ratio of 0.9% in 2007 (0.9 in 2007). None of these companies show up in the 100 largest R&D spenders non-EU;

A more detailed assessment of R&D for green innovations, using websites and field survey interviews, was performed for an EU funded project (SRS (2008))[9]. This assessment confirms that innovation in the energy sector may not predominantly be carried out by classical energy companies. Industries with elevated research activities in low-carbon energy technologies include companies active in industrial machinery, chemicals, energy components as well as some dedicated technology firms (eg in wind, photovoltaics).

Even so, the R&D intensities in those sectors remain low compared to other emerging sectors. For the wind, PV and biofuel sectors, the R&D intensities are in the order of 2.2-4.5%. Even though they are well above the R&D intensities of traditional energy companies, they fall largely behind the R&D intensities of other sectors that experienced a boom in recent years, such as the IT-related sectors.

6. Explaining a failing private green innovation machine: the need for government intervention

There are several arguments explaining why green private innovation activities may be hampered.

[6] OECD, ANBERD (2007) data show that the EG&D sector's share in World Business R&D went from 0.9% in the period 90-95 to 0.5% in the period 2000-2004. To compare: in the EU (2004), the EG&D sector accounts for 0.85% of total Business R&D versus 2.2% of Value Added.
[7] While the AAGR of total Business Enterprises increased by 3.5% in the period 2000-2004, the AAGR of the EG&D sector was -3.5% (Source: OECD, ANBERD (2007)
[8] While the OECD uses questionnaire information from an inventory of all R&D active firms, the IPTS-R&D Scoreboard data use company account information from the 1000 largest EU and non-EU R&D spenders. (Source: IPTS)
[9] SRS project (2008): Analysis of Energy RTD expenditures in the European Union. Results of the Work Package 4 of the SRS NET & EEE project under FP6 ("Scientific Reference System on new energy technologies, energy end-use efficiency and energy RTD").

- The strongest benefits from green technologies are social rather than private (**environmental externality**); As a consequence, the private willingness to pay for green innovations will be too low from a social perspective, unless there is a clear and correct price on the externality.

- A classic reason for a lack of innovation is the **appropriability problem**. Firms will be reluctant to innovate when they cannot fully appropriate the returns from these innovations. This argument may hold particularly for green innovations as they are typically complex, cumulative process innovations, where classic patent protection may not be as effective, if not complemented with other appropriation mechanisms

- Another classical barrier for innovation is access to **finance**. Financial constraints will be even more binding for green innovations, as, particularly the more breakthrough type of green innovations, carry a high technical risk/uncertainty. But also important for green innovations are the higher commercial risks/uncertainty, due to the uncertain market conditions, related eg to the uncertainty in the price for carbon.

- For green technologies that have passed the prototyping stage, there are still significant learning effects during the initial stage of market introduction. Customers may want to wait to adopt the new technologies till at a later stage, when their costs have gone down. In the absence of early lead users, learning effects cannot materialize, prohibiting these technologies to come to their most cost efficient configurations.

- On the market, new green technologies face competition from the existing more dirty technologies, who enjoy an initial installed based advantage. Taking into account that research resources will be directed towards their most profitable applications, the innovation machine left on its own will favor to work on the dirty technology, impeding the take-off of the clean technology (Acemoglu, Aghion, Bursztyn and Hemous (2009)).

In addition to the above mentioned arguments for low private green innovations, the incentives for innovation in the sector of "Electricity Generation & Distribution" are particularly low, due to a.o.:

- regulation, which induces risk aversion, reducing the incentives to invest;
- low levels of competition in the sector nationally and fragmentation internationally
- difficult access to the grid for new technologies;
- technological issues to be resolved, like energy storage (batteries);

The private green innovation machine cannot be expected to be effective on its own. It needs government intervention. In a Bruegel Policy Brief, Aghion, Hemous and Veugelers (2009) discuss how this government intervention should be designed in order to effectively turn on the private green innovation machine, and more generally to fight climate change, at the lowest possible cost for growth. In particular the analysis strongly supports the case of a *portfolio of instruments including simultaneously carbon prices and R&D subsidies.* A price for carbon to provide an incentive for carbon-saving investments is obtained most clearly through a carbon tax, provided the tax rate is set sufficiently high and is predictable in the long term. A cap-and-trade system can achieve the same result as a tax but requires a considerable amount of information and expertise to get the emission-allocation process right, creating more room for error and exposure to political pressure. In tandem with a sufficiently high and stable carbon price, R&D support for clean technologies is needed.

Of course, one could always argue that to some extent a carbon price on its own could do the trick (discouraging the use of dirty technologies also discourages innovation in dirty technologies). However, relying on the carbon price alone leads to excessive consumption reduction in the short run, and would therefore be a more 'costly' policy scenario.

Also removing non-market barriers, easing the substitution from dirty to green technologies (regulatory restrictions, standards, access to the grid…) is an important government policy lever. The effectiveness of environmental subsidies and taxes are raised when clean technologies more easily substitute for the dirty ones.

Intervention does not need to be permanent: Government intervention is crucial at earlier stages, but market forces can perform a large part of the job of reallocating production and innovation activities towards clean sectors, provided they are given the right incentives. Government should have an exit strategy for its interventions, particularly for subsidies to specific technologies, as soon as the private innovation machine for these technologies is self-supporting.

(i) In the short term when we are still anticipating better technological alternatives to be available in the future, support schemes for currently available technologies should be designed time-consistently to avoid creating too big gaps to bridge for new, more radically clean technologies still in the pipeline;

(ii) As more advanced backstop technologies are unlikely to be available before 2020, the temporary use and support of transition technologies, need to be factored in. Particularly interesting candidates for transition technologies are those for which the transition or substitution from dirty technologies can be made at lower costs (like Carbon Capture and Storage). In any case, support for transition technologies should be temporarily, switching to other radically cleaner technologies as soon as viable

(iii) substantive early stage deployment support to help bring new clean technologies to the market and neutralize the installed base advantage of the older, dirtier technologies. As it will take time for more radically clean technologies to be developed and to be available and adopted on the market, this further justifies an early start to government support for these technologies and warns against using too strict time targets for reaching CO2 reductions, as this favors existing somewhat cleaner technologies relative to new more radically cleaner technologies.

7. Assessing public interventions for green innovation

Analysing patent applications for renewable energies, Johnstone et al. (2008) confirm with econometric analysis that both R&D policies and market introduction policies, when implemented, have a significant impact on the green patenting activity in a country. So, are governments deploying the right effective policies for stimulating the private green innovation machine? And which ones? In a Bruegel Policy Contribution, Aghion, Veugelers & Serre (2009), examined in detail the record of green government policies for innovation and concluded that we still are a long way off from an ideal policy support.

On **carbon prices**, the evidence showed not only the low level of carbon taxes in most countries, but there is also a high dispersion in carbon taxes across countries, leaving a world wide carbon price a far distant reality. At EU level, the first phases of the European Union's Emission Trading Scheme (ETS) established a carbon market, but at low and volatile levels. Beyond the discussion on whether current taxes and cap-and-trade systems in place generate a sufficiently high carbon price to induce green innovations, there is an issue of the carbon price being far from long-term predictable. It is particularly this latter feature that is important as it serves as an incentive for green innovations.

On **subsidies to green R&D**, again the evidence showed the poor performance of the major policy actors. Public R&D spending targeted to environment and energy efficiency is a very minor share of total public R&D spending.[10].

Japan is clearly the frontrunner with respect to public funding for energy R&D, spending 0.11% of GDP on this in 2006. Compared with Japan, the aggregated EU figure (0.02% of GDP in 2007) is low and almost unchanged from 2006. Also when comparing the energy-related part of public R&D expenditures in relation to the overall public R&D expenditures, the share of energy R&D in total public R&D budgets was 2.9% in 2007 for the EU, compared to a share of 15.2% in Japan and of 1.1% in the USA. Japan is thus clearly the forerunner in terms of public budgets spent on energy R&D, correlating with its forerunner position in CET patents.

[10] Unfortunately, there is little data available on public spending that is comparable across countries. As source for R&D subsidies the *GBAORD Government Budget Appropriations or Outlays on R&D data* are used (Eurostat). Although the data have serious limitations and are only reported with an important time lag, they are available across a wide set of (OECD) countries. Note, however, that a comparison between individual EU Member States and Japan or the USA is distorted due to the fact that the budgets from the EU Research Framework Programme are not included, which can play an important role e.g. for nuclear fusion

The data on green subsidies are reported with serious time lags (with 2007 as latest year) and therefore do not include the more recent efforts that governments may have made. The next section takes a closer look at the current efforts at EU level to stimulate clean energy technologies.

8. Mobilizing innovation for Climate Change in Europe in future: the Strategic Energy Technology Plan (SET)

Under the chapeau of the Europe 2020 Strategy ("promoting a more resource efficient, greener and more competitive economy"), the Commission will develop its strategy for transition to a low carbon economy by 2050. Within the context of Europe 2020, the EU has beefed up the technology pillar of its Energy and Climate Policy. In october 2009, it launched its **Strategic Energy Technology Plan** (SET-Plan). The SET Plan is the all-encompassing technology roadmap for creating a low-carbon and renewable energy-based European economy. SET is the sun around which all existing and future European energy research programs will orbit. The goal is to coordinate fragmented policies and programmes and organise energy research efforts across Europe in a coherent and efficient manner behind a clear set of technology targets in partnership with the private sector.

The priority for the SET Plan is to accelerate the development of low-carbon energy sources 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 that bring together companies, the research community, member states and the Commission in risk-sharing, public-private partnerships. In addition there is also a Smart Cities Initiatives and the EERA (European Energy Research Alliance), aimed to coordinate and accelerate research and development of new generations of low carbon technologies.

The SET Plan envisions raising the total public and private investment in low-carbon energy technologies from the current €3bn per year to around €8bn per year. This would represent an additional investment, public and private, of €50 billion over the next 10 years.

These are all great-sounding plans – but who will pay for this? SETIS, which is the SET-Plan Information System, managed by the EC JRC, has tried to (i) assess the amounts currently being invested in SET technologies, both by the public and the private sector and (ii) assess the total funds needed to achieve the objectives set out in the roadmaps of each EII.

Table 2

2007 Technology Area	Share of Area in total Public R&D	Share of EU in total Public R&D funding	Share of Private in total R&D funding
Hydrogen&Fuel Cells	13%	29%	61%
Wind	5%	12%	76%
Photovoltaics (PV)	8.5%	17%	58%
CCS	3%	30%	81%
Biofuels	4%	17%	77.5%
Smart Grids	3%	23%	77.7%
Solar (CSP)	2%	13%	58%
Nuclear Fission	37%	16%	43%
Nuclear Fusion*	25%	42%	0%
TOTAL	100% (=476 mill Euro)	25%	53%

Source: EC-JRC (2009)

Note: * Nuclear Fusion, although a technology closely related to SET priority technologies, has no EII and is therefore not included in the SET-plan.

According to these estimates, almost 70% of the total national (nuclear and non-nuclear) R&D budgets directed towards SET-Plan priority technologies originate from three Member States: France, Germany, the UK. 25% of the total public R&D budgets is spent by the EU. Most of the public budget goes to nuclear. Nuclear also has the highest ratio of public to private investment. For non-nuclear energy, Hydrogen & Fuel cells and PV are the largest recipients of public R&D funds, they also have the highest ratio of public to private investment. CCS, closely followed by Biofuels, Smart Grids and Wind have the highest ratio of private to public investment.

Based on these numbers, JRC estimated the total amounts of R&D investments needed to match the roadmaps designed by the EIIs. Especially Solar and CCS are the SET priority that will be soaking most of the money.

Table 3

2007 Technology Area	Current R&D investments relative to Needed
Hydrogen&Fuel Cells	74%
Wind	38%

Solar (PV+CSP)	18%
CarbonCaptureStorage (CCS)	13%
Biofuels	23%
Smart Grids	81%
Nuclear Fission	39%

Source: EC-JRC (2009)

Note: * Nuclear Fusion, although a technology closely related to SET priority technologies, has no EII and is therefore not included in the SET-plan.

Where will the money come from? To launch the first industry initiative in CCS in 2009, the Commission tapped €1.05 billion in EU Crisis funds. To bolster resources dedicated to SET between 2010 and 2013, the EC is lobbying individual Member States to take the financial lead on the other five industrial initiatives which did not receive EU Crisis funds, to get projects rolling. But the major battle will be over the 2014-2020 budgets.

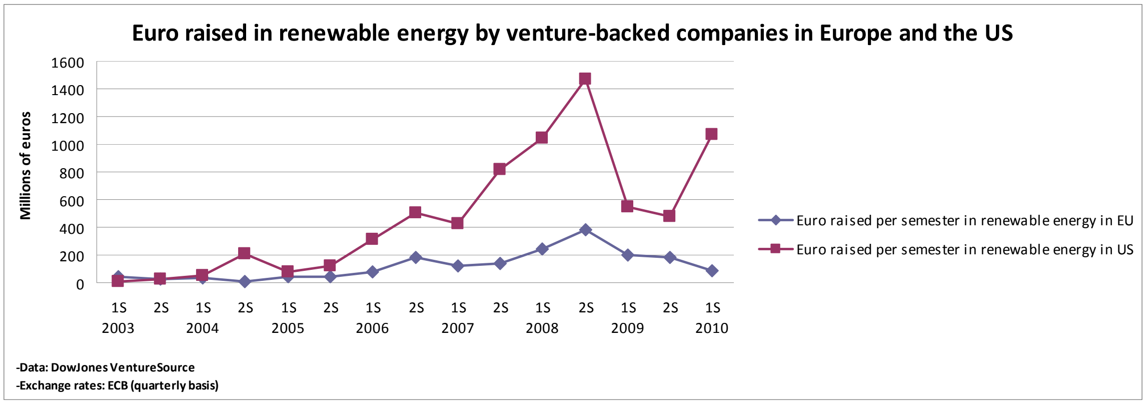
The new European Emissions Trading System enables, from 2013 onwards, the creation of a virtuous cycle of auctioning revenues being reinvested at national level in the development of more efficient and lower cost clean technologies. The use of the revenues is determined by the Member States, but at least 50% should be used for climate change related activities, including in developing countries.

300 million EU Allowances set aside from the New Entrants Reserve of the Emissions Trading Scheme (ETS) 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 Community level.

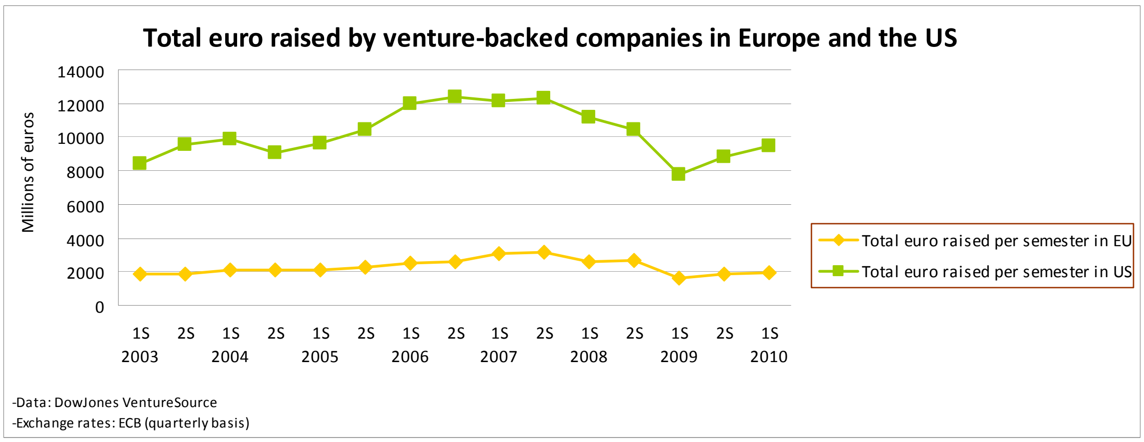
But beyond finding public funding, it is clear that private funding needs to be leveraged. The SET-plan will succeed or not depending on whether this will happen. Will the private sector and their financiers be willing to co-fund SET projects?

That this may not be so evident, is seen from the following graph, which plots the trend in VC funding for renewables in the Europe and the US. These amounts which were trending up in 2007-2008, have been hard hit by the crisis. But while they seem to have recently recovered in the US, they continue to trend downward in Europe. This is all the more remarkable as the downward trend seems to have stopped for VC in general in Europe. Is this a reflection of the European private (venture capital) market not convinced that governments will support the development of green markets and share the financial costs of green investments? For the US , the strong upward trend in 2010 in renewable VC (stronger than the overall upward trend in VC funding in the US) would suggest that the US private (venture capital) market has more confidence in green markets and technologies being supported by governments.

Graph 3A



Graph 3B



CONCLUSIONS

If governments want to leverage the needed private innovation machine, they will have to provide a well designed time consistent policy, reducing commercial and financial risk by 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 effective as possible. This requires that they will be able to leverage private funding. Beyond efficiently targeting and timing of public budgets to projects, avoiding the risks inherent in industrial policy, this calls perhaps first and foremost for government attention to establish a sufficiently high and predictable carbon price. A well-functioning carbon market is essential for driving low-carbon investments and achieving global mitigation objectives in a cost-efficient manner. For the EU, this is perhaps the biggest threat for its SET plan: the lack of sufficiently high carbon price. To this end, a larger effort should be devoted to integrate carbon taxes among EU MS. At the same time, the ETS system and the emission of allowances should be designed to leverage innovation. A move to a 30% target which would involve fewer allowances being auctioned would reinforce innovation incentives, but only if designed time- and innovation-consistently.

The patent data have shown that the world of green technologies is a multipolar one, with many geographically dispersed sources of new clean energy technologies. What would benefit the development of green technologies most, is an international carbon price. Coordination of green policies internationally among the major players, such as linking compatible domestic cap-and-trade systems should therefore be high on the policy agenda.