

February 19th 2015

# Transition Through Innovation

## ***How innovation can contribute to building a low carbon economy at an affordable cost***



**A report prepared for**



## REGIONS OF CLIMATE ACTION

by



Report & summary available at:  
<http://report.ttalliance.org>



## Disclaimer

*This report is the result of the work performed by l'Observatoire du Long Terme and CVA for R20-Regions of Climate Action. It is based on many reliable sources such as main existing reports on climate change and carbon emissions<sup>1</sup>, discussions with climate/innovation experts, companies, policy makers, etc., as well as a panel of case studies provided by industrial contributors and presented in section A of the Appendix.*

*This report is a compilation of these contributions with further analyses made by our team so as to provide a neutral and fact-based picture of the potential of “Affordable Green Innovations” (AGIs). This central concept, defined later in more detail, describes innovations which reduce greenhouse gases at the lowest possible cost.*

*Although this report is based on material communicated to us by our contributors and many experts, the opinions, estimates, and recommendations contained herein are not necessarily those of any individual contributor.*

*Last, because this report aims at giving a global view on a very large scope, and because our goal was to open a debate on the role of innovation in mitigating climate change, the recommendations were positioned and maintained at a strategic level. Many detailed analyses on how to accelerate specific innovations in a given context, or on how recommendations would apply in a specific country, were reserved for further discussions or publications.*

*Readers are encouraged to participate in this discussion with their own contributions on twitter using the #ttalliance hashtag, or by e-mail using the contact [contact@ttalliance.org](mailto:contact@ttalliance.org) address.*

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<sup>1</sup> See list in Appendix

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## Introduction

### a. Context of the initiative

Since the 2008 financial crisis, many have shown skepticism regarding the possibility of tackling climate change at an affordable cost. The major points that lead to such skepticism are the following:

- Low carbon solutions are often considered costly for many strategic sectors, such as electricity, heat production or transport. In a context of increased competition between nations, the decision to lead an active strategy to reduce carbon emissions can thus appear to be a risky bet ;
- Leading low carbon strategies imply public investments or R&D financing whereas for many countries, the ability to generate new investments has been reduced by the financial crisis ;
- Energy transition has translated into increased energy costs in many countries. Even though these costs were often caused by inadequate energy policies, they have been often wrongly interpreted as proof that de-carbonization is not possible without significant purchasing power losses.

In this context, the goal of the Transition Through Innovation (“TTI”) initiative is to analyze how innovation can contribute to reducing the carbon intensity of global economies, while having a positive or neutral impact on cost competitiveness and purchasing power. This work is partly based on a “micro economic” view, using a large panel of existing innovations that help reduce greenhouse gas (GHG) emissions at a very low cost provided by companies of every size, location and industry<sup>2</sup>. This work is also built on a more “systemic” analysis of how innovation works in practice based on company interviews, a large number of contributions, analyses of existing reports, and discussions with climate or innovation experts. Our analysis uses a general-interest point of view, focused on improving the benefits of all world citizens and taxpayers.

This work revolves around the concept of “affordable green innovations” (AGIs), which can be defined<sup>3</sup> as products or services with a significant potential for reducing GHG emissions and whose total cost per ton of CO<sub>2</sub> equivalent<sup>4</sup> avoided is affordable. This is a crucial concept because the more AGIs are invented and developed, the lower the cost of the climate transition.

Moreover, very few reports so far have analyzed the full potential contribution of such products or services in the fight against climate change. Some reports extrapolate the contribution of existing technologies. However, they never account for technologies that will be invented if the cost of carbon increases significantly or if green innovation policies are implemented. Although it is very difficult to forecast how many new technologies will be created, it is not realistic to assume implicitly that none will be invented. Moreover, designing policies based on this assumption might become self-fulfilling prophecies by hampering innovation.

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<sup>2</sup> See appendix.

<sup>3</sup> See next page for a more detailed definition.

<sup>4</sup> This concept is defined in part I c).

### What are “affordable green innovations”, and why do they matter?

*In order to reduce greenhouse gas (GHG) emissions at the lowest possible cost, the world needs solution which (i) contribute to **reducing GHG emissions** (or to capturing existing emissions), (ii) have the lowest possible cost per ton of CO2 avoided (or per ton of CO2 equivalent for other GHGs) and (iii) have the largest possible scope for further implementation. This is precisely how we defined Affordable Green Innovations, which are products or services that are:*

- **Green**, meaning that they contribute to reducing GHG emissions. Of course, the concept of green products can be much larger than GHG emissions, and these innovations can have other benefits, but in the context of this report we only focus on the GHG impact.
- **Innovative**, meaning that their potential for further distribution is large enough that they can still have a significant contribution to GHG emissions reduction objectives. This is a fairly large definition of an innovation - for example, it covers well known or old products if their current served market is significantly lower than the total addressable market.
- **Affordable**, meaning that these products have a low cost, or no cost at all. The cost considered is the additional cost of using the innovation, estimated in terms of cost per ton of CO2 equivalent avoided, compared to the “usual” solution they are replacing. For the innovation to be affordable, this cost must be lower than the estimates for the existing “reference CO2 price”, which define the average cost of tackling climate change (this reference value will be discussed further, but while there is still no global consensus on such a value, an order of magnitude of 50\$/ton can be used). In other terms, to be affordable, the innovation must contribute to lowering the estimated cost of tackling climate change.

*A theoretical way to reach GHG objectives at the lowest possible cost would be to identify all the possible green innovations (existing or not), then to classify them by increasing cost per ton of CO2 equivalent and finally to develop each innovation to the largest possible extent, by increasing cost order, until the global or country GHG emissions reduction goals are met.*

*This method would ensure that GHG emissions goals are met at the lowest possible cost, but this is of course purely theoretical. Indeed, we cannot realistically identify all the possible innovations, since some of them are unknown. Moreover, classifying all the existing innovations and updating this list would be extremely time-consuming.*

*A more practical approach is to accelerate the creation and/or the growth of innovations whose cost per ton of CO2 equivalent is lower than the “reference cost of CO2” estimated by climate experts. This is the approach favored by this report.*

## b. Our objective: providing examples of AGIs and policy recommendations

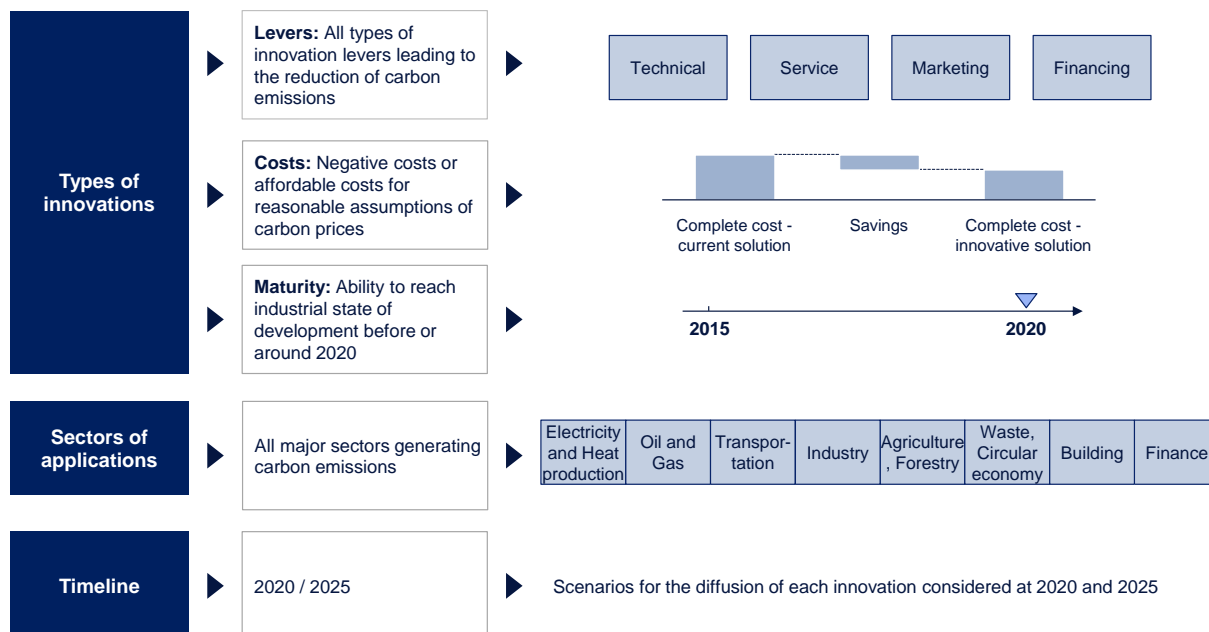
The objectives of the “TTI” initiative can be summarized as follows:

- **Developing a panel of AGIs covering all sectors, regions and types of companies.** This will help understand precisely how AGIs work, how to measure their possible carbon abatement potential and how to identify the main bottlenecks for further development. This panel also helps demonstrate that AGIs can be developed in all industries, regions and types of companies ;
- **Showing how AGIs can help solve the apparent contradiction between increasing world carbon performance and protecting the competitiveness and purchasing power of countries committed to tackling climate change.** Indeed, the large majority of innovations studied in this report successfully allow end-customers to simultaneously reduce costs and carbon emissions ;
- **Providing a systematic set of policy recommendations, covering all possible roadblocks that could limit the development of AGIs.** These recommendations aim at accelerating the creation, development and distribution of AGIs at a local, national and international level. These recommendations are based on a general interest point of view – i.e. they are meant to improve the situation of world citizens and taxpayers, and are economically meaningful ways to solve a general interest issue (reducing GHG emissions) at the lowest possible economic cost. These recommendations were developed after discussing with a large number of experts and analyzing the main existing reports on climate and green innovation.

We selected our set of AGIs using the following criteria:

- **Innovations are mature enough to be developed in the short / medium term (i.e., around 2020) under realistic assumptions ;**
- **Innovations reduce GHG at an affordable cost.** In fact, many of the innovations in our panel have a *negative cost* – meaning that they lead to lower costs after taking into account benefits such as energy savings ;
- **Innovations selected can be used to “test” hypotheses or recommendations** applicable to major sectors (e.g. electricity, industrial processes, transport), different regions (e.g. developed or emerging countries) and different levers for emissions reductions (e.g. better monitoring, fuel switching).

Figure 1: Scope of the initiative



The “TTI” report is the collaborative effort of a group of companies and climate or innovation specialists that shared their expertise on some of the innovations they have been working on in the past decades. They were asked to put themselves in the position of a “world climate minister” so as to provide “general interest” policy levers to accelerate the development of AGIs – i.e. levers which make sense from a general interest point of view, rather than from any specific interest point of view. Our team then further developed these propositions to offer a comprehensive set of policy recommendations. The following chart displays the main contributors to the project.



Figure 2: Panel of contributors to the initiative



## Part I – Greenhouse gases and climate: what do we know and what should be done?

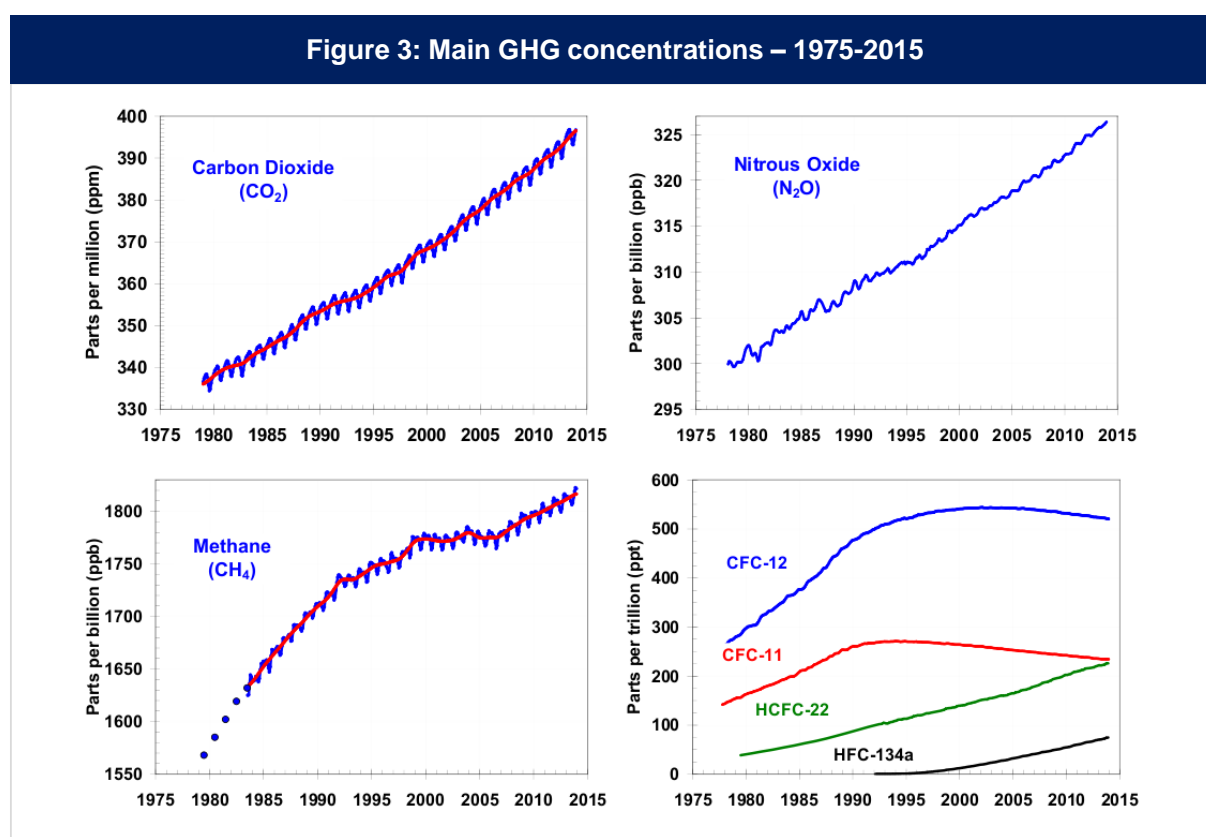
*This section summarizes the current consensus on climate change and greenhouse gas (GHG) emissions. This first part is mainly targeted for readers whose prior knowledge on climate issues is limited. **Other readers can focus on the last two pages of part I before reading part II and part III.***

### a. GHG and their environmental impacts

#### Concentration trends

In the last 35 years, the concentration of GHG<sup>5</sup> in the atmosphere has dramatically increased. Expressed in ppm (parts per million)<sup>6</sup> of CO<sub>2</sub> equivalent<sup>7</sup>, global emissions have risen from 385 ppm of CO<sub>2</sub> equivalent in 1980 to circa 480 ppm eq-CO<sub>2</sub> in 2013.

The charts below, published by the Earth System Research Laboratory, illustrate the corresponding increase of global GHG concentrations at worldwide level since the early 1980s. They show a continuous growth of GHG concentrations for both carbon dioxide and nitrous oxide. Carbon emissions have been accelerating since the mid-1990s, with an average CO<sub>2</sub> growth rate of about 1.4 ppm per year before 1995 and 2.0 ppm per year thereafter. The increase is more modulated for methane and C-gas emissions.



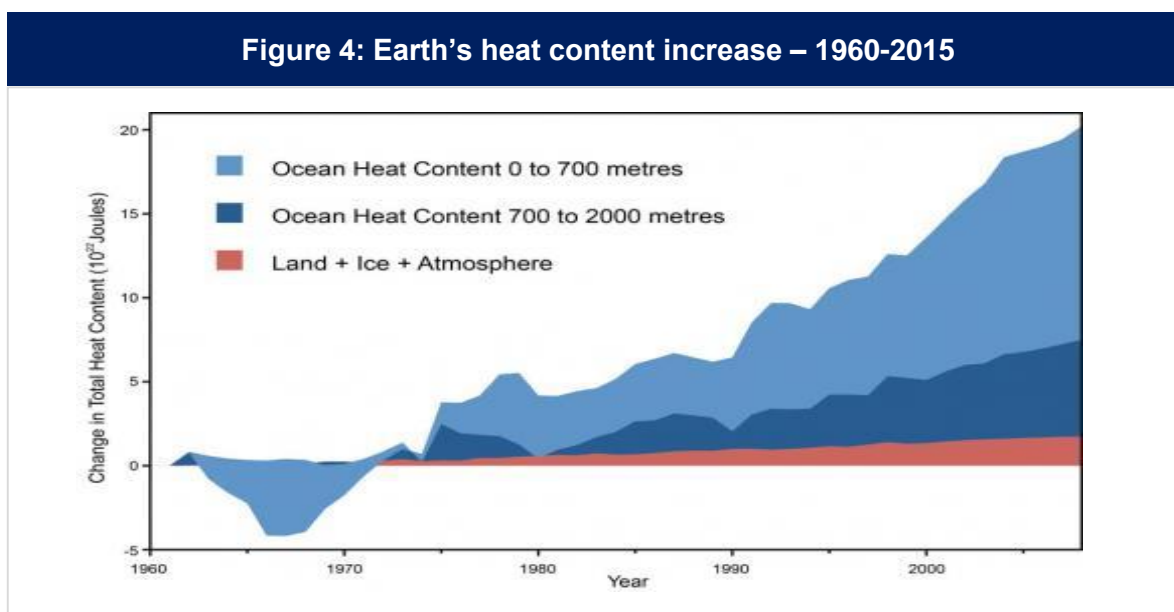
Source: National Oceanic and Atmospheric Administration

<sup>5</sup> Greenhouse gases, or GHGs, are gases whose presence increases the greenhouse effect by absorbing or emitting infrared radiations, which causes a rise in the Earth's temperature. The main GHGs present in the atmosphere are water vapor, carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), Nitrous oxide (N<sub>2</sub>O), ozone (O<sub>3</sub>) and chlorofluorocarbon gases (CFCs), also known as F-gases.

<sup>6</sup> Measured as the number of molecules of carbon dioxide (or equivalents) divided by the number of all molecules in the air expressed in parts per million, or ppm of CO<sub>2</sub> equivalent

<sup>7</sup> The impact of GHG emissions in terms of global warming is often expressed in CO<sub>2</sub> equivalents. This describes how much global warming a given amount of GHG may cause over a given period (usually 100 years), using the equivalent amount of CO<sub>2</sub> as a reference.

In the same time, as shown in the graph below, the Earth's overall heat content has been growing over the past decades.



Source: "Comment on Ocean heat content and Earth's radiation imbalance"; *Physics letter; A*, Nuccitelli et al; 2012

The scientific community has been analyzing these phenomena for decades and concluded that man-made GHGs are a major contributor to heat content increases and, in turn, the acceleration of climate change. It is also commonly accepted<sup>8</sup> that some form of climate change is inevitable.

### Potential scenarios and impacts

According to the Intergovernmental Panel on Climate Change<sup>9</sup> (IPCC), Earth's average temperature could increase by up to 4.8 degrees by the end of the 21st century in a "business as usual" scenario<sup>10</sup>. This rise would have significant negative consequences (Figure 5), and could potentially generate very high economic costs, equivalent to a loss<sup>11</sup> of 5-20% of our annual income (or GWP<sup>12</sup>) in 2050 in a "business as usual" scenario.

<sup>8</sup> See UNEP and IPCC

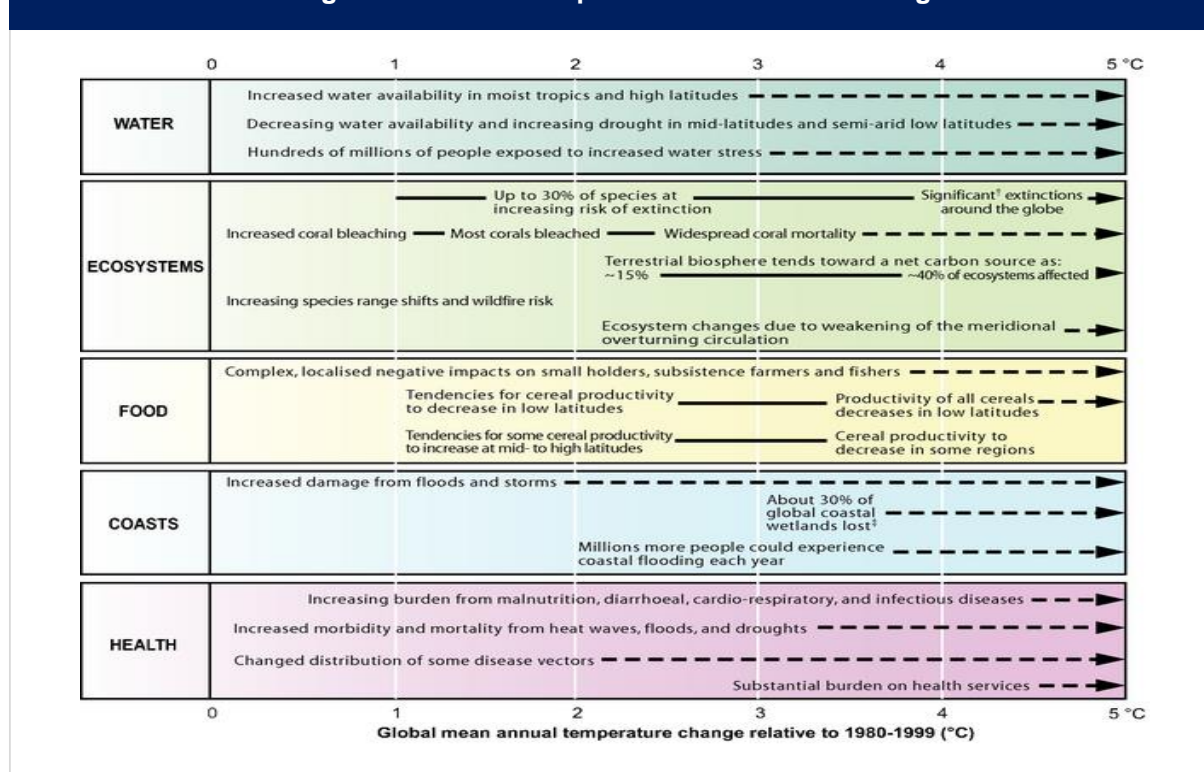
<sup>9</sup> See IPCC's 5th report.

<sup>10</sup> See Intergovernmental Panel on Climate Change's 5th report, *Climate Change 2013: The Physical Science Basis*, 2014

<sup>11</sup> Estimates based on the *Economics of Climate Change* report (released for the British government on 30 October 2006 by economist Nicholas Stern). See [http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/media/4/3/executive\\_summary.pdf](http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/media/4/3/executive_summary.pdf)

<sup>12</sup> GWP, or Gross World Product, is the monetary value of all the finished goods and services produced each year in the world. In 2013, the GWP was around 75 trillion dollars.

Figure 5: Main consequences of Earth's warming



Source: IPCC's 4<sup>th</sup> report

Given the amount of current GHG emissions and how difficult it is to reduce them, a temperature increase is inevitable. The question therefore becomes: by how much should we limit this increase to reach a level which mitigates ecological damages while having an acceptable economic cost? Although this level has been largely debated<sup>13</sup>, the present consensus is that mankind should limit the temperature rise to 2°C by the end of the 21<sup>st</sup> century.

Actions to limit temperature increases to 2°C would cost 1% to 5% of GWP, a much lower figure than the “cost of inaction” mentioned earlier (5% to 20% of GWP). It is important to note that the 1% to 5% estimate does not fully value the potential of innovation, as it is mainly inferred based on existing technologies. This idea will be further explained in the rest of this report.

The IPCC's 4<sup>th</sup> report estimates that limiting global warming to less than +2°C compared to preindustrial levels (i.e. 1870, considering a 50% confidence rate), will require limiting the GHG concentration to a maximum of 500 ppm of CO<sub>2</sub> equivalent.

To stabilize the GHG concentration, we should reduce GHG net emissions to zero<sup>14</sup>. Since lowering GHG emissions is a long and complex process, this “reduction to zero” has been translated into progressive milestones ensuring emissions are first stabilized, then reduced<sup>15</sup>. With an estimated 480 ppm eq-CO<sub>2</sub> in 2013, we are now very close to the “maximum” level of 500 ppm and have no time to lose.

<sup>13</sup> See IPCC 5th report or The New Climate Economy report for more information on this.

<sup>14</sup> A zero net GHG emissions level is a level at which emitted GHGs are fully compensated by GHGs absorbed both naturally (by oceans or forests for examples) or artificially (by carbon capture technologies).

<sup>15</sup> We will most probably have to reach a *negative* level of emissions in the likely scenario that we overshoot the 500 ppm eq-CO<sub>2</sub> before we stop emitting GHGs. See UNEP's Emissions Gap Report for more information.

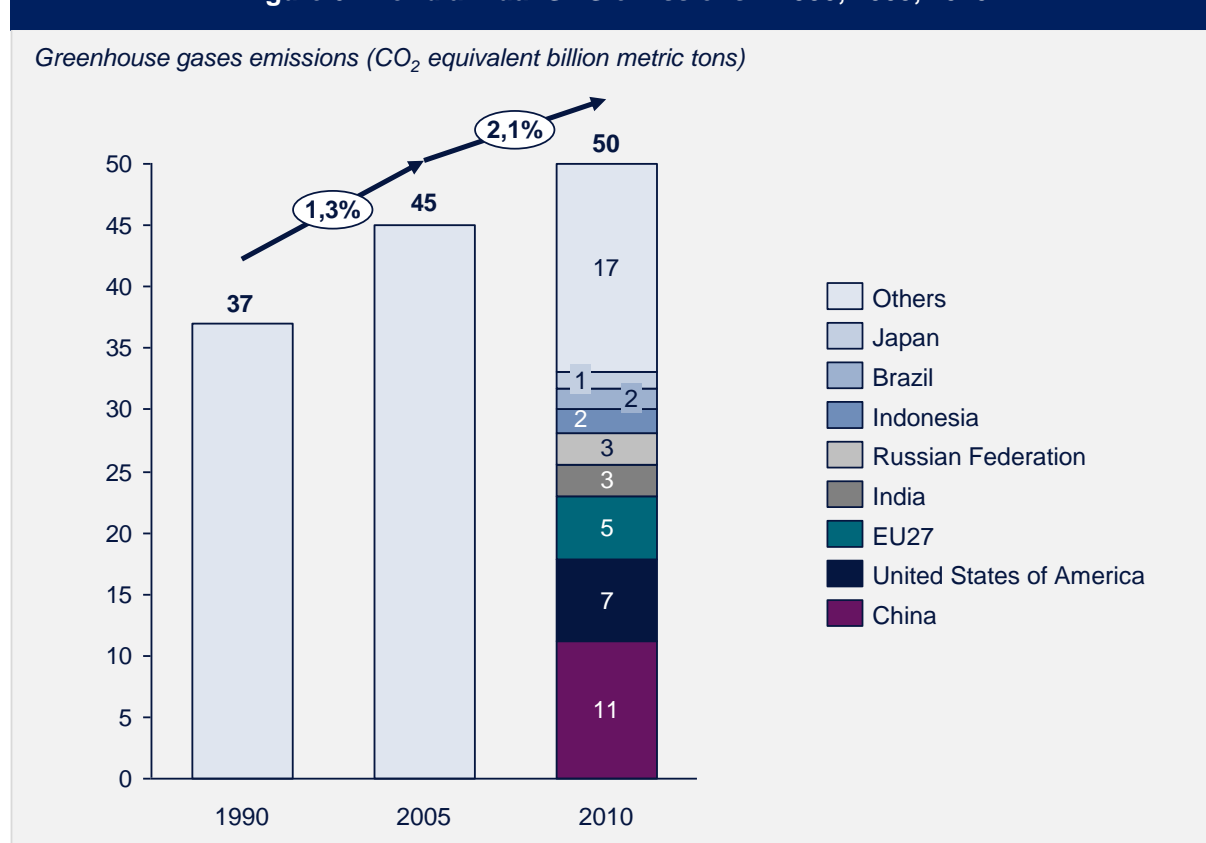
## b. Who emits GHGs?

### Emissions by country

Worldwide yearly GHG emissions reached 37 Gt CO<sub>2</sub> equivalent in 1990 and have been growing in the last decade to a 50 Gt CO<sub>2</sub> equivalent threshold in 2010.

In 2010, China was the largest emitting country, with 11 Gt, followed by the USA and the European Union (EU 27) with 7 Gt and 5 Gt respectively. All three together account for more than 45% of total emissions. Developed countries such as the USA and members of the EU have however been on a decreasing or stable emissions trend, while most of the growth has been driven by emerging countries, in particular China. In the last decade, the emerging countries share of emissions evolved from 50 % to 60 %, and this proportion will keep increasing in the future as the demand of emerging economies for energy, transportation or other carbon intensive products grows<sup>16</sup>.

**Figure 6: World annual GHG emissions – 1990, 2005, 2010**



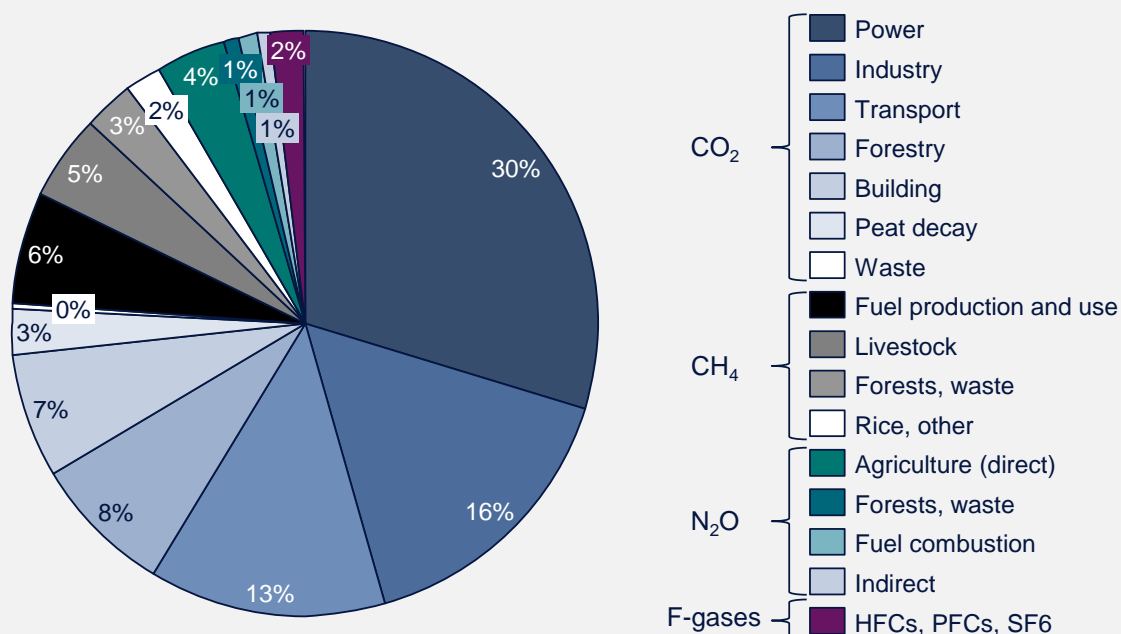
### Emissions by sector

CO<sub>2</sub> accounts for approximately 76% of worldwide emissions in Gt CO<sub>2</sub> equivalent, followed by CH<sub>4</sub> (16%), N<sub>2</sub>O (6%) and F-gases (2%). Three sectors are responsible for more than 50% of worldwide emissions: Energy, Industry and Transport.

<sup>16</sup> For example, there is only one passenger vehicle per 30 residents today in China (compared to one vehicle per 1.3 residents in the United States). Similarly, China's annual petroleum consumption is now 2.5 barrels per person, whereas it is 6.7 in Mexico and 22.4 in the United States.

**Figure 7: World annual GHG emissions by gas and sector – 2010**

GHG emissions (% of CO<sub>2</sub> equivalent billion metric tons)



**Total: 50.1 Gt**

Sources: UNEP, JRC/PBL EDGAR

### c. GHG reduction targets and country pledges

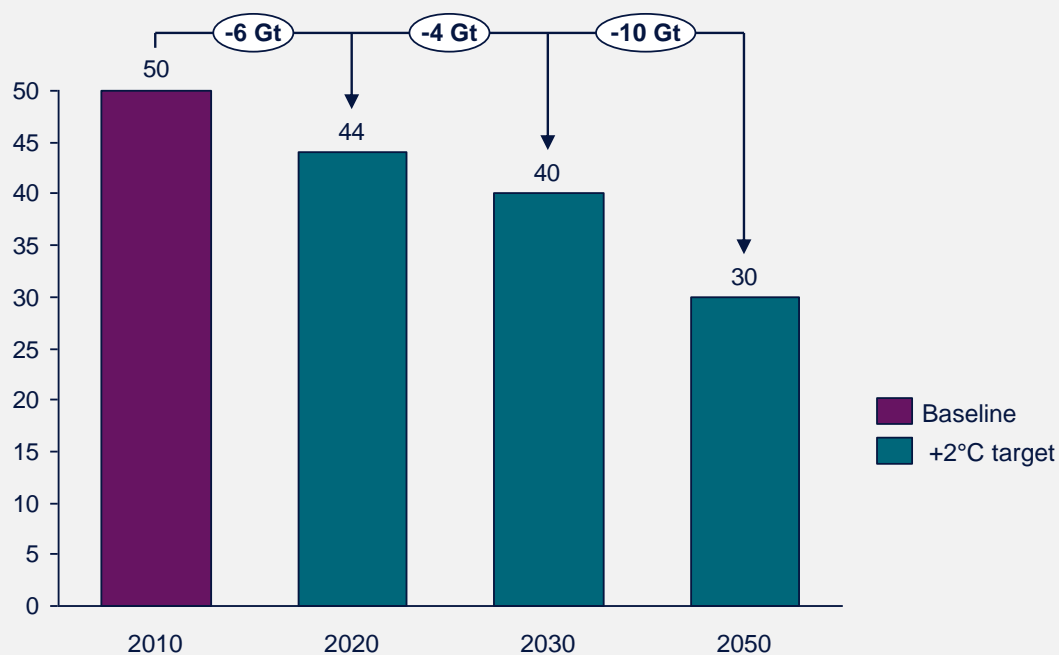
#### Emissions targets

Limiting future global warming within a +2°C range would require<sup>17</sup> stabilizing annual GHG emissions to a maximum of 44 Gt per year by 2020. Compared to current yearly emission levels (around 50 Gt per year), this would imply a decrease of 6 Gt eq-CO<sub>2</sub> over the period. After 2020, we should reduce emissions to 40 Gt/year by 2030 and 30 Gt/year by 2050. This means reducing GHG emissions by 12% in 2020 compared to 2010, by 20% in 2030 and by 40% in 2050.

<sup>17</sup> Source: "Emission Gap Report", 2013, UNEP.

**Figure 8: World annual GHG emissions – 2010, 2020e, 2030e, 2050e**

*The evolution of GHG emissions under the +2°C scenario (CO<sub>2</sub> equivalent billion metric tons)*



Sources: UNEP, JRC/PBL EDGAR



## GHG emissions reductions: how are they calculated?

*There are many methods for GHG calculations\*, but most of them use the same underlying principles:*

- **CO2 equivalents.** *The impact of GHG in terms of global warming is often expressed in CO2 equivalents. This describes how much global warming a given amount of GHG may cause over a given period (usually 100 years), using the equivalent amount of CO2 as reference.*
- **Baseline.** *GHG reductions associated with a specific solution usually depend on a baseline. For example, the carbon emission reduction of a car sharing service is not the same if this service replaces individual cars or public transportation. This baseline can vary across countries (for instance, the respective share of individual cars and public transportation is not the same everywhere). It also depends on many parameters, such as the category targeted (commuters and students use their car differently) or timing (the CO2 content of electricity varies).*
- **Direct and indirect emissions.** *Emissions can be direct (for example, related to the fuel used by a car) or indirect (for example, the disposal of a car).*
- **Standard estimates.** *The precise calculation of GHG reduction may be difficult to calculate. Most of the time, a good estimate based on standard parameters is a more practical option than a perfect but unfeasible calculation. For instance, it is possible to use activity data (such as the number of kilometers of car travel) and emission factors \*\* (like the standard CO2 tons emission per kilometer for an average car).*

\* See for example 2006 IPCC Guidelines for National Greenhouse Gas Inventories, "Including mandatory greenhouse gas emissions reporting guidance" (<http://www.gov.uk/defra>), ISO 14064 or the WRI/WBCSD Corporate Accounting and Reporting Standard.

\*\* IPCC (<http://www.ipcc-nggip.iges.or.jp/EFDB/main.php>) as well as US Environmental Protection Agency, European Union or International Energy Agency issued standard values for the most common emission factors

## GHG pledges and future scenarios<sup>18</sup>

In a business-as-usual scenario, GHG worldwide annual emissions are expected to reach 59 Gt by 2020<sup>19</sup>: this is where world population growth and economic development will lead us if no major change is enforced.

Several countries are committed to limiting their GHG emissions, under conditional or unconditional pledges. If we take into account these pledges, GHG emissions could be reduced by up to 7 Gt per year and reach 52 Gt CO2 equivalent in 2020 instead of 59 Gt. However, this is far from being guaranteed as not all countries are currently on track to meet their pledge. Moreover, the economic slowdown which followed the 2008 crisis contributed to limiting GHG emissions, but this contribution will not be sufficient to meet official targets when economic growth rebounds. Considering only countries which have made necessary efforts and are on track to meet their 2020 pledges, worldwide emissions will only be reduced by 3 Gt and will reach 56 Gt per year by 2020.

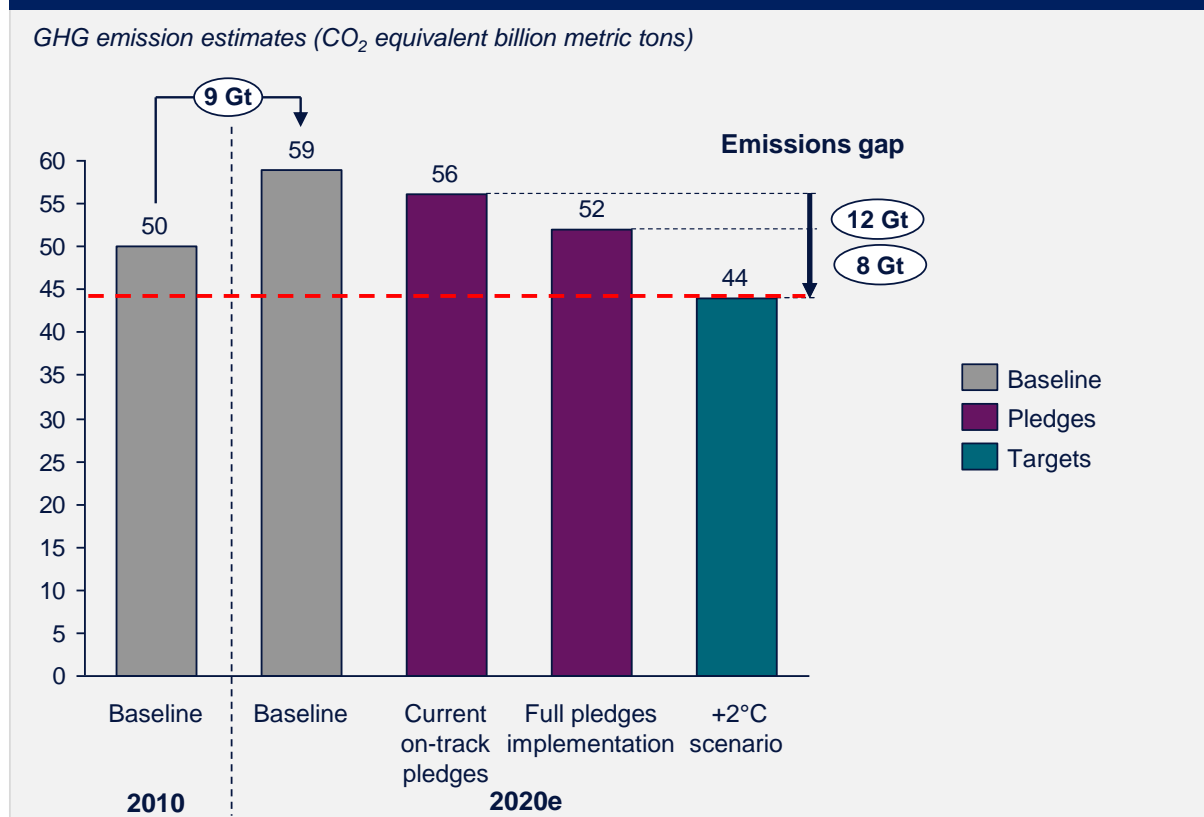
In both cases, there will be a gap between the level of future GHG emissions, and the level we should reach to keep the world average temperature increase under 2°C. If current pledges are respected, we will reach a 52 Gt level instead of a 44 Gt target and this gap will be 8 Gt. If these pledges are only partially met, this gap will be 12 Gt, because emissions will be 56 Gt per year instead of 44 Gt.

<sup>18</sup> GEO scenarios by UNEP as reported in the 2004 and 2013 Reports

<sup>19</sup> Within a high confidence range of 56 – 60 Gt



**Figure 9: World annual GHG emissions – 2010, 2020e**



Sources: OECD, UNEP

#### d. The role of innovation to reduce the cost of tackling climate change

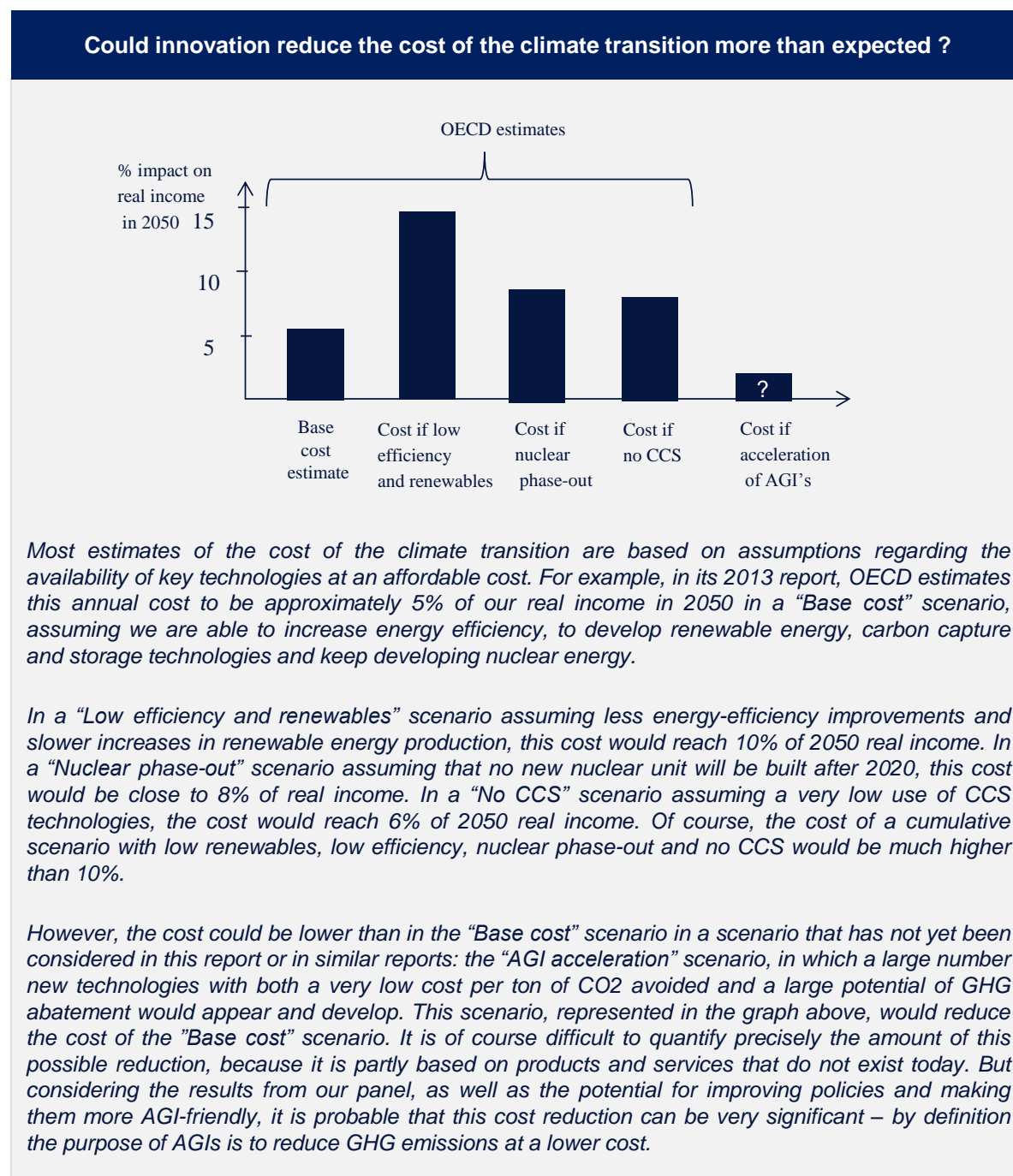
##### Existing estimates for the cost of fighting climate change do not fully value the role of innovation

As mentioned earlier, a 2°C increase scenario could cost 1% to 5 % of the world's annual income (GWP) in 2050. However, these estimates are based on economic models which, by construction, focus mainly on existing technologies and partly underestimate the potential benefits of innovation.

To be sure, many reports mention the role of green innovations - for example the New Climate Economy Report states that "innovation is central to economic growth, (...) and makes it possible to continue growing our economies in a world of finite resources" – but their estimates for the cost of the climate transition are based only on existing technologies (like renewable energy or carbon capture and storage).

Because innovation is partly unpredictable, the models used cannot estimate the benefits of inventions that could be discovered in the coming years, if the appropriate policies were implemented. They also focus on large emission reduction potentials: smaller innovations with low individual potentials are overlooked even if their cumulative contributions could bring significant GHG reductions at a very low cost. Moreover, existing reports emphasize policy recommendations supporting a limited number of specific pre-identified technologies rather than taking a "systemic" approach to create a context favorable to the creation and large-scale development of a "multitude" of AGIs, many of which have yet to be invented.

As a consequence, the role of AGIs and the corresponding policies that would encourage their development is consistently undervalued. **This is in fact very good news: if we are able to implement the policy recommendations mentioned later in part III, we can reduce the cost of the climate transition to levels lower than the current estimates** (see box).



Source: Pricing carbon, OCDE, 2013 and team analysis

## Economic history shows that the contribution of innovation is often greater than expected

Mankind has already been confronted with challenges that at first seemed too costly to solve from an economic standpoint because they could jeopardize growth, purchasing power or employment. However, innovations quickly offered solutions that decreased economic costs in comparison to those estimated by a static model based on existing possibilities.

For example, in Dickens' time, the cost of implementing paid leave or prohibiting child labor would have been considered excessively high and utopic, if it was not for major industrial innovations (many of which not predictable initially) that ended up enabling better working conditions at a reasonable economic cost.

This does not entail that economic models are irrelevant or useless. Rather, it shows that in the medium to long term, they only produce estimates that should be considered as a baseline that can be improved significantly with more innovation. Economists know that in the long term what explains most of the increase in the wealth of nations is innovation coupled with productivity and capital intensity rather than using more human or natural resources.

If we apply this reasoning to climate issues, the current cost estimates of the climate transition already tell us that it is less expensive to reduce GHG emissions and limit temperatures increases than to do nothing. This is the first positive news. However, there is a second good news: these cost estimates will only prove exact in the "worst case scenario" in which we fail to stimulate AGIs to reduce GHG emissions at an even lower cost.

Innovations presented in this report demonstrate that all regions of the world, and all GHG emitting sectors, can develop affordable green innovations that can bring about change in a nearby future. Besides those shown in the report, many innovations are still at the R&D stage, or do not even exist to this day. This report also highlights the fact that incentives to develop AGIs are still very low, a fact that becomes apparent when comparing our policy recommendations with reality.

For many of the innovators we interviewed, their products or services were largely based on a "leap of faith" which assumed the world would need lower carbon technologies rather than a purely financial decision profitable in today's context. This also means that the number of innovations and the potential impact of AGIs could have been much larger. If given the appropriate context, many innovations inexistent today can emerge across all industries and geographic regions, and the development of existing AGIs can be accelerated and extended.

## e. Summary: why we need to develop Affordable Green Innovations

In summary, we need to address a gap of 8 to 12 Gt of GHG emissions by 2020 if we want to limit temperature increases to 2°C and avoid high economic costs. These estimates assume that the countries already committed to emission reductions will find affordable ways<sup>20</sup> to fulfill their commitments, despite economic growth and decreasing oil prices which contribute to higher emissions. Moreover, if the cost of the pledges proves too high, strong political pressures could lead committed countries to reduce their ambitions: **AGIs will be needed to ensure existing pledges are implemented.**

However, even with existing pledges, the GHG emission gap will still be at least of 8 Gt. This gap could be further reduced by new commitments in the context of the COP 21 summit, but to convince political leaders to do so, they will need **affordable ways to reduce GHG emissions**. Finally, in countries not committed to specific pledges **the only way to reduce emissions will be either through foreign aid, or through "profitable green innovations"** (AGIs with a zero cost per ton of CO<sub>2</sub> avoided) which will be implemented because it makes economic sense to do so, even in the absence of significant climate policies.

For all these reasons, **AGIs should be the focus of climate policies in the coming years** to ensure global targets translate into real impacts. This approach is **complementary with the current international negotiations**. Existing and future pledges should prioritize the implementation of

<sup>20</sup> Pledges do not necessarily include detailed commitments on precise levers or actions.

policies favorable to AGIs, because affordable solutions will be needed to reach the objectives set by country pledges. Additionally, the more AGIs are made available, the easier it will be for new countries to make new pledges.

## Part II – Panel analysis and first learnings

*This section describes our innovation panel as well as the first lessons we learned from analyzing it – for example how emissions are reduced, at what cost, and which roadblocks are currently preventing a large development of these innovations. A more detailed and systemic list of policy recommendations will be presented in part III, and a description of each innovation can be found in appendix.*

### a. Description of the innovations considered in this report

Our panel includes 40 innovations and reflects the variety of possible solutions in the matter of carbon emission reduction (industry sectors, company sizes, geographical locations or business models).

#### Focus on methodology

- *The following analyses are based on the material communicated by contributing companies.*
- *Transversal assumptions have been standardized, so as to ensure consistency throughout the report. In particular, transversal assumptions have been taken on average metrics for car usage, for average energy mix at worldwide levels, for corresponding average carbon emitting rates, for cost of financing, etc. Results and outputs are therefore average estimates derived from standard calculations, based on standard assumptions and considering standard conditions for implementation.*
- *The following analyses do not aim at comparing the relative attractiveness of one innovation versus another.*
- *The report focuses on assessing a global potential for GHG abatement at worldwide level, whenever possible. However, due to the different level of maturity of innovations quoted in the report, some discrepancies remain. To ensure consistency, we have tried to normalize the potential assessment as much as possible, by considering an “optimistic and realistic scenario”:*
  - *“Realistic” : in line with existing trends and macroeconomic conditions*
  - *“Optimistic” : considering that major roadblocks identified at this stage for the future development of the innovation will be overcome*

**Figure 10: Classification of the innovations**

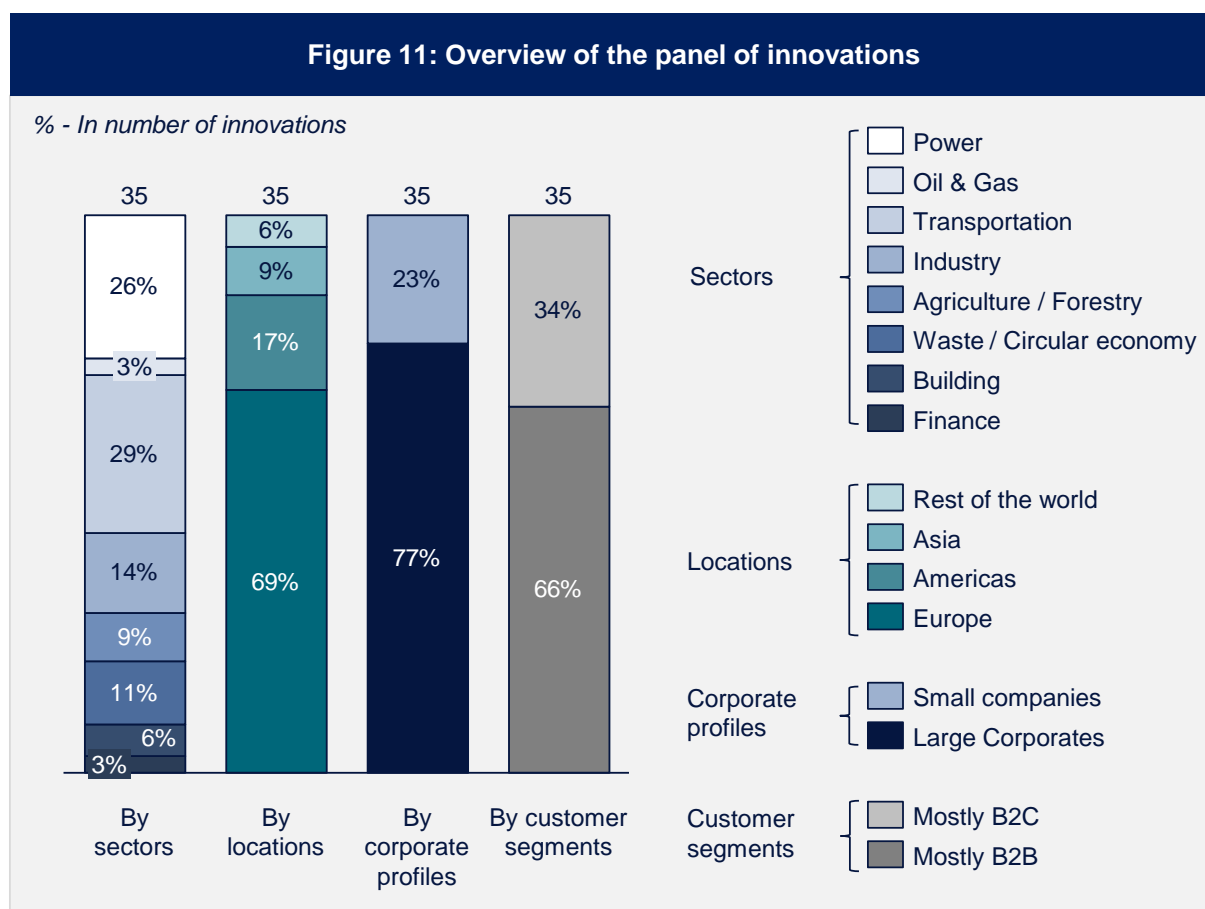
Sector	Category	Innovation	Carbon benefits
Power	Onshore wind	Furtive wind turbine blades : weather & military radars	Increased renewable geographical coverage
	Offshore wind	Haliade 150, the new generation offshore wind turbine	Enhanced turbine for offshore wind
	Hydro	Asynchronous hydro pump storage for ancillary services	Avoided thermal backup capacity
	Solar CSV	Efficient solar generation by concentration	Avoided thermal resources
	Storage / Capture	CSS solutions for thermal plants	Carbon capture & storage
	Demand response	Automated demand shifting	Avoided thermal backup capacity
	Smart metering	Smart metering as a consumption optimization lever	Decreased household electricity consumption
	Community Mngt	Community Energy Management System	Power management at local level
	Urban planning	Urban modeling platform	Smarter & reduced energy consumption
Oil and gas	Upstream	Flared gas used in replacement of Diesel	Avoided diesel power generation
Transportation	Car & Maritime fuel	Natural gas as a fuel for road & maritime transportation	Lower emissions
	Hybrid cars	Full Hybrid Technology	Lower emissions
	EV - Motorcycles	Zero FX Electric Motorcycle	Lower emissions and higher torque
	H2 / FCEV	Hydrogen mobility / FCEV	Zero local emissions
	Smart cities	Smart traffic solution to optimize transportation systems	Less congested cities and lower emissions
	EV Car sharing	Urban car-sharing program based on ultra compact EV	Optimized car use and lower emissions
	Bike sharing	Bike-sharing program	Lower car / transportation use
	Airplane	Smart take-off monitoring	Lower fuel consumption in the climbing phase
	Train	Trip optimizer	Driving optimized for lower emissions
Industry		Mobility CO2 performance	Substitution to lower emissions options
	Steel	Lighter and stronger steel for the car industry	Reduced car weight, consumption and emissions
	Chemicals / HFC	Fire protection systems using HFC gas	Replacement of harmful GHG
	Chemicals / SF6	Replacement of SF6 as an insulator in electrical systems	Replacement of harmful GHG
	Oxycombustion	Using oxygen in the glass industry	Reduced energy consumption
Agriculture, forestry	Reverse Osmosis	Thin-film polyamide membrane to produce potable water	Energy savings
	Agroforestry	Insetting via agroforestry	Natural carbon absorption
	Fertilizers	Using a slurry pipeline	Avoided train transportation
Waste, circular economy	Smart Farming	Virtuous loop in the rapeseed biodiesel production sector	More efficient biodiesel production
	Plastic treatment	Increased reprocessed plastics in soda bottles	Decreased energy consumption
	Liquid wastes	Anaerobic digestion of liquid wastes	Biogas produced instead of being released
	Digital heating	Using heat produced by processors	Heating & data center cooling savings
Building	Blast furnace gases	Using blast furnace gas in the steel slab reheating process	Valorization of alternative energy sources
	Building	Electrochrome glass	Reduced energy losses & cooling savings
Finance		High performance glass wool as thermal isolation	Better insulation / decreased energy consumption
	Green Bonds	Green bonds financing	Increased funds available for green investments

## Sectors of origin and emission reduction levers

The innovations considered in the initiative cover eight key emitting sectors. The Power and Transportation sectors appear to be the most prominent with 9 and 10 innovations quoted respectively. The Oil & Gas or Financing sectors are less represented, with only one innovation each.

The diversity of the innovations is also reflected in terms of their origin, with contributions from all 5 major continents (Europe, Americas, Asia, Africa and the Middle East), in terms of corporate profiles, with contributions from both large blue-chip corporates and smaller innovative start-ups, and in terms of customers targeted, with B2B and B2C solutions.

Figure 11: Overview of the panel of innovations



## Emission reduction drivers and business models

Four main groups of emission reduction drivers explain how the innovations in the panel reduce GHG emissions:

### 1- Reducing unit emissions

- **Fuel or energy switching:** using lower carbon energies to replace more carbon-intensive sources
- **New Design / Mechanics:** improving mechanical design, enabling for increased efficiency and thus decreased GHG emissions
- **New / Improved materials:** using innovating materials and/or chemicals with a lower GHG footprint
- **Recycling:** reprocessing used materials and reducing waste

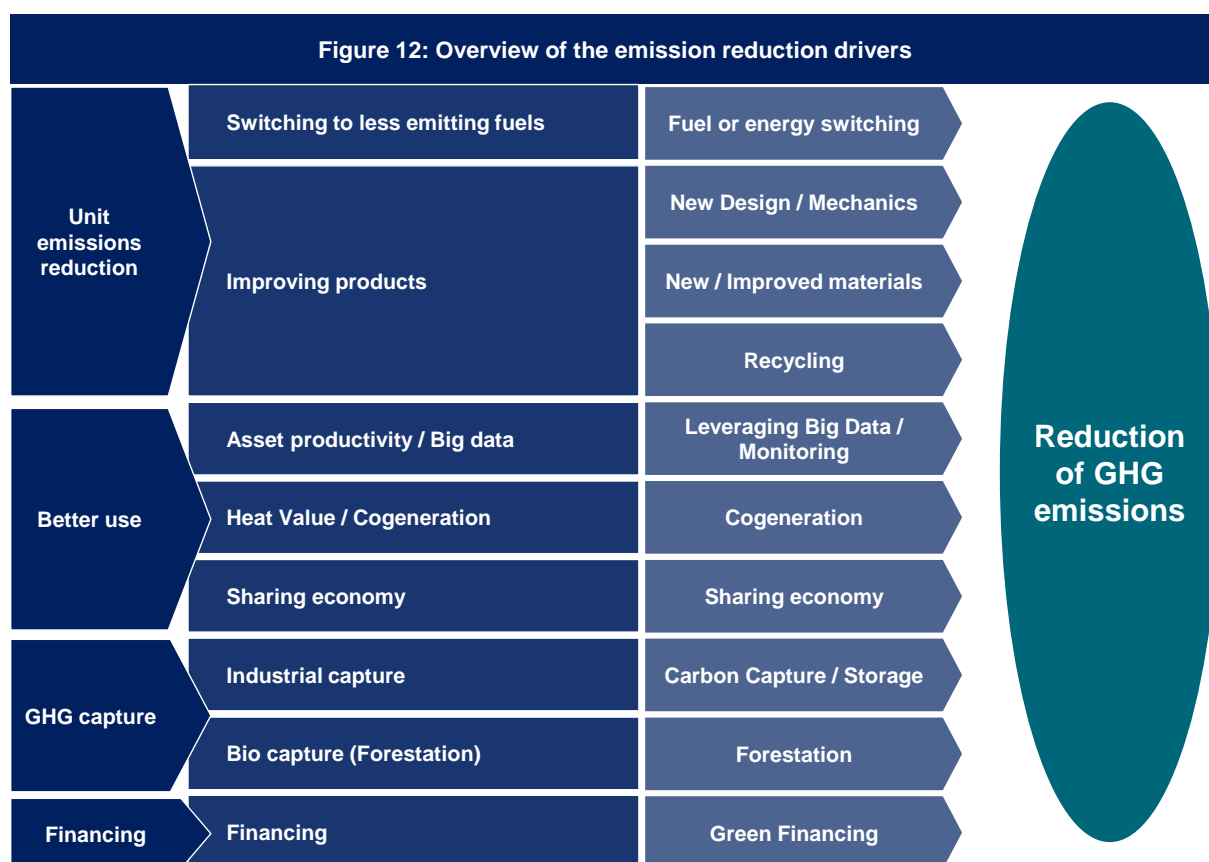
### 2- Optimized use

- **Leveraging Big Data / Monitoring:** monitoring equipment more efficiently so as to decrease consumption and avoid waste
- **Cogeneration:** recuperating and valorizing by-products (for example heat)
- **Sharing economy:** sharing systems so as to increase unit usage and avoid waste

### 3- GHG capture

- **Carbon Capture / Storage:** capturing carbon (or other GHG) and storing them instead of releasing them in the atmosphere
- **Forestation (Bio capture):** using a natural alternative for the above-mentioned GHG capture / storage solutions

- 4- **Financing:** innovating financing solutions allowing a larger utilization of some of the former levers





## Detailed description of the innovations according to the emissions reduction levers

Figure 13: Description of the innovations – (1/4)

Emission reduction lever	Category	Innovation description	Carbon benefits
Fuel or energy switching	Car & Maritime fuel	► <b>Natural gas (LNG/CNG) as a fuel for road &amp; maritime transport</b> Replacement of traditional carbon-intensive fuels such as diesel / gas	115 Mt CO <sub>2</sub> potential avoided p.a. by 2025, of which ~49 Mt from marine transport and ~37 from small and large vehicles
	Hybrid cars	► <b>Full Hybrid Technology for cars</b> Replacement of conventional ICE (Diesel & Petrol) vehicles	~21 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to ~14 million vehicles in circulation
	EV - Motorcycles	► <b>Electric 2 wheel vehicles</b> Replacement of conventional motorcycles by electric motorcycles	~45 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to an ambitious target of ~143 million vehicles in circulation by then
	Liquid wastes	► <b>Anaerobic digestion of liquid wastes</b> Enabled use of biogas as a fuel for electricity production (renewable)	~0,02 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to a target 40 plants
	Hydrogen / FCEV	► <b>H2 vehicles / FCEV</b> Vehicles using hydrogen as a fuel (FCEV)	~3 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 1 million FCEVs by then
	Oxycombustion	► <b>Combustion by oxygen in the glass industry</b> Process of burning a fuel using pure oxygen instead of hot air	~1 Mt CO <sub>2</sub> potential avoided p.a. by 2020, by increasing the share of oxy-combustion in glass furnaces from 10 to 20%
New Design / Mechanics	Onshore wind	► <b>Furtive wind turbine blades enabling more potential sites</b> Reduced RCS, interference, reflection of radar waves by blades	~100 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 50 GW globally
	Offshore wind	► <b>A new generation 6 MW turbine for offshore wind</b> Increased efficiency through longer blades and elastic coupling	~70 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 5-6 GW installed
	Hydro	► <b>Asynchronous hydro pump enabling storage and ancillary services</b> , also when in pumping mode. Avoided thermal capacity serving as grid backups	~7 Mt CO <sub>2</sub> potential avoided by 2020, corresponding to 9 GW thermal capacity avoided on 2000 hours p.a.
	Solar CSP	► <b>Efficient solar by concentration</b> Production of energy by solar concentration	~3 Mt CO <sub>2</sub> potential avoided by 2020, corresponding to 3 GW installed worldwide
	Fertilizers	► <b>The slurry pipeline, to transport phosphate concentrate over 200km</b> . Replacement of conventional transportation mode by train	~1 Mt CO <sub>2</sub> potential avoided p.a. by 2020, transporting 38 Mt phosphate production annually

Figure 14: Description of the innovations – (2/4)

Emission reduction lever	Category	Innovation description	Carbon benefits
New / Improved materials	Steel	► <b>Lighter and stronger steel for the automotive industry</b> 25% weight reduction in cars steel parts, i.e. ~100kg cut per vehicle	~8 Mt CO <sub>2</sub> potential avoided p.a. by 2020 Corresponding to a ~25% penetration rate in the annual sales of new vehicles by then
	Chemicals / HFC	► <b>Fire protection systems using HFC gas</b> Replacement of carbon-intensive HFC gases by a sustainable fluid	99% reduction of GHG Greenhouse impact divided by 3500
	Chemicals / SF6	► <b>Replacement of SF6 as an insulator in electrical systems</b> , in particular in gas-insulated substations and electric lines	~63 Mt CO <sub>2</sub> potential avoided p.a. by 2020 in an optimistic scenario, covering 80% of the total 2800 t SF6 in circulation
	Building	► <b>Electrochrome glass</b> Self-tinting glass in replacement of other isolation solutions such as shades, blinds, ... and improved carbon efficiency by square meter	~300 Mt CO <sub>2</sub> potential avoided p.a. by 2020 as per the US Department of Defense
		► <b>High performance glass wool as thermal isolation</b> Increased performance of traditional thermal insulant	~1 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 4 million housings retrofitted p.a. at worldwide level
	Reverse Osmosis	► <b>Thin-film polyamide membrane to produce potable water</b> Chemical solution to separate potable water from salt and impurities in replacement of energy-consuming processes	~0,2 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 1,5 Mt cumulated over 10 years (2015-25)
Process / Recycling	Plastic treatment	► <b>Increased reprocessed plastics in soda bottles</b> Organization of a collecting network and investment in reprocessing plants to avoid waste with an improved carbon footprint	~0,03Mt CO <sub>2</sub> potential avoided per year by Great Britain Continuum
	Smart Farming	► <b>Virtuous loop in the rapeseed biodiesel production sector</b> Improved efficiency of the rapeseed farming sector used for the production of biodiesel fuels	~4 Mt CO <sub>2</sub> potential avoided p.a. by 2020, Assuming an average rapeseed biodiesel emission of 42 g CO <sub>2</sub> e/MJ

Figure 15: Description of the innovations– (3/4)

Emission reduction lever	Category	Innovation description	Carbon benefits
Leveraging Big Data / Monitoring	Demand response	<b>Automated demand shifting solution</b> Avoided additional thermal capacities used as backups and ancillary services on the grid	~500 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 'negative' electricity consumption
	Smart metering	<b>Smart meters and 'Big Data' management</b> Decreased energy losses on the network and better consumption management at household level	~550 Mt CO <sub>2</sub> potential avoided p.a. by 2020, depending on the energy mix of each country
	Smart cities	<b>Smart traffic solution to optimize congested cities</b> Avoided cost of traffic congestion, estimated 8% of total corresponding cost (e.g. \$6.4bn annually for a city such as Lyon)	~4 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 20 cities equipped by then
	Airplane	<b>Opti-Climb, a smart solution for take-off monitoring</b> Saved fuel usage in the plane's climbing phase	~50 Mt CO <sub>2</sub> potential avoided p.a. by 2020
	Train	<b>Trip optimizer, a smart auto-control system for trains</b> Itinerary optimization for train transportation	~324 Mt CO <sub>2</sub> potential avoided p.a. by 2020
		<b>Improved railway performance for the French railway system</b> Increased usage and replacement from alternatives such as plane or road, better efficiency of the system	~1 Mt CO <sub>2</sub> potential avoided p.a. by 2020, for France only
	Community Management	<b>Community Energy Management System</b> Smart monitoring and governance system enabling monitoring of energy production at local level	This solution is an enabler to other solutions for which carbon emissions avoided can be calculated.
	Urban planning	<b>Urban modeling platform based on a systemic approach</b> Global understanding of the impacts of urban projects on energy, CO <sub>2</sub> emissions and air quality, enabling better urban planning	~100 Mt CO <sub>2</sub> potential avoided p.a. by 2020 in large cities worldwide

Figure 16: Description of the innovations– (4/4)

Emission reduction lever	Category	Innovation description	Carbon benefits
Co-Generation	Upstream (Oil & Gas)	<b>Flared gas used in replacement of diesel in the Oil &amp; Gas sector</b> Valorization of flared gas emitted during the drilling process	~0,03 Mt CO <sub>2</sub> potential avoided p.a. by 2020, in replacement of diesel consumption
	Digital heating	<b>Digital heater</b> Recovering heat generated from high performance processors	~5 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 2 million heaters installed
	Blast furnace gases	<b>Using blast furnace gas in the steel slab reheating process</b> Valorization of gases generated in the industrial process	~0,5 Mt CO <sub>2</sub> potential avoided p.a. by 2020, corresponding to 20 sites installed out of the 1100 in use around the world
Sharing economy	EV car sharing	<b>Citelib by Ha:mo</b> A new type of urban mobility based on ultra-compact electric vehicles connected to public transport	Still in an experimental phase
	Bike sharing	<b>Bike sharing ecosystem</b> Replacement of other ICE systems, direct and indirect (demonstrative value)	~0,6 Mt CO <sub>2</sub> potential avoided p.a. by 2020 based on an estimate of 20 additional cities
GHG Capture / Storage & Forestation	CO <sub>2</sub> Capture & Storage	<b>CO<sub>2</sub> Capture &amp; Storage from thermal power plants</b> Avoiding carbon emissions in the atmosphere	~39 Mt CO <sub>2</sub> potential avoided p.a. by 2020, and more than 1 bn ton by 2030, from both the Power and Industry sectors
	Bio-capture / Agroforestry	<b>Insetting via agroforestry</b> Integrating high-impact socio-environmental projects within a company's supply chain. Better land management to avoid intensive monoculture	~50 Mt CO <sub>2</sub> potential avoided p.a. by 2020
Green Financing	Green Bonds	<b>Green Bonds Financing</b> Financing green projects	Indirect effect only. Facilitates the growth of emissions reducing products or services

### c. GHG abatement potential of the innovations included in our panel

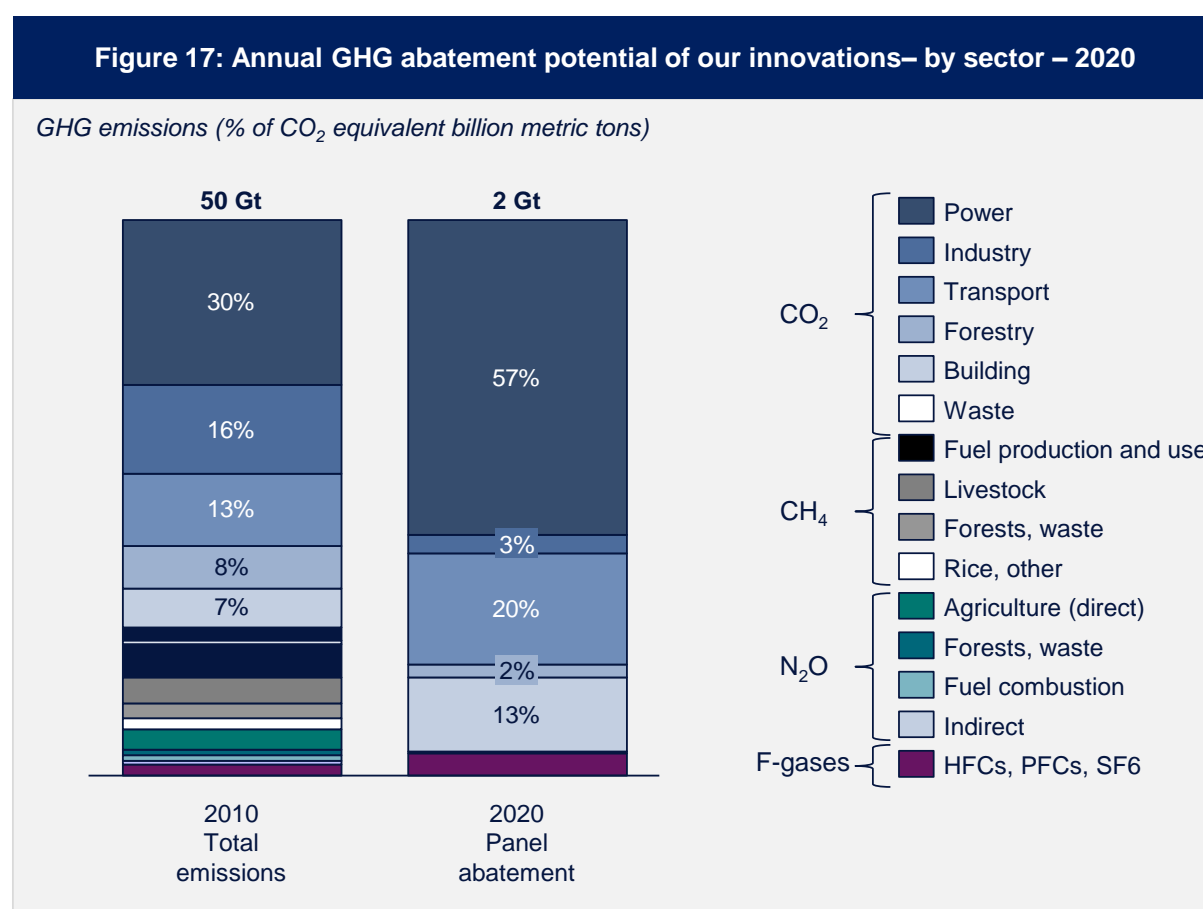
By 2020, the total cumulated GHG abatement potential of the innovations included in our panel is estimated at circa 2 Gt GHG emissions avoided annually. This corresponds to 25% of the 8 Gt gap in terms of GHG emissions.

Considering that our panel is just a sample of the AGIs existing today, which itself probably represents a small part of the innovations that could have been invented with more favorable policies, this is also

a very positive message regarding our future ability to reach a zero net emission target at an affordable cost.

### GHG abatement potential by sector of origin

The Power, Transport and Building sectors are the most significant with 57%, 20% and 13% of the panel's total abatement potential respectively. Other sectors like Industry are less represented, but this might be linked to the way our panel was built. Indeed, whereas we selected “generic” products or services in our panel, many of the solutions which reduce emissions in industrial processes are “project-specific” and individually tailored optimizations of the engineering process and thus could not be selected.



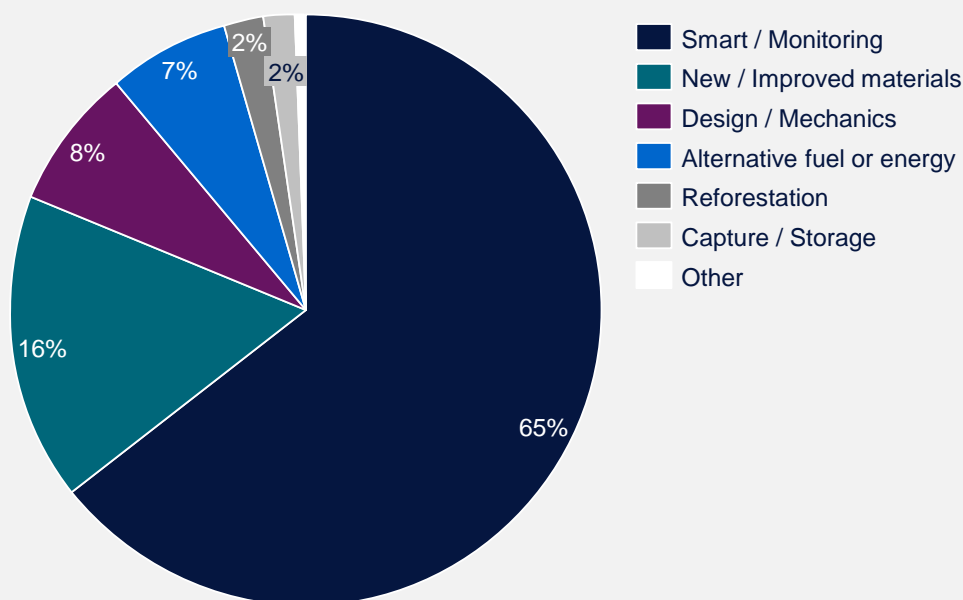
### GHG abatement potential by Emission Reduction Driver

In terms of underlying emission reduction drivers, **Leveraging Big Data / Monitoring** appears as the most important lever, generating 65% of the panel's potential GHG savings by 2020. Corresponding innovations include diverse solutions mostly in the Power and Transportation sectors such as smart metering, smart traffic management, demand response, trip optimization, etc.

**New / Improved materials** are the second largest lever in the panel, generating almost 20% of corresponding potential carbon savings by 2020. Such innovations include both existing materials with improved efficiency (glass wool with increased thermal efficiency as an insulant, lighter and stronger steel for the automotive industry...), or replacement of existing greenhouse materials, in particular chemicals (replacement of SF6 gas in fire protection systems, in electric systems, etc.). Other levers account for only 10% of the panel's total potential by 2020.

**Figure 18: Annual GHG abatement potential of our innovations – by emission reduction driver – 2020**

*GHG emissions (% of CO<sub>2</sub> equivalent billion metric tons)*



**Total abatement potential of our panel: 2.3 Gt by 2020**

#### d. Cost of GHG abatement of the innovations in our panel

##### Merit order<sup>21</sup> by sector

Many of the innovations included in our panel have a negative cost. This means that their owner will save money by using these innovations rather than the usual technologies. From our panel selection perspective, it was a surprise to see that profitable green innovations are in fact much more common than we thought. Moreover, most of the innovations in our panel that are not currently profitable are still affordable and therefore make economic sense<sup>22</sup> without further improvement.

The average “cost” is estimated at circa - 45-50 €/ton eqCO<sub>2</sub>. The negative sign means that using these innovations both reduces CO<sub>2</sub> emissions and saves money, thus confirming the “Transition Through Innovation” thesis: through innovation, it is indeed possible to improve overall competitiveness while reducing GHG emissions.

Transportation shows the lowest affordability due to the heavy investments related to necessary infrastructures (in particular EV, CNG, or H<sub>2</sub> charging points), but also because co-benefits were not

<sup>21</sup> A merit order curve is a way of ranking carbon emission reduction solutions by increasing costs, together with the amount of carbon that they will allow to avoid or save. The vertical axis expresses the average cost per ton of CO<sub>2</sub> of the solution. More specifically, a negative cost means that the innovation offers a positive business model. The horizontal axis shows the potential of carbon emission reduction of each solution (in CO<sub>2</sub> equivalent).

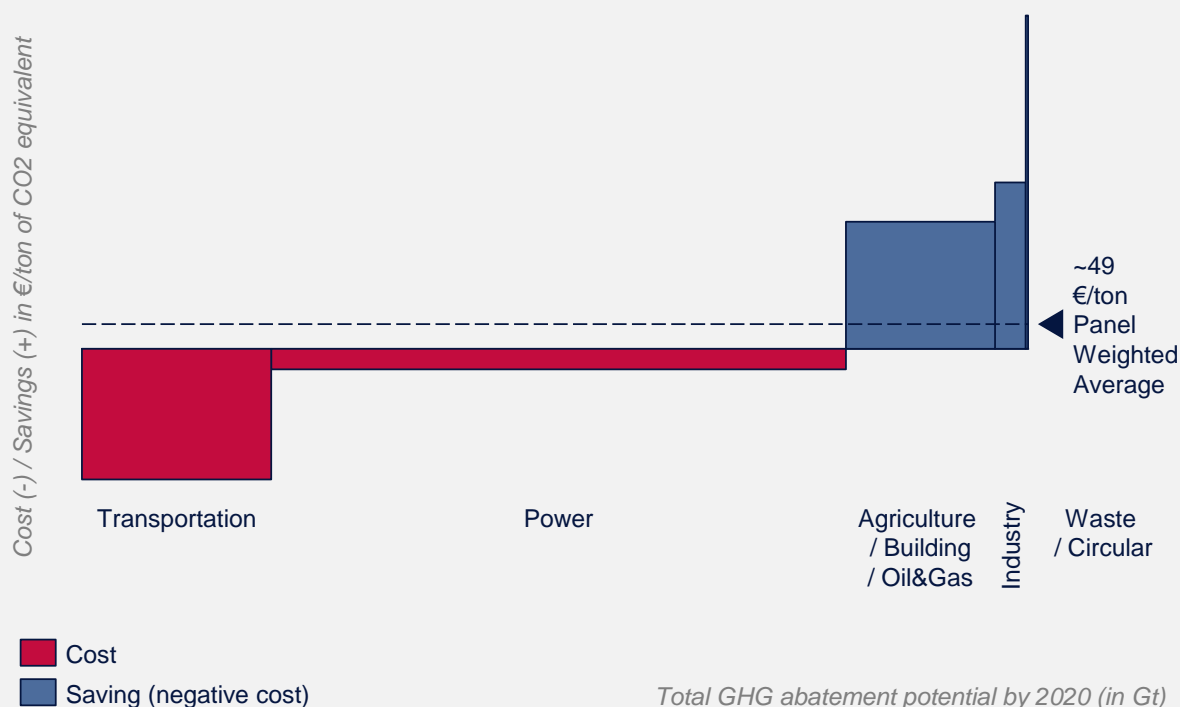
<sup>22</sup> Meaning that even if they are not profitable without public intervention, the level of support they need is only the recognition of the value of their GHG emission reductions at a reasonable price. See part III for more details on this “reasonable value” GHG emissions reductions.

taken into account<sup>23</sup>. However, some solutions are particularly profitable like electric two wheelers used for relatively small commuting travels. Affordability in the Power sector is also relatively low: solar, wind, and other renewable energies still require their carbon benefits to be compensated compared to traditional sources, in particular in the current context of low oil and gas prices. However, these costs are globally in line with most estimates of the reference value for CO<sub>2</sub> (c. 50 \$/ton eq-CO<sub>2</sub>): in a world where CO<sub>2</sub> emission “externalities<sup>24</sup>” would be priced, our innovations for Power would be profitable.

Last, Waste / Circular Economy solutions clearly outperform the cluster, with excellent profitability overall due to their ability to leverage on past historical investments on which significant synergies are extracted.

**Figure 19: Overview of the panel of innovations – average costs per TqCO<sub>2</sub> by sector – 2020**

*Merit order of our innovations, classified by decreasing cost (savings) (in €/ton of CO<sub>2</sub> equivalent)*

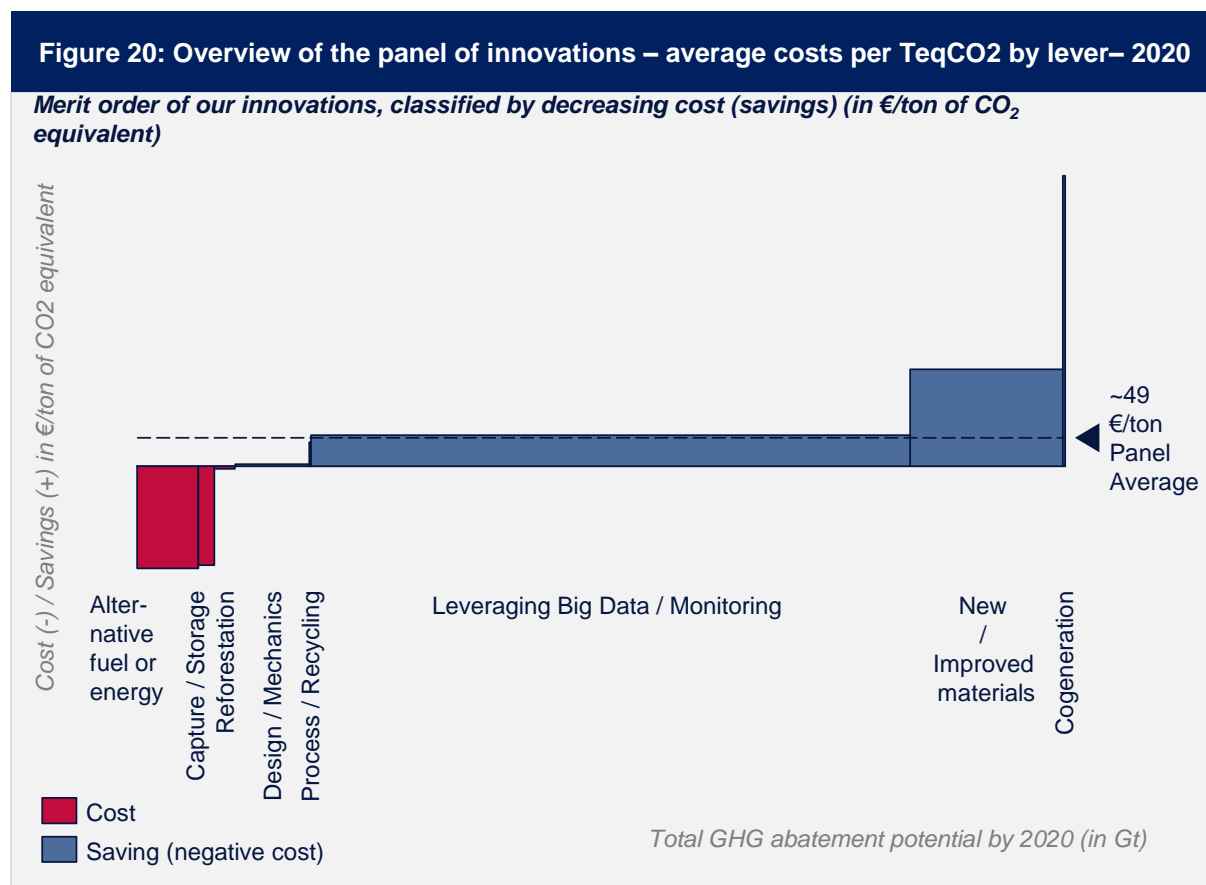


<sup>23</sup> These solutions bring co-benefits like reducing the time lost in traffic jams, which bring no extra revenue. If customers of such innovations were compensated for these co-benefits, the profitability of these solutions would increase significantly.

<sup>24</sup> In the economic literature, positive externalities refer to the benefits some economic agents can bring to others without being compensated for them – like reducing CO<sub>2</sub> emissions or carbon capture.

## Merit order by emissions reduction driver

**Cogeneration** shows the best profitability, followed by **New / Improved materials**. The potential of **Leveraging Big Data / Monitoring** is also significant. The **Alternative fuel or energy** and the **Capture / Storage** levers are not profitable, but still affordable on average. Solutions in this category are less mature than other ones, and still need investments to reach a better cost position: as of today, much less was invested in carbon capture than in improvement of fuel engines or in optimization algorithms.



## Going beyond merit orders

Merit order curves have been largely used in discussions on climate technologies – including in the present report. They are useful tools to rank the “average” potential efficiency of climate technologies, but show several limitations that should be taken into account by policymakers:

- They only give an average view, which might lead to erroneous conclusions depending on the subset on which this average is calculated. For example, in our panel, new designs / mechanics appear profitable “on average”, but include both profitable and not profitable cases: judging all the technologies on this “average” would miss the fact that some are very profitable.
- They are calculated on standard conditions – some innovations might not be competitive in these standard conditions, but very efficient in other situations. For example, the cost of photovoltaic energy production varies significantly according to the other alternative energies available locally and the level of sunlight.

- Technology might evolve very quickly – for example it has been the case for offshore wind or photovoltaic energy production.

Therefore, policymakers should probably avoid trying to “judge” a technology on the average cost of its category and should rather focus on clarifying the calculation methodologies and the reference value per ton of CO<sub>2</sub>-equivalent a technology must reach to be considered viable in a specific context.

#### e. What prevents a large distribution of our panel’s innovations?

*This section describes the roadblocks mentioned by the companies of our panel. A more systematic analysis of all the possible roadblocks encountered by affordable green innovations, as well as a comprehensive list of associated policy recommendations, will be presented in part III.*

#### Typology of roadblocks mentioned in the panel

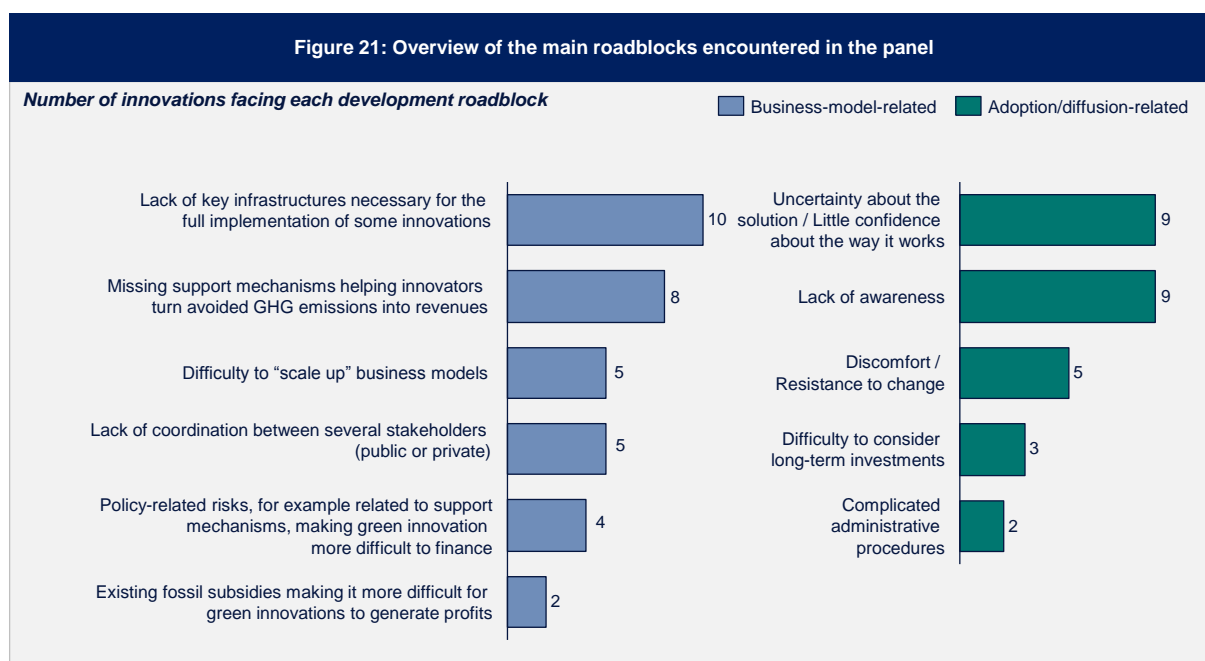
**Some roadblocks make the business model less viable.** They are conditions that make the profitability of these technologies less attractive, compared to their more carbon-intensive alternative. For instance, enabling demand response or some specific ancillary services provided to electricity grids requires the value of such services to be recognized and remunerated. The main economic roadblocks are:

1. Missing support mechanisms that would value the drop in GHG emissions and turn it into revenues;
2. Difficulties to scale up business models to reach large and global markets;
3. Lack of key infrastructures necessary for the full implementation of some innovations;
4. Policy-related risks, such as regulation instabilities or other factors making financing more risky;
5. Lack of coordination between several stakeholders (public or private);
6. Existing fossil fuel subsidies making a green alternative less profitable.

**Other roadblocks relate to behavioral conditions or adoption costs.** Despite profitability consumers and businesses remain reluctant to adopt a new technology. This could be due to insufficient awareness and information on this new technology, uncertainty as to its long-term benefits, or aversive reactions to risks or changes in habit and lifestyle caused by the new product. The main behavioral roadblocks are:

7. Uncertainty about the solution / little confidence shown by potential customers regarding the new solution. Corresponding innovations typically needed a proof of concept or a “third-party” performance certification, in order for customers to be convinced of both their effectiveness and reliability;
8. Lack of awareness about the solution / need for a better communication: potential customers do not know the solution exists or ignore the amount of savings it would guarantee;
9. Discomfort or switching costs (real or anticipated) induced by the need to change habits / consumer reluctance to change;

10. Difficulty for some consumers (in particular in the B2C markets) to consider long term investments even though the business model is positive, unrelated to economic considerations;
11. Complicated or long administrative procedures.



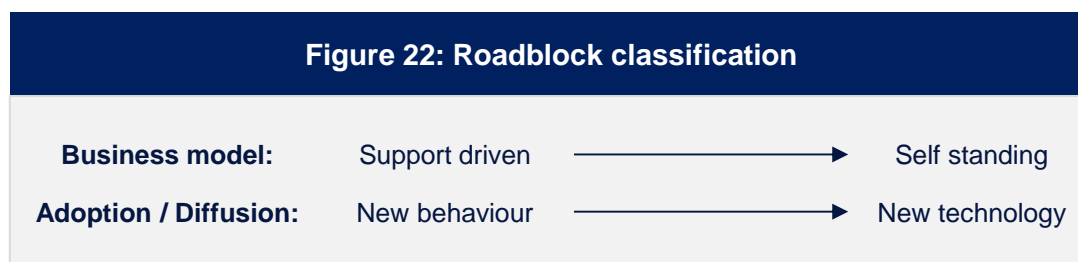
Lack of infrastructures – or difficult access to existing infrastructures – appears as the most common roadblock in our panel. For instance, in the power sector, many of the new services (e.g. demand response or storage delivering ancillary services to the grid) do not yet have a legal framework that enables the valorization of the corresponding services to the grid.

Another common roadblock is associated with the inherent degree of uncertainty faced by consumers when they adopt new products. For example, for electric or CNG vehicles, users often do not feel fully confident that their usual transportation needs will be met, and that the new solution is safe enough. They also do not precisely know what will be the resale value of the vehicle in the secondary market.

Third, the next most common roadblock is related to the fact that support mechanisms are usually limited in scope and in space. It is very difficult to scale up a first success into an international development, due to the fact that reducing carbon emissions is not valued consistently across borders.

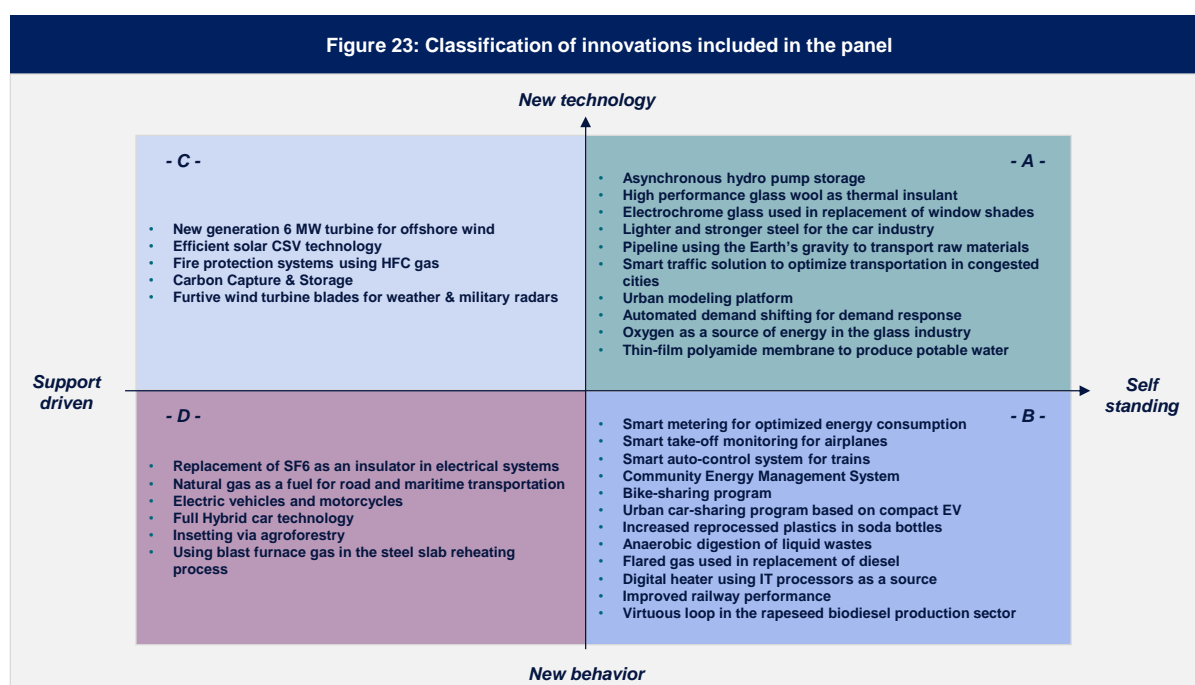


## Typology of innovations included in the panel



**“Self-standing” innovations** are profitable for both end-users and producers, compared to the existing solution they replace. “Self-standing” innovations account for the largest share of the panel. Conversely, **“Support driven” solutions** need a support mechanism to reach a positive business model. This does not mean that they need a “subsidy”: in a context in which GHG emissions are an “externality”, a support mechanism is not a subsidy but rather a “market price correction”<sup>25</sup> that allows final users of these products to benefit from the GHG reduction they are generating. Of course, following our definition of AGIs, the level of this support needs to stay reasonable compared to the level of GHG reductions allowed by this product or service.

**“New Technology” solutions** can deliver the desired outcome once implemented, and their impact is guaranteed and systematic. This is the case, for instance, for a more efficient airplane engine or an insulated window in a building: once installed, they contribute to reducing GHG emissions and their impact can be considered secured without further action. On the contrary, **“new behavior” solutions** require a significant adaptation effort, and their efficiency will depend on the user’s ability to change his behavior and/or environment.



This classification leads us to four main categories of green innovations, based on the kind of support needed to accelerate their development:

<sup>25</sup> See for example « Pricing carbon », OECD, Policy Perspectives, 2013.

### **(A) Self-standing innovations based on new technologies**

**Self-standing innovations based on new technologies (A)** should expand relatively quickly depending on how positive their business model is. Such innovations are for example the high performance glass wool insulant or the cogeneration solution. Most of the corresponding innovations do not require public support and only face “light” roadblocks such as:

- 1- Lack of key infrastructures required for full implementation;
- 2- Low awareness / information about the solution;
- 3- Complicated administrative procedures.

For instance, some low-carbon construction materials are in this category: many users (especially individuals) do not evaluate or monitor their performance. As a consequence, user awareness of the benefits of better carbon efficiency is low, which makes it difficult for professionals in charge of developing new projects to push for these solutions.

### **(B) Self-standing innovations depending on new behaviors**

**Self-standing innovations depending on new behaviors (B)** require significant and sustained behavioral or system changes. Typical examples include IT solutions designed to optimize the fuel efficiency of trains: train drivers will have to adapt their habits to this new tool before they increase efficiency. Efficient buildings are another example: they contribute to reducing costs of energy overall, but might not lead users to consume less. On the contrary, increased consumption is often observed in a rebound effect as consumers adapt their behavior to lower energy costs. The main roadblocks faced by such innovations in our panel are:

- 4- Lack of key regulations necessary for the full implementation of some innovations (for instance, absence of legal framework for demand response, automatic demand shifting or EV car sharing, ...);
- 5- The risk that customers increase their overall consumption due to a difficulty to adapt their behavior in the long run;
- 6- Uncertainty about the solution, little confidence about the way it works or need for a “proof of concept”;
- 7- Absence of coordination between stakeholders and “chicken and egg” problems. A typical example for this is the development of gas mobility: even if this solution can be cost effective without any specific support, the suppliers of charging stations need enough cars on the road to develop large charging station networks, and potential car users need large station networks before considering gas mobility.

### **(C) Support-driven innovations based on new technologies**

**Support-driven innovations based on new technologies (C)** are innovations whose business model is not profitable in the absence of revenue related to the reduction of GHG emissions. Typical examples might include renewable energy, carbon capture and storage solutions, or fire protection systems using HFC gas. Developing such solutions requires a public support mechanism, which makes sense from an economic point of view as long as the support needed is “affordable” (i.e. the cost per ton of CO<sub>2</sub> avoided remains low). Corresponding roadblocks for these innovations in our panel are:

- 8- Lack of an adapted support mechanism or limited stability of such mechanisms;
- 9- Increased risk profile and difficulty to finance, in particular caused by unstable policies / lack of visibility provided by public authorities over the lifetime of projects (on carbon prices, on feed-in tariffs, on capacity targets, etc.);

- 10- Difficulties to scale-up because support mechanisms are different from one country to another, making the international development of such innovations more difficult.

**(D) Support-driven innovations based on new behaviors**

**Support-driven solutions based on new behaviors (D)** are the most challenging innovations since they cumulate most of the above-mentioned roadblocks.

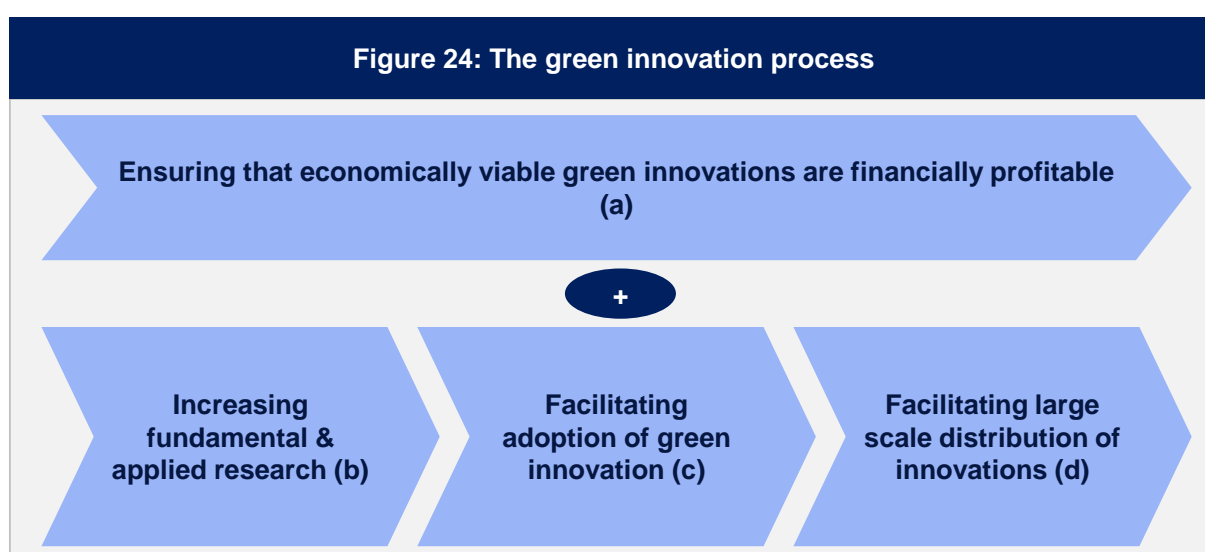
This is the case for electric vehicles (EV), which require upfront investments (infrastructure or vehicle cost) and behavior changes, while adoption appears risky (risk of running short of supply, resale value uncertainties, aftersales services availability, etc.).

## Part III – Policy recommendations<sup>26</sup>

*This section analyzes all the possible roadblocks that can hamper the emergence of affordable green innovations (AGIs), using both the cases studied in part II and a “systemic” view of how innovations are developed by companies. Then, we suggest a large set of policy recommendations which not only address each of the roadblocks but also make sense from a general interest point of view.*

### Preamble: How to accelerate innovation? A “systemic” view.

In order to cover all of the roadblocks hampering the development of AGIs at the largest possible scale, we first analyzed every step of “the green innovation process”<sup>27</sup> (see chart hereunder) through which green innovations go before reaching a large number of customers on a global scale:



- First, **innovation opportunities must be profitable**: no innovation will grow significantly if it entails a monetary loss. Our definition of AGIs implies that they are “economically viable”<sup>28</sup> because they reduce carbon emissions at a cost per ton of CO<sub>2</sub> that is lower than the “economic value” of CO<sub>2</sub>. By definition, this means that they “add value” economically speaking, because they can “extract” GHG from our economy at a cost that is lower than the value of the reduced gases. However, being economically viable does not necessarily mean being financially profitable, for a number of reasons developed in the following pages. For such reasons, we need adapted policies dedicated to ensuring that AGIs can be financially profitable.
- To ensure that as many economically viable green innovations as possible are discovered, potential innovations will have to go through three consecutive steps:
  - Undertaking **fundamental or applied research** that could lead to their discovery ;
  - Designing a product or a service and having it **adopted by early customers** which will confirm the potential of the innovation;

<sup>26</sup> These recommendations are based on a large number of sources, including the main existing reports on climate change and green innovation, discussions with experts and a detailed analysis of the innovation case studies presented in this report. All these recommendations aim at accelerating the development of AGIs in a general interest perspective, ie one that makes economic sense for citizens as well as taxpayers.

<sup>27</sup> The innovation process view is, of course, a simplified view: innovation is generally not a linear process.

<sup>28</sup> See box next page.

- Distributing the innovation **at the largest possible scale** in order to maximize the amount of global carbon reduction.

### Economically viable or financially profitable ?

A solution is **economically viable (or makes economic sense)** if the economic value of its benefits is higher than the economic cost of producing and operating it (including the cost of financing). For example, if the economic value of reducing emissions by one ton is estimated at \$50, a road that reduces emissions by one million tons of CO<sub>2</sub> over its lifetime which costs \$15 million is economically viable, because the value of its benefits (\$50 million = \$50 per ton of CO<sub>2</sub> multiplied by one million) is higher than its cost (\$15 million). **A solution can be economically viable, but not profitable:** in this example reducing CO<sub>2</sub> has an economic value, but does not generate revenue (unless, for example, a public support mechanisms exists that pays a sum equal to the value of the carbon reductions).

A solution is economically profitable if the sum of the revenues attached to it is higher than the cost of producing and operating it (including the cost of financing). This notion is relatively common: it means that it is possible for the producer and the user of the solution to increase profits. **A solution can be financially profitable, but not economically viable:** for example a noncompetitive energy intensive industry with profits solely guaranteed by the fact that it uses a highly subsidized fossil fuel is not economically viable, because the sum of its cost is lower than the sum of its benefits after taking into account the negative economic value of its emissions and the “true” economic value of its fuel, without subsidy.

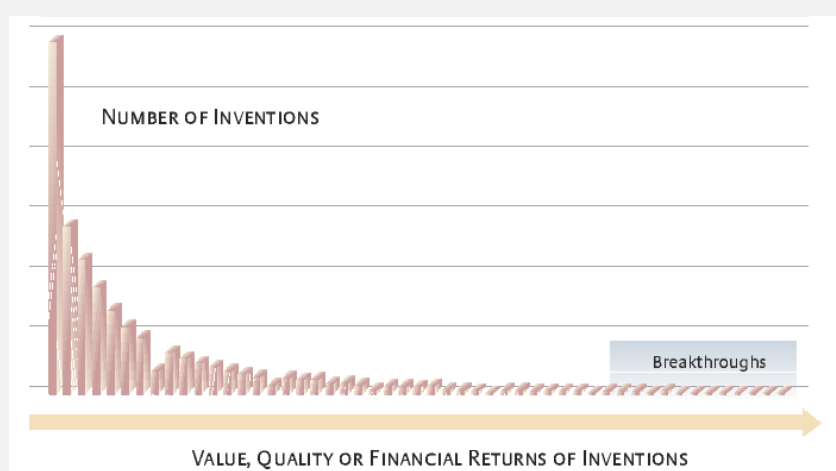
This “process approach” represents how companies consider innovation opportunities. They will not start any project unless they are sure to succeed through all the steps of the process. As a consequence, green innovation approaches focused on some recommendations or on specific parts of this process but ignoring others will probably not be effective.

To be sure, this process is a schematic view: in practice, innovation is not necessarily linear, and some innovations will skip specific steps (for instance, fundamental research). In fact, the innovation process is partly random and highly complex, and this has several policy implications (see box).

## Innovation policy: supporting big bets and unleashing the power of the multitude

Empirical data shows that innovation returns are usually distributed following a “highly skewed” curve\*, in which a few “breakthroughs” will bring very high returns and the majority of the innovative investments will bring low or negative returns. This phenomenon is larger than green innovations, and has been observed for a large scope of creativity-based activities\*\* (e.g. science, film making, book writing). If a better selection or a better execution of projects can contribute to improving the number of innovative and profitable projects, the shape of the curve itself cannot be changed. This means that before finding great innovations, many projects will be launched, but with only a small percentage of them proving successful.

**Figure 25: Typical distribution of invention returns**



Source: *Breakthroughs and the “Long Tail” of Innovation*, MIT Management Review, Fall 2007

This brings several policy consequences, for example:

- Many research or innovation support programs will show disappointing results in most cases, balanced by huge successes in a few cases. In other words, the price to pay to find breakthrough technologies is to explore many options, most of which will fail ;
- Policies focused on a small numbers of national champions or trying to “pick winning technologies” too early will not bring enough diversity\*\*\*. They must be complemented by strategies aiming at “unleashing the power of the multitude”, such as open innovation strategies;
- Research might bring disappointing results for long periods of time before a breakthrough technology appears\*\*\*\*. Unless public research or support mechanisms help sustain the level of R&D investments, this might lead to under-investment and significant “stop and go’s” since companies will adjust their spending to the results of their R&D.

\*See G. Silverberg & B. Verspagen, *The size distribution of innovations revisited: An application of extreme value statistics to citation and value measures of patent significance*, Journal of Econometrics, 2006 or D. Harhoff & al., *Exploring the tail of patented invention value distributions*, ZEW Discussion Papers, 1997

\*\*See for example M. E. J. Newman, *Power laws, Pareto distributions and Zipf’s law*, Contemporary Physics 46, 323-351 (2005)

\*\*\*See F.M. Scherer & Dietmar Harhoff, *Technology policy for a world of skew-distributed outcomes*, Research Policy, 2000.

\*\*\*\*See D. Sornette & D. Zajdenweber, *Economic returns of research : the Pareto law and its implications*, European Physical Journal B, 8 (4), 653-664 (1999).

## Main recommendations

This is a summary of the main recommendations detailed in the following pages. As mentioned earlier, this is an interdependent set covering all the steps of the innovation process: failing to implement one of them might cause the rest of the recommendations to be much less effective.



### **a) Ensuring that economically viable green innovations are financially profitable:**

#### **a.1) Giving a clear value to the reduction of emissions**

- 1) *Providing adapted tools and methodology guides to estimate carbon emissions reduction*
- 2) *Defining a long term reference value for the price of carbon so that all innovators can easily assess the long term affordability of their project*
- 3) *Dealing, if needed, with the existence of adjustment costs or jobs concerns for GHG emitting industries (cement, fossil fuels,...) using a “dual carbon pricing strategy”*

#### **a.2) Facilitating the integration of innovations**

- 1) *Ensuring that infrastructure investment decisions value carbon reductions*
- 2) *Valuing infrastructure's role as “innovation catalysts”*
- 3) *Ensuring an efficient risk allocation and avoiding “anti-economical” risk transfers*

#### **a.3) Developing green finance and innovative financing tools**



### **b) Increasing fundamental and applied research:**

#### **b.1) Aligning stakeholders and technological potential**

- 1) *Aligning public R&D resources with ambitions*
- 2) *Organizing technology roadmaps discussions on a regular basis*
- 3) *Coordinating stakeholders when many of them share the benefits of one innovation*

#### **b.2) Increasing research collaboration**

#### **b.3) Developing specific R&D incentives taking into account R&D spillover effects**



### **c) Facilitating the adoption of green innovations:**

#### **c.1) Increasing customer information on technologies**

- 1) *Encouraging long term approaches for public procurement*
- 2) *Improving information on benefits, risks and risks mitigation options*

#### **c.2) Adopting plans based on technology roadmaps**



### **d) Facilitating large scale distribution of innovations:**

#### **d.1) Sharing Best Available Technologies by sectors and regions**

#### **d.2) Keeping strong Intellectual Property Rights (IPR) to maintain high incentives for innovators**

#### **d.3) Extending Environmental Goods agreements (EGA)**



## a. Ensuring that economically viable green innovations are financially profitable

*Our definition of AGIs incorporates the notion that these innovations “make economic sense”: they reduce carbon emissions at a cost per ton of CO<sub>2</sub> that is lower than the “economic value” of CO<sub>2</sub>. However, being economically viable does not necessarily entail financial profit, unless specific mechanisms are implemented.*

### Main roadblocks identified

#### **There is not always a clear methodology to assess carbon emissions and emission reductions.**

A number of methodology guides do exist<sup>29</sup> but they need to be adapted to local contexts such as variations in carbon value of avoided kilowatt-hour. Moreover, they must be translated into simpler tools targeted for a larger scope of companies (especially smaller ones) and public decision-makers, to give them easy ways of assessing whether an innovation can potentially make sense or not.

**There is no clear reference value for avoided carbon emissions.** Innovators do not base their business models on tons of CO<sub>2</sub> equivalents, and need to translate avoided emissions made possible by their innovation into an estimate of the economic value of these reductions. For this they need a long term “reference value” for avoided emissions, so that they are able to know if their project has any chance to “produce” GHG emissions at a cost that is low enough to makes economic sense. Even if some countries do not translate this reference value into policies like carbon pricing in the short term, it would give a “long term guidance<sup>30</sup>” on carbon costs, which would make planning long term innovations much less uncertain.

**Support mechanisms do not cover all technologies and innovations.** As noted in part II, some innovations are “self-standing” and do not require a carbon price to be profitable. However, all the studies conclude that such innovations will most probably not bring sufficient emission reductions to reach the 2°C target. Hence, we will also need additional solutions which reduce carbon emissions with a cost, while still making economic sense<sup>31</sup> - which means that they are “affordable”.

By definition, these innovations will not be profitable without a support mechanism that turns avoided carbon emissions into revenues. In practice, such support mechanisms do not cover every possible innovation (they are often focused on energy production technologies) and are rarely technology neutral (their level per ton of CO<sub>2</sub> varies depending on the technology used). Of course, public money is scarce but support mechanisms focused at very affordable innovations would cost less for a given amount of emissions reduction.

**Even in the cases where public support mechanisms exist, there are significant disparities in the level of incentives across countries.** Developed countries use different incentive structures or levels, and varying policy tools to support green innovations. In many other parts of the world there are no incentives at all. Even within Europe, there is a large and diverse set of support mechanisms. Consequently, it is difficult for an innovator to imagine a unique business model that turns an emission reducing idea into a profitable solution for a large market. This will both slow down the growth of green innovations, and give innovators in smaller countries a competitive disadvantage; because they will have to take into account multiple support mechanisms in order to “scale up” their innovation.

**Innovators in some countries have no option to find a support mechanism to make their innovation profitable.** This is especially the case in the less developed countries. As a result, innovation capabilities (like context specific knowledge, or the ability to use local distribution models) in these countries will be underused, or not used at all. One should not think that these countries only

<sup>29</sup> See box “Greenhouse gas emissions reductions: how are they calculated?” in *part I- Greenhouse Gases emissions: current status and future efforts*

<sup>30</sup> Making such a “reference value” public is an easier step

<sup>31</sup> i.e., when the cost of using the innovation per ton of CO<sub>2</sub> avoided is lower than a reference value.



need “second hand” technologies already developed in other countries: “leapfrogging”<sup>32</sup> can sometimes make it easier to develop some innovations in emerging countries (e.g. the Kenyan M-PESA mobile payment system, which reduces the transaction costs of cash). With “reverse innovation”<sup>33</sup>, products first created for emerging markets (who needed lower costs or “rugged” products), were later successfully distributed in developed countries. Last, the best way to secure a globally strong intellectual property<sup>34</sup> system is to ensure that there are enough intellectual property owners in each region of the world.

**Access to key infrastructures can be a real challenge.** Some innovations make sense in theory but need to be integrated into existing infrastructure. For example, smart demand response solutions can reduce emissions by lowering the electricity demand when it is produced with a large share of fossil fuels. However, to turn this theoretical economic model into a profit, innovators will need some type of mechanism that lets them get a profit from the benefits they bring to the overall system.

**Green innovations sometimes bear unnecessary risks related to uncertainties in the design of support mechanisms or, more broadly the context offered to green investments.** These risks make green innovation harder to finance, or even less attractive than other opportunities (like medical or information technology investments).

The most obvious risks are support mechanism changes, grid connection delays or regulation complexity: in most countries, there have been frequent changes and significant uncertainties during the last years.

Other risks are related to the design of support mechanisms. For example, a fixed tariff makes renewables projects much easier to finance than a premium over electricity market prices, which will fluctuate over time and expose renewable energy producers to market risks that might prove difficult to finance. Estimates show that using **a feed-in tariff rather than a feed-in premium can reduce financing costs by 4 to 11% on the electricity price**<sup>35</sup>.

**Better financing can improve the profitability of green projects.** Many green projects are subject to high financing costs related to the uncertainty of the development phase, whereas they have a much lower risk profile during the operating period. For instance, there are many risks associated to developing a wind farm (permit and grid connection delays, wind turbines installation and testing, etc.). On the other hand, a mature wind farm associated with a fixed feed-in tariff will generate stable cash flows. Thus, **having the ability to separate the project financing of development phases from investments in mature projects** helps raise additional money on mature markets projects, and in turn increase the funds available for the risky development phases of green innovations.

**Some innovations are financially viable only after taking into account “co-benefits”, i.e. benefits other than GHG emissions reduction.** For instance, green mobility solutions like gas mobility reduce CO<sub>2</sub> as well as fine particle<sup>36</sup> emissions. Another example is benefits related to congestion: time lost in traffic can be very high (up to 1% of GDP<sup>37</sup>). A better urban design allows drivers to avoid peak times: fine particle emissions will be reduced, as well as the number of hours lost in traffic. These are valuable “co-benefits”, but they will bring no revenue unless a specific scheme is

<sup>32</sup> Leapfrogging is a concept used when developing countries skip less efficient technologies and move directly to more advanced technologies.

<sup>33</sup> See for example “The Case for ‘Reverse Innovation’ Now”, Business Week, October 2009.

<sup>34</sup> This is key to secure innovators’ profits, see further in this chapter.

<sup>35</sup> Climate Policy Initiative (CPI), Policy impacts on financing of renewables (p5), 2011

<sup>36</sup> According to the United States Environmental Protection Agency (EPA), “small particles less than 10 micrometers in diameter pose the greatest problems because they can get deep into your lungs, and some may even get into your bloodstream”. Source : <http://www.epa.gov/airquality/particlepollution/health.html>

<sup>37</sup> See OECD Economic Surveys: Netherlands 2010, page 89.

implemented. Some “almost affordable innovations” will need a way to value these co-benefits<sup>38</sup> to be really “affordable”.

**Finally, fossil fuel subsidies make green innovations less attractive than they should be.** According to the International Energy Agency’s 2014 Energy Technology Perspectives report, “fossil fuel subsidies were more than five times higher than renewable energy subsidies in 2012 with \$554 billion fossil fuel subsidies versus \$100 billion”<sup>39</sup>.

## Solutions

### *a.1) Giving a clear value to the reduction of emissions*

#### **1) Providing adapted tools and methodology guides to estimate carbon emission reductions**

Estimating both the level of carbon emissions and the reduction of carbon emissions can be relatively complex and requires precise methodologies. Such methodology guides exist at the global level<sup>40</sup>. However, they could be completed by methodologies adapted to local or industry specific needs. Such guidelines would be useful to provide information adapted to a local context (e.g. carbon content of the electricity mix, average emission per kilometer traveled, etc.). Moreover, existing guides are usually relatively complex, while simpler forms might be better adapted for non-specialist government decision takers (e.g. in local government).

These guidelines also need to be adapted to small companies or even students considering a climate project, to help them assess the carbon impact of their technologies. Existing methodologies have often been developed for scientific or regulatory<sup>41</sup> purposes, but not to give potential innovators a clear signal of what makes economic sense or not in their local context. Simpler tools, while staying consistent with more detailed methodologies, would provide a quick method for verifying if one idea is affordable now or in the near future.

#### **2) Defining a long term reference value for the price of carbon so that innovators can quickly assess the long term affordability of their project**

Innovators need both methodologies to assess the level of emissions reductions and a “value for carbon”, which tells them the “intrinsic value” of their emissions reductions<sup>42</sup>. This “intrinsic reference value” is not what is sometimes called a “carbon price”. It is more a long term target for climate policies: even if policies vary in the short term or if different countries choose to implement carbon policies at different speeds or have sectorial priorities (e.g. developing renewable energy, or green mobility) or sensibilities (e.g. protecting coal industry against brutal adjustments) such a long term value is a very important tool on which long term plans could be “pegged”.

<sup>38</sup> Economically, it means setting a price on positive externalities other than reducing GHG emissions.

<sup>39</sup> [http://www.iea.org/publications/freepublications/publication/Tracking\\_clean\\_energy\\_progress\\_2014.pdf](http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf)

<sup>40</sup> See box “greenhouse gas emissions reductions: how are they calculated?” part II.

<sup>41</sup> For example in the context of the implementation of emissions norms or of schemes like the European ETS.

<sup>42</sup> From an economic point of view, the cheapest way to leverage innovation is to ensure the discovery of all the possible ways (including the ones that we have to invent) to reduce carbon emissions, and then to extend each of these solutions as much as possible starting from the most affordable to the least affordable, until the carbon emission reduction targets are reached. In practice, it is not possible to know the cost of all possible innovations, and we can only estimate the “maximum cost per ton of CO<sub>2</sub>” that would be reached in the optimal strategy. Then, we can incentivize economic agents to invent and to develop technologies which cost less than the “maximum cost of CO<sub>2</sub>”. See box “What are affordable green innovations, and why do they matter?” in the introduction part of this report.

Unfortunately, such a “long term reference value” does not exist today, and carbon price estimates vary greatly among studies<sup>43</sup>. More research, as well as international consensus, will be necessary to provide a clearer target. This is a complex task, which implies defining, namely:

- the way national carbon markets are interconnected. Interconnected markets allow resources to be allocated in countries where the cost per ton of CO<sub>2</sub> avoided is the lowest. This contributes to lowering the CO<sub>2</sub> price target and the cost to tackle climate change, because more resources can be allocated where the cost of reducing emissions is the lowest. Of course, this market interconnection is only possible with a certain level of coordination as well as common and reliable methodologies to assess carbon emissions reductions ;
- the scope of GHG and the emitting sectors considered (the larger the scope, the lower is the target price because efforts will be spread on other gases than CO<sub>2</sub>). For practical reasons some carbon emission sources (like stock farming in very poor countries) are not easy to control and might be excluded.

However, what is needed is a commonly accepted<sup>44</sup> order of magnitude, applicable to the main innovation sectors and stable over time and that can be an efficient guide to innovation. As a result, any innovator will be able to quickly estimate if an idea makes sense, or if he still has to reduce costs before reaching an acceptable cost per ton of CO<sub>2</sub>.

Combined with clear methodologies and the industrial policy matrix presented later in section b, such a reference value would provide much better clarity on both the desired innovation and the appropriate policies to support them.

As mentioned in the beginning of this section<sup>45</sup>, stimulating green innovation implies dealing with both a few large key projects and a “multitude” of smaller innovations. Large projects can be supported on a “case by case” basis. On the other hand, smaller projects are too numerous to be dealt with individually, and often involve companies which do not have an easy access to decision-makers or regulators. These companies will be the ones benefiting the most from having public and clear information available.

### **Pricing carbon implicitly or explicitly**

A carbon reference value is useful to estimate if an innovation makes sense from an economic point of view but does not bring revenues. Innovations that are not “self-standing”<sup>46</sup> will require a way to turn carbon emission reductions into revenue in order to be profitable.

The appropriate way to “price carbon” depends on both the product and the context (see box “Standards or price mechanisms?”). This can be done explicitly by providing revenues to solutions that reduce emissions or by increasing the costs of large emitters. It can also be done implicitly, by setting a standard that leads customers to use products that reduce emissions.

In this report, even if we sometimes use the terms “carbon price” or “support mechanism” for the sake of simplicity, we take no side in the debate about what kind of pricing mechanism should be preferred. Our only message is that governments willing to reduce global GHG emissions at the lowest possible cost while stimulating affordable innovations should focus their efforts on policies incentivizing the most affordable solutions.

<sup>43</sup> Estimates for what should be the price for CO<sub>2</sub> vary a lot – for example OECD’s “Pricing carbon, Policy Perspectives” (2013) average estimates vary from 24 to 114\$/ton of CO<sub>2</sub>.

<sup>44</sup>For example, several reports seem to consider an order of magnitude of 50 \$/ton of CO<sub>2</sub> as acceptable, which is the value we used in the present report for “affordable”.

<sup>45</sup> See box “Innovation policy: supporting big bets and unleashing the power of the multitude” at the beginning of part III.

<sup>46</sup> See part II.

From a green innovator's perspective, support mechanisms should:

- have a predictable level across time – the higher the uncertainties on the revenues derived from a support mechanism, the less this support mechanism can be taken into account in business plans without a high discount;
- be outcome based, i.e. focus on reaching an affordable cost per ton of CO<sub>2</sub> rather than implementing a specific technology. In practice, it is rarely the case - for example, it is possible to estimate “implicit carbon prices” based on existing renewable feed-in tariffs (FIT). They usually vary a lot from one technology (e.g. wind, solar) to another, which makes reducing emissions much more expensive than using an “affordable technology” approach;
- be technology neutral or, at least, include the most promising emission reduction technologies – for example, technologies like power storage or electricity demand management could in theory get a support mechanism based on the avoided emissions;
- minimize the “complexity costs” (cost of complying with specific regulations, filing processes or standards, etc. ).

### 3) The existence of adjustment costs or job concerns for GHG emitting industries (cement, fossil fuels, etc.) can be dealt with using a “dual carbon pricing strategy”

A unique carbon price is difficult to fully implement in the short term because it imposes the same economic pressure to both “carbon-reducing” sectors and “carbon-emitting” sectors, the latter raising significant adaptation issues:

- **Carbon-reducing sectors** (e.g. renewables, green mobility) will benefit from giving a price to carbon: since they contribute to reducing emissions it will translate into a new source of revenue.
- **Carbon-emitting sectors** (e.g. energy intensive industries) will suffer from a carbon price approach because it will increase their costs. Governments also need to take into account the competitive implications of having strong constraints in some countries, and lighter ones in other countries. Ideally, emitting sectors need a carbon price set at a level they can afford which increases over time.

These requirements seem contradictory, but a unique carbon price is the addition of a “carbon benefit” granted to emission reducers and a “carbon penalty” aiming at emitters. In the long term, both should equal the “long term reference value” of carbon, but, for practical reasons, it is possible to treat the “benefit” and the “penalty” differently by implementing a “dual price” for carbon:

- A “carbon benefit” focused on emission reducing sectors. This benefit should be as close as possible to the target level for CO<sub>2</sub>, to give the innovator a “true” price signal.
- A “carbon penalty” focused on emitting sectors in order to lead them to reduce their emissions. The level of this “penalty” will increase progressively, at a speed reflecting the adaptation capacities of the sectors concerned by it. The starting level of these “negative incentives” might even be close to zero depending on the importance of the emitting sectors and the capacity of countries to achieve a fast climate transition. Even when starting from a low level, giving a clear target and a feasible path is a good way to support green innovations in emitting sectors.

In practice, this “dual pricing” strategy resembles what exists in Europe. Indeed, the ETS mechanism sets a moderate price for CO<sub>2</sub> limited to the 11,000 biggest emitters in Europe. It is combined with subsidies for renewable energy, which provide a support per ton of CO<sub>2</sub> much closer to the “target level” for CO<sub>2</sub> prices.

In fact, no country in the world has implemented a “unique” carbon price – i.e. the same price for all possible emitting sectors – but many are using tools that define carbon prices on specific markets. For instance, the Australian carbon pricing scheme, repealed mid-2014, was limited to emitters over 25,000 tons of CO<sub>2</sub> per year, excluding the agriculture and transportation sectors.

### Standards or price mechanisms?

There are two ways to drive the economy to reduce its emissions: either by enforcing standards that oblige households and companies to use lower emissions technologies, or by using a “market approach”, giving carbon emissions a price, which provides emitters and innovators with incentives to develop innovations that reduce emissions.

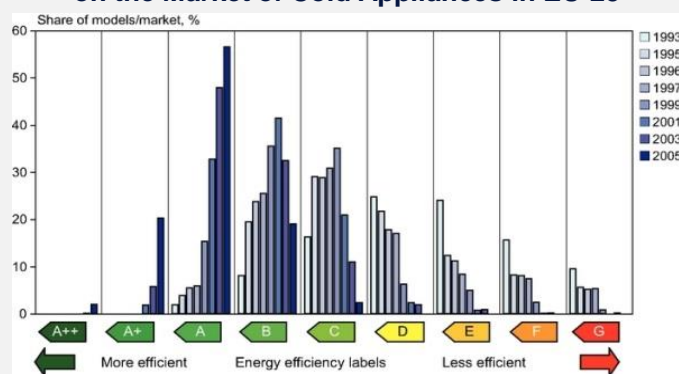
The second approach might give a larger role to innovation. Conversely, a model based on standards will generally need to define more precisely the technologies accepted and new solutions or new ways to reduce emissions will need a new regulation to be issued. This can be a problem for sectors in which innovators are small or have no access to regulators or where technologies evolve faster than top-down regulations.

It is easier to take into account a carbon price than a norm in a business model: any ton of CO<sub>2</sub> avoided will bring additional revenue and will make the innovation more competitive. Such an “economic approach” is also generally preferred to change the behavior of “economically rational agents” (companies or individual for which carbon emission is such a big issue that they will make calculations and adapt their behavior if needed). For example, airlines buying plane engines or industrial companies buying carbon emitting equipment will make their choice based on the full lifetime cost of ownership, including fuel savings and carbon related revenues.

Carbon trading schemes offer a good route to scale up carbon pricing on a global scale. There have already been promising moves to develop schemes and link existing ones. Carbon trading enables emission reductions to be made in the most cost-effective locations and sectors, allowing the direct transfer of resources to incentivize innovation and investment. A European Commission report estimated that global carbon trading could lower the cost of emissions reductions by up to 50% - from 1% of global GDP.

On the contrary, regulations are preferred for less “analytical” emitters (which might agree to reduce their emissions, but do not want to make the calculations to find what they should do, especially when buying small products). For instance, most of us will not calculate the lifetime cost of energy and carbon cost when buying a fridge, but labels informing customers about the more ecofriendly products had a positive impact on sales.

**Figure 26: The Impact of the EU Appliance Label on the Market of Cold Appliances in EU-25**



Labels A++ to G, G being the least efficient.

Source: CECED, 2005



## *a.2) Facilitating the integration of innovations*

### **1) Ensuring that infrastructure investment decisions value carbon reductions**

Efficient or new infrastructure contributes to reducing GHG emissions, but this benefit does not appear in a purely financial business model. To ensure that the contribution of infrastructure projects to GHG reduction is correctly taken into account, infrastructure investment decisions need to include “shadow carbon revenues” and “shadow carbon costs”, based on the long term reference value of the ton of CO<sub>2</sub> previously mentioned.

#### **Shadow price**

A shadow price is not a “price” per se, but rather an economic estimation of a price that should be paid for (or incurred) and helps account for economic impacts/effects not integrated in traditional market prices. This concept can be used to ensure that economic agents take into account the impact of “externalities” they are causing to other agents, by forcing them to include in their costs (or their revenue) an economic estimate as if it was a real financial flow. For example, shadow rents are sometimes used in the public sector to guarantee that administrations using publicly owned buildings do not use a larger surface than they would if they had to pay a real market price rent.

#### **Example of infrastructure carbon benefits: grid modernization**

Smart grid technologies include network management software and telecoms, power electronics (e.g. HVDC lines, Flexible AC Transmission Systems), substation automation, switchgear and power transformers. When applied together with smart generation, electricity interconnectors, back-up capacity, storage options and demand side response, smart grids can open up new possibilities in managing power supply and demand, and can greatly increase the system’s resiliency as well as its carbon emissions.

Smart Grids are key to optimizing generation and transmission, increasing renewables penetration, and minimizing losses. The relevant investments are usually subject to public investment decisions, regulations or permitting rules.

### **2) Valuing the role of infrastructure as “innovation catalysts”**

Some innovations reduce emissions by optimizing other equipment or devices sharing the same infrastructure. It is the case for remote payment devices on highways, power storage facilities or electricity demand management equipment and software. They can play a key role as “innovation catalysts” because, if designed for this purpose, they can facilitate the creation of future innovations.

However, this is not necessarily the case: for example, depending on their specifications and the ability of innovators to connect to them, smart meters can open the way to further innovations, or not. Pricing is another issue: innovators need to be able to connect to existing infrastructures at a reasonable price. In parallel, they must be fairly remunerated for the emission reductions they bring.

The design of this pricing can be relatively complex, because what is needed is a new way to incentivize green innovations while fairly treating existing players. For instance, the addition of renewable energy capacities in Europe made developing renewables a dilemma for large utilities: because of an improper market design (mainly, the absence of “capacity payments<sup>47</sup>”), they lost

<sup>47</sup> Capacity markets are support mechanisms granting flexible electricity capacities a revenue for their ability to potentially supply electricity when demand exceeds offers, for example when demand is high and the absence of wind or sun reduces the electricity production.

money each time renewable capacities were added to the grid. Large utilities were initially well positioned to contribute to the renewable energy targets. However, because of the market design, they were put in a situation in which they were not fully incentivized to develop renewables, since it meant lower profits for their existing capacities (see box).

### Renewables and flexible capacities: friend or foe?

The development of renewable energy in Europe led to a situation in which flexible energy production capacities (e.g. thermal energy capacities) started being used during shorter hours, only when wind or solar energy produced no electricity. This turned into a financial problem for utilities, because the initial business model for these flexible capacities were based on a different context in which they were supposed to be used – and generating revenues - for a larger number of hours. The situation became worst with the economic crisis, which reduced electricity demand to unexpected levels while, at the same time, new renewable capacities were added.

*De facto*, the market design opposed green and thermal technologies, instead of building on their complementarity. Renewables and thermal energy are not substitutable on a “one-to-one” basis, but are complementary: at today’s energy storage costs, every renewable energy capacity needs a “flexible energy production backup” to ensure energy production even in the absence of wind or sun. The electricity system needs to remunerate these “backup” capacities, ready to produce when demand needs them - in the opposite situation, flexible capacities will be “mothballed” (withdrawn from the grid) if they are not used for enough hours, and investments in new flexible capacities will be stopped. As a consequence, there will be blackouts in the middle term.

The energy market had an imperfect structure because it only remunerated energy production. Instead, it should also have remunerated energy capacity, i.e. the potential ability to provide energy when required. Therefore, it was not the development of renewables itself which was problematic, but rather the imperfect design of the electricity market within which they operated. This imperfection translated into significant losses for utilities with thermal capacities. Consequently, the development of renewables became a dilemma for these big energy companies because the more renewables were added, the less their existing thermal capacities were used, thus increasing their losses.

A market design remunerating capacities able to respond to demand peaks on a competitive basis would have been more favorable to the development of renewables.

The management and regulation of existing infrastructure is often optimized for efficiency rather than accelerating possible innovations. Stimulating innovation is not necessarily a priority for infrastructure regulators, and access to infrastructure and its pricing is often suboptimal from an innovator point of view.

The architecture of infrastructure should also take into account a “new paradigm”: consumers will increasingly be “prosumers”, injecting energy or adapting their demand according to prices. This will lead to a completely different way to manage energy, and requires new standards and regulations. Infrastructure as “innovation catalyst” should also be a stronger priority for regulatory authorities.

Investment decisions are usually based on a cost-benefit analysis. Most of the time, the benefits associated to innovations made possible by this infrastructure are not included in this analysis. This makes the cost-benefit analysis less favorable than it should be, and does not value the design options that would ignite the largest number of innovations. This could be corrected by estimating the value of potential innovations based on the existence of a new infrastructure. For example, smart grid investments or the roll out of smart meters will bring new data on energy consumption behavior, and open new ways of matching demand and production. The volume and nature of this data, as well as the ability of third parties to access it, will differ if the project is designed to fulfill the basic needs of distribution networks or to maximize the future innovation potential.

### 3) Ensuring an efficient risk allocation and avoiding “anti-economical” risk transfers

Renewable energy companies face different kinds of risks when developing their projects:

- Some uncertainties can be reduced or eliminated (like regulation complexity, unexpected tariff changes, etc.)
- Some risks can be controlled – like the performance level of a wind turbine. These risks should be allocated to the company best positioned to control them (usually the turbine operator and/or its supplier via a maintenance contract)
- Other risks cannot be avoided or reduced, but should be “pooled” at the appropriate level so as to minimize their costs. Such are risks related to the energy demand, or to market energy prices or to weather conditions, for example.

In order to reach the highest possible efficiency, and to reduce costs, innovators and green project developers should<sup>48</sup> only bear risks they can assess or manage the best, while leaving the rest to more competent parties. This is particularly true when smaller companies are involved, with limited possibilities to finance or pool complex risks.

For instance, a small operator installing a limited number of wind turbines has little control over electricity market risks. He will have more difficulties financing his projects if he fully bears the electricity market price volatility, than if he is remunerated on the basis of a fixed feed-in-tariff.

This can lead to a situation where small wind farm operators disappear, and the wind electricity potential is reduced to areas attractive for very large operators only. It will also increase the cost of producing electricity, because of increased financing costs. On the contrary, a feed-in-tariff limiting the risk exposure to what operators can best manage (e.g. wind level, number of hours of production per year) will be less expensive.

#### Supporting renewables: tariff or premium?

##### ***Feed-In-Tariff (FiT)***

A FiT regime is a support mechanism which offers a fixed price per kW, providing a fixed return to the producer. It is usually associated with a “grid priority”, which means that an income is guaranteed every day of the year, but this is not always the case.

##### ***Feed-In-Premium (FiP)***

A FiP mechanism provides a premium per kWh above market prices for electricity. As a result, the total revenue (market price + premium) is dependent on the market price for electricity whereas FiTs are independent of market prices.

### Ensuring green innovators from all geographic regions can find a path to profitability

#### Ensuring green innovations can find their way in all geographic regions

For historical and financial reasons, green innovation incentives are less developed in underdeveloped or emerging countries. While most of these countries do not have the possibility to implement large support mechanisms, ensuring that they have at least one form of support (feed-in-tariff or even a

<sup>48</sup> There are many reasons for this, like the law of large numbers (which state that the risk for a sum of risky projects is lower than the risk of one individual project) or the fact that market level risks are better anticipated and managed by market level operators with a long experience of electricity markets (like grid operators).



“carbon innovation support fund” aiming at valuing carbon emission reductions) would guarantee that innovation capacities are not left unused. Furthermore, it would increase the number of AGIs aiming at less developed markets where the cost per ton of CO<sub>2</sub> avoided is often lower than in developed countries.

### **Ensuring risk and risk mitigation technologies are debated on a factual basis**

Innovations bring benefits, but might raise new risks. One of the most debated examples today is perhaps shale gas, banned in several countries. Often this ban was decided without exhaustive and scientific information regarding the possible technologies which might reduce risks and the amount of available resources. This is also true of less publicly debated risks, such as the above-mentioned impact of renewables on thermal energy production capacity: renewables were sometimes wrongly accused of being the cause of these difficulties. In fact, very few pointed out the appropriate solution, which was to create capacity and flexibility markets.

The lack of discussions based on facts and data has many adverse consequences. It leaves room for irrational arguments, makes rational decisions politically difficult and increases the cost of fighting climate change. Moreover, technologies that could help reduce such perceived risks are neither evaluated appropriately, nor developed.

One way to change this would be to organize technology roadmap discussions on a regular basis. They should address not only benefits and risks, but also the available technological options to reduce these risks as well as the success factors needed to develop the most affordable innovations. Recommendations regarding technology roadmaps will be developed in section b.1.

### ***a.3) Developing green finance and innovative financing tools***

Today, for all the reasons outlined above, the risk/profitability profile of green investments is often unattractive. Thus, the issue is not yet about how to finance it, but how to ensure that such unnecessary risks or costs are reduced and that economic benefits are translated into revenues. This situation cannot be solved by financial innovation alone - we need to address all the policy issues mentioned in this report.

However, as policies improve, there will be an increasing number of economically viable innovations in search of financing. Since building a new “ecosystem” takes time, it is important to immediately start deepening the green innovation financing capabilities<sup>49</sup> and the funds ready to be invested in green innovations.

The first step in this direction is to implement policies that secure investor rights as well as capacities that can help attract investors:

- Policy/legal frameworks, e.g. rule of law, contract law, land ownership, foreign investment best practices;
- Financial services and institutions in place to ensure timely financial flows;
- Human capital, especially in investment related services.

Subsequently, public tools can be developed, like France’s “Grand Emprunt”, a €35 billion public fund launched in 2010 to finance general interest projects (including green projects). This fund invests in innovative companies, or enters into public-private R&D investment partnerships. It earns a market rate of profit based on a share of the future sales of the innovative products, while having the ability to take into account general interest considerations (like emission reductions) in their investment

<sup>49</sup> Ability to analyze green innovation investment cases, ability to advise green innovators to accelerate their development...

decisions. In emerging countries, Multilateral Development Banks, Export Credit Agencies and other International Financial Institutions will continue to play a pivotal role for the deployment of cleaner technologies and for capacity building.

Another way to increase the share of funds available for green innovations is to develop “green finance”: funds dedicated to green investments. They will aim at earning a market rate of profit, but are specialized in green investment, and are marketed to investors willing to invest in green technologies.

Furthermore, some green projects already have a favorable risk/profitability profile, like existing wind or photovoltaic farms benefiting from a long term fixed feed-in-tariff. “Yieldcos” allow owners of such projects to resell them to other investors, so as to focus on new projects development with higher risk. This increases the amount of money available for new projects while allowing risk-averse investors to participate in mature green projects.

### Innovative green financing

New vehicles for low-carbon investments have been developed in recent years – including “Yieldcos”, crowd-funding and “green bonds” \*. According to the Climate Policy Initiative report on the Roadmap to a Low Carbon Electricity in the US and Europe, when structured appropriately, these instruments could reduce the financing costs for low-carbon electricity by up to 20%.”

**Yieldcos** helps create a “secondary market” for green projects so that renewable operators can sell mature and low-risk projects to less specialized investors, and reinvest their financial resources in new innovative projects. The development of standard refinancing schemes for the benefit of institutional investors during the operational phase of the project can substantially help green investors focus on the origination and construction phases of the projects, and offers them established take-out routes.

**Crowd-funding** is a participative financing technique based on raising monetary contributions from a large number of people, typically through the Internet. This innovative financial technique is increasingly used to support climate change projects, albeit on small and local scale for the time being.

**Green bonds** are issued by companies or public entities to finance environmental projects for developing renewable energies or improving energy efficiency. Until recently, green bonds were subscribed by institutional investors like the World Bank. Green bonds are capturing more and more demand from Socially Responsible Investment (SRI) funds (see the green bond case study in annex).

\* The New Climate Economy Report, 2014, Better Growth Better Climate

\*\* Climate Policy Initiative (CPI), 2014, Roadmap to a Low Carbon Electricity System in the U.S. and Europe

### b. Increasing fundamental and applied research

*Any plan aiming at accelerating green innovation needs to ensure research efforts are positioned at the right level and are structured in a way which maximizes the chances of finding efficient solutions. This is a complex task: as explained in the introduction, innovation is partly non-deterministic, which means that key breakthroughs can appear where nobody expects them.*

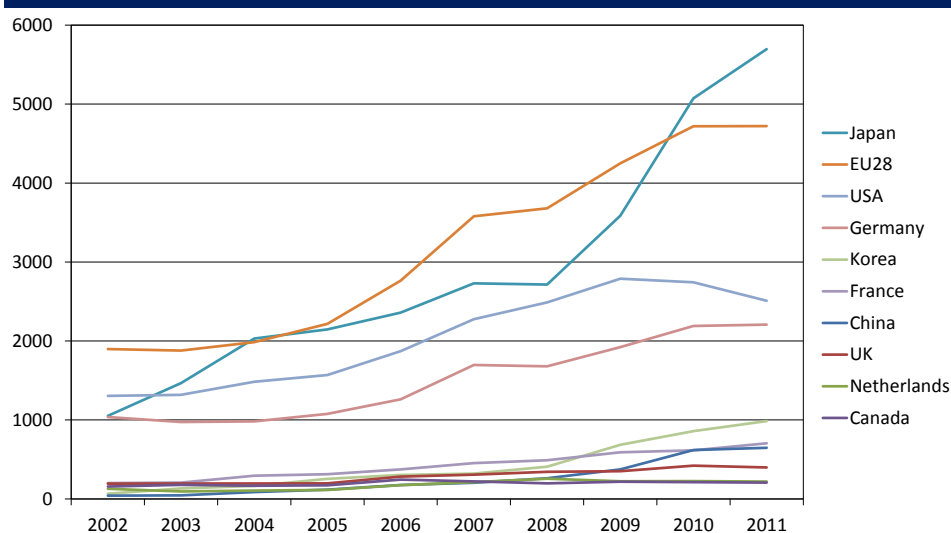
## Main roadblocks identified

### *Signs that climate innovation might be less of a priority in many countries*

**Based on patent data, the innovation pace seems to be slowing.** Patent statistics is one of the most robust indicators of the level of innovation activity, even if most green technologies are not patented, and even if the number of patents does not necessarily reflect patent quality.

Following a significant increase from 2005 to 2008, the number of patents on climate related technologies decreased or increased at a slower pace after the crisis in many countries (Figure 27). Globally, the number of patents increased by 60% from 2004 to 2007 and by 51% from 2007 to 2010, and the share of patents focused on climate technologies decreased during the last year globally: climate patent kept increasing, but the rest of the patents increased more rapidly.

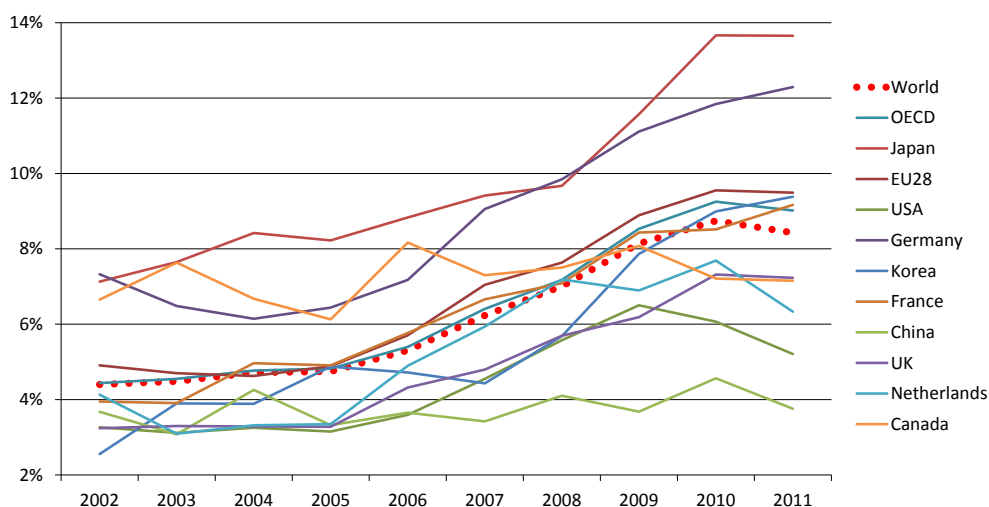
**Figure 27: Number of patents on climate related technologies**



Source<sup>50</sup>: OECD database, August 2014, Patents filed under PCT

<sup>50</sup> Countries presented are the world's 9 biggest countries for climate patents, i.e. patents for energy generation from renewable and non-fossil sources, combustion technologies with mitigation potential (e.g. using fossil fuels, biomass, waste, etc.), technologies specific to climate change mitigation, technologies with potential or indirect contribution to emissions mitigation, emissions abatement and fuel efficiency in transportation, energy efficiency in buildings and lighting.

**Figure 28: Share of climate related technologies in the total patent (10 main countries)**



Source: OECD database, August 2014

Similarly, **despite the increasing awareness of climate change and the need for innovative technologies, R&D growth in the energy sector has slowed down in recent years.**

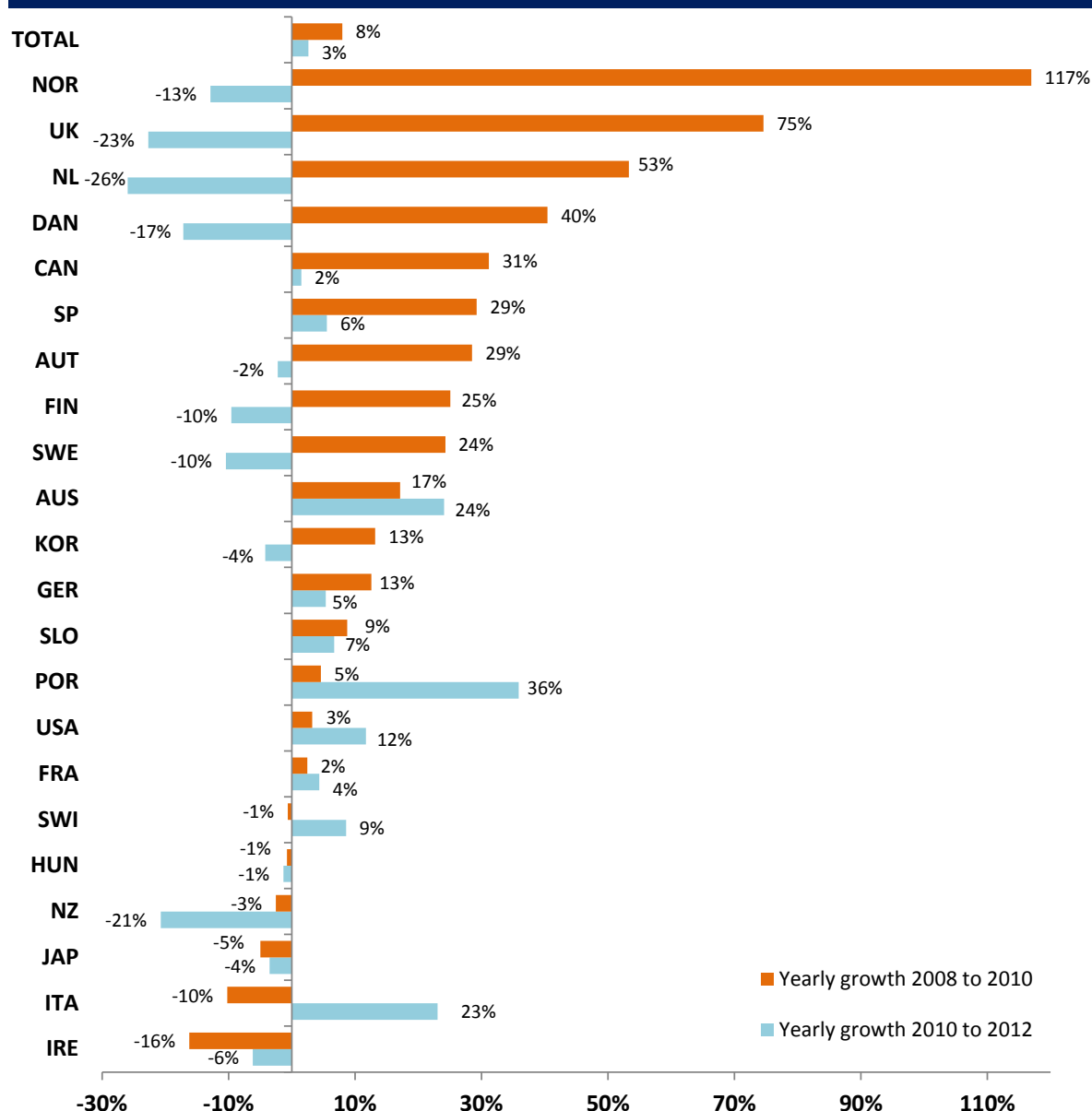
Today's lower growth also relates to the current economic context, heavily affected by the 2008 financial crisis which caused a slowdown of the demand, financing difficulties and the issues experienced by European utilities<sup>51</sup>. This led to a lower demand for new investments combined with a lower investment capacity from companies involved in green innovations. Other external causes are probably involved, like the shift of R&D and private equity focus from energy or cleantechs to industries offering better and quicker returns, such as IT and biogenetics<sup>52</sup>. As a consequence, cleantech investments dropped and the growth of private R&D on energy<sup>53</sup> slowed (Figure 29).

<sup>51</sup> See the box "Renewables and flexible capacities: friend or foe?", section a.2)

<sup>52</sup> This shift is partly related to the less attractive risk/profitability profile of green innovations.

<sup>53</sup> Energy R&D statistics are the closest indicator for R&D in "green innovations", for which there is no specific statistic.

Figure 29: R&D in energy is slowing

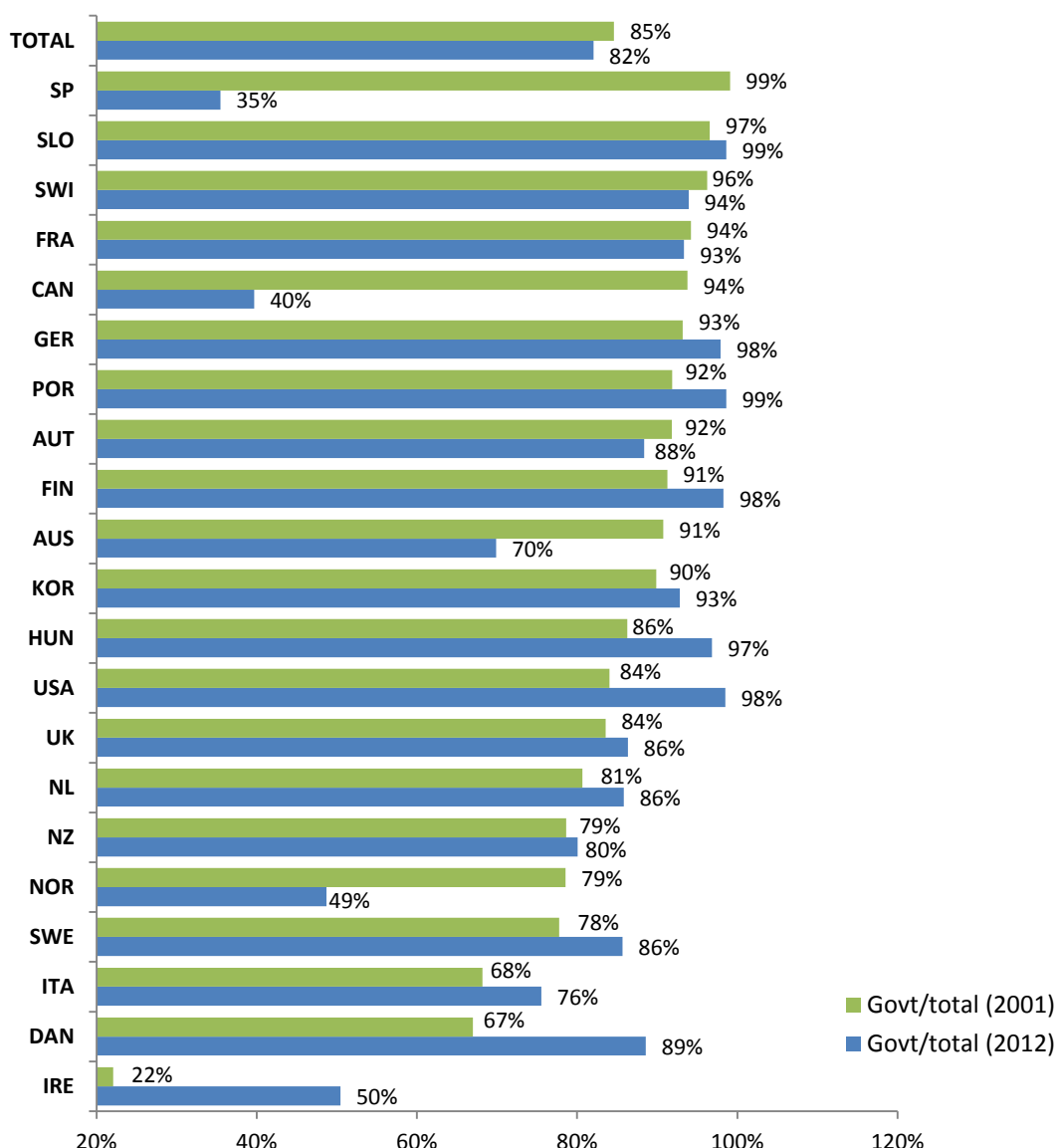


Data: IEA R&D database<sup>54</sup>

At the same time, many governments reduced their deficits, and public R&D suffered from this. Instead of being an “automatic stabilizer” compensating for private R&D decreases, public R&D in fact reduced as a share of the total energy R&D spending (Figure 30). This slowdown came precisely when the climate change context needed the exact opposite: accelerating investments focused both on improving existing green technologies and generating more AGIs.

<sup>54</sup> The budgets taken into account here are for R&D in energy efficiency technologies, fossil fuels, renewable energies, nuclear technologies, hydrogen and fuel cells, other cross-cutting technologies, power and storage technologies.

**Figure 30: Global decrease of governmental share in R&D budgets**



Data: IEA database

**R&D is subject to spillover effects, meaning that the payoff for the owner of the intellectual property is usually lower than the “societal benefits” of the innovation.**

While R&D slowed during the recent years for both macroeconomic (economic crisis) and microeconomic (the risk/profitability profile of green investments) reasons, there are structural reasons explaining why investments in R&D are usually “too low” compared to the optimal level from a general interest point of view.

This phenomenon has been largely documented in the economic literature<sup>55</sup> and is related to the fact that innovators usually only capture a part of the benefits of their innovation. Of course, the stronger the intellectual property, the higher their investment, but even in a situation where these rights are

<sup>55</sup> For example, see “Innovation and economic growth”, G. Cameron, 1996, Centre for Economic Performance for a review on R&D spillovers literature.

perfectly protected, some benefits (like inspiring indirectly other innovations in a way that respects IP) are basically “given away”.

Therefore, individuals and companies tend to invest less than the “optimal level” of R&D, because they base their investments on the share of revenue they can secure, which is smaller than the sum of the benefits provided to society. Social returns to R&D are considered to be around 50%, whereas private returns have been estimated at around 20-30%<sup>56</sup>.

This applies to all R&D investments, but if one wants to ensure that “green” R&D and innovation are set at the optimal level to reduce the cost of dealing with climate change, one needs to take into account that, without support mechanisms, spontaneous R&D investment will still be lower than they should be from an economic point of view.

**Opportunities exist for emerging economies and developing countries to attract investments in R&D** in clean technology sectors. However, **emerging countries usually have had limited financial and human resources dedicated to green R&D**. There are three consequences of this underinvestment. First, it increases the cost of reducing carbon emissions, because there are less solutions addressing issues specific to emerging markets. Given that there is more room for improvement on carbon efficiency in emerging countries than in developed countries, the same amount of resources allocated to reducing emissions on the former can have a much stronger impact than on the latter. Second, it is probable that developed countries can benefit from innovations coming from emerging markets. Examples of reverse innovations<sup>57</sup> show how “frugal” technologies developed for emerging markets can later be adopted by developed countries, even for high tech products like medical imagery<sup>58</sup>. The third consequence is that it creates a situation where intellectual property is less evenly distributed, and makes global discussions to ensure a strong protection of intellectual property and trade secret more difficult.

### *An imperfect coordination*

**Some innovations require coordination between several stakeholders.** For example, the development of greener mobility requires tax stability (under public responsibility), specific infrastructure (natural gas or electric charging stations), specific vehicles (developed by car companies) and a minimum number of vehicles sold (so that car and infrastructure companies can turn a profit). Without strong coordination, infrastructure companies will postpone investments until there are enough green vehicles in circulation. Similarly, potential users will wait for charging stations and models adapted to their needs before buying a new vehicle, and car companies will wait for customers before investing R&D and marketing budgets to design, produce, and sell new vehicles. Consequently, the development of green mobility will be much lower than in a situation with better coordination.

An imperfect coordination might also occur as a consequence of inadequate regulation. This has been the case of the European energy market where the absence of a capacity market resulted<sup>59</sup> in a misalignment between renewable energy goals and price signals sent to utilities owning large flexible power capacities.

**The coordination between public and private R&D efforts is key.** For instance, university-industry R&D collaboration is very positively correlated with the patent activity (Figure 31). Many reports

<sup>56</sup> Nicholas Stern, Stern review, The Economics of Climate Change, Part IV: policy responses for mitigation, 2006

<sup>57</sup> It refers to innovation first seen and used in emerging countries before spreading to developed countries. This type of innovation typically focuses on needs for low cost products developed in emerging countries, and is then sold in new markets in developed countries.

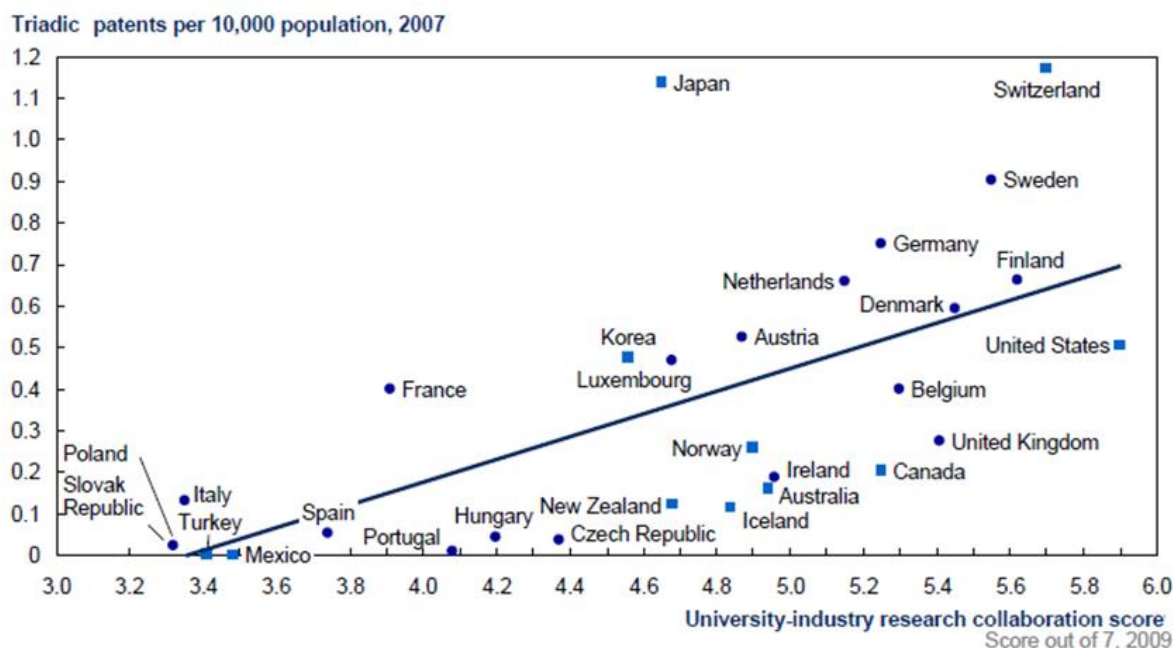
<sup>58</sup> See for example “Frugal ideas are spreading from East to West”, The Economist, March 2012.

<sup>59</sup> See box “Renewables and flexible capacities: friend or foe?”, Part III, section a.2)



address the need to better coordinate public research priorities and private efforts so governments have already made numerous efforts both at the national, regional and local level.

**Figure 31: Impact on innovation of university-industry collaboration**



Source: McKinsey&Company<sup>60</sup>

Nevertheless, companies in our panel confirmed that improving coordination between R&D efforts, both between public and private efforts and at the industry level, is still possible and would accelerate green innovation. There are still relatively few clusters dedicated to green technologies. New coordination initiatives are needed. For instance, building energy efficiency experts pointed out the interest of global partnerships between the low energy construction sector, building material sector and smart grid sector to coordinate R&D efforts.

**Green policies have often tried to achieve multiple objectives** including climate (“decarbonizing” economies) or industrial policy goals (trying to create “national champions” or to develop national capabilities and jobs in green technologies) as well as country planning (supporting industries creating jobs in a specific place). Each of these objectives is, of course, legitimate.

However, multiple target policies are usually less effective than a clearer set of policies, each of them addressing a clear issue with a unique tool, and ensuring that each issue is addressed in a cost effective way. Multiple targets make the assessment of policies more complex but do not improve overall efficiency. For instance, a \$100 million project creating 100 jobs and reducing emissions at a cost of \$1000 per ton of CO<sub>2</sub> avoided will make no sense. From a climate policy point a view, there are many policies that can reduce 10 or even 100 times more CO<sub>2</sub> at the same cost. From an employment point a view, there are cheaper ways to address job issues.

**The way technological possibilities are taken into account in green policies can be improved.** There are many green technologies, their cost can evolve quickly (it has been the case for wind turbines, storage, solar panels), and their efficiency varies a lot depending on the context (level of sun,

<sup>60</sup> Patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO). Research collaboration score based on responses from 13 000 business leaders on a scale from 1 = minimal or non-existent to 7 = intensive and on-going



condition of the electricity network, level of carbon content of alternative solution etc.). The information available on green technologies is abundant, but not always accurate or up to date. As a consequence, it is very difficult for governments to assess projects and prioritize their support. Public decision-makers at every level often lack clear and fact-based maps of the performance, in the present and foreseeable future, of the available technologies.

As mentioned in the beginning of part III<sup>61</sup>, **support for green innovation needs to** focus both on a small number of “key technologies”, involving significant investments<sup>62</sup> and a “multitude” of smaller innovations (which might need smart regulation as much as investments). Our panel gives many examples of how these smaller solutions can reduce GHG emissions while being profitable. However, R&D support plans are often designed for the big “key technology” projects and are not adapted to support smaller solutions, even when they are very affordable.

## **Solutions**

### ***b.1) Aligning stakeholders and technology potential***

#### **1) Public R&D resources aligned with ambitions**

In a context of increasing climate ambitions, and considering the potential impact of affordable innovations to reduce the cost of climate change, R&D efforts are needed more than ever. It is of course not easy to largely increase public R&D when public spending needs to be reduced and R&D budgets compete with other priorities. Tools like public-private risk-sharing, which can leverage private sector investments and expertise while accelerating and scaling up delivery of projects or infrastructure, can help resolve this contradiction.

#### **2) Technology roadmaps discussions organized on a regular basis**

Technology roadmaps that help track the main technologies contributing to GHG emission reductions (see box), would help align public expectations and support plans to existing possibilities. Such tools should be first developed at the global level, and adapted at regional or national level. They could also be used to give better information on technological risks and risk mitigation options<sup>63</sup>. The IEA's ETP<sup>64</sup> is a good example in terms of process and outcome that could be extended to a larger scope than global energy technologies.

<sup>61</sup> See box “Innovation policy: supporting big bets and unleashing the power of the multitude”

<sup>62</sup> This is, for example, the case of technologies like carbon capture and storage, and the focus of initiatives like the UN Sustainable Development Solutions network's “PPP for technology” process.

<sup>63</sup> See section (a) of this chapter.

<sup>64</sup> International Energy Agency's “Energy Technology Perspectives” is a good example focused on the main energy technologies at the global level.

### What should be in a technological roadmap?

A technological roadmap is a reference document detailing both the main technologies, their cost and the success factor that would accelerate their development. The IEA's Energy Technology Perspectives\* is a very interesting example of what a technological roadmap should resemble in the energy sector. This document could be taken as a model for other emitting sectors. Moreover, since the cost and the ability to develop an innovation depends on a local context and a reference situation, such roadmaps could need to be adapted and updated at regional level to take into account the local situation.

Such a roadmap should include:

- The main AGIs, indicating their current and future CO<sub>2</sub> abatement potential, their cost per ton of CO<sub>2</sub> avoided, the highest and lowest costs estimates that can be reached by 2025 (for example, based on a scientific consensus method)
- The “emerging technologies”, which are not necessarily affordable or mature, but which could open new ways to reduce emissions
- Conditions of success, risks, solutions to optimize success and reduce costs or risks
- Factual documents based on the work of experts in scientific, industrial and innovation fields
- Regular updates to take into account technological and scientific evolutions

\*Energy Technology Perspectives  
Source: <http://www.iea.org/etp/>

### 3) Better coordination for innovations whose benefits are shared between different stakeholders

Many public decisions (e.g. infrastructures, smart networks, research priorities, regulations) need to be aligned with the precise state of the technology, and its possible evolution in the foreseeable future. On the other hand, the viability of many innovations can be affected by public decisions (e.g. infrastructure plans, tariffs structure, regulations).

A better alignment is needed at the supranational level (like Europe), at the national level (where, in many countries, research priorities and key regulations are defined), and at the regional levels (where infrastructures, education capacities are defined). This alignment need can only be reached by improving the dialogue between policymakers and the private sector. This dialogue is needed at a global level, where “blind spots” must be addressed (see below “*Identifying the blind spots of the industrial matrix*”). This dialogue can take many forms, but should:

- Base itself on technological roadmaps in order to ensure plans are aligned with possibilities, and to identify where improvements are required;
- Help identify complementary technologies or coordination needs in cases where distinct stakeholder have to develop them jointly;
- Help coordinate private-public initiatives between national/regional infrastructure planning or research priorities, and private commitments to develop new products;
- Be a place where the information on risks and risk mitigation options is discussed<sup>65</sup>;
- Help adapt regulation or other policy levers needed to accelerate innovation.

<sup>65</sup> See section a.2)3) on *Ensuring an efficient risk allocation and avoiding “anti-economical” risk transfers*

Lastly, this dialogue should be technologically neutral (i.e. looking at affordability to decide which technology should be selected) rather than selecting a few winning technologies early on in the innovation process, which might end up not being the most efficient.

### Identifying the “blind spots” of the industrial matrix

Government decisions are usually very complex but focus on two main goals:

- **Affordability:** for a given amount of money, governments want to reduce emissions as much as possible. In a way, they want to “buy” avoided CO2 emissions at the lowest possible cost by supporting the most affordable technologies adapted to the country’s specific context;
- **Industrial strategy:** supporting a new technology can help create a competitive advantage, which could increase growth and jobs.

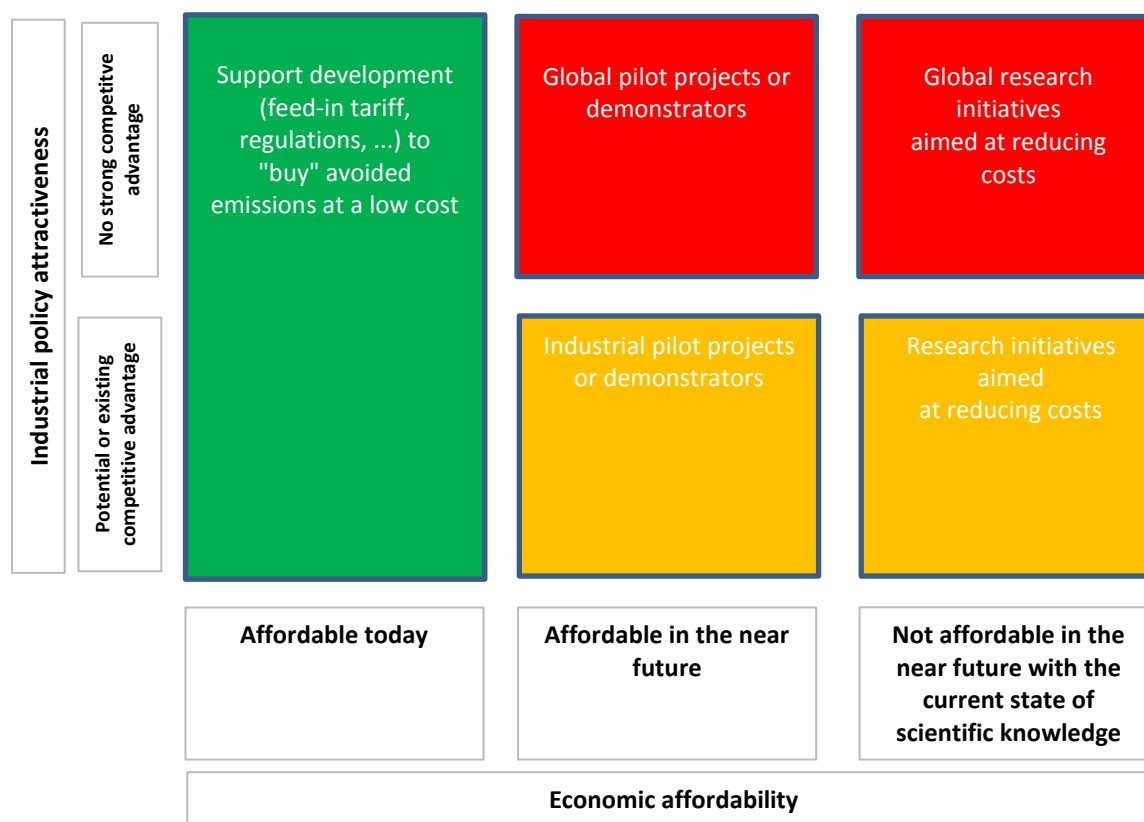
While both goals are legitimate, they often do not address the same technologies. The following chart presents the “optimal” strategies depending on when an innovation becomes economically affordable (short or long term) and if there is a possibility to develop a country’s competitive advantage. At a national level, a mixed approach will be needed most of the time, including affordable technologies developed for their contribution to a low-cost climate strategy, and technologies contributing to an industrial strategy, which need to be improved before being affordable.

As shown in Figure 32, some innovations will fall in “blind spots” (in red), in which it might be in no country’s interest to develop them – regardless of the long-term contribution of the technology to GHG goals. This is the case for technologies which are key to tackle climate change, but still not affordable and for which it is no country’s interest to invest massively. The carbon capture and storage technology could be an example<sup>66</sup> of this.

For this reason, reducing global carbon emissions cannot merely be done by adding country or regional plans: a global coordination is needed for technologies falling in the “blind spots” of the industrial strategy matrix.

<sup>66</sup> See box on carbon capture and storage, part II.

**Figure 32: The green innovation industrial strategy matrix**



### ***b.2) Increasing research collaboration***

Cooperation between the private and the public sector plays a key role in fostering development of innovative technologies. Cooperation between universities and company research centers should also be developed. Public authorities should moreover encourage public-private contracts<sup>67</sup> and discuss research and innovation priorities with industry experts.

Open innovation is another way to encourage cooperation between large and small companies. It is essential for anticipating future breakthroughs, stepping up the innovation cycle, and encouraging companies to acquire outside sources of innovation to improve product lines. The aim is to shorten the time required to bring products to market, or release internally developed innovations, which do not fit the company's business model but could be effectively used elsewhere. Public authorities can support open innovation through incubators to identify and stimulate the creation of "green" start-ups/ technologies linked to academia to develop innovative eco-systems.

### ***b.3) Developing specific R&D incentives taking into account R&D spillover effects***

The most practical solution to ensure that innovators take their investment decision based on both their revenues and the benefits for others ("spillover effects") is to reduce R&D cost using a specific

<sup>67</sup> Rapport sur le développement dans le monde, Un meilleur climat de l'investissement pour tous, Interventions sélectives, Banque mondiale, mars 2005

mechanism. For example, France provides a research tax credit<sup>68</sup> to companies, allowing a tax credit equal to 30% to 40% of R&D expenses<sup>69</sup>.

Another solution adapted to situations in which resources to support R&D are limited is to create and fund an investment vehicle dedicated to green R&D investment<sup>70</sup>. Public-private risk sharing can also help leveraging private investment and expertise while accelerating and scaling up delivery of projects and infrastructure.

### c. Facilitating adoption of green innovations

*As presented in part II, projects that successfully complete the R&D stage might be adopted very slowly by potential clients, even in cases where the innovation is profitable. There are many possible causes of this, some of which require a specific support to stimulate adoption or improve information on innovative green solutions.*

#### Main roadblocks identified

As explained in part II, **some innovations are “behavior-driven”**: users will have to change their behavior to adopt them, which might make them reluctant to use these product or services. As well, some **efficiency improvements might stay theoretical if users do not behave in the expected way**. This is typically the case for energy efficient buildings where, for example, temperature should be regulated using the air conditioning, and opening a window might reduce significantly the building's efficiency.

**Although the public sector should be a role model, this is not always the case in practice.** For example, tenders from the administration or public utilities often focus on the immediate cost rather than the “total cost of ownership”. This “total cost” includes the procurement cost, as well as all the costs related to the product during its life, energy, disposal costs and even a “carbon shadow price” to take into account GHG emission reductions.

**Consumer awareness of available technologies and their risks or benefits is sometimes low.** For instance, one of the reasons for the slow distribution of electric motorbikes is that people are not necessarily conscious of the financial benefits. They do not know that many models are profitable or that some models' torque is higher than most gasoline fuelled motorbikes. They also do not know if they will be able to adapt their driving behavior to this product (there are less stations and charging takes more time).

Shale gas and nuclear energy are perfect examples of new technological developments being stopped in some countries based on incomplete information without conducting further scientific research. Discussions on which proportion of the energy mix they should represent, and how the associated risks should be dealt with, are of course legitimate. However, taking such decisions without a scientific assessment of the consequences in terms of pollution can result in unexpected increased carbon or fine particle emissions and cause more deaths than the “riskier”<sup>71</sup> energy sources.

**Some technologies requiring large investments cannot be developed without a clear adoption plan.** This is the case for carbon capture and storage<sup>72</sup>, for instance. On the contrary, the “Velib” bike-sharing solution in Paris is an example of how a first public-private partnership can facilitate the

<sup>68</sup> France's R&D tax credit is an example of such R&D incentives

<sup>69</sup> This scheme is not limited to green R&D

<sup>70</sup> The green climate fund (GCF) is an example of such initiative. This fund was created within the framework of the UNFCCC to redistribute money from the developed to the developing world. See [http://unfccc.int/cooperation\\_and\\_support/financial\\_mechanism/green\\_climate\\_fund/items/5869.php](http://unfccc.int/cooperation_and_support/financial_mechanism/green_climate_fund/items/5869.php)

<sup>71</sup> See “Electricity generation and health », A. Markandya and P. Wilkinson, *The Lancet*, 2007

<sup>72</sup> See box on carbon capture and storage (CCS) in part II

emergence of new innovations. The city of Paris<sup>73</sup> was used as a “pilot site” to develop the Velib solution, thus carving a path for other major cities to follow. Subsequently, the Autolib concept of electric car sharing inspired from a similar model also helped Parisian drivers experience the electric car technology at no risk (they only pay a monthly and hourly fee).

## Solutions

### *c.1) Developing actions to increase customer information on technologies and facilitate adoption*

#### **1) Encouraging long-term approaches for public procurement**

Public tenders, especially for large emission equipment, should be based on the “total cost of ownership” including a valuation of GHG emissions using a “shadow price” of carbon<sup>74</sup>. This is especially true for innovations for which the public sector (national or sub-national) is the main client, such as demand-response, energy storage or renewable energy technologies.

At the city level, the concept of “Smart Cities” embodies this idea that a better planning based on a long-term cost/benefits analysis would largely increase investments in such technologies. Cities have a key role to play in improving the integration and management of transportation, water, waste, electricity, and information technology so as to create a greener environment. A new model of governance between public and private actors is also necessary in order to achieve an overall performance that is far superior to the usual “batch”-based piecemeal approach of procurement contracts. This new model implies **many changes like entering into procurement contracts in a non-sequential and non-compartmentalized way, defining global performance targets, which need legal, regulatory or approaches modifications** in most of the countries.

This approach can be innovative compared to the usual way public utilities are planned and/or coordinated. A way to accelerate this would be to **support pilot smart city initiatives**, which could later be replicated by other cities.

#### **2) Improving information on benefits, risks and risk-mitigation options**

Misunderstandings from both citizens and important decision-makers on the benefits and risks of technologies have inhibited their development. This can only be prevented by supplying more factual information regarding these technologies, their potential risks, the existing solutions to reduce the risks, and the research efforts that could help reducing them even more. The technology roadmaps mentioned in section b.1 provide a starting point for such information.

### *c.2) Adoption plans based on technology roadmaps*

Subsidizing **profitable and behavior-driven**<sup>75</sup> innovations is not the best way to support them - after all, they are already profitable. Instead, such innovations need public actions, like new regulations, public information or pilot projects, that will accelerate their adoption.

A way to help potential customers understand the benefits of green innovations is to **encourage projects that allow them to test the products**, in the hopes that they can either overcome fears or try new behavioral changes without risks. This is, for example, what the “Autolib” electric car project in Paris achieved.

<sup>73</sup> The solution had been developed in other, but smaller, cities before.

<sup>74</sup> See the box on “shadow price” in the section a.2)

<sup>75</sup> These concepts are defined in part II.

Some **technologies cannot be developed without large scale demonstrators** that help better understand “real life” costs and feasibility. This is the case for key technologies (such as carbon capture and storage), which will be necessary to achieve the climate transition, but which are still “unaffordable”. Such technologies will need investments and public support before they can be “affordable”. Defining which technologies need to be supported could be based both on technology roadmaps<sup>76</sup> – which will help identifying key technologies and assess their “affordability” potential – and on the “industrial policy matrix” presented in section b.

Dedicated funds could finance such experimentations, as it is done with the €400 million “demonstrateur recherche” fund<sup>77</sup> focused on research pilot projects in the energy, transportation and housing sector.

#### d. Facilitating large scale distribution of innovations

*Accelerating the global distribution of AGIs can be a cost-efficient way to reduce emissions, because it will increase the number of options available to clients. A larger distribution of AGIs will also help reduce their costs through economies of scale and cover large R&D investments.*

#### Main roadblocks identified

**Individuals or companies are not necessarily aware of the best available technologies (BAT) they could purchase.** Some clients are able to adopt the best available technologies very rapidly. For examples, airlines usually quickly implement fuel-efficient technologies for their new engines. This is because it not only has a significant impact on their profits but also awards them productivity gains which are crucial in their highly competitive industry. However, the development of innovation can be much slower for other industries. As a consequence, they often use less advanced technologies, even when superior greener and more affordable options exist. Overall, this has very significant consequences: according to the International Energy Agency<sup>78</sup>, using the best technologies could lead to 24% energy savings in the chemicals and petrochemicals sectors.

**Insufficient Intellectual Property (IP) protection or threats to weaken IP rights** limit investments in green innovations as well as the development of green innovations in countries where intellectual property is not guaranteed. The gap between patent protection in developed and developing countries is narrowing quickly: in 1998, 1 in 20 patents for the relevant technologies was protected in a developing country, whereas in 2008 it was 1 in 5<sup>79</sup>. That said, the gap remains and propositions to weaken IP rights still resurface from time to time: the sole existence of these debates is an incentive to invest less in green innovation and to prefer investments for which rights are better secured.

**Lastly, tariff and non-tariff barriers<sup>80</sup> to trade exist for all products, and green goods are no exception.** For example, tariffs on environmental goods can be as high as 35%, which poses a significant barrier to the large-scale distribution of green innovation. The same applies for non-tariff barriers: one of the cheapest ways for governments to accelerate emission reductions at no cost is to facilitate access to foreign green innovation, and, inversely, to help their domestic technologies access global markets.

<sup>76</sup> See box “What should be in a technological roadmap?”, section b.1)

<sup>77</sup> [http://www.actu-environnement.com/ae/news/fonds\\_demonstrateurs\\_recherche\\_7548.php4](http://www.actu-environnement.com/ae/news/fonds_demonstrateurs_recherche_7548.php4)

<sup>78</sup> IEA, Energy Technology Perspectives 2014, Tracking Clean Energy Progress 2014, 2014  
[http://www.iea.org/publications/freepublications/publication/Tracking\\_clean\\_energy\\_progress\\_2014.pdf](http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf)

<sup>79</sup> Copenhagen Economics A/S AND the IPR Company APS, Are IPR a barrier to the transfer of climate change technology?, 2009

<sup>80</sup> Non-tariff barriers are any measure other than import duties (tariffs) employed to restrict imports, like export subsidies, customs surcharges, lengthy customs procedures, unreasonable standards and inspection procedures or import licensing and import.



## Solutions

### *d.1) Sharing Best Available Technologies by sectors and regions*

Improved information on existing BATs and the related savings potential would help promote AGIs. These BAT lists could be identified for the key sectors (and updated at the country or regional level for sectors like construction) using a methodology similar to that of the International Energy Agency for its yearly “Energy Technology Perspectives”.

Sharing information on BAT can be done by sector and by geographic region, at all levels. It could also be extended to policies accelerating the implementation of green affordable solutions. For example, China’s success<sup>81</sup> in developing the use of electric two wheelers (e.g. scooters, motorcycles and bicycles) can be used by other countries. Sharing information on the levers used to develop BAT in a specific country would help public decision takers accelerate green innovations in their area. Much remains to be accomplished in order to benchmark efficient green innovation policies and encourage private-public dialogues.

### *d.2) Keeping strong Intellectual Property Rights (IPR) to maintain high incentives for innovators*

#### **Keeping strong Intellectual Property Rights**

Investing and developing new technologies to address climate change is not possible without recouping these investments if they succeed. **Strong intellectual property rights (IPR) are critical for this and bring both clarity and predictability to the marketplace.** Keeping a strong intellectual property protection system is key, both to ensure the development of existing innovation and to give incentives to develop new ones, especially in countries where IP is viewed as weak.

Similarly, technology distribution, in the sense of technologies being adopted locally, know-how being shared, and the local population and workforce learning how to use it, is also enabled by meaningful intellectual property protection. Without it, technology providers will be reluctant to share what they know.

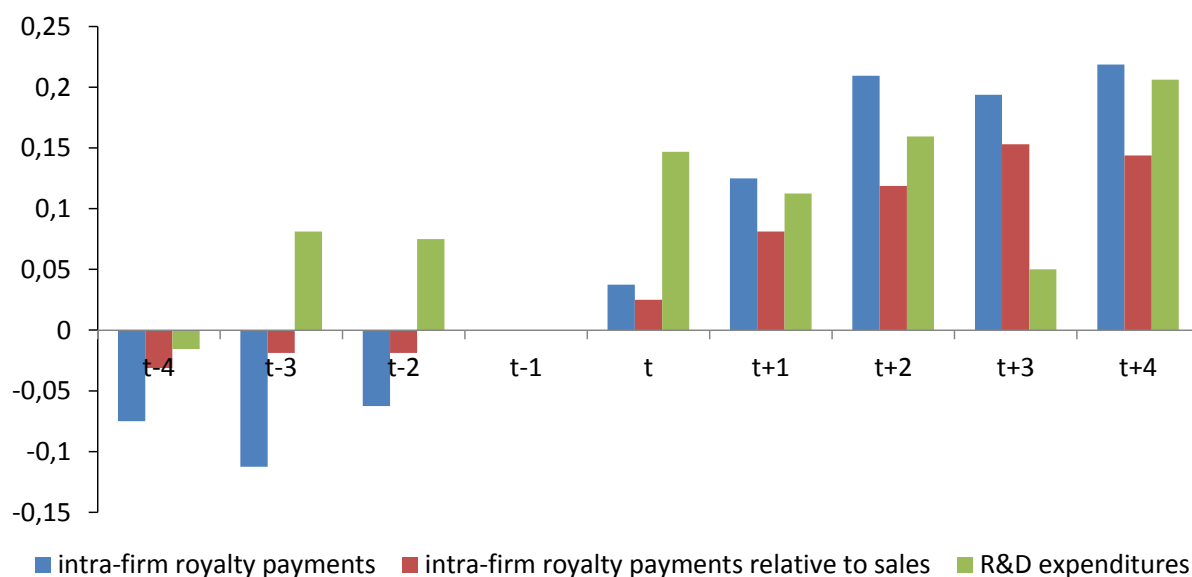
The exchange of knowledge between providers, users, and those who will maintain the technology is critical in accelerating the deployment of solutions to address climate change. Therefore, the existence of strong IPR enables the introduction of technology to new markets much more rapidly. This point is highlighted in Figure 33<sup>82</sup> showing the effect of IPR reforms in emerging economies: technology transfers and R&D increase the year after IPR reforms are put in place (time “t”).

<sup>81</sup> This market is significantly increasing in the Asia Pacific region to reach 335 million units of two-wheel vehicles in China by 2018. See Pike research, Electric Two-Wheel vehicles in Asia Pacific, 2012, <http://www.navigantresearch.com/wp-content/uploads/2012/04/ETVAP-12-Executive-Summary.pdf>

<sup>82</sup> Copenhagen Economics A/S AND the IPR Company APS, Are IPR a barrier to the transfer of climate change technology?, 2009



**Figure 33: Technology transfer before and after IPR reforms**



Source: Copenhagen Economics, *Are IPR a barrier to the transfer of climate change technology?*

### Facilitating access to existing IP without reducing incentives to innovate

An effective way to increase access to existing IP without reducing innovation incentives is to simplify the access to licensed technologies. This is exactly what is achieved by tools like WIPO Green, an interactive marketplace promoting innovation and diffusion of ecofriendly technologies launched by the World Intellectual Property Organization<sup>83</sup>. Indeed, it gathers a large portfolio of innovations reducing GHG emissions and involves innovators (companies or individuals) willing to commercialize or license their technology.

#### *d.3) Extending Environmental Goods agreements (EGA)*

The current initiatives seeking to improve trade in the fields of renewables, waste management, and water are crucial in helping reduce the cost and access of ecofriendly technologies worldwide (see box).

This logic could be extended further by including more countries, expanding the list of green goods to ensure key AGIs are covered and completely eliminating tariffs and non-tariff barriers (including standardization initiatives) on the covered items.

<sup>83</sup> <https://webaccess.wipo.int/green/>

### Environmental Goods agreements (EGA)

On July 8th, 2014, the United States and thirteen other WTO members - Australia, Canada, China, Costa Rica, the European Union, Hong Kong, Japan, Korea, New Zealand, Norway, Singapore, Switzerland, and Chinese Taipei - launched negotiations on the Environmental Goods Agreement. The current negotiating parties account for 86% of global trade in environmental goods, amounting to nearly \$1 trillion each year.

The EGA aims to eliminate tariffs on environmental technologies such as wind turbines, water treatment filters, and solar water heaters. Removal of these trade barriers will improve access to important green and energy efficient technologies for businesses and consumers. It will also increase the ability of manufacturers to enhance their sustainability and spread R&D investments on a larger scale. This will make investing in “green products” more profitable, and allow companies to invest in product developments which are not profitable on a national scale but can become so only on an international scale.

The EGA negotiations will build on a list of 54 environmental goods on which APEC leaders agreed to reduce tariffs to five percent or less by the end of 2015.

## Appendix

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# Introduction

The following case studies provide a broad panel of “Affordable Green Innovations<sup>1</sup>”. These products or services already exist and their efficiency has been tested in real life cases. All sectors (Transportation, Agriculture, Building, Industry, Waste, Power, Oil & Gas, Finance,...) are represented in this panel, and the case studies are based on real case information provided by a large number of contributing companies of all sizes (multinational and SME), and from various countries (developed and emerging) completed by our analysis.

In order to make them accessible to the greatest possible number of readers, they are presented in a simplified way, explaining how the innovation works and showing its impact in terms of carbon emission reductions, as well as the economic status (profitable, affordable or affordability being improved<sup>2</sup>). It is important to note that some of these innovations act as enablers for other green innovations and thus their economic status was not specified. For example, green finance does not reduced emissions directly, but helps implement other innovations that will reduce emissions.

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<sup>1</sup> This concept is defined in the box “What are “affordable green innovations”, and why do they matter?” in the *Introduction* section

<sup>2</sup> Profitable means that revenues exceed the expenses, costs and taxes over the solutions’ lifecycle. Affordable means that the innovation reduces carbon emissions at a cost per ton of CO<sub>2</sub> that is lower than the “economic value” of CO<sub>2</sub>. Affordability being improved means that the solution is still being improved with the goal of making it affordable. Some innovations vary between affordable and affordability being improved depending on the context of their deployment.



# 1. Zero XU electric motorcycle

*Higher torque, lower emissions*

Company: Zeromotorcycles

## (A) Overview of “usual” solutions: Gasoline motorcycles

Transport is a major source of carbon dioxide emissions...

- Based on emission standards for new vehicles, passenger vehicles emit 0.09g of smog forming pollutants per mile driven, while motorcycles emit 1.29g per mile.
- A motorbike can be 14 times more polluting per mile than a car when it comes to smog forming pollutants (e.g. triggers asthma).

## (B) Synthetic description of the innovation



Zero Motorcycle developed electric motorcycles that significantly reduce carbon emissions

- The power tank energy storage allows it to travel 61km in the city for the XU Model
- New models exist with a much better autonomy.
- This motorcycle represents a significant reduction in carbon emissions compared to traditional models. If electricity is produced using renewable energy, there are no emissions at all.

## (C) Impacts in terms of reduction of carbon emissions by 2020

**45 million tons  
of CO<sub>2</sub> avoided  
by 2020**

Profitable
Affordable
Affordability being improved

Depending on the energy mix of the country, the amount of CO<sub>2</sub> emitted by a motorcycle such as the Zero XU is estimated at ~22 gCO<sub>2</sub>/km on average. Considering an average motor vehicle of the same category, this corresponds to an average ~63 gCO<sub>2</sub>/km avoided.

By 2020, 143 million vehicles will be in circulation, creating a significant installed park of e-scooters and e-motorcycles worldwide. Considering an average driving profile, the global impact of CO<sub>2</sub> avoided by 2020 thanks to electric motorcycles is estimated at circa 9 million tons of CO<sub>2</sub> avoided.

# Zero XU electric motorcycle

*Higher torque, lower emissions*

## **(D) Major roadblocks and first policy recommendations**

- The major roadblocks are the relatively low financial incentive linked to energy management optimization and the resistance to change:
  - Low customer awareness: 150 million electrical two wheelers are used in China but they are hardly mentioned in developed country mobility plans.
  - Limited number of “fast charging” stations.
  - High upfront cost of the electric vehicle in a context where ordinary buyers are not able to consider long term return on investment.
  - Depreciation of the electric vehicle and used vehicle market (“chicken and egg issue”).

## 2. Natural gas as a fuel

*A short term alternative for road and maritime transportation*

Company: GRTgaz

### (A) Oil fuels will reduce their market share in the coming years

Natural gas is an efficient and low cost way to replace oil fuels in the transportation sector.

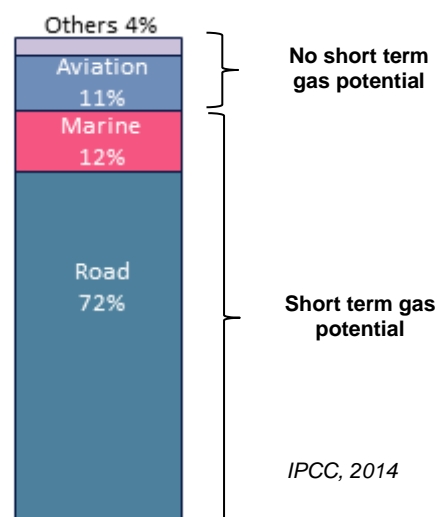
Despite increasing prices and limited reserves, oil fuels account today for 93% of the energy consumption in the transportation sector. They emitted 6.8 GtCO<sub>2</sub> in 2011 ( Tank-To-Wheel analysis).

Those are mainly driven by the road (76.3%), air (11%), and maritime (9%) sectors. (EIA, 2014)

The road transportation sector is mainly powered by gasoline (for passenger cars) and diesel (for medium and heavy-duty vehicles).

In the maritime sector the tightening sulphur emissions legislation forces the ship-owners to either install expensive scrubbers or switch from heavy fuel oil (HFO) to alternative fuels (natural gas or diesel).

CO<sub>2</sub> emissions in the transportation sector in 2011



### (B) Natural gas is a key player of the energy transition

Annual fuel consumption



Natural gas can be used as a fuel in its gaseous (CNG) or liquefied (LNG) form.

Natural gas is a fossil fuel that is mainly composed of methane. Its combustion reduces particles by 90% and NO<sub>x</sub> by 70% compared to diesel, and CO<sub>2</sub> by 20%.

Biogas produced from organic waste can also be used and reduces CO<sub>2</sub> emissions up to 70% compared to gasoline (Well-To-Wheel analysis).

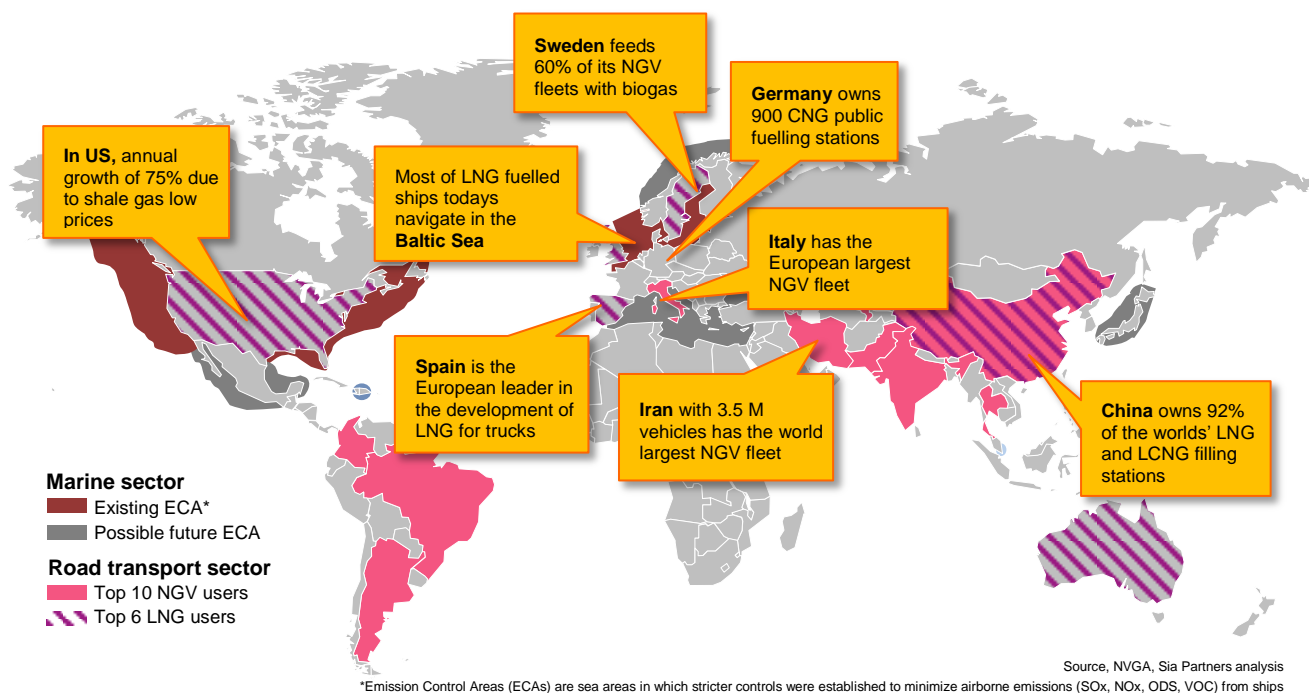
For small to medium vehicles, gas is compressed from the gas network to ~200 bars and distributed in filling stations.

For larger vehicles (heavy duty trucks and ships), it can be liquefied at -163°C and distributed in cryogenic tanks, increasing significantly the autonomy of the vehicle.

# Natural gas as a fuel

## *A short term alternative for road and maritime transportation*

### Map of today's NGV development



### (C) Impacts in terms of reduction of carbon emissions by 2025

**115 million tons of CO<sub>2</sub> avoided per year by 2025**

7.74 GtCO<sub>2</sub>eq was emitted from road and marine transportation in 2010 on a Well-to-Wheel analysis.

- In a baseline scenario, these two sectors would emit 10.08 GtCO<sub>2</sub>eq by 2025.
- In an optimistic scenario with a strong introduction of gas in transportation, these emissions could be reduced to 9.97 GtCO<sub>2</sub>eq, which represents 115 MtCO<sub>2</sub>eq of GES emissions avoided by 2025.

The use of LNG in marine transportation could reduce GHG emissions by 49 MtCO<sub>2</sub>eq by 2025, representing 6% of today marine transportation emissions.

The use of CNG for small and medium vehicles and LNG for heavy ones could reduce by 37 MtCO<sub>2</sub>eq GHG emissions by 2025.

In addition the use of 12.5% of biomethane would further reduce GHG emissions by 29 MtCO<sub>2</sub>eq.

<b>Profitable</b>
Affordable
Affordability being improved

# Natural gas as a fuel

*A short term alternative for road and maritime transportation*

## **(D) Major roadblocks and first policy recommendations**

---

- Absence of CNG vehicles in some major vehicle segments.
- Need for:
  - The development of national public CNG fuelling stations networks, based on nationwide network program.
  - A stronger implication of fuel distributors to commercialize CNG within existing fuelling stations.
  - An attractive taxation on CNG price to go with the development takeoff period, with a good visibility to facilitate investment decisions.
  - More communication on the benefits on CNG vehicles (economical, environment and usage).
  - Technological neutrality (gas mobility is often not present in public green mobility plans)

### 3. USIBOR hot stamping steel

#### *Lighter & stronger steel to cut CO<sub>2</sub> emissions*

Company: Arcelor Mittal

#### (A) Overview of “conventional” solutions

- Until now, car manufacturers mainly used conventional steels for cold stamping - in particular for safety-critical structural parts called the ‘body-in-white’ (e.g. bumper beams, door reinforcements, roof, dash panel cross members).
- With such pieces requiring both stiffness and strength, steel amounts to a significant share of a vehicle's total weight, which has direct consequences on its fuel consumption profile. For instance, an average vehicle weighs ~1,500 kg, of which ~400 kg comes from steel pieces corresponding to ~30% of the total.
- Considering that such an average vehicle consumes approximately 5 L/ 100 km and releases ~2.5 kg CO<sub>2</sub> per liter of fuel consumed, it typically releases ~125 g/km CO<sub>2</sub>, which is in line with the European norm of 130 g/km maximum.



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#### (B) Synthetic description of the innovation

- Steel producers have been improving the resistance of their materials since the mid 1990's, to enable thinner and stronger structures for the automotive markets. Hot stamping is now regarded as the major manufacturing technique for the future, offering the associated benefits of weight reduction and stronger parts, with same level of safety to passengers.
- Arcelor Mittal's proprietary 1500MPa steel grade, USIBOR 1500, makes it possible for automotive manufacturers to save up to ~25% on the total weight of an average vehicle's steel pieces, i.e. ~100kg per vehicle.
- Considering the same running and consumption profiles, an average vehicle would then only emit ~117g/km CO<sub>2</sub>, corresponding to ~7-8g of CO<sub>2</sub> saved per km.
- From the end-user's perspective, the business model of hot stamping steel is therefore positive, driven by fuel savings over the vehicle's lifetime.

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**~8 million tons  
of CO<sub>2</sub> avoided  
per year by  
2020**

**Profitable**

Affordable

Affordability being  
improved

- With ~1.01 billion vehicles in use as of today, the global automotive transportation sector releases an average ~1.9 billion tons of CO<sub>2</sub> annually (for average running profile of 20,000km per vehicle p.a.)
- By 2020, the global park of vehicles is expected to grow by ~4% annually, reaching ~1.32 billion units in circulation by 2020 in a “baseline” scenario. This would correspond to an average ~40M vehicles sold annually.
- The corresponding 1.32 billion installed base of traditional vehicles would then generate an annual 2.5 billion tons of CO<sub>2</sub> annually.
- Considering Hot Stamping Steels such as USIBOR 1500 could gradually reach a ~25% penetration rate to 2020 on the sale of new vehicles (i.e. ~6m additional new vehicles per year), there would ultimately be an existing park of ~50M vehicles in circulation using HSS technologies by 2020.
- These 50M ‘light-weight’ vehicles would then generate 117 gCO<sub>2</sub>/km annually, instead of ~125 gCO<sub>2</sub>/km for traditional vehicles.
- In total, there would ultimately be ~8M tons of CO<sub>2</sub> avoided annually by 2020, corresponding to a total 24M tons cumulated by 2020 over the period.

# USIBOR hot stamping steel

## *Lighter & stronger steel to cut CO2 emissions*

### **(D) Major roadblocks and first policy recommendations**

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- Due to high transportation costs, steel is essentially a local market, in which production sites must be located near consumption sites.
- The market of new vehicles is mostly driven by countries such as China and India. By 2020, an assumed 50% penetration rate for new ultra-resistant steels heavily relies on the capacity of key players to open new production sites in corresponding countries. In practice, it means opening new production sites in China, India, etc.
- However, with an initial upfront investment of 700 to 800M€ per plant, the challenge is daunting.
- Ultimately, two major directions have been identified to help the substitution of HSS to traditional steel :
  - Create an international and regulated environment in favour of “green” investments in such countries through generalisation of Life cycle assessment methodologies.
  - Find efficient and innovative financing mechanisms to support producers open new capacities overseas.



## 4. Power generation using flared gas

### *Reducing flared gas emissions*

Company: Clarke Energy

#### (A) Overview of “usual” solutions

- Gas flaring is the burning of natural gas that cannot be processed or sold. ~150 billion m<sup>3</sup> are flared every year.
- In the places where gas is flared, diesel engines are used for power generation, but:
  - Diesel is expensive and not available on site,
  - There are risks regarding transportation up to site (300km in the desert)



#### (B) Synthetic description of the innovation



Major advantages of Power Generation with Flared Gas / Biogas:

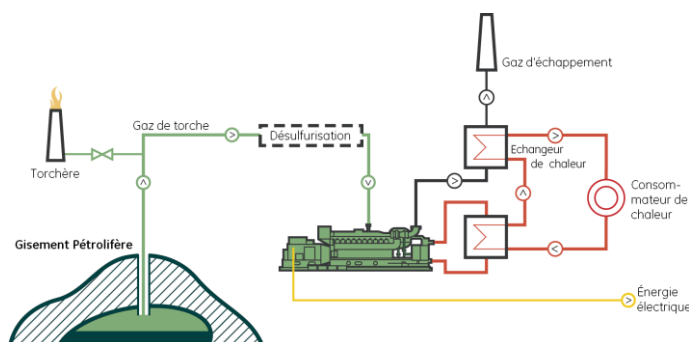
- Flared gas emissions are reduced (CO<sub>2</sub> reduction)
- Gas engines are used instead of diesel engines (risk and CO<sub>2</sub> emission for transportation)

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**30,000 tons of CO<sub>2</sub> avoided per year by 2020 (Clarke only)**

<b>Profitable</b>
Affordable
Affordability being improved

- The potential of flared gas over the world is equivalent to the annual gas consumption of Germany and France together.
- ~2,574 tons of CO<sub>2</sub> will be avoided per year, by 1MW/year
- It corresponds to ~30,000 tons of CO<sub>2</sub> avoided by 2020.



# Power generation using flared gas

## *Reducing flared gas emissions*

### **(D) Major roadblocks and first policy recommendations**

---

Major roadblocks have been identified...

- The culture of using diesel engines as first options when power generation is needed on isolated sites
- The need to stop subsidies for diesel consumption when a significant volumes of gas is flared
- The need for specific infrastructures

## 5. “Automated Demand Shifting” solution

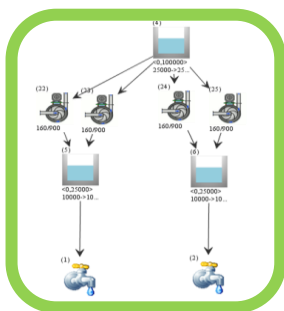
### *Optimizing electricity consumption*

Company: Actility Energy

#### (A) Overview of “usual” solutions

Many energy intensive industries have optimized their electricity consumption to minimize their costs considering fixed tariffs and do not take into account the potential offered by demand response opportunities.

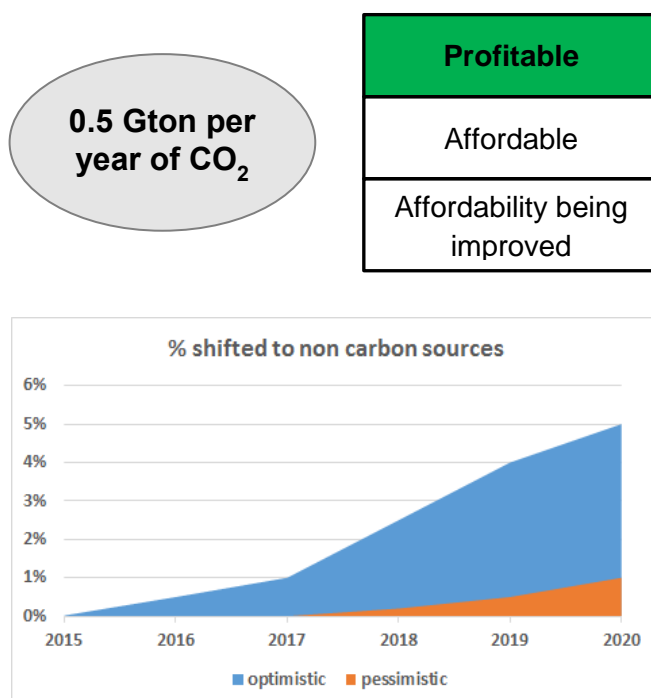
#### (B) Synthetic description of the innovation



Many industries use electricity in their production process. Therefore managing the product inventory by modulating the production rate can be a cost efficient form of indirect electricity storage. Actility “Automatic Demand Shifting” solution is an online algorithm that leverages this indirect energy storage capacity to store excess renewable energy from the grid at peak production times, and vice-versa, to reduce consumption at peak times (carbon intensive electricity mix).

With this solution, demand can react in real-time to the electricity energy mix, which can save money and/or generates revenues. This technology is an algorithm implemented mostly as cloud solution, requiring only low cost local interfaces with existing control systems.

#### (C) Impacts in terms of reduction of carbon emissions by 2020



By 2020, CO<sub>2</sub> could be avoided on an annual basis at different levels

- Industry: Flexibility of about 5% of average power consumption would be given. Noting that industry is about 30% of a country's power consumption.
- Residential: Flexibility of water boilers is about 50% of power consumption up and down, representing 1/2 of the residential demand with no electric heating, and about 6% in electric heating homes.
- Transport: modulation of EV charging

# “Automated Demand Shifting” solution

## *Optimizing electricity consumption*

### **(D) Major roadblocks and first policy recommendations**

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- In the industrial sector, the major roadblocks are the relatively low financial incentive linked to energy management optimization and resistance to change.
- In the residential sector, the major roadblock is the high initial cost of installation in the residential sector in a context where ordinary citizens are not able to consider long term return on investment (5-8 years).
- Key policy guidelines:
  - Do not hide or cap electricity price volatility (e.g. do not spend public subsidies to pay for options to cap prices).
  - Create a legal framework to capture positive externalities not taken into account in market prices.
  - Add dynamic energy management requirements to new construction standards, not just absolute energy usage reduction objectives: the energy mix is more important than the absolute value of energy consumption.
  - Lower installation costs in the residential field by promoting standard interfaces to boilers and heating systems.

## 6. Q.Rad digital heater

### *The Cloud HPC Revolution (High Performance Computing)*

Company: Qarnot Computing

#### (A) Overview of “usual” solutions

- The Q.Rad digital heater is a sustainable alternative to data centers. It avoids data center costs related to infrastructure, maintenance, and cooling by spreading valuable heat directly in buildings, for free.
- Data centers consume 1.5 to 2% of all global electricity, growing at a rate of 12% per year. Cooling accounts for approximately 50% of a data center's electricity bill. In the meantime, households continue to spend on average \$2,000 yearly on heating.
- The High Performance Computing market, relying mostly on data centers' computing power, is expected to grow at about 7% over the next 5 years. Alternatives are necessary to address a growing demand while limiting negative impact on the environment.

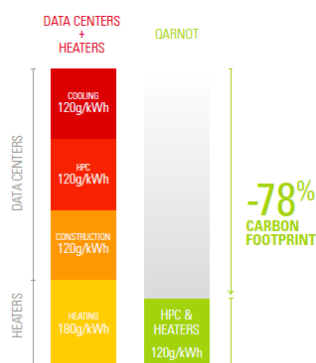
#### (B) Synthetic description of the innovation



- The Q.Rad is a connected electric radiator embedding high performance processors as a heat source. Totally silent, it gets its computing instructions from the Internet. The Q.Rad technology is easily scalable and deployable worldwide and only requires fiber optics Internet.
- By processing computation workloads, the Q.Rad heats all types of premises, for free. It also allows Qarnot's clients to enjoy unlimited affordable green computing power, thus democratizing HPC for SMEs.
- Thanks to our “Qarnot facts” label delivered after each job performed, our HPC clients can instantaneously measure the positive impact of every workload and easily communicate the important footprint reduction.

QARNOT facts	
Job #1358	03/25/2014 13:54:12
Backtest_1423.py	
<b>Period</b>	<b>2500d</b>
Precision	1.0E-6
Sampling	1.5E+6
Avg. time	2m 28s
<b>Computation</b>	<b>4d 6h 32m</b>
Job duration	45 min
Average #CPUs	134
Data in	1.6 GB
Data out	956 MB
<b>CO<sub>2</sub> saved</b>	<b>160 g</b>
Energy consumed	11 kWh
Energy saved	32 kWh
People heated	2.7 man days

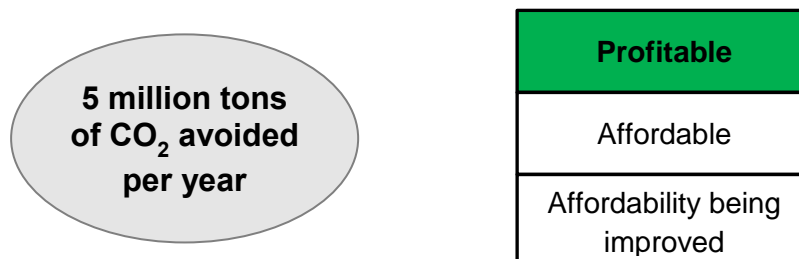
Each Q.rad consumes	2 000 kWh/y
Each Q.rad avoids	7 000 kWh/y
Each Q.rad emits (nuclear electricity) *	0,13 tCO <sub>2</sub> e/y
Each Q.rad emits (gas electricity) **	1,00 tCO <sub>2</sub> e/y
Each Q.rad emits (avg mix 30/70%)	0,74 tCO <sub>2</sub> e/y
Each Q.rad avoids (avg mix 30/70%)	2,59 tCO <sub>2</sub> e/y
* Nuclear electricity	66 gCO <sub>2</sub> e/kWh
** Gas electricity	500 gCO <sub>2</sub> e/kWh



## Q.Rad digital heater

### *The Cloud HPC Revolution (High Performance Computing)*

#### (C) Impacts in terms of reduction of carbon emissions by 2020



Scenarii	Units		Avoided MtCO2e
Data center power (2007) *	330	Twh	
Data center power (2020) *	1 012	Twh	
Realistic 2020	500 000	Q.rads	1,29
Optimistic 2020	2 000 000	Q.rads	5,18

\* source (<http://www.greenpeace.org/international/Global/international/planet-2/report/2010/3/make-it-green-cloud-computing.pdf>)

#### (D) Major roadblocks and first policy recommendations

- The major existing roadblocks to the innovation are...
  - Dual-faced business model bootstrapping: financing equipment to bootstrap HPC offer.
  - Cloud computing service adoption versus traditional in-house data center hosting.
- The main conditions for its development are...
  - Infrastructure improvement: Q.Rads can be deployed in a whole building or in a single flat covered by fiber optics Internet
  - Mandatory and strict regulations for corporate ITC carbon footprint (in-house and subcontracted ICT).

## 7. R&D program in Lyon

### *Making Lyon a Smarter City*

Company: IBM

#### (A) Overview of “usual” solutions

- The purpose is to reduce urban congestion and, as a consequence, fuel consumption or pollution:
  - Cities / County with congestion issues
  - Aiming at 30% of CO<sub>2</sub> emissions related to transports



#### (B) Synthetic description of the innovation

- The new system collects data in real time, and analyses it to produce predictive city information used to improve traffic. Transportation operators can optimize the traffic using specific tools.
- Traffic prevision is based on real-time data. The city can use these tools to take better planning decisions and optimize freight delivery.
- Car traffic could be reduced by 8%, car usage could fall from 60% to 50% in Lyon, and freight deliveries could be reduced by 20%.

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**4 million tons of CO<sub>2</sub> total worldwide potential by 2020**

By 2020, the annual amount of CO<sub>2</sub> should represent:

- 8% of car traffic, longer delivery freights, more car use
- 200,000 tons/year CO<sub>2</sub> saved by 2020 for Lyon
- 1,2M tons of CO<sub>2</sub> by 2020

<b>Profitable</b>
Affordable
Affordability being improved

- Frost & Sullivan<sup>1</sup> estimates that 26 global cities will be smart cities at worldwide level by 2025, with more than 50% of these smart cities in Europe and North America.
- Considering that the innovation could be replicated in 20 other cities by 2020, large and small, the total potential annual CO<sub>2</sub> reduction would amount to 4Mt p.a. from such smart traffic solutions.

(1) Frost & Sullivan: “Global Smart Cities market to reach US\$1.56 trillion by 2020”



## R&D program in Lyon

### *Making Lyon a Smarter City*

#### **(D) Major roadblocks and first policy recommendations**

---

- The major existing roadblocks to the innovation are budget constraints, network density, basic information and security.
- Main conditions required for its development:
  - Need for specific infrastructures: integrated real time database, open data platform, traffic prediction, multimodal real time journey planner and mobile personal assistant.

## 8. Trip optimizer

*A smart monitoring solution for trains*

### (A) Overview of “usual” solutions

Trains are driven by individual operators based on their style and experience. The variation in their capabilities and the variations in the train setup (structures) cause large inefficiencies in the operator’s performance.

### (B) Synthetic description of the innovation

Trip Optimizer auto Control System for Trains

- Trip Optimizer uses advanced optimization algorithms to pre-plan the velocity profile based on train makeup, track topography and speed limits. The Trip Optimizer closed loop control functionality drives the throttle/dynamic brakes to meet the plan.



Typical Locomotive 1200 kl Annually	10% Savings Per Loco Per Year	Units
FUEL	120,000	Liters
CO <sub>2</sub>	324	Tons
NO <sub>x</sub>	3.347	Tons
PM	63,000	Grams

### (C) Impacts in terms of reduction of carbon emissions by 2020

**324 million tons  
of CO<sub>2</sub> avoided  
per year by 2020**

**Profitable**

Affordable

Affordability being  
improved

- 4,000 systems installed today with nearly 7,000 under contract.
- 10,000 systems should be installed by 2020 assuming average install rate of ~1,000.
- 324 million tons should be saved annually by 2020.

### (D) Major roadblocks and first policy recommendations

- Cultural change: railroad industry accepting to have a computer driving a freight train.

## 9. Full hybrid technology

### *Full hybrid technology for the automotive industry*

Company: Toyota & Lexus

#### (A) Overview of “usual” solutions

- Hybrid technology has an increasing role in replacing conventional ICE (Diesel & Petrol) vehicles
- 28 full Hybrid vehicles are currently on sale in 80 countries worldwide (as of September 2014)
- Toyota plans to introduce a Full Hybrid technology model in all ranges in early 2020s
- Full hybrid technologies emit neither CO<sub>2</sub>, nor Nox/Particulate matters during EV driving range. The lowest CO<sub>2</sub> level achieved today is 49 g/km (Plug-in Hybrid)

#### (B) Synthetic description of the innovation



2014 Toyota & Lexus Full Hybrid range available in France. © Toyota France

- Toyota Full Hybrid technology is a series-parallel technology that combines electric motors together with conventional petrol engines.
- Full Hybrid technology does not need any recharge infrastructure and allows low consumption together with limited CO<sub>2</sub> / NOx or particulate matter emissions.
- Real driving tests show that up to 60% of daily trips can be achieved without using ICE engine when driving a Toyota or Lexus Full Hybrid vehicle.

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**~21 million tons  
of CO<sub>2</sub> avoided  
per year by 2020**

- 7 million Toyota & Lexus Full Hybrid vehicles have been sold since 1997. Assuming that 1 million additional vehicles are sold annually (official annual Full hybrid sales target is over 1Mio units / year), the total installed base would then amount to 14 million vehicles by 2020.
- Assuming an average standard vehicle drives an average 20,000 km per year, emitting 125 gCO<sub>2</sub>/km, the corresponding amount of CO<sub>2</sub> avoided by a full hybrid vehicle, emitting only 49 gCO<sub>2</sub>/km, would be of ~1,5 ton CO<sub>2</sub> per year per vehicle.

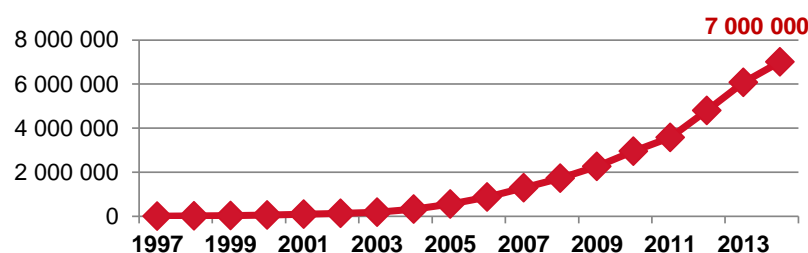
# Full hybrid technology

## *Full hybrid technology for the automotive industry*

### (D) Major roadblocks and first policy recommendations

- The cost of batteries as a major EV component still requires further improvements to accelerate Full Hybrid technology democratization towards all segments in the market.
- Main conditions for its development are :
  - Increased awareness on low consumption / CO<sub>2</sub> emissions advantages of Full Hybrid technology.
  - As Hybrid is representing around 1% to 3% of the market today (depending on regions), incentives like low CO<sub>2</sub> Governmental Bonus for final user in France are still required in forthcoming years to ensure Full Hybrid technology will be widely accepted by consumers.

<b>Profitable</b>
Affordable
Affordability being improved



## 10. Citélib by Ha:mo

*A new type of urban mobility based on ultra-compact EV connected to Public transport*

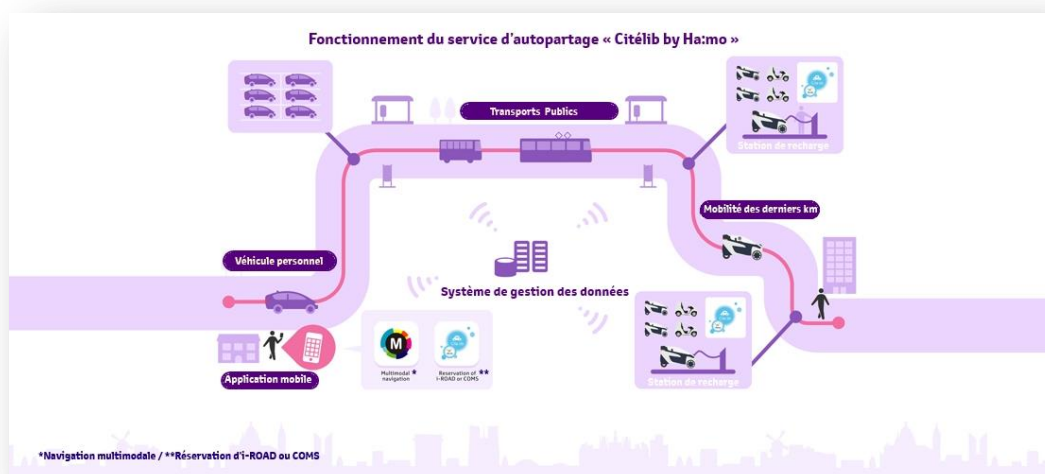
Company: Toyota

### (A) Overview of “usual” solutions

- Citélib by Ha:mo will complete the multi-modal public service, currently existing in Grenoble.
- This experimentation has been taking place in Japan (at Toyota-city since October 2012) and in France (Grenoble) for 3 years (until 2017).



### (B) Synthetic description of the innovation



- Two models of the innovation (35 three-wheel Toyota i-Road and 35 four-wheel COMS) will be available for short city trips in 27 charging stations – including one-way trips from one station to another – and will be linked to the existing public transportation system.



- To estimate the cost to the final end user, a simple pricing plan dubbed “3, 2, 1 euros” for respectively the first, second and third 15-minute increments will be proposed to Grenoble citizens.
- For annual local transport card subscribers, the price will be reduced, at 2+1 euros for respectively the first and subsequent 15-minute increments.

## Citélib by Ha:mo

*A new type of urban mobility based on ultra-compact EV connected to public transport*

### **(C) Impacts in terms of reduction of carbon emissions by 2020**



- This new car-sharing program was launched in October 2014 in Grenoble (France) for 3 years testing. Evaluation of CO<sub>2</sub> savings and feedback will be gathered by Toyota and other partners during that period.

### **(D) Major roadblocks and first policy recommendations**

- Main condition required for its development:
  - Recharge infrastructures need to be deployed and widespread in order to be in a position to extend such a service to more cities.

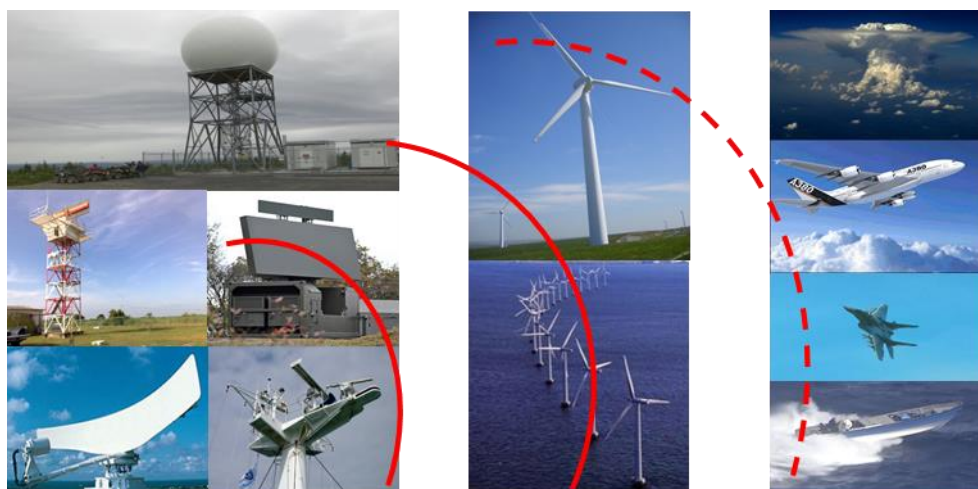
## 11. RFBlade (Radar Friendly Blade)

*Improving the cohabitation between radars and wind turbines*

Company: COFELY INEO

### (A) Overview of “usual” solutions

- In many cases, wind turbines interfere with weather radars, Defence and Civil Aviation, causing a loss of radar detection (masking or false echoes) due to the rotation of the turbine blades, which disrupts the propagation of electromagnetic waves.
- In view of this, the authorities in France, Europe, etc. refuse a large number of construction permits representing a potential of a minimum 3GW in France and 20GW of blocked projects in the world. If technical solutions are not quickly found, more and more wind energy projects will not see the light of day. In France the initial target of the Grenelle Environment Forum, set at 19 GW of onshore wind energy by 2020, will be impossible to achieve.
- The so-called RFBlade INEO Defense technology is proving to be very promising in the development of “discrete” wind turbines for radar-sensitive locations





## RFBlade (Radar Friendly Blade)

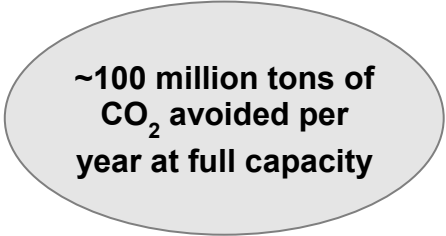
### *Improving the cohabitation between radars and wind turbines*

#### **(B) Synthetic description of the innovation**

- As a specialist in telecommunications, radar environment and radio- electrical product manufacturer, Cofely Ineo (through its subsidiary INEO DEFENSE) has mastered for several years the so-called “RF Blade” technology adopted in a number of military applications.
- INEO DEFENSE is developing this unique technology designed to enhance radio-electrical transparency of the wind turbine blade in the form of a 'compensated grid' inserted into the skin by the blade manufacturer. The internal structures (spars), possibly made from carbon composite, will be able to be masked if required using a standard absorbent. This solution would have the advantage of being able to adapt to all types of blade architecture, both onshore and offshore.
- RFBlade is the sole technology offering the following advantages :
  - **Important reducing of the masking effect** on radars (by improvement of the blade transparency) and **false echoes** (by reducing the Radar Cross Section of the rotating blades)
  - **Effective on Multiple frequencies or broad bands** allowing the skin to be adapted to several types of radars simultaneously for example weather forecasting and aviation
  - **No change in shape or mass of the blade and its design**
  - **Minimal extra cost** in the order of several % of the total price of the machine, compatible with the extra cost of freeing up sites currently prohibited because of their proximity to radars. No maintenance work required.
  - The expected improvement would **help reduce the prohibited area around a radar by 75% to 90%.**

#### **(C) Impacts in terms of reduction of carbon emissions by 2020**

- RF Blades solution addresses both military, weather and air civil radars
- A first assessment considering only the weather radars shows a great potential of carbon reduction
- With above 800 weather radars worldwide, including ~500 in the top 15 Wind Power capacity countries, there is a large market potential, which this solution can address.
- Assuming ~90MWe of wind turbines power per weather radar (~600km<sup>2</sup> new accessible zones), ~45GWe can be installed in zones that were previously non-accessible.
- Assuming 26% utilization, by the Top 15 countries' 100TWh, it would trigger savings of ~100+MtCO<sub>2</sub> from equivalent coal plants production (1tCO<sub>2</sub>/MWh).



**~100 million tons of  
CO<sub>2</sub> avoided per  
year at full capacity**

# RFBlade (Radar Friendly Blade)

*Improving the cohabitation between radars and wind turbines*

## (D) Major roadblocks and first policy recommendations

- Development of wind energy in radar-sensitive locations appears as crucial for the energetic transition policy but requires maintaining the balance of interests of the actors in charge of weather forecasting, airspace surveillance and winding energy industry.
- Regards to partners ongoing collaborations (Industrial , R&D Center, Operators...) and its confidence in RFBlade innovative solution, INEO DEFENSE wants to be a major player.
- Main conditions for its development require a political contribution from public authorities in order to :
  - 1/ facilitate (financial support & authorizations) experimental demonstration in wind farm demonstrating the positive and beneficial contribution of the innovation
  - 2/ establish regulation and certification standard taking into account the positive contribution of this innovation

Profitable
Affordable
Affordability being improved

## 12. Slurry pipeline

### *Replacing trains by a pipeline*

Company: OCP

#### (A) Overview of “usual” solutions

- Mainly used in the production of fertilizers, phosphate ore is extracted from the mining areas of Khouribga, Benguerir, Youssoufia and Boucraâ-Laayoune. Currently, 26.4 million tons\* of phosphate are extracted annually in Morocco, which holds nearly three-quarters of world reserves.
- Phosphate ore is transported by train either to Casablanca for export or to Jorf Lasfar to be valued fertilizer chemical industries group. The train transportation is power consuming and has a limited capacity of phosphate transfer.
- To change this, OCP has installed a slurry transportation pipeline system from Khouribga mines to Jorf Lasfar Terminal. This pipeline system combines energy and cost efficiency by avoiding train transportation, drying and re-humidifying phosphate ore for chemical processes. It is environmentally friendly since the slurry is transported by natural gravity using much less power energy.

#### (B) Synthetic description of the innovation

- The slurry pipeline used by OCP is the longest phosphate pipeline worldwide (187km). It starts at the head station in Khouribga mining site and ends at the terminal station at Jorf Lasfar and can operate on a continuous basis a maximal feed rate of 4,400 tons per hour.
- Phosphate ore is mined, washed, milled, de-slimes, in some cases processed through a flotation process and thickened to produce phosphate slurry with the required characteristics and pumped to the main slurry pipeline head station at Khouribga.
- Phosphate ore is stored in the tank farm at the head station, from where it is pumped to the terminal station at Jorf Lasfar. It then feeds the existing and future planned chemical plants that produce either phosphoric acid or fertilizers. The other portion of slurry phosphate which is intended to be exported is transferred to the packing facilities where the pulp is filtered, dried and agglomerated.
  - In terms of innovation, the slurry pipeline's transportation system relies on natural gravity: the altitude gap between Khouribga and Jorf Lasfar is around 800 meters and phosphate pulp can be transferred without high energy efforts.
  - Besides, different phosphate grades are prepared at the wash plants and kept separate throughout this process, by plugs of water to minimize mixing of the product grades.
- Slurry pipeline displays a nominal performance of 3700 tons per hour, above the existing worldwide phosphate pipelines.
- As a result, the carbon footprint will improve by 22%, assuming a yearly production of 38M tons in 2019, OCP expects to reduce its CO<sub>2</sub> emission by 930,000 tons per year.



Pipeline route between the Khouribga and Jorf Lasfar sites

\* OCP annual report, 2013; \*\*Depending on the capacity production and transport of phosphate ore which will be enhanced quickly from 26 MT/year to 38 MT/year

# Slurry pipeline

*Replacing trains by a pipeline*

## (C) Impacts in terms of reduction of carbon emissions by 2020

**930,000 tons  
of CO<sub>2</sub> avoided per year  
by 2020\*\* for OCP only**

- In the context of an increase of the annual production capacity and transportation of phosphate ore from 26.4 million of tons / year today to 38 million tons / year, this new transportation process will reduce CO<sub>2</sub> emission by 930,000 tons per year.

Profitable
Affordable
Affordability being improved

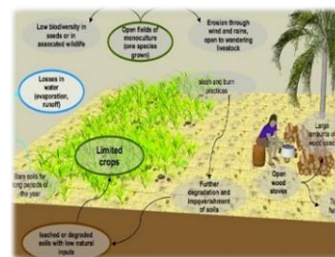
## 13. Insetting via agroforestry

### *Planting trees to offset carbon*

Company: Pur Projet

#### (A) Overview of “usual” solutions

- Carbon offsetting (compensating GHG emissions by funding projects not related to the actor's activities and supply chain) and agroforestry projects can be implemented everywhere, especially in tropical regions where deforestation is dramatic



#### (B) Synthetic description of the innovation

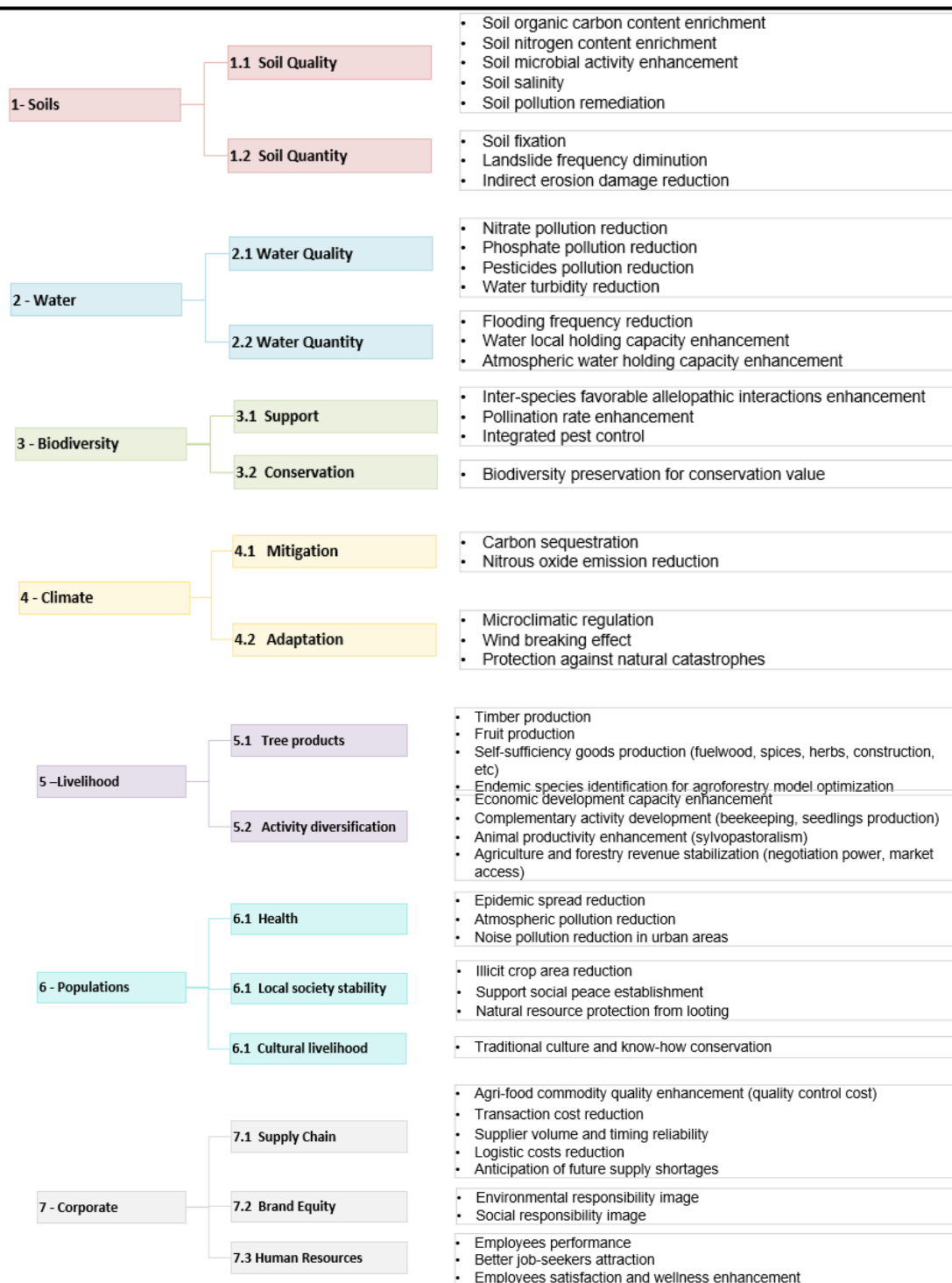
- Insetting: integrating high-impact socio-environmental projects within a company's supply chain to restore and activate the ecosystems upon which it depends, thus generating value for the supply chain actors, the company, and the environment.
- Agroforestry: land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy, and sustainable land-use systems.
- Switching from intensive monoculture to agroforestry models.
- Coffee agroforestry model culture carbon footprint is negative: -5Teq CO<sub>2</sub> /ton of coffee, considering a 20 years sequestration cycle



# Insetting via agroforestry

## *Planting trees to offset carbon*

### (C) Benefits generated by insetting via agroforestry projects for the environment, the company and farmers



# Insetting via agroforestry

*Planting trees to offset carbon*

## (D) Impacts in terms of reduction of carbon emissions by 2020

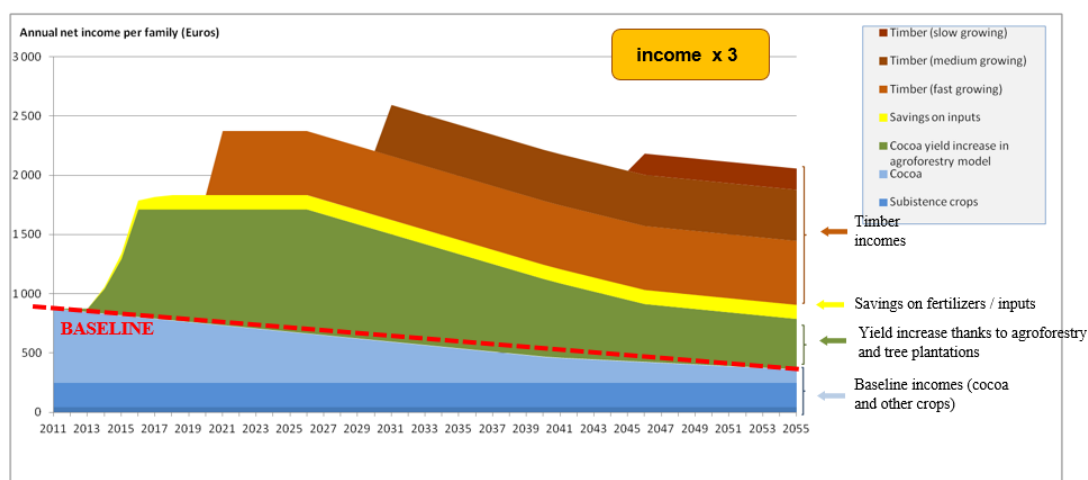
**Agroforestry:**  
~0.5 Gtons of CO<sub>2</sub> avoided per year by 2020

**Pur Project:** 15-20 Mtons of CO<sub>2</sub> captured and avoided by 2020

Profitable
<b>Affordable</b>
Affordability being improved

### Model of farmers annual net income increase in project scenario

Kuapa Kokoo project – cocoa (Ghana) (€/year)





## 14. Anaerobic digestion with multi-stage HYFAD digester

*Better waste treatment*

Company: GreenWatt

### (A) Overview of “usual” solutions

- High water content solid waste is a waste type difficult to treat efficiently :
  - Its high water content makes transportation uneconomical.
  - The waste is unstable, which makes storage unfeasible.
  - It is not burnable, neither compostable.
  - It has low energy content (200-500kWh/ton) and so does not give valuable reasons for prioritizing its treatment.
- Treating this solid waste emits ~ 110 kgCO<sub>2</sub>/t (composting).



### (B) Synthetic description of the innovation



- This innovation implies a multi-stage anaerobic digestion system based on HYFAD innovation.
- Emissions of CO<sub>2</sub> are negative: the technology turns an emission into green energy as biogas replaces fossil fuel. No extra carbon is released.
- The solution pays for itself by selling the energy produced.
- It also recycles nutrients to natural carbon and other element cycles.

### (C) Impacts in terms of reduction of carbon emissions by 2020

**20,000 tons of  
CO<sub>2</sub> avoided  
per year by  
2020 for  
GreenWatt only**

- By 2020 about 40 digestion plants will be operating
- That will represent about 20,000t CO<sub>2</sub>/year of avoided emissions thanks to green energy obtained by waste treatment.

# Anaerobic digestion with multi-stage HYFAD digester

*Better waste treatment*

<b>Profitable</b>
Affordable
Affordability being improved

## (D) Major roadblocks and first policy recommendations

- Lack of public awareness about the technology
- Implementation of such projects can be long (e.g. project development, administrative procedures, authorisations).
- Permitting, authorization, etc. could be simplified and a single point of contact should be set-up for all procedures.
- Other needs:
  - Efficient green energy policy
  - Subsidies to compensate the classic energy production process subsidies

## 15. Low GHG fire protection systems

*Combining safety and energy-efficiency*

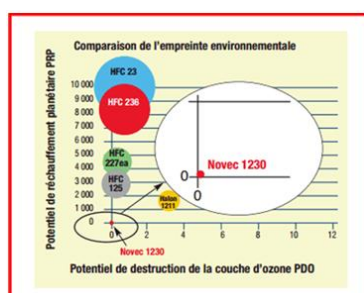
Company: 3M

### (A) Overview of “usual” solutions

- Fire protection system with HFC are used everywhere in the world
- HFCs used in fire protection have very high global warming potential (GWP) values



### (B) Synthetic description of the innovation



- Novec™ 1230 Fire Protection Fluid is a new molecule designed to reach a GWP 3500 times lower than existing solutions. It is an advanced, "next generation," clean agent designed to balance industry concerns for performance, human safety, and the environment.
- This makes Novec 1230 fluid the first option to non-sustainable technologies suitable for use in a wide range of offshore and land-based operations/applications to protect occupied spaces, critical equipment, and most of all people.

### (C) Impacts in terms of reduction of carbon emissions by 2020

- Virtually every HFC installed will ultimately end up in the atmosphere and contribute to global warming unless they are recovered and destroyed.

Profitable
Affordable
Affordability being improved

- As of today the innovative solutions has a 30 % upcharge compared to other existing solutions: reduction from 3500 (HFC227ea) to 1 CO<sub>2</sub> equivalent
- By 2020, considering possible gains and improvements, the difference might evolve towards a 20% upcharge.

## 16. Distributed demand response

*Turning electricity consumers into energy savings producers*

Company: Voltalis

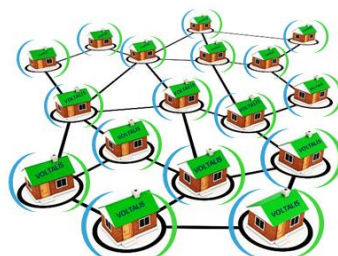
### (A) Overview of “usual” solutions

- Electricity cannot be stored on the grid: balance between supply and demand has to be maintained constantly. It is usually secured through backup production capacities (thermal plants). This can be expensive, and can slow the growth of intermittent renewables and of new loads such as electric vehicle.
- Energy efficiency policies expect the consumers to better master their consumption, but existing Home Energy Management Services are often too expensive to allow a massive adoption by the end-users.

### (B) Synthetic description of the innovation



- Voltalis solution turns electricity demand into a flexible and reactive “virtual production capacity”. This solution aggregates energy savings from millions of homes when the grid needs it, at local, regional or national levels.
- This generation is based upon synchronized shedding of thermal electrical consumption (heater, water boilers, air conditioning, HVAC...) in a large number of residential and tertiary sites, using proprietary algorithms that use the thermal inertia of the buildings to ensure a preserved comfort.
- End users also benefit, for free, from a precise monitoring of their electricity consumption and other dedicated services, for more energy efficiency.
- This technology is already certified by the largest European TSO, rolled out on more than 100,000 houses, and operated on real energy markets since 2008.
- Over ten years, the carbon impact of the Voltalis device is 64 kg of CO<sub>2</sub> per unit. This takes into account production, packaging, transport and operation of the device.



**Save money**

**Be green**

**Join the community**

**For free**

- The Voltalis device, installation and service can be financed through its energy production, and thus proposed for free to the end user.
- End-users benefit from energy savings, both due to the shedding, to the monitoring and extra services proposed. A typical gain is 15% of the energy bill.
- The gain in terms of CO<sub>2</sub> is even higher; depending on the country energy mix. In France for example, a house participating in distributed demand response with Voltalis reduced its CO<sub>2</sub> emissions due to electricity by 30%.
- Last, distributed demand response represents investments 10 to 20 times lower than traditional peak load production (including T&D).

# Distributed demand response

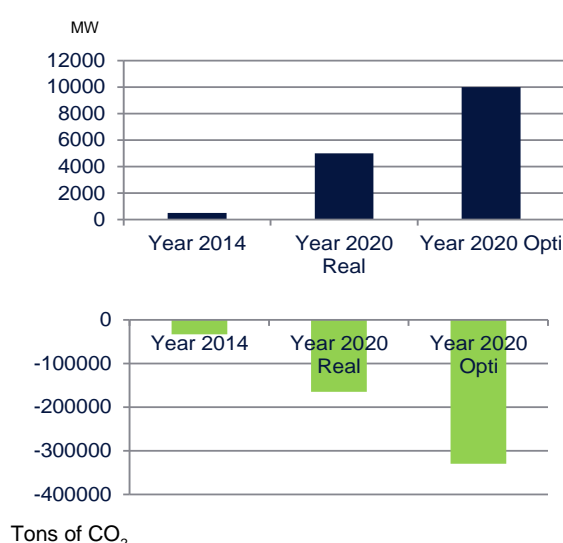
*Turning electricity consumers into energy savings producers*

## (C) Impacts in terms of reduction of carbon emissions by 2020

- By 2020, Voltalis could reach a 5 to 10 GW peak capacity
- Since 2008, Voltalis has built a 500 MW peak capacity of distributed demand response, which can be dispatched every day and many times a day.
- Voltalis' ADR technology would avoid the emission of 330,000 tons of CO<sub>2</sub> per year by 2020.

**330,000 tons  
of CO<sub>2</sub> avoided per  
year by 2020 for  
Voltalis only**

Profitable
Affordable
Affordability being improved



## (D) Major roadblocks and first policy recommendations

- *Distributed Demand Response* is a relevant solution for a large number of countries around the world since there are thermal loads (hot or cold), grid constraints and growing renewables almost everywhere.
- The national regulations must be adapted to allow the production of “non consumption” to participate in energy markets on the same terms as traditional production. Two issues must be addressed:
  1. Reducing the load of X MW during Y hours must be recognized and allowed to bid on the same markets on a non-discriminatory basis.
  2. A measurement tool of thermal loads only is required, that can work on a real time basis, and which can lead to accept other data than those of DSO meters or than traditional profiles, potentially collected by the operator.
- Several countries have implemented the first point, opening to industrial demand response, an interesting resource but much more limited than the residential sector. A European Directive has already required the integration of shedding production into all wholesale energy markets. France is the first country to address both issues; opening to real distributed demand response on all energy markets (including capacity market and balancing market) and making possible the construction of several GW within the next few years.

## 17. Electrochromic glass

*SageGlass, a dynamic solar control window*

Company: Saint Gobain

### (A) Overview of “usual” solutions

SageGlass' innovation is used like conventional means of solar control in buildings such as

- Blinds and shades
- Mechanized sunshades
- Double-skin facades
- Louvers





# Electrochromic glass

## *SageGlass, a dynamic solar control window*

### (B) Description of innovation

SageGlass is part of the category of *dynamic solar control*, which allows buildings to automatically block sunlight and solar heat gain as needed.

Technology mechanisms...

- Darkens or “tints” a coated surface.
- Lithium ions transfer from the counter electrode layer to and Electrochrome layer (EC) to tint the glass when needed.
- Tinted glass reflects heat and light – reducing glare and heat entering a building through the window.
- Requires only a low-voltage power supply, less than 5 volts.
- A curtain wall of 150 square meters requires less electricity to operate than a 60 watt (60W) lamp.

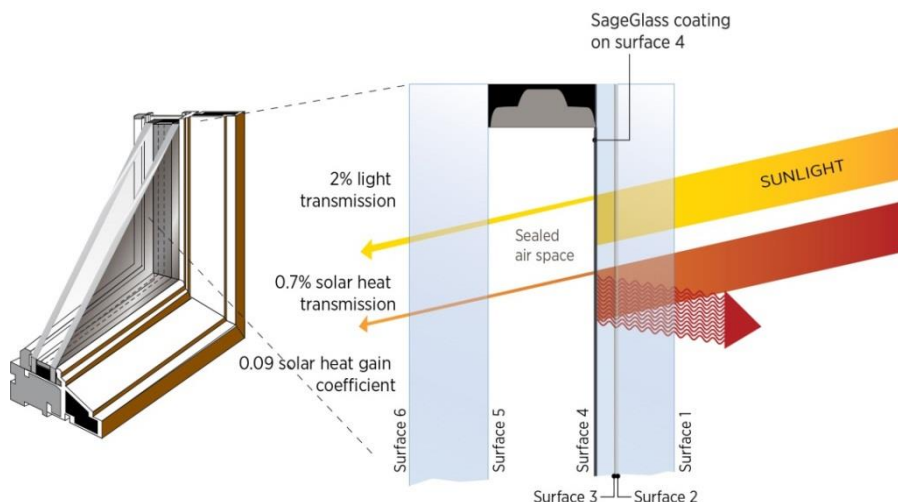
...and benefits:

- Reduced electrical lighting by increased use of day lighting.
- Reduced heating or air-conditioning (HVAC) needs.
- Reduced electricity use, thus CO<sub>2</sub> produced from power plant
- Lower need for blinds, shades or louvers and hence reduced carbon impact on the environment.
- Reduced glare.
- Increased window-to-wall ratio (WWR).
- Better comfort (better view and connection to the outdoors).



*SageGlass*

SageGlass laminated insulating glass unit (IGU) - tinted state



# Electrochromic glass

## *SageGlass, a dynamic solar control window*

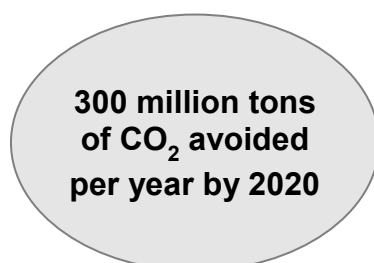
### (C) Impact on Reduction of Carbon Emission

- SageGlass doubled glazed windows result in 45% energy savings compared to a single pane window and 20% compared to ASHRAE 2007 standard.
- SageGlass also results in a lower use of carbon-impacting materials in a building because the tinting is built into the glass, and does not require using additional materials for solar control.

#### Minimum Annual Energy Savings for SAGE Dynamic Glazings Compared to Static Commercial Glazing Types

	Static Single Pane (no daylighting controls)	ASHRAE 90.1-2007	Commercial Triple
SageGlass Double	45%	20%	NA
SageGlass Triple	53%	34%	14%

Eight story office building, 160,000 total sq. ft., 60% window-to-wall ratio



<b>Profitable</b>
Affordable
Affordability being improved

- The US Department of Energy includes electrochromic windows like SageGlass in its roadmap to achieving zero-energy buildings. The DOE's Lawrence Berkeley National Laboratory, considers electrochromic glazing to be the next major advance in energy-efficient technology.
- According to researchers at the DOE's National Renewable Energy Laboratory, the full deployment of dynamic, highly insulating glazing can save up to 5% of the US energy budget. That is equivalent to over 160GW of electricity generated annually by fossil fuels. Such savings could reduce CO<sub>2</sub> emissions by 300 million metric tons.
- SageGlass costs the same, or less, than conventional glass when you consider the total cost of ownership.

### (D) Roadblocks and Policy Recommendations

Barriers to increased adoption of electrochromic glass include:

- Still relatively low product awareness among architects and building owners.
- Price relative to conventional solutions.
- Limited governmental support (standards / behavior change).



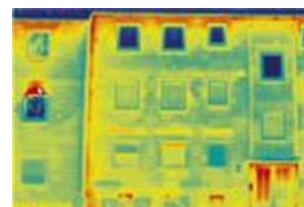
## 18. High performance insulants

### *Better home insulation*

Company: Saint Gobain

#### (A) Overview of “usual” solutions

- Usually insulants are made out of glass wool with thermal conductivity of 45 mW/mK
- With such an insulant, a building emits 55 kg CO<sub>2eq</sub>/m<sup>2</sup>/yr



#### (B) Synthetic description of the innovation



- This new technology glass wool has a thermal conductivity of  $\lambda$ 30mW/mK.
- It decreases thermal losses compared to the same thickness of glass wool, improving the thermal performance by almost 50%.
- Using this solution, a building would emit only 30 kg CO<sub>2eq</sub>/m<sup>2</sup>/yr

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**1 Mt CO<sub>2</sub>  
avoided per  
year by 2020**

**Profitable**

Affordable

Affordability being  
improved

- 500,000 houses / year in France could benefit from a retrofit
- Baseline scenario: 0% of Retrofit French market with Glass Wool at  $\lambda$ 45mW/mK.
- Realistic scenario: 10% of retrofit market, 50,000 housings/year, for 100m<sup>2</sup> (surface of the house), would decrease of  $\lambda$  to 30mW/mK resulting in 25 Kg CO<sub>2eq</sub>/m<sup>2</sup>/yr saved.
- Optimistic scenario: Decrease of  $\lambda$  to 25mW/mK and increase of market share to 30%. If  $\lambda$ 25mW/mK, the building emits 24 kg CO<sub>2eq</sub>/m<sup>2</sup>/yr, resulting in 31 Kg CO<sub>2eq</sub>/m<sup>2</sup>/yr saved
- Realistic scenario: 125 000 tons CO<sub>2eq</sub>/year for a 100m<sup>2</sup> housing (25\*100\*50000)
- Optimistic scenario: 465 000 tons CO<sub>2eq</sub> saved /year (31\*100\*150000)
- France accounts for 1/8<sup>th</sup> of the total worldwide potential
- Potential World = 1 Mt CO<sub>2</sub> annually by 2020

## 19. Opti-climb

### *Reducing plane fuel consumption*

Company: Safety Line

#### (A) Overview of “usual” solutions

- Every aircraft burns several tons of fuel at each flight.
- Fuel consumption is not fully optimized.



#### (B) Synthetic description of the innovation



- The innovation mechanism is based on machine learning from flight data recorders to produce individual models for each aircraft and use those models to optimize climb fuel consumption.
- It is different from previous technologies because it uses “real life” data to adapt the performance of each aircraft.
- The benefit is an economy of 200 kg to 1,000 kg of fuel per flight.

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**8 to 50 M tons  
of CO<sub>2</sub> avoided  
per year by  
2020 Opti-climb  
only**

Profitable
Affordable
Affordability being improved

- This product is still in an experimentation phase.
- 8M tons of CO<sub>2</sub> by 2020 should be saved in a “baseline” scenario (based on the existing product and considering a 10% market share).
- By 2020 improvements will be made and a 3% global fuel reduction could be reached. In this case it would avoid 24M tons CO<sub>2</sub> that would be achieved.
- In an optimistic scenario, the solution could be installed in the aircraft flight management computers and could reduce emissions by at least 50M tons of CO<sub>2</sub>.

# Opti-climb

## *Reducing plane fuel consumption*

### **(D) Major roadblocks and first policy recommendations**

---

- The main roadblock could be the speed of adoption by airlines.
- To make this innovation successful, the main lever is to demonstrate its benefit at an airline scale, which requires a test customer willing to witness the efficiency of the solution.
- Support from authorities could help, but the main driver is the fuel savings that can be achieved.

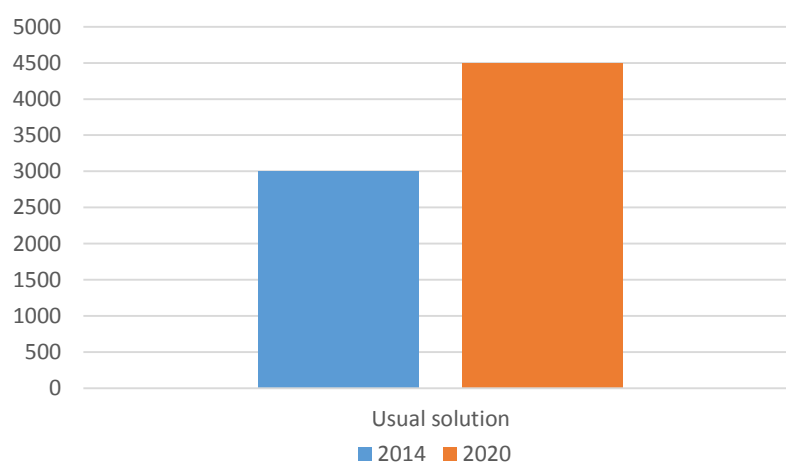


# Opti-climb

## *Reducing plane fuel consumption*

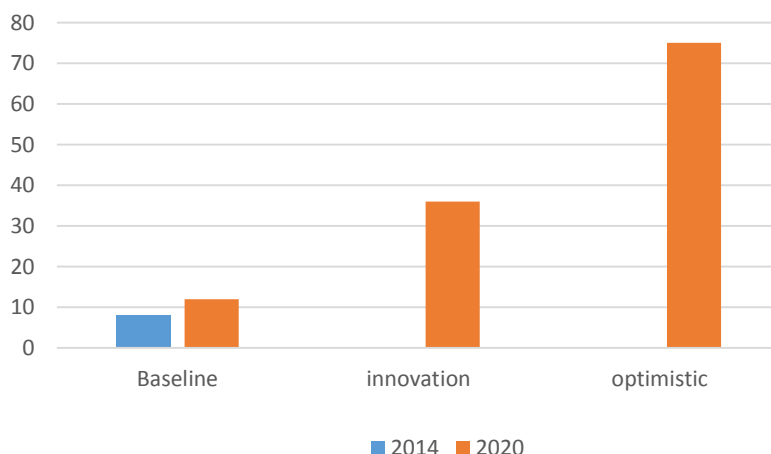
### Illustrative charts

**Illustration of aviation related CO<sub>2</sub> emissions without improvement (in M of tons)**



- The number of aircraft should increase by 50% as of 2020

**Illustration of a substitution effect:  
Impacts in terms of CO<sub>2</sub> emissions by 2020 (in M of tons)**



- Using a data analytic solution only, the emissions can be decreased by at least 1.5%.

## 20. Shrinking the impact of the drink in your hand

### *Recycling plastic bottles*

Company: Coca-Cola Enterprises

#### **(A) Overview of “usual” solutions**

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Coca-Cola Enterprises (CCE) manufacture, sell and distribute some of the best known drinks in the world across Northern Europe.

Packaging is usually carbon intensive and too often ends up in landfill, even though nearly all our packaging materials can be recycled. Coca-cola Enterprises want to change this and support the principles of a circular economy; ensuring maximum value can be gained from the efficient use of natural resources.

They have therefore invested €12.5 million in two recycling joint ventures in Great Britain and in France in recent years, to significantly increase the amount of PET plastic which can be reprocessed locally and re-used in our plastic bottles.

#### **(B) Synthetic description of the innovation**

---

- Approximately 60% less energy is used in producing recycled PET (rPET) than the virgin material. However, recycling levels are lower for PET than for metals. To address this, the company has invested in plastics reprocessing.
- In Great Britain, the joint venture with EcoPlastics, Continuum, is the largest, most sophisticated plant of its kind in the world.
- In France Infineo, an industrial project on the site of APPE, is a major investment to develop circular economy packaging. The facilities bring the recycling process full-circle, with used plastic packaging sorted and reprocessed domestically, before returning to shelves as part of another bottle within six weeks.
- The Continuum Recycling plant more than doubled the amount of food-grade recycled plastic (rPET) previously created in Britain. While Infineo increases the production capacity of food-grade recycled PET in France by 70%.

#### **(C) Impacts in terms of reduction of carbon emissions by 2020**

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- In 2013, the use of recycled and renewable materials, together with initiatives to use less packaging, reduced the carbon impact of the manufacturers business by 21,800 tons of CO<sub>2</sub> eq.
- Cola Cola reached its commitment to use 25% rPET in all bottles by the end of 2012 and 32% in 2013.
- In France Infineo, has increased the rPET plant capacity by 70%.
- In Great Britain Continuum has saved around 33,500 tons of CO<sub>2</sub> per year- the equivalent of taking over 15,715 cars off the road.

# Shrinking the impact of the drink in your hand

## *Recycling plastic bottles*

### **(D) Major roadblocks and first policy recommendations**

---

Major roadblocks to the innovation are:

- Changing consumer recycling behaviour over the long-term.
- Ensuring existing facilities are fully used. For this, Coca Cola needs to secure a minimum volume of recycled bottles and to boost sources of locally available high-quality recycled PET.
- Recycling behaviors:
  - In 2014 Coca Cola completed a six-month study with the University of Exeter called 'Unpacking the Household' to understand the barriers to recycling in the home. The research revealed that recycling is often not a conscious decision but an instinctive routine built into our everyday lives – in other words, an unconscious habit.
  - Coca Cola partnered with open innovation platform, OpenIDEO.com and its 60,000 strong community for an 11-week challenge aimed at sourcing ideas that address 'how to establish better recycling habits at home.' Through this collaborative approach to innovation they aim to draw on the best ideas to make the recycling solutions of the future a reality today.

## 21. Bike Sharing

*Easy way to move around*

Company: JC Decaux

### (A) Overview of “usual” solutions

- Bike sharing is not necessarily a replacement for a “usual solution” but rather an alternative to cars and motorcycles in the city. It facilitates the use of public transports by providing a solution to the “last-mile” issue - between the nearest reachable public transport and people’s home – and by creating a complementary mobility option both simple and accessible.
- Initially, it had been compared with the purchase of a private bike, which involves an initial investment from the cyclist, implies the risk of being stolen and also requires maintenance.
- Bike-sharing brings indirect positive effects by increasing the number of bicycles used. It also improves cyclists’ safety, and makes owning a “private” bicycle more attractive. Moreover, it gives a significant visibility to cycling in the city.

### (B) Synthetic description of the innovation



- Many cities are discovering the benefits of e-Bikes: they allow people to go farther or uphill without effort.
- Implementing shared e-bike systems should develop further bicycle use, making it a good substitute for cars or motorcycles.
- In September 2014, the usual (non-electric) shared bicycles saved CO<sub>2</sub> savings were estimated at about 1,926 tons CO<sub>2</sub> in Paris.

The positive outcomes and low financial costs of electric bicycles should, similarly to Velib, participate in its development:

- Since its opening in 2007, Velib project has shown how easy cycling in cities could be, and while improving a city’s worldwide visibility and image.
- Since 2010, pro-active communication and significant service improvement contributed to the increase of the number of users and of yearly subscribers.
- Electric bicycles will push this growth even farther in the coming years.
- Due to its financing through advertising, the cost of Velib rental is very low and therefore accessible to all.



# Bike Sharing

*Easy way to move around*

## (C) Impacts in terms of reduction of carbon emissions by 2020

**619,227 tons of  
CO2 avoided per  
year by 2020**

Profitable
Affordable
Affordability is being improved

## (D) Major roadblocks and first policy recommendations

- There are currently no major roadblocks to the innovation, except in a situation where it is impossible to have a financing model based on advertising. Such models are necessary for a rapid development of the technology by scaling it up and deeply changing transportation habits.
- Development requires specific structures and implies adaptations to match the need of users as much as possible. This could be challenging for places where space is limited.
- The weak points of large scale bike-sharing schemes like Velib in Paris are avoiding vandalism, and ensuring the accessibility of bicycles.



## 22. Steel Slab Reheating Furnaces+DRB

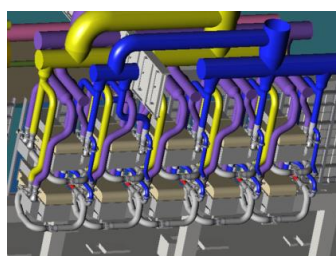
### *Valorizing blast furnace gases in the steel slab reheating process*

Company: CMI Groupe

#### (A) Overview of “usual” solutions

- Steel slabs must be heated up at more than 1200°C before being rolled in Hot Rolling Mills.
- Traditional Steel Slab Reheating Furnaces burn only high calorific value fuel: 50 to 150 MW of fossil fuel input is needed per furnace each year.
- Each traditional SSRF emits typically around 100.000 t/y of CO<sub>2</sub>. There are about 1,000 units around the world, reheating steel slabs causing around 100 million tons CO<sub>2</sub> emissions per year.
- Integrated steel plants produce quantities of very low calorific value gases: the Blast Furnace gases. These are hardly valorized: they are either burned off (without yield) or used in industrial boilers to produce energy (with poor yield).

#### (B) Synthetic description of the innovation



- The key objective of CMI's innovation is to develop a better usage of Blast Furnaces Gases produced in integrated steel plants.
- CMI's innovation consists in the design of a safe combustion process using very low calorific value gases (i.e. Blast Furnace gases) for the reheating of steel slabs, and this in accordance with the EN746 norm.
- The innovation is called SSRF+DRB<sup>+</sup>: Steel Slab Reheating Furnaces with Double Regenerative Burners. It has been developed and patented by CMI.
- Using SSRF+DRB<sup>+</sup>, fossil fuel can thus partially be replaced by Blast Furnace gases in the slab reheating process.
- The resulting global CO<sub>2</sub> savings have a dual source: better valorization of blast furnace gases and lower consumption of fossil fuel.
- Projects are profitable after 3 to 5 years.
- Potential CO<sub>2</sub> savings are estimated between 20% and 30% per SSRF using the DRB<sup>+</sup> technology.

#### (C) Impacts in terms of reduction of carbon emissions by 2020

**500,000 tons  
of CO<sub>2</sub>  
avoided per  
year, by 2020  
for CMI only**

- About 1,000 traditional SSRF are in use worldwide, around 40% of which are installed in integrated steel plants.
- According to estimated steel production growth, 1,100 SSRF could be in use around the world in 2020.
- Realistically, CMI could install 10 SSRF+DRB<sup>+</sup> by 2020.
- Optimistically, CMI would install 20 SSRF+DRB<sup>+</sup> by 2020.
- Based on the optimistic scenario, 500,000 tons CO<sub>2</sub> could be avoided each year as from 2020.
- For each additional 100 SSRF installed in integrated steel plants upgraded with de DRB+ technology, 2.5 MT of CO<sub>2</sub> will be avoided each year.

## SSRF+DRB<sup>+</sup>

*Valorizing blast furnace gases in the steel slab reheating process*

Profitable
Affordable
Affordability being improved

### (D) Major roadblocks and first policy recommendations

- Technical constraints and payback time can be considered as main roadblocks to the spread of SSRF+DRB<sup>+</sup> :
  - Converting existing furnaces to new technologies can sometimes be difficult.
  - New-built furnaces can be easily equipped, but complete renewal of furnaces will take several decades.
  - Typical simple paybacks of modification of existing furnaces are between 3 to 5 years, which may be an issue for steelmakers.
- Proving its theoretical efficiency on a real industrial demonstration could boost the dissemination of the technology. The first SSRF+DRB<sup>+</sup> are currently being installed in a European integrated steel plant.
- National or international incentives to invest in technologies dedicated to reduce CO<sub>2</sub> emissions could contribute to a larger spread of this innovation.

## 23. French railways CO2 performance

### *Better information and mobility choices*

Company: SNCF

### **(A) In France, trains represent 10% of the traffic and less than 1% of the CO<sub>2</sub> emissions – SNCF wants to improve these figures**

In 2013 SNCF had:

- High speed and intercity trains (~ 58 Bpass.km)
- Regional trains in 21 regions (~ 26 Bpass.km)
- More than 3,000 stations in France
- Keolis group: ~ 200 multimodal networks in 14 countries worldwide
- SNCF Geodis: world 6<sup>th</sup> freight and logistics operator



### **(B) CO<sub>2</sub> ecosystem for low carbon door to door mobility**

EN FRANCE

Trajet TGV Nantes - Lyon / empreinte CO<sub>2</sub> train\*, avion\*\*, voiture\*\*\* (kg CO<sub>2</sub> / passager)



Since 2006 SNCF developed low carbon solutions and a CO<sub>2</sub> expertise to improve its performance

- Door to door solutions for a low carbon mobility:
  - Regional train + car-sharing in Rhône-Alpes
  - iDVROOM: carpooling solution by SNCF to help customers travel door to door
  - Web Platform for door to door mobility: [mytripset.voyages-sncf.com/](http://mytripset.voyages-sncf.com/)
- CO<sub>2</sub> information to help customers make the right choice of mobility between:
  - Trains
  - Others modes: planes, buses, cars
- External costs avoided for the community by using trains instead of cars

### **(C) Impacts in terms of reduction of carbon emissions by 2020**

Profitable
Affordable
Affordability being improved

- CO<sub>2</sub> footprint of SNCF is 2Mt CO<sub>2</sub> for all transportation operations. SNCF improved this footprint since 2007, but an impactful solution would be to increase passenger traffic in public transports and to reduce car traffic.
- Each year SNCF customers avoid CO<sub>2</sub> emissions...
  - by using TER instead of cars: ~ 1.6 MtCO<sub>2</sub>
  - by using Transilien instead of cars: ~ 1.9MtCO<sub>2</sub>
  - by using TGV instead of cars and planes: ~ 5MtCO<sub>2</sub>
  - by using rolling highways: ~ 0.5 MtCO<sub>2</sub> (2020)

# French railways CO<sub>2</sub> performance

*Better information and mobility choices*

## **(D) Major policy recommendations**

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Public transports should be promoted...

- for their energy and CO<sub>2</sub> performance
- for their positive services to the community
- for their social value: regional development, contribution to local economies, etc.
- for the external costs avoided compared to individual mobility

## 24. Celluguard Dustergerent

### *Protection against desert dust*

Company: Agata

#### **(A) Overview of “usual” solutions**

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The world produces more and more solar energy, which now represents about 0.5% of total energy produced. The best places for production are deserts, such as Atacama in Chile, Mojave in the USA or Sahara in Africa. Yet, one of the greatest barriers of deserts is dust. Indeed, 1g of dust per 1m<sup>2</sup> mirror reduces up to 40% of efficiency. Celluguard desert coating technology can increase productivity by at least 20-30%.



Source: [http://saferenvironment.files.wordpress.com/2009/02/desert\\_solar\\_energy\\_1.jpg](http://saferenvironment.files.wordpress.com/2009/02/desert_solar_energy_1.jpg)

#### **(B) Synthetic description of the innovation**

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Solar power plants are covered by spraying a thin layer of cellulose in an amount of 30 g/m<sup>2</sup>. A tight coating is obtained that is ecological and very tolerant to heat and light.

This technology is very affordable: the cost of hedging 1ha is approximately of 1,000-2,000 USD. In contrast, other products on the market, such as polymeric solutions, are very expensive and harmful for the environment. Polymers break down into noxious acids and salts.

## 25. Biomethane as a motor combustible

### *Reducing vehicle CO<sub>2</sub> emission*

Company: UPS

#### **(A) Diesel engines are mainly used for long run transportation**

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Diesel engine is the most common technology available in trucks

- On average, per liter diesel emissions of CO<sub>2</sub> represent...
  - 0.58g/L during the upstream phase
  - 2.49g/L during the operation phase
- According to ADEME (French environmental agency):
  - Light professional vehicles (3.5 tons) emit 1.068g per ton and per KM (1.068g/t/Km)
  - 19t trucks → 332g/t/Km and 40t trucks → 175g/t/KM)

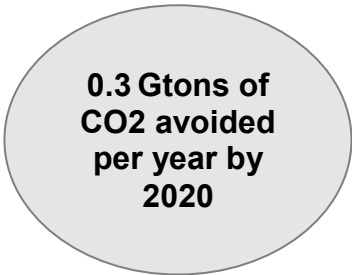
#### **(B) Using Biomethane instead of diesel**

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- Biomethane is a renewable natural gas, chemically equivalent (CH<sub>4</sub>), but made from organic waste, such as food, agriculture products, etc.
- Biomethane emits around 70% less carbon than an energy equivalent amount of diesel.
- Assuming that methane would otherwise have leaked into the atmosphere (as is often the case with agricultural manure, as it is stored in the open before being used to make fertiliser) the saving can be close to 100%.
- Biomethane can be used as compressed gas in every kind of vehicles and as liquid gas in big trucks.
- For professionals, costs are mainly driven by vehicle conversion. This can be negligible for some vehicles or on the contrary particularly expensive, such as for trucks.

#### **(C) Impacts in terms of reduction of carbon emissions by 2020**

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**0.3 Gtons of  
CO<sub>2</sub> avoided  
per year by  
2020**

- Currently, transports for goods by road represents roughly 7Gt of CO<sub>2</sub>
- In 2020, according to the ITF (International transport Forum), it will represent 7.8Gt of CO<sub>2</sub>
- Using 5% of biomethane would enable to reach about 7.5 Gt in 2020
- Thus, 0.3 Gt could be avoided in 2020
- The value can be significantly improved if we also use natural gas for vans (3.5 tons) for urban deliveries

# Biomethane as a motor combustible

## *Reducing vehicle CO2 emission*

### **(D) Major roadblocks and first policy recommendations**

---

- Biogas can be injected into the natural gas network and distributed in carriers facilities. When liquefied, it can be stored in tanks.
- However, using this energy on a large scale implies...
  - Building factories that produce biomethane and creating the appropriate logistic chain to collect waste or other organic outputs
  - Building filling station, and ensuring fuel distributors can propose this energy in their existing stations
  - Producing liquid biomethane for trucks on a higher scale
- The main conditions for its development would be...
  - The creation of production units
  - The development of filling stations
  - More vehicles able to run on natural / liquid gas



## 26. HeatOx technology

### *Combustion with Oxygen and natural gas preheating at high temperature*

Company: Alglass

#### **(A) Overview of “usual” solutions**

- Glass is manufactured at very high temperatures in smelters heated by fuel combustion, with hot air, then formed and packaged.
- Glass is most often melted in large capacity «regenerative» furnaces
- The melting process is the most energy-intensive phase, representing 60 to 80 % of total glass manufacturing energy consumption.
- The combustion of natural gas or oil and the decomposition of raw materials during the melting process emit CO<sub>2</sub>. Each year, the glass industry emits around 22 Millions of tons (MT) of CO<sub>2</sub> in Europe (95 MT worldwide).



#### **(B) Synthetic description of the innovation**

Oxy-combustion is the process of burning a fuel using pure oxygen instead of using hot pre-heated air. Oxy-combustion improves combustion efficiency:

- Flue gas volume is reduced by approximately 75%.
- Nitrogen oxide emissions is reduced well below authorized limits.
- Fuel consumption reduces by 10 to 40% depending on glass type.

Preheating oxygen and fuel with flue gases from combustion products makes it possible to recover part of the energy contained therein and to improve the energy efficiency of this type of combustion. The ALGLASS™ HeatOx innovation for combustion using pure pre-heated oxygen reduces combustible consumption by an additional 10%.

Heating a glass furnace entirely with « cold » oxygen is not always economically viable while with « hot » oxygen (« HeatOx »), it becomes profitable thanks to an additional 10% fuel savings compared to « cold » oxygen - reaching a total 25% fuel savings compared to air combustion.

In some applications, Oxy-combustion is cost neutral or results in savings while it can be more expensive for other applications, especially for furnaces with bottles production. Besides, considering the wide range of energy prices in the world, the cost effectiveness varies greatly and must be assessed individually.

Initial cost estimates indicate that the ROI of ALGLASS™ HeatOx technology is less than 3 years when the price of natural gas is equal to or higher than 35€/MW.



# HeatOx technology

*Combustion with Oxygen and natural gas preheating at high temperature*

## (C) Impacts in terms of reduction of carbon emissions by 2020

**1.4 Million tons of CO<sub>2</sub> avoided per year by 2020**

Profitable
Affordable
Affordability being improved

The manufacturing processes of mineral products such as glass, lime, and cement are responsible for 50% of industrial processes CO<sub>2</sub> emissions.

The proposed innovation aims at reducing energy consumption by using pre-heated oxygen and natural gas thanks to ALGLASS HeatOx. Taking into account CO<sub>2</sub> emissions related to Oxygen production and the CO<sub>2</sub> reduction from fuel savings, a 15% CO<sub>2</sub> emissions reduction is estimated in average (versus air fuel).

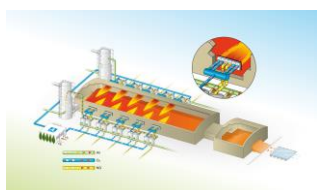
Increasing the share of the glass furnace with oxy-combustion from 10% (currently) to 20% in 2020, 1.4 million of tons per year would be avoided globally.

This solution could be extended to other manufacturing « high temperatures » processes such as melting and heat treatment, for 'primary smelting' of steel and non-ferrous metals, foundries and non-ferrous recycling processes as well as steel re-heating furnaces, but also for cement and other 'Basic mineral non-metallic Materials'. In that case, a reduction of carbon emission by up to 30 Mt CO<sub>2</sub>/year could be achieved, these sectors representing around 3 500 MtCO<sub>2</sub>/year.

## (D) Major roadblocks and first policy recommendations

The set-up and implementation of this technology using hot oxygen and natural gas with different types of glass furnace will require equipment, and hence capital cost which, in the current environment, is a challenge.

Stricter standards on CO<sub>2</sub>, NOx and other polluting emissions in industrial processes would encourage investments in such innovative technologies.



## 27. Hydrogen Electrical mobility

### *Potential of Fuel Cell Electric Vehicle for sustainable energy and transport system*

Company: Air Liquide

#### **(A) Overview of “usual” solutions**

Internal combustion engines (ICE) powered by traditional fossil fuel engines are responsible for a significant portion of local pollutant and noise emission.

Over the next 40 years, transport should therefore shift from purely oil-driven solutions to lower carbon solutions, including fuel cell electric power-trains.

#### **(B) Synthetic description of the innovation**



Hydrogen can be easily produced from renewable electricity (solar, wind...) by electrolysis, from biomethane or fossil fuels like natural gas in centralized or distributed production facilities.

Used in fuel cell, hydrogen combines with the oxygen present in the air to produce electricity, with water as the only by-product.

Fuel Cell Electric Vehicles (FCEV) are efficient for mid- and long-distance journeys, which represent 75% of CO<sub>2</sub> emissions of the transport sector. They do not generate any pollution at the point of use (no particles and low noise). The automotive industry has announced that Fuel Cell Electric Vehicles will go on sale by 2015-2017.

#### **(C) Impacts in terms of reduction of carbon emissions by 2020**

**Up to 2.7  
Mtons of CO<sub>2</sub>  
avoided per  
year by 2020**



According to H<sub>2</sub> production pathways, FCEVs will emit more or less CO<sub>2</sub> at tailpipe.

- Traditional ICE would occur ~160 g CO<sub>2</sub>/km.
- FCEV powered by hydrogen produced from natural gas will emit ~120 g CO<sub>2</sub>/km and ~30 g CO<sub>2</sub>/km when produced from biomethane.
- CO<sub>2</sub> emissions would fall to ~10 g/km if H<sub>2</sub> is produced from renewable electricity.

In an optimistic scenario, we could consider the deployment of 1 million FCEVs in 2020 in EU and a 25% share of the total EU passenger car market in 2050.

- With 1 million FCEVs on the road, and by dedicating decarbonized H<sub>2</sub> production to transport, we could save between 1.8 and 2.7Mt CO<sub>2</sub>/year.

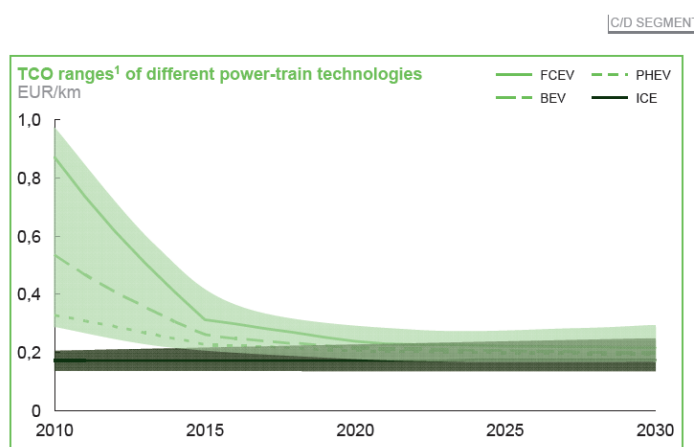
# Hydrogen Electrical mobility

## *Potential of Fuel Cell Electric Vehicle for sustainable energy and transport system*

### (D) Major roadblocks and first policy recommendations

- Given satisfactory testing in a customer environment - with more than 500 cars covering over 15 million kilometers and 90,000 refueling - the focus has now shifted from demonstration to planning commercial deployment so that FCEVs, like all technologies, may benefit from mass production and economies of scale.
- The emerging FCEV market (2010-20) requires close value chain synchronization and external stimulus in order to overcome the first-mover risk of building hydrogen retail infrastructure.
- While the initial investment is relatively low, the risk is high and therefore greatly reduced if many companies invest, coordinated by governments and supported by dedicated legislation and funding.
- For the emergence of this industry in the transport sector, the support of the creation of the necessary distribution infrastructures at global scale is essential. Are therefore needed:
  1. Keeping strict reduction targets for GHG emissions (60% for the transport sector and 80-100% for the energy sector by 2050 compared to 1990 levels).
  2. Allocating advanced carbon credits to early adopters and infrastructure investors (public or private) recognizing their effort in creating the base for future deployment of low-carbon technologies – with virtually no cost up front and with a strong potential to attract the financial community to support the energy transition.
  3. Implementing the mechanism of “Californian ZEV program” in several leading countries, which would be interconnected to stimulate demand for cleaner transport.

Profitable
Affordable
<b>Affordability being improved</b>



1 Ranges based on data variance and sensitivities (fossil fuel prices varied by +/- 50%; learning rates varied by +/- 50%)

## 28. The process of progress rapeseed diester

### *Improving the environmental performance of rapeseed biodiesel from field to wheel*

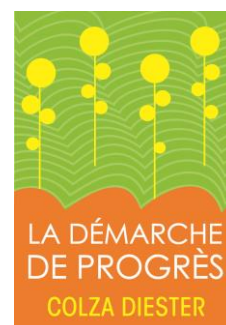
Company: Sofiprotéol

#### (A) Overview of “usual” solutions

The Process of Progress Rapeseed Diester aims at improving the environmental performance (energy, GHG emissions, biodiversity and water) of rapeseed biodiesel from field to wheel.

Rapeseed biodiesel replaces up to 7% of diesel in Europe. French rapeseed biodiesel reduces GHG emissions by 40 to 60% compared to European fossil reference. The latter accounts for 83.8 gCO<sub>2</sub>eq/MJ and is given in the Renewable Energy Directive 2009/28/CE.

Ecofys estimates that the marginal GHG emissions displaced by the introduction of biofuel are approximately 115 gCO<sub>2</sub>eq /MJ of energy delivered by biofuels.



#### (B) Synthetic description of the innovation



Since 2007, the Process of Progress Rapeseed Diester, led by Sofiprotéol, Cetiom and SAIPOL, contributes to improving environmental balance of the rapeseed biodiesel production chain.

Farmers, technicians, grain collectors, processors, and industrials are engaged in a proactive progress loop: all stakeholders of the rapeseed biodiesel sector are involved. Their common effort to enhance energy consumption and GHG emissions from rapeseed biodiesel, led them to carry out relevant investments to improve industrial processes (35% energy savings have already been achieved between 2010 and 2012) and operational action plans for farmers.

In addition to environmental benefits, the project brings many other advantages, for example:

- The rapeseed biodiesel sector employs nearly 20,000 people and more than 10,000 farmers are engaged in the Process of Progress
- It reduces energy dependency over fossil resources

# The process of progress rapeseed diester

## *Improving the environmental performance of rapeseed biodiesel from field to wheel*

### (C) Impacts in terms of reduction of carbon emissions by 2020

**At least 3.8  
million tons of  
CO<sub>2</sub> avoided  
per year by  
2020 in France  
(source:  
Ecofys)**

Assuming an average rapeseed biodiesel emission of 42 g CO<sub>2</sub>eq/MJ nowadays, rapeseed biodiesel avoids the emission of approximately 1900 kT of CO<sub>2</sub> equivalent in 2014 in France.

Considering the objective of the Process of Progress Rapeseed Diester, between 2,200 and 2,300 kT of CO<sub>2</sub> could be avoided annually by 2020 in France.

With this in mind “realistic” and “optimistic” scenarios can be suggested

- “Realistic”: in 2020, rapeseed biodiesel will reduce GHG emissions by at least 50% compared to fossil fuel.
- “Optimistic”: considering major roadblocks identified below, we consider that more than 60% of GHG emissions reduction is achievable compared to fossil fuel.

Profitable
Affordable
Affordability being improved

In 2010, PricewaterhouseCoopers conducted a study to assess the socio-economic and environmental weight of French biodiesel sector, of which rapeseed biodiesel is the major contributor. The table below gives the main results of the 2010 study and updates according to changes in French Domestic Taxes.

This study considers tax and social security revenues, French domestic tax, as well as environmental externalities of the biodiesel sector. In comparison with fossil diesel, results show that the economic contribution of the biodiesel sector for the state is much higher than the fossil diesel sector and allows limited environmental externalities. In addition, the biodiesel sector is a relevant employer, as it generates nearly 20,000 direct, indirect and induced jobs.

# The process of progress rapeseed diester

## *Improving the environmental performance of rapeseed biodiesel from field to wheel*

	Unit	Diesel (2010)	Rapeseed biodiesel (2010)	Difference 2010 (Rapeseed biodiesel – diesel)	Diesel (2016)	Rapeseed biodiesel (2016)	Difference 2016 (Rapeseed biodiesel – diesel)
Tax and social security revenues	Euros/hl eq. diesel	0,7	9,4	8,7	0,7	9,4	8,7
Domestic consumption tax		42,84	37,9	-4,9	48,81	48,81	0
Environmental externalities		-42,3	-35,6	6,7		-35,6	6,7
Total		-	-	10,5	-	-	15,4
Estimation of the economic weight of the French biodiesel sector for the state, including environmental externalities	Million Euros	-	-	260	-	-	383

Assumptions considered:

- Diesel consumption of 33 million tons in 2010 and 2020.
- Incorporation rate of vegetal oil biodiesel of 7%, of which 80% are considered as rapeseed biodiesel

## (D) Major roadblocks and first policy recommendations

The main challenge of the Process of Progress is to reconcile productivity and environmental performance. Indeed, the latter can be achieved per unit of output by increasing seed yield while adjusting the quantities of inputs made.

Yield and fertilization are the two main levers. CETIOM works with rapeseed producers and motivates major collection agencies. Following the diagnostics performed on each collection basin and monitoring of GHG emissions, action plans are implemented by storage agencies for farmers involved in three areas: nitrogen nutrition, yield and innovative techniques.

Concerning nitrogen fertilization, controlling nitrogen is also a money-saving lever. Improvement should be made to reach an optimal dose for cultivation and to avoid over-fertilization. Many action plans regarding the latter issue have concrete impacts. For example, the Decision Support Tools help provide the amount of fertilizer that plants need- the use of leguminous cover crop to avoid erosion and nitrogen leaching, etc.



# The process of progress rapeseed diester

## Annex (1/3)

### Continuous progress

*In the Improvement Initiative, things are dynamic: each year, the question arises of what we have accomplished and how to improve it by always trying to raise the bar ... The ambition is huge: 4 strands of action: GHG, energy, biodiversity and water. The idea is first to perform diagnostics of farmers' practices in order to perform energy and GHG emission audits, then implement action plans to improve their performance, and finally gradually to extend the approach to the other environmental issues. Today we have managed to expand the approach: it no longer concerns only energy results, but also GHG results, and we are now beginning to look at the water and biodiversity issues.*

**Francis FLENET** agronomist at Cetiom, is responsible for the development of environmental indicators and paths for progress.



### 50% reduction in GHG emissions thanks to rapeseed: the way forward!

*The rapeseed growers have the opportunity to contribute to the reduction of GHG emissions – and thus the fight against global warming - while building a profitable outlet for their production.*

*It is a win-win situation!*

*As long as farming practices adopted generate savings, which they most likely will, it is part of a triple win system!*

**Antoine Morin**, from Diester Industrie



### Committed Rapeseed Producers!

*I am committed to the Improvement Initiative with my storage agency to ensure the sustainability of production of rapeseed in France.*

*Every year I am committed to completing a survey of my cultivation practices for this crop.*

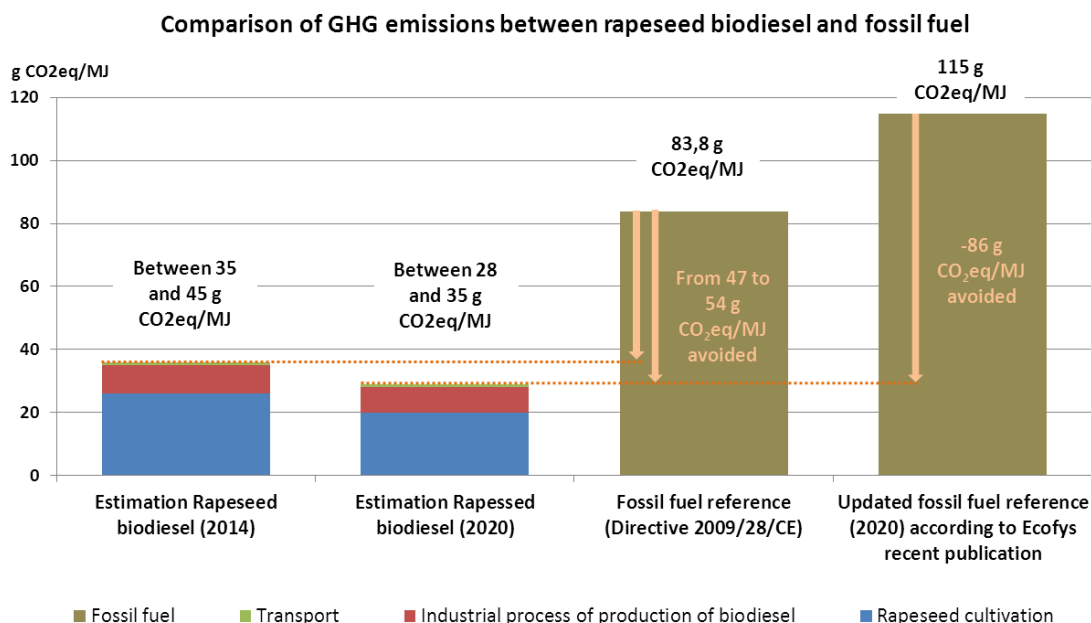
*With my counsellor and Cetiom, we work in particular on optimizing nitrogen fertilization with the objective of limiting the dose to the needs of the plant and optimizing the efficiency of the use of fertilizers. At our level, we are striving to improve the environmental performance of biofuels from rapeseed.*

**Dominique Clyti**, agriculteur près de Nogent-sur-Seine.

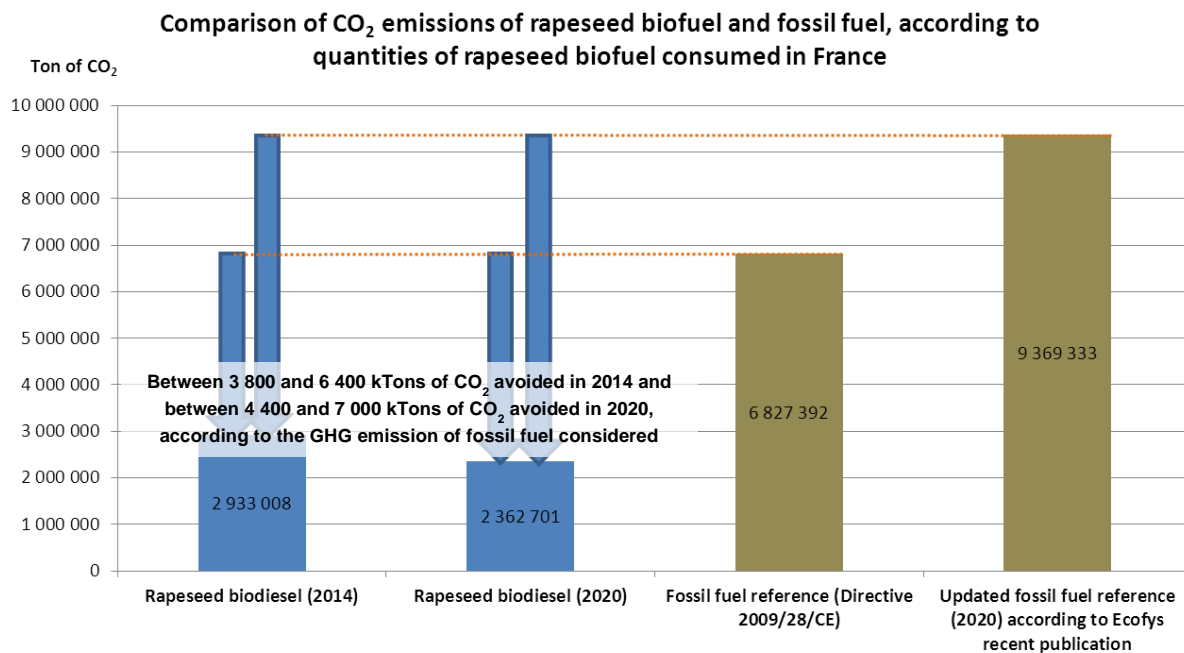


## The process of progress rapeseed diester

### Annex (2/3)



Biodiesel emissions are measured in grams of CO<sub>2</sub> equivalent (gCO<sub>2</sub>eq) per megajoule (MJ) of energy produced. The margins of progress in the agricultural upstream are the most important because agricultural production accounts for 70% of GHG emissions, against 30% for industry and transportation.



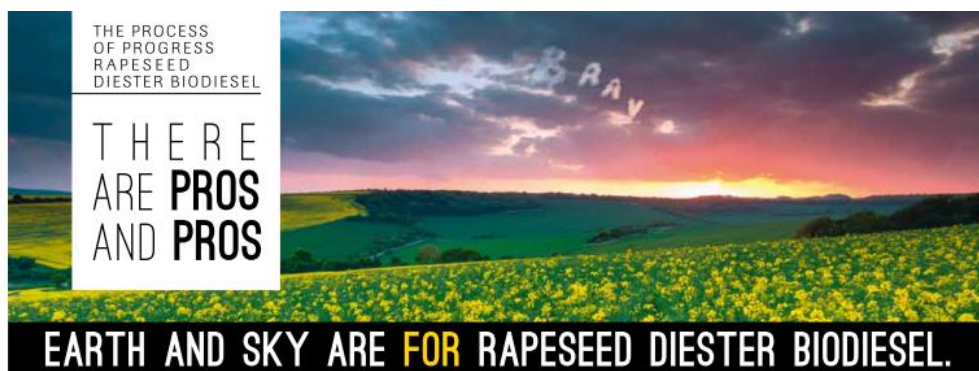
Considering rapeseed biodiesel produced and consumed in France, the amount of CO<sub>2</sub> avoided is relevant, especially when updated emission values for fossil diesel are taken into account. Assumptions were:

- Diesel consumption of 33 million tons in 2010 and 2020.
- Incorporation rate of vegetal oil biodiesel of 7%, of which 80% are considered as rapeseed biodiesel



# The process of progress rapeseed diester

## Annex (3/3)

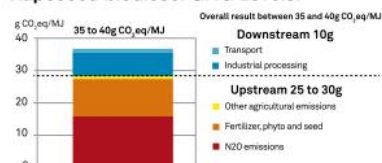


The reduction of GHG emissions is a priority.

**50%** less GHG emissions by 2017 compared to fossil diesel.

To meet societal expectations and current regulatory requirements (including the Renewable Energy Directive 2009/28/EC), the Improvement Initiative has incorporated a series of measures: its partners have invested millions of euros to change, firstly, agricultural practices of farmers and storage agencies and secondly, the processing tools. The results are encouraging because GHG emissions have been reduced by 10%. But the efforts and improvements undertaken must be continued and magnified! The regulatory target of a 50% reduction in GHG emissions is a mandatory condition for the sustainability of the biodiesel Diester activity.

Rapeseed biodiesel GHG Levels.



Biodiesel emissions are measured in grams of CO<sub>2</sub> equivalent (gCO<sub>2</sub>eq) per megajoule (MJ) of energy produced.

The margins of progress in the agricultural upstream are the most important because agricultural production accounts for 70% of greenhouse gas emissions, against 30% for industry and transportation.

**FARMERS' INCOME IS FOR RAPESEED DIESTER BIODIESEL.**

More than **10,000** farmers are taking part in the process.

Agricultural participation in the Improvement Initiative is already a success because, in 2012, there were 92 storage agencies involved, nearly 300,000 hectares covered by the surveys and more than 10,000 farmers involved. You too can help expand on these first results by engaging in the biodiesel Diester® Improvement Initiative.

Increasing yield and environmental performance is possible.

Controlling nitrogen fertilization is a way to save money.

4 complementary actions in agriculture.

1. System for rapeseed surveying.
2. GHG diagnostic.
3. Action plans, monitoring and annual adjustment.
4. 20gCO<sub>2</sub>eq/MJ Club, to identify more environmentally-friendly cultivation practices and innovations.

Continuous progress

In the Improvement Initiative, things are dynamic: each year, the question arises of what we have accomplished and how to improve it by always trying to raise the bar. The ambition is huge: 4 strands of action: GHG, energy, biodiversity and water. The idea is first to perform diagnostics of farmers' practices in order to perform energy and GHG emission audits, then implement action plans to improve their performance, and finally gradually to extend the approach to the other environmental issues. Today we have managed to expand the approach: it no longer concerns only energy results, but also GHG results, and we are now beginning to look at the water and biodiversity issues.



Francis FLENET, agronomist at Cetiom, is responsible for the development of environmental indicators and paths for progress.

Room for progress upstream.

Beyond the GHG emissions of the sector, agriculture is also very concerned by the problems of biodiversity and water quality, which are key issues in environmental performance. So, it is in the fields that the potential for reducing the environmental impact is the greatest.

The "20 gram Club", a powerful ally.

**THE ECONOMY AND JOBS ARE FOR RAPESEED DIESTER BIODIESEL.**

**35%** energy savings already achieved in industry.

Massive investment and the use of industrial synergies have already resulted in an energy saving of nearly 35% in Diester biodiesel production units between 2010 and 2013. For example, the replacement of certain gas boilers by systems using biomass has significantly reduced consumption of fossil fuels and GHG emissions.

What actions are being taken in industry and logistics?

1. Diagnosis of environmental performance of production units.
2. Reduction of energy consumption.
3. Investments in energy production from biomass.
4. Optimization of logistics flows.

Public-spirited factories.

Nearly 20,000 jobs created.

Are you for it? Join us!  
[www.ProgresColzaDiester.fr](http://www.ProgresColzaDiester.fr)



Terros OléoPro is the brand name of the stakeholders in the French vegetable oil and protein sector.



## 29. Haliade 150 - 6MW

*Offshore wind turbine efficient at low wind speeds*

Company: Alstom

### (A) Overview of “usual” solutions

- The Haliade<sup>TM</sup> 150- 6MW is a new generation of offshore wind turbines. It is an alternative to common fuel power generation plants such as nuclear, gas, oil and coal. On the short run, it will not replace this kind of solution but offshore wind will actively contribute in the diversification of low carbon emission sources of energy.



### (B) Synthetic description of the innovation



The Haliade<sup>TM</sup> 150- 6MW contains many innovations. First the length of its blades provides a high yields even at low wind speeds. The Haliade<sup>TM</sup> 150- 6MW is equipped with a permanent magnet generator which provides a high reliability by limiting the number of rotating parts. Then, the torque is transferred to the generator through an elastic coupling system called Pure Torque®. This innovation prevents from transverse loads and thus protects the generator from additional sources of failure. These two systems reduce maintenance operations thus reducing the number of interventions with associated CO<sub>2</sub> emissions.

Unlike conventional gearboxes, the Alstom Direct Drive technology does not need oil to lubricate the rotating parts of the gearings. In addition to the risk of oil leakage and direct ocean pollution, all CO<sub>2</sub> emission related to production, recycling but also logistics and maintenance are therefore avoided.

### (C) Impacts in terms of reduction of carbon emissions by 2020

**Around 70 Mtons  
of CO<sub>2</sub> avoided  
per year by 2020**

Profitable
Affordable
<b>Affordability being improved</b>

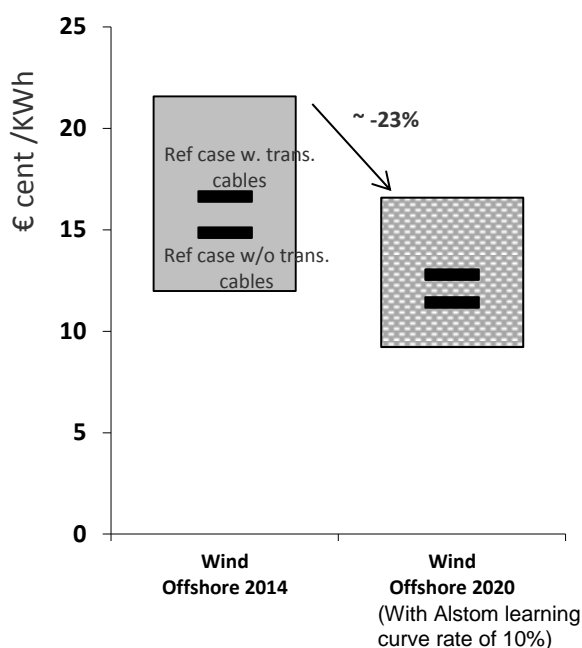
By 2020, a large amount of CO<sub>2</sub> will be avoided:

- First estimates of CO<sub>2</sub> emissions per unit of energy generated (kWh) show 11.5 g eq CO<sub>2</sub> /kWh for an Haliade<sup>TM</sup> 150- 6MW installed on a jacket foundation in France. It represents around 10,000 tons of CO<sub>2</sub> avoided per unit.
- Today, the installed capacity of offshore wind is 7.2 GW. Based on the report from IPCC and the World Steel association, the average CO<sub>2</sub> emissions worldwide is 500 g eq. CO<sub>2</sub> /kWh. This means that for each kWh generated by offshore wind, the CO<sub>2</sub> avoided by the offshore wind industry is 488g. Today, the CO<sub>2</sub> avoided is estimated at 12 Mtons per year.
- On a baseline scenario, Alstom estimates at 39.5 GW the total capacity installed worldwide in 2020 and Bloomberg estimates it at 37.5 GW. This means that the CO<sub>2</sub> savings based on offshore wind vary from 70 Mtons to 75 Mtons equivalent of CO<sub>2</sub> per year.

## Haliade 150 – 6 MW

### *Offshore wind turbine efficient at low wind speeds*

- Current LCoE for Wind Offshore costs to end-user around 16€ cents/kWh, according to Alstom
  - For 2020, the offshore wind industry has set a target at 100GBP/MWh (around 120 €/MWh - 12 cts/kWh) through volumes, innovation and reliability improvements.



## (D) Major roadblocks and first policy recommendations

- The offshore wind industry faces many roadblocks. The most important one is the visibility for investors and industrial companies on the volumes and the feed-in tariffs. These two major elements are crucial to anticipate the market evolution and to be able to invest in infrastructure, R&D programs, industrial partnerships...
- Main condition for its development would be....
  - Ad-hoc regulatory and commercial framework and clear agenda of public call for tender
  - Simplified administrative frame for permitting process and grid connection
  - Binding targets for Renewable Power and CO<sub>2</sub> reduction
  - Strong and predictable CO<sub>2</sub> price in the long term
  - Stable revenue streams to unlock investments: via feed-in tariffs, feed-in premium, contracts for difference

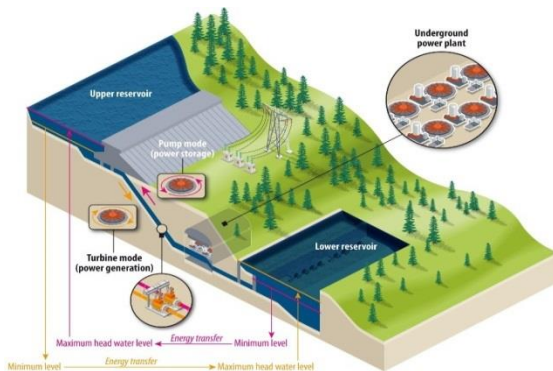
## 30. Pump storage plant

*Store electrical energy using water energy*

Company: Alstom

### (A) Overview of “usual” solutions

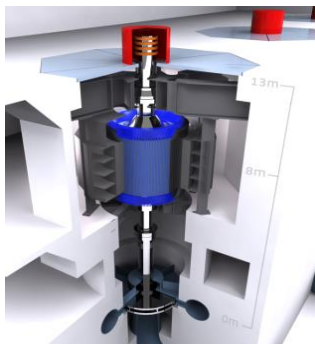
Pumped hydro Storage Plant (PSP) is the most mature storage concept in respect of installed capacity, storage volume and operation benefits. The principle is to store electrical energy by utilizing the potential energy of water.



When excess energy is available the water will be pumped and stored in an upper reservoir/pond. On demand, the energy can be released, being transformed into electrical power within a couple of minutes.

Besides balancing the peak and off-peak periods PHS provides ancillary services such as frequency, primary and voltage control to the power grid. The conventional technology can only supply this service while in generation mode.

### (B) Synthetic description of the innovation



The innovation requires pumped storage plants to be equipped with variable speed generators, allowing the former to supply energy regulation also in pumping mode. It however requires a new generation of Hydro generators able to operate at an asynchronous mode.

The variable speed technology enables PSPs to continuously provide flexible balancing services both in generating and in pumping mode. It thus avoids costly provision of these services by part-loaded conventional generators and most importantly enhances the ability of the EU system to absorb significant amounts of intermittent generation.

### (C) Impacts in terms of reduction of carbon emissions by 2020

**7 million tons  
of CO<sub>2</sub> avoided  
per year by  
2025**

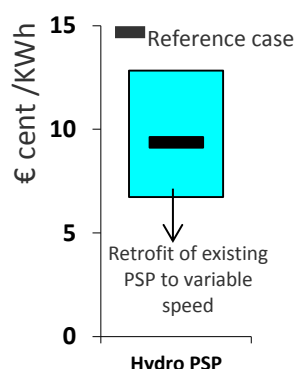
- It is difficult to estimate potential CO<sub>2</sub> gains as no unit has been retrofitted as of today. Yet, a 270MW pilot project has been launched in France with EDF
- It appears that 30GW of European PSP could be upgraded by 2025 profiting from their necessary refurbishment after 30 years of operation
- Upgrading 30 GW of European PSP would provide as much as 9GW additional regulation allowing to switch off around 9 GW of thermal generation during at least 2,000 hours per year and therefore avoiding the equivalent 7 million tons CO<sub>2</sub> emissions.

# Pump Storage Plant

*Store electrical energy using water energy*

Profitable
<b>Affordable</b>
Affordability being improved

- Today, building a new variable speed PSP would cost around 1000€/kW installed. Retrofitting existing plant would cost about 100€/kW and would avoid long permitting procedures.
- The cost for upgrading 30GW can roughly be estimated at €3b
- PSP LCoE (2014) ranges between 6,7-12,8 € cents/kWh with an average electricity price when pumping at 3 € cents/kWh. Retrofitting an existing plant to variable speed represents an economical solution (source Alstom)
- However, as PSP power plants most often operate as a peaker, its economics depends more on the differential between the electricity price paid when pumping and the electricity price received when producing, rather than the LCoE alone



## (D) Major roadblocks and first policy recommendations

- Technically, the upgrade of fixed speed units to variable speed needs to solve several challenges, the most important one being the ability to fit a ~10% larger generator in an existing plant with limited capability to adapt the civil work. This challenge will be addressed in eStorage project by the development of a pilot project
- Economically, the present market framework does not provides revenues at the level of the value provided by variable speed pumped storage plants while the regulatory framework create barriers for their development. For instance while energy storage systems provide essential services to balance the grid, they are still considered as electricity consumers and have to pay grid fees impacting negatively their business model
- One of the goal of the eStorage project is to demonstrate that the only support needed to allow the dissemination of this innovation is to create a market and regulatory framework that compensates this energy storage technology at the actual value it delivers to the grid.



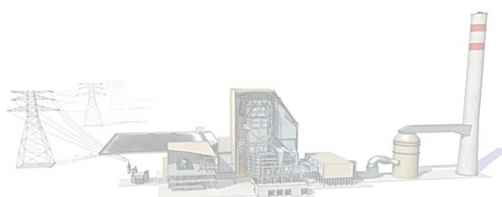
## 31. CO<sub>2</sub> Capture utilization or storage

### *Add-on technology to coal and gas power plants*

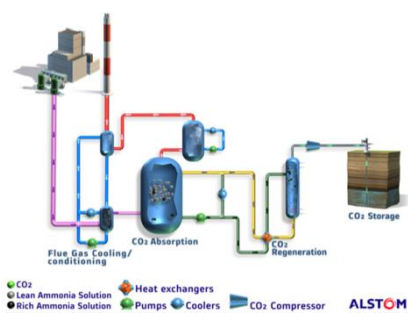
Company: Alstom

#### (A) Overview of “usual” solutions

- Fossil-fuels, which represent 2/3 of electricity production today, and CCS are the unique solutions able to address related CO<sub>2</sub> emissions.
- The technology relies on a balanced energy mix- a key aspect of energy security and affordability. Indeed, CCS allows fossil fuels to have a key role in future clean energy systems.



#### (B) Synthetic description of the innovation



- The technology works as an add-on to coal and gas power plants that then, would become CO<sub>2</sub> -free. It is also applicable to other industries using fossil fuels by capturing CO<sub>2</sub> storage before, during or after combustion.
- Captured CO<sub>2</sub> is conditioned for permanent underground storage or industrial utilization (CCU&EOR).
- CCS-enabled power plants can capture 90% of CO<sub>2</sub> from the combustion,
- Net emission can even be reduced to zero or be negative when biomass is fired or co-fired.
- No other solution than CCS exists and can reach 2°C scenario for energy-intensive industries

#### (C) Impacts in terms of reduction of carbon emissions by 2020

Estimates of impacts in terms of reduction of carbon emission rely on an example: White Rose CCS project in the UK (the largest project worldwide)

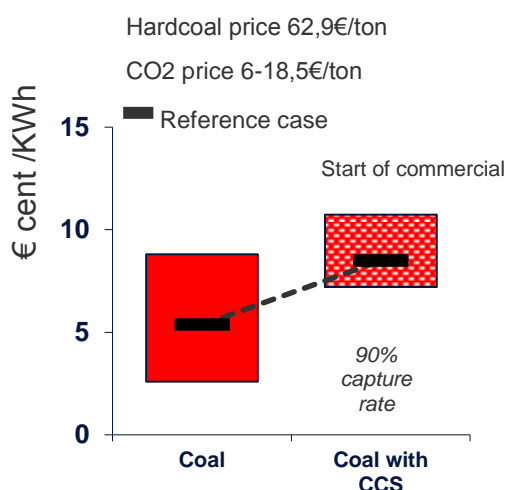
- A new modern ultra-supercritical 426MWe (gross) Oxy-Power Plant (Drax Selby, UK) has been installed, allowing for more than 300 MWe Clean power - equivalent to the needs of 630,000 homes.
- There, 100% of the flue gas is treated and 90% of the CO<sub>2</sub> is captured representing about 2 million tonnes CO<sub>2</sub>/year and biomass co-firing leading to zero - or negative - CO<sub>2</sub> emissions.
- Then, White Rose is scheduled to form the anchor project for National Grid's regional CO<sub>2</sub>, providing transport and offshore storage network.
- As a result, CO<sub>2</sub> ends up being permanently stored in a deep saline formation offshore, beneath the North Sea.

**39 million tons of  
CO<sub>2</sub> captured per  
year by 2020**



# CO<sub>2</sub> Capture utilization or storage

## Add-on technology to coal and gas power plants



Alstom - CoE study in Europe (2014 costs-no inflation)

- LCoE, is the “measurable” effect of the technology for electricity producers and end-users.
- The chart shows that the effect of CCS on LCoE is of 90% and 45% Capture

Profitable
Affordable
<b>Affordability being improved</b>

## (D) Major roadblocks and first policy recommendations

- CCS technologies are ready for validation at large-scale, but face delay in large-scale project implementations: cost reduction efforts are still needed to make it “affordable”.
- CCS needs an ad-hoc regulatory and commercial framework (similar to renewables).
- The main condition for its development would be:
  - In the long term, strong and predictable CO<sub>2</sub> price when clean power market and technologies will be mature
  - In the short term, bring confidence in the revenue streams to unlock investments: via feed-in premium, or tradable certificates when carefully designed –i.e. similar to what renewables benefitted from
  - Regulatory framework and infrastructure deployment for CO<sub>2</sub> transport and Storage
- Demonstrators like the White Rose CCS Project in the UK aim at showing how to successfully implement CCS commercially- when putting together the above-mentioned conditions.

### Glossary:

**CCS** : CO<sub>2</sub> Capture and storage

**CCU** : CO<sub>2</sub> Capture and utilization

**T&S** : (CO<sub>2</sub>) Transport&Storage

**LCoE** : Levelized Cost of Electricity

**EOR** : Enhanced Oil Recovery



## 32. Gas for grid g3

### Alternative to SF<sub>6</sub> for HV applications

Company: Alstom

#### (A) Overview of “usual” solutions

Sulphur Hexafluoride (SF<sub>6</sub>) is an excellent insulator. It is widely used in the electrical industry in high-voltage (HV) equipment that is used to transmit electricity and protect the substation. However, SF<sub>6</sub> is also a GHG, listed in the 1997 Kyoto Protocol, with a potentially significant impact on global warming.

Gas	Life time (years)	GWP* (100 years)
CO <sub>2</sub>	20 to 100	1
CH <sub>4</sub>	12	23
N <sub>2</sub> O	114	296
Fluoride gas	HFC	HFC-23 : 260
	PFC	CF <sub>4</sub> : 50 000
	SF <sub>6</sub>	3 200
	NF <sub>3</sub>	740
		17 200

#### (B) Synthetic description of the innovation



Until now, for high voltage applications, there was no economical alternative to SF<sub>6</sub> that featured equivalent switching and voltage-withstand capabilities.

Alstom is the first in the world to launch a clean alternative to SF<sub>6</sub> for HV applications.

Alstom's SF<sub>6</sub>-free solution has an extremely low global warming potential (GWP) compared to SF<sub>6</sub>, with a 98% reduction of the SF<sub>6</sub> GWP. It is safe to handle and has no impact on ozone depletion.

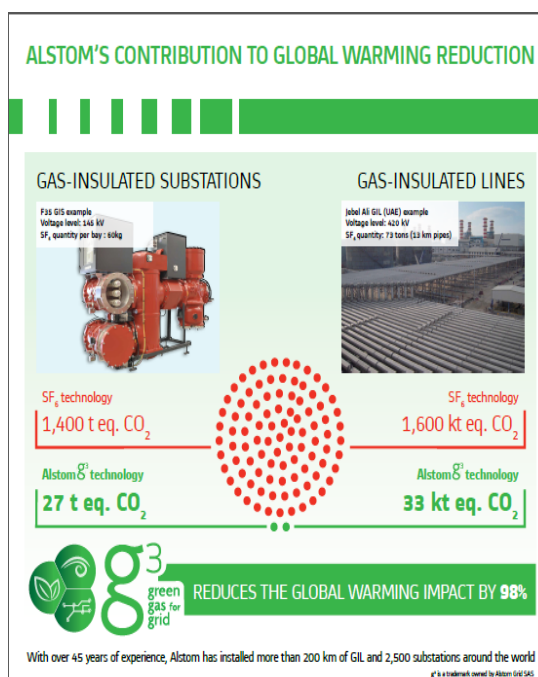
#### (C) Impacts in terms of reduction of carbon emissions by 2020

63 million tons of CO<sub>2</sub> avoided per year by 2020

Profitable

Affordable

Affordability being improved



# Gas for grid g3

## *Alternative to SF6 for HV applications*

### **(D) Major roadblocks and first policy recommendations**

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- Two major roadblocks have been identified...
  - Market Acceptance
  - Low carbon market pricing
- ...and would require
  - R&D funding for manufacturing
  - Carbon market
  - Regulatory incentives

## 33. Community Energy Management System

### *Managing energy locally*

Company: Alstom

#### **(A) Overview of “usual” solutions**

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- Usually local authorities do not manage their energy mix, because production is often done in a central manner. Every aspect of energy production transport and consumption is subcontracted to private companies or given to the end user without coherent strategy.
- Every territory will be concerned by the revolution of low cost decentralized energy in the future.
- CO2 emissions could be reduced while leveraging local energy sources and reducing fossil fuels.

#### **(B) Synthetic description of the innovation**

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- The innovation is a combination between an energy governance giving a larger role to local authorities and the use of IT platforms
- Data from different sources is collected and analyzed, instead of being spread in multiple and isolated systems.
- The ultimate benefit is to facilitate the relocation of energy production capacities locally, enabling local job creation and appropriate use of low carbon local energy sources. This opens new energy optimization opportunities between sources, and improves flexibility enrolment and local balance between producers and consumers.

#### **(C) Impacts in terms of reduction of carbon emissions by 2020**

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- The cost per ton of CO2 metric is not adapted for this case – this solution is an enabler to exploit every local energy source without rebuilding entirely the networks. It has a strong indirect impact, but depending on local energy sources available.
- In a context when decentralized renewables will reach grid parity, decentralized production will be a reality for most of the developed countries and almost every developing country.

#### **(D) Major roadblocks and first policy recommendations**

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- As energy regulation has been designed for centralized production, some adaptations need to be considered like the ability to organize local balancing markets, ancillary services and to create a frame for a public service for local data.
- This solution is based on internet of things development and software systems provided by local hosting capabilities.

## 34. 660 MW USC CFB Boiler

*Improved efficiency for low cost fuel boiler*

Company: Alstom

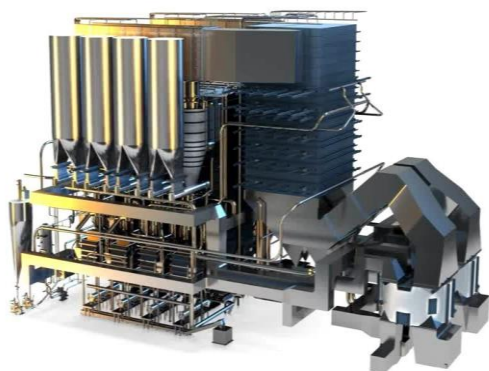
### (A) Overview of “usual” solutions

The usual choice for providing electric power from low cost fuels is pulverized coal/sub-critical technology, still representing over 43% of power plants exports over the last 5 years. Those plants typically operate at steam pressures of 178 bar and temperatures of 565°C, and achieve, at best, efficiencies of up to 38%(LHV) for the most recent units.



India: 2x300 MW Standardised  
Pulverised Coal Power plant

### (B) Synthetic description of the innovation



Alstom 660 MW USC CFB Boiler

Circulating Fluidized Bed (CFB) boiler technology has been used for over 25 years and regularly improved. This innovation brings it to Ultra Super Critical (USC) steam conditions: 275 bar and 620°C and a 660 MW size which meets the bulk of market demand in emerging economies, and is capable of achieving efficiencies over 44% (LHV), depending on fuel quality and cooling conditions.

USC CFB technology allows to efficiently utilize a wide variety of fuels, including high ash, high moisture, high sulfur, and low heating value fuels that are unsuitable for other firing systems. The technology also inherently meets stringent stack emissions thanks to the easy control of SO<sub>2</sub> emissions by addition of a limestone sorbent and a very low NO<sub>x</sub> production due to the mild combustion temperature.

The innovation was launched in June 2013, targeting the fast growing East-Asian power markets.

### (C) Impacts in terms of reduction of carbon emissions by 2020

**150 Mtons of  
CO<sub>2</sub> avoided per  
year by 2020**

USC technology delivers up to 12% less CO<sub>2</sub> emissions compared to sub-Critical technology and up to 6% less CO<sub>2</sub> emissions compared to Super-Critical technologies. According to the IEA (New Policy Scenario), 170 GW of new sub-critical plants are going to be added until 2020. Should those plants be constructed with USC technology instead, this would result in global savings of about 150 million tons savings annually. Moreover, USC by providing a high starting efficiency are well suited for being retrofitted with CCS. Should those plants be constructed as CCS-Ready and retrofitted later to CCS effective, an additional annual saving of 950 million tons CO<sub>2</sub> emissions would be possible.

## 660 MW USC CFB Boiler

### *Improved efficiency for low cost fuel boiler*

Profitable
<b>Affordable</b>
Affordability being improved

The sensitivity of the Levelized Cost Of Electricity (LCOE) to a switch from sub-Critical technology to Ultra Super Critical technology depends on various fuel costs, assuming a CO<sub>2</sub> cost equal to zero. When inexpensive fuels are available, like the low quality locally mined lignite found in several East-Asian countries, the cost penalty could be as much as 5% and the default choice will be sub-Critical technology. For imported fuels, trading between 40 and 100 €/ton depending on quality and market conditions, we would be close to break-even. For high price fuels like biomass, the choice would shift to USC technology, with positive economical returns.

## (D) Major roadblocks and first policy recommendations

Ultra Super Critical Technology faces difficult penetration (<15% of global export market) especially when local inexpensive fuels are available. In absence of a world carbon price there is a fierce and successful competition from low cost suppliers delivering cheap sub-critical turnkey power plants. Those suppliers are often backed by generous export finance from their home governments, while the high technology western suppliers are penalised by the dwindling international financial institution support for coal projects. This has favoured expansion of climate stranded assets as retrofit to CCS will not be possible on sub-Critical units.

The main conditions for its development:

- Development of a strong world-wide price for carbon
- Policies, international finance and export credit to support deployment of the best available (USC) steam parameters (275 bar, 600°C) along with CCS readiness on world class coal power plant projects

## 35. Urban planning tool addressing energy and GHG

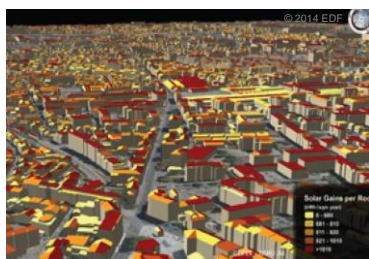
*Empowering local government decision making*

Company: EDF

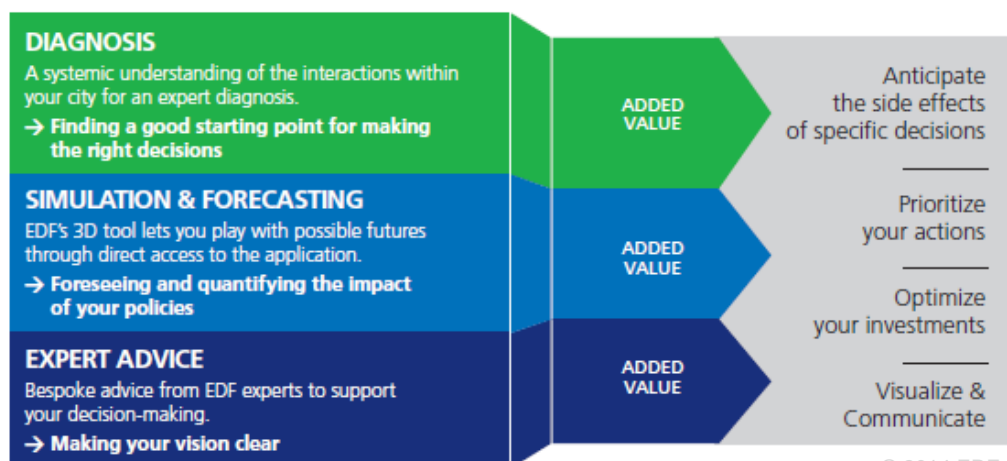
### (A) Overview of “usual” solutions

- Cities use significant quantities of energy and account for a large part of global of CO<sub>2</sub> emissions and energy consumption. Yet, CO<sub>2</sub> and air quality are generally poorly taken into account during urban planning.
- Moreover, urban planning issues are often addressed separately from environmental ones - working in sector silos.

### (B) Synthetic description of the innovation



- EDF's solution targets local elected official and technical services (land use, housing, transport) of large cities, in order to serve citizens, firms and investors.
- This service, built on a shared vision of the cities' targets, is based on a technological innovation allowing the **whole urban system** to be addressed in a more systemic manner and with a “Energy and Low Carbon” perspective.
- An **urban modeling platform** enables to understand impacts of urban projects on energy, CO<sub>2</sub> emissions and air quality.
- Based on this **systemic approach**, energy systems and CO<sub>2</sub> emissions can be optimised during the planning phase, by using effective levers of action such as urban morphology, density, functional diversity, renewable energy potential, efficient electricity grids, cooling and heating networks and by optimising building consumptions and emissions related to mobility.





# Urban planning tool addressing energy and GHG

## *Empowering local government decision making*

### (C) Impacts in terms of reduction of carbon emissions by 2020

**100 Mtons of CO<sub>2</sub> avoided per year by 2020**

- As of today ,cities worldwide account for 31 GtCO<sub>2</sub>
- 2020-Baseline scenario: 35.2 GtCO<sub>2</sub>
- 2020-“Realistic & optimistic” scenario: 35.1 GtCO<sub>2</sub>
- The urban planning tool can contribute to 100 MtCO<sub>2</sub> avoided per year in 2020.
- As of today, the cost (per city) is estimated to be c. 200k€.
- By 2020, possible gains and improvements are estimated to be ~50 k€ per city.
- The innovation can contribute to saving 1 MtCO<sub>2</sub>/year per city.
- The average savings per city would therefore be 5c€/tCO<sub>2</sub>/year.

Profitable
<b>Affordable</b>
Affordability being improved



### (D) Major roadblocks and first policy recommendations

- Energy, CO<sub>2</sub> and air quality are generally poorly taken into account in urban planning. Moreover, in a traditional way, urban planning issues are addressed separately, working in sector silos.
- This innovation would need a better awareness regarding its added value for the whole urban system. Urban systems require being addressed in a more systemic manner and in an “Energy and Low carbon” perspective.



## 36. Icebat: cold ice storage technology, for off-peak energy storage

*Release of cooling energy during demand peak*

Company: FAFCO

### (A) Overview of “usual” solutions

- The most common cooling systems are cooling towers, which vary in size and power, either as heating, ventilation and air conditioning (HVAC) cooling towers or as industrial cooling towers.
- There are different types of heat transfer and air circulation mechanisms.
- However, these solutions require customers to have cooling towers capacities equal to their highest peak in energy demand, as no energy can be sustainably stored.
- As a result, they have many on/off cycles and low utilization rates, as demand is generally non-existent during the night, but can face severe peaks during the hottest summer days.



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### (B) Synthetic description of the innovation

- ICEBAT consists in storing water in a box which can be frozen into ice to store cooling energy when industrial demand and energy prices are low, and releasing its cooling energy potential on demand.
- Storage units type and volume is adapted to customer needs (standard internal, external or hybrid melt systems – 1.5x1.5x2m to 12x12x4.2m for steel units and up to 12x6.5m for concrete units)
- This technology is mature and has been developed and commercialized by FAFCO for 30 years
- ~5°C temperature charge, for ~8h, discharge can be as fast as 1h, with less than 2% thermal losses/day
- Highest energy density in KWh/m<sup>3</sup> occupied and 30 years estimated life expectancy
- 5-50% cuts in installed cooling power capacity and volume, and increased continuous utilization
- Expected pay-back period of 0-7 years on all projects

Profitable
Affordable
Affordability being improved

## 37. SunPower C7 Power Plant

### *Unique Low-Concentration PV Technology*

Company: TOTAL

#### **(A) Environmentally friendly power generation**

##### **SunPower's innovative C7 technology offers electricity from the sun with minimal impact**

- SunPower's C7 low-concentration photovoltaic (LCPV) solution generates power without the use of traditional hydrocarbon fuels
- Economically competitive where direct normal irradiance (DNI) from the sun is high
- LCPV leverages SunPower's industry-leading high-efficiency solar cell technology and environmental stewardship to minimize cost and GHG emissions
- Reduces emissions by approximately 500 gCO<sub>2</sub>/kWh compared to traditional fuels

#### **(B) Features of SunPower's innovative C7 technology**



##### **SunPower's C7 Power Plant is the only low-concentration photovoltaic solution available at commercial scale**

- Lower levelized cost of electricity (LCOE) through innovative LCPV technology combined with precision tracking and a low-cost, durable system of mirrors
  - By tracking and reflecting sunlight onto high-efficiency SunPower solar cells, a 100-MW<sub>p</sub> power plant can be built using only 17 MW<sub>p</sub> of solar cells
  - Complex cell manufacturing processes are therefore replaced by simpler and less expensive commodity materials such as trackers and mirrors
  - SunPower's C7 technology is particularly well adapted to regions with high direct normal irradiance
  - Rapid manufacturing in proximity to the plant site improves cost-effectiveness and contributes to the local economy
- Modular power blocks combine single-axis trackers with six rows of parabolic mirrors for concentrating sunlight, enabling preassembly, simplifying construction, and promoting power plant scalability
  - GHG emissions are comparable to SunPower's "one-sun" PV solutions, which by virtue of their high efficiency are already lower than for standard PV technology



# SunPower C7 Power Plant

## *Unique Low Concentrated PV Technology*

### (C) Impact on carbon emissions by 2020

**2000 ktons of  
CO<sub>2</sub> avoided  
per year by  
2020**

Profitable
<b>Affordable</b>
Affordability being improved

- SunPower is currently building two C7 power plants, one of 20MW<sub>p</sub> in the US and another of 70MW<sub>p</sub> in China
- Installations are expected to reach 2–3 GW<sub>p</sub> by 2020, with continuing growth thereafter
- This would avoid an estimated 2000 ktons of CO<sub>2</sub>/year!
- The C7 LCPV solution is expected to be cost competitive with “usual” solutions including one-sun solar PV wherever SunPower deploys it
- IEA estimates the required investment will be slightly less than 1,000 USD/kW by 2020 in China (Source: *IEA Solar PV Technology Roadmap 2014*)
- There will be **no additional cost** to the end user, only the benefit of a greener solution!

### (D) Policy recommendations and potential roadblocks

- The projects currently under construction will confirm investor interest in SunPower’s C7 power plant solution and establish a track record to substantiate bankability
- Level playing field with all suppliers of cells and modules worldwide with no competition bias
- Bonus for innovation or specific allocation in solar energy program (for example government bidding processes or FIT “to allow for scale up”)

## 38. Dow Filmtec™ ECO Reverse Osmosis Elements

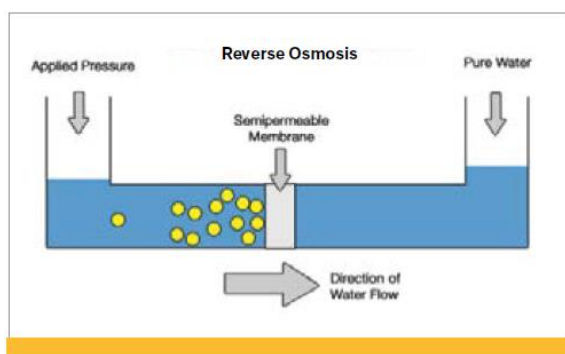
*Better water purification with less energy*

Company: Dow Chemicals

### (A) Overview of “usual” solution

- The world's population is predicted to reach 8.3 billion by 2030. By that time, global water requirements are expected to grow by 50% under an average economic growth scenario, and available water supplies will only satisfy 60% of anticipated demand.
- How is that possible, with so much of the world's surface covered with water? One of the main reasons is the fact that only 2.5 percent of the world's water is fresh water. Producing the fresh water necessary to quench our thirst, from brackish water or seawater, is an unprecedented challenge.

Source	
Oceans	97,25 %
Ice caps & glaciers	2,05 %
Underground water	0,68 %
Others	0,02 %



- Reverse Osmosis (RO)** has a long and successful history in meeting the water quality and quantity challenge. By separating salt and other impurities from water at the molecular level, RO comprises the finest level of filtration available.
- The RO membrane is a nano-structured composite that is fabricated into commercially viable modules, which are in turn the building block of modern RO systems.
- Since the development of RO in the late 1950's and early 1960's, the scope for its application has been continually expanding.

### (B) Synthetic description of the innovation

- DOW FILMTEC™ ECO Reverse Osmosis Elements, a new family of RO products invented by Dow Water & Process Solutions scientists, includes an advanced, thin-film polyamide membrane chemistry along with a new, low-pressure-drop feed spacer configuration.
- Since 1995, Dow achieved a 64% reduction in energy required to desalinate brackish water**, greatly surpassing our 2015 sustainability goal of 35 percent.
- There is currently no product in the market that can deliver water quality equivalent to that of FILMTEC™ ECO Elements at the same low pressure. When using alternatives, industrial water producers have to compromise on quality or energy, resulting in increased operational expense.
- Plants that switch from conventional RO elements to FILMTEC™ ECO Elements have less impact on the environment and less strain on their bottom line.
- FILMTEC™ RO Technology enables robust performance over a longer lifetime through lower energy use, which reduces regeneration costs and **results in operational savings between 16 and 19 %**.

# DOW FILMTEC™ ECO Reverse Osmosis Elements

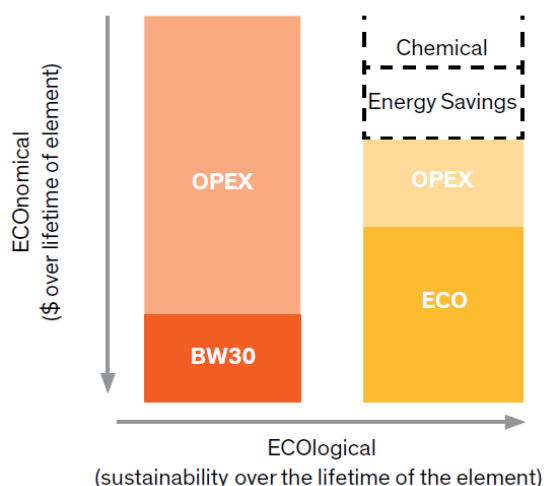
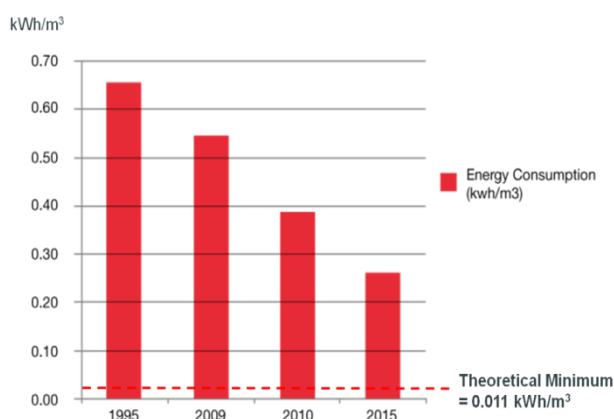
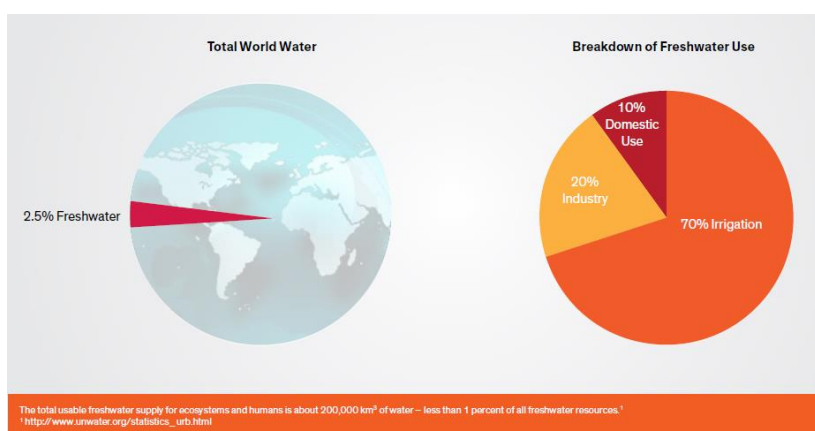
*Better water purification with less energy*

## (C) Impacts in terms of reduction of carbon emissions

**1.5 million tons of CO2 avoided by 2025**

- This innovation delivers up to 40% lower salt passage, while consuming 30% less energy than industry standard RO elements.
- Based on current sales plans, we expect that in the next 10 years (2015-2025), this breakthrough technology will result in the production of over 15 trillion cubic meters of clean water (the volume of over 6 million Olympic-sized swimming pools) while saving over 2 billion kilowatt-hours of energy and over 1.5 million metric tons of CO2 emissions.

<b>Profitable</b>
Affordable
Affordability being improved



## 39. Free-flow toll lanes

*No more lost fuel at the tollbooth*

Company: VINCI autoroutes

### (A) Overview of “usual” solutions

**What is the “usual” solution this innovation would replace ?**

- Traditional toll collection systems are based on a ‘stop and go’ principle : drivers must stop at toll gates to pay the toll.
- The toll gates open only when the toll fare has been collected, whatever the means of payment used : cash, card or transponder.



Photo: Jean-Philippe Moulet

### (B) Synthetic description of the innovation



Photo: M. Martini

- 225 free-flow toll lanes have been implemented by VINCI Autoroutes.
- Non-stop 30km/h Electronic Toll Collection enables drivers to go through the toll gates without stopping but still uses toll gates to prevent violations.
- Free-flow systems do without the toll gates; vehicles are detected as they pass by detectors and the toll fare is applied. Because there is no toll gate these systems are more prone to violations.
- Free-flow lanes were first tested on a stretch of freeway built by a VINCI subsidiary in California. Their success inspired the introduction of the non-stop 30km/h system on existing toll infrastructure in France.

### (C) Impacts in terms of reduction of carbon emissions by 2020

**54 081 tons of  
CO<sub>2</sub> avoided per  
year by 2020  
(Vinci highways  
only)**

**How much CO<sub>2</sub> will be avoided on an annual basis by 2020 ?**

- The use of non-stop 30 km/hour electronic toll lanes prevented the release of 50 947 tons of CO<sub>2</sub> emissions in 2014, or 137 823 tons since they opened in 2011.
- With our baseline being a 100 % use of traditional “stop and go” toll collection systems, the continued use of non-stop toll lanes would result in 54 081 tons of avoided CO<sub>2</sub> emissions per year in 2020, assuming a 1% traffic growth rate.



## 39. Free-flow toll lanes

*No more lost fuel at the tollbooth*

### (D) Total cost of the innovation

<b>Profitable</b>
Affordable
Affordability being improved

#### How much will it cost to the final end user ?

- Each passage through a non-stop 30 km/h toll lane results in a 0.03 L reduction in fuel consumption for light-weight vehicles and 0.3 L in fuel savings for trucks.
- Today, this represents €2,718,924 in customer savings for light weight vehicles and trucks combined (assuming a fuel price per liter of €1.3).
- In 2020 this will represent €2,886,193 in customer savings (assuming a fuel price per liter of €1.3 and a 1% per year traffic growth rate).
- 

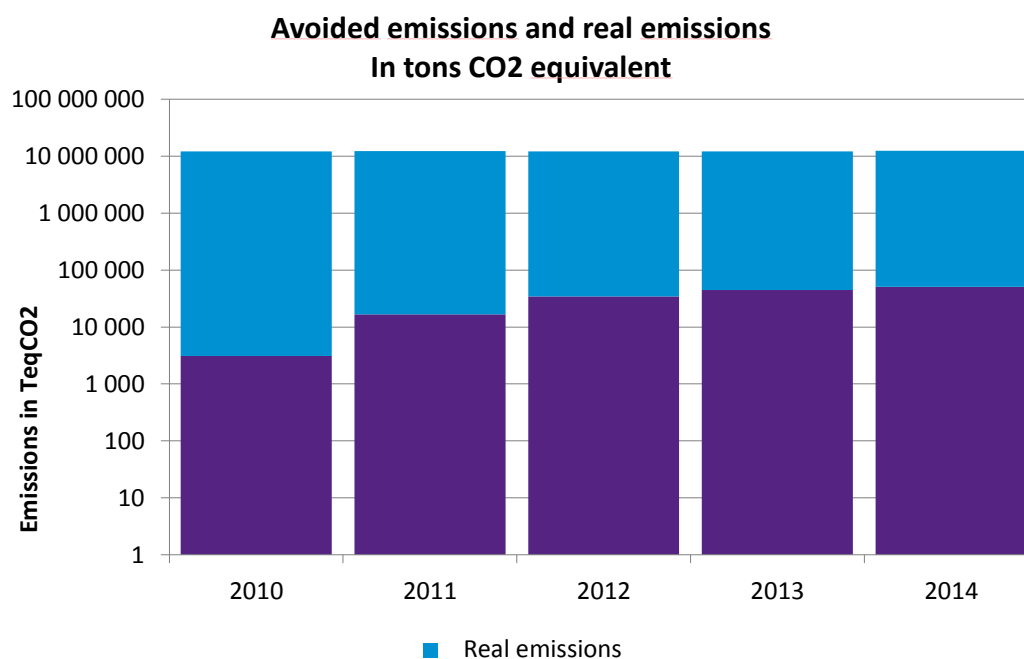
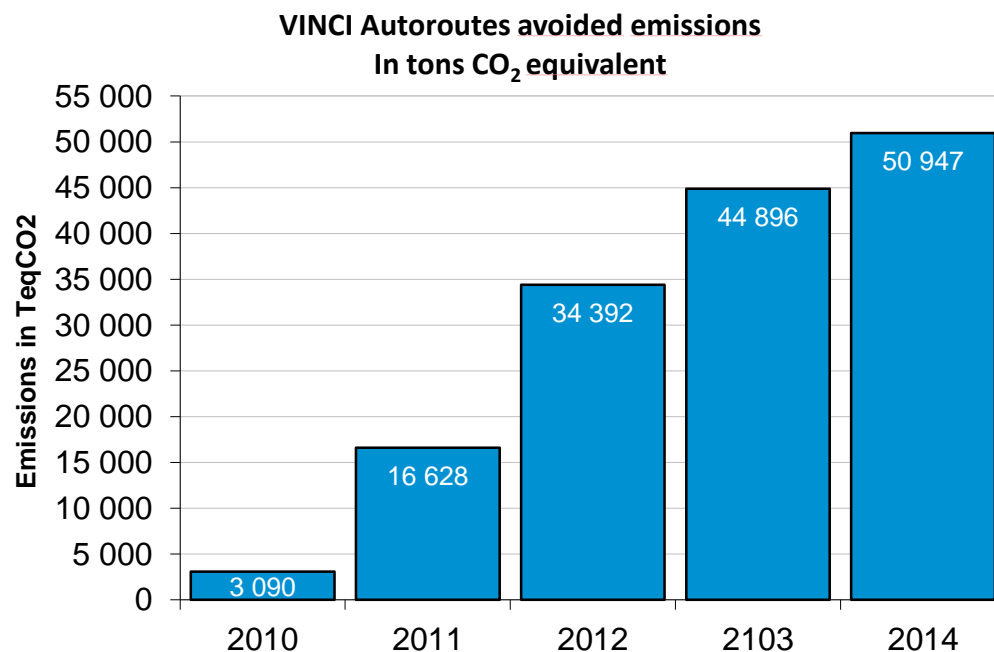
### (E) Major roadblocks and first policy recommendations

- The expansion of free-flow lanes across VINCI's freeway system in France does not face any significant financial hurdles.
- A small proportion of customers, such as short-term visitors to France not equipped with badges, will always require access to stop-and-go lanes with more traditional payment systems. The presence of at least one stop-and-go lane per toll point will therefore always be required.



## 39. Free-flow toll lanes

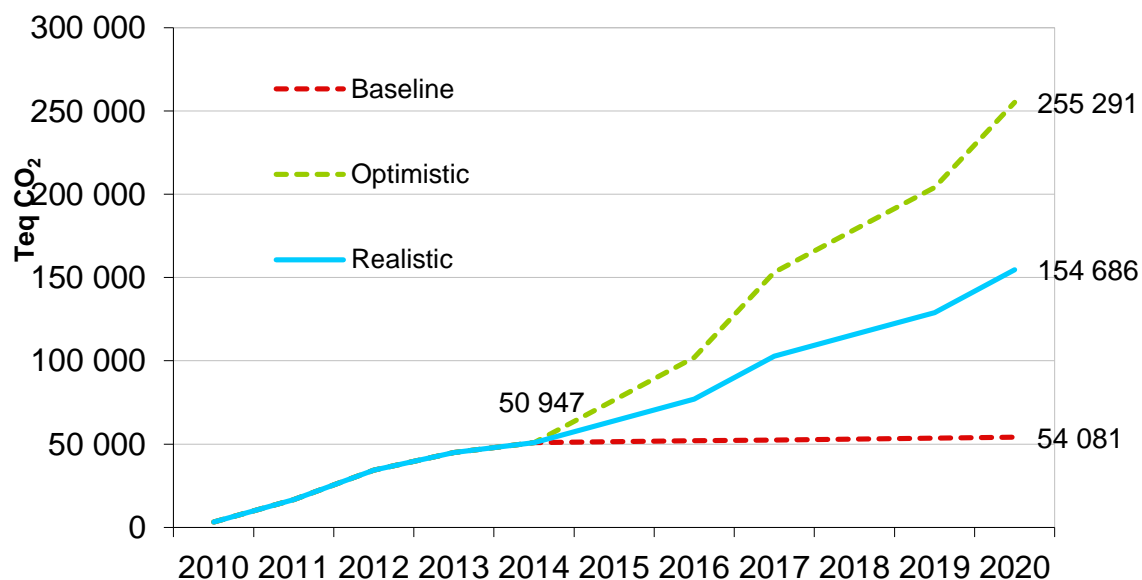
*No more lost fuel at the tollbooth*



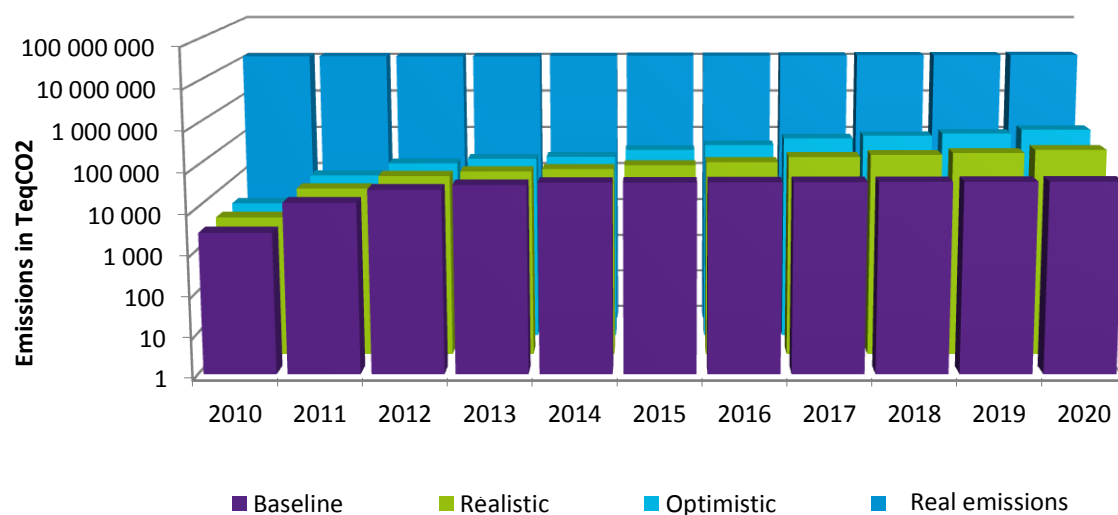
## 39. Free-flow toll lanes

*No more lost fuel at the tollbooth*

**"Baseline" vs. "Realistic & Optimistic" scenarios**



**Avoided emissions and real emissions  
In tons CO<sub>2</sub> equivalent**



## 40. Green bond financing

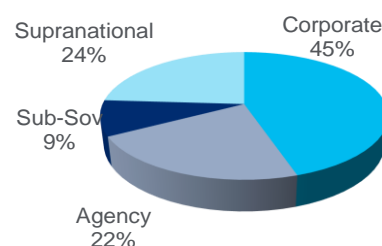
*An opportunity to communicate environmental responsible strategies*

Company: CITI

### (A) Overview of Green Bonds

- Green bonds are an alternative to plain-vanilla bonds.
- Green bonds' financial documentation characteristics, pricing and capacity are in line with similar plain-vanilla bonds. Yet, proceeds are dedicated to specific climate or environmental sustainability initiatives.

Green Bond Issuer Type



### (B) Green Bond Key Characteristics

Green bond offerings provide issuers with the opportunity to communicate socially responsible strategies, dedicate proceeds to specific initiatives and to capture demand from the rising number of Socially Responsible Investment (SRI) funds

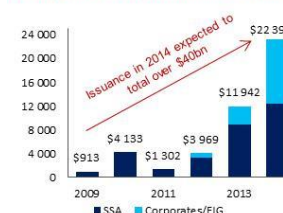
- An issuer designates proceeds for climate-friendly / environmental / socially responsible / sustainable use – either by ring-fencing, direct project exposure or securitization.
- Green Bonds exclusively target climate and/or environmental sustainability purposes while SRI bonds are tied to “socially responsible” investment broadly.
- Transaction marketed to the traditional institutional investor community as well as SRI specific investors, will receive special focus during the allocation process.
- While pricing and capacity should be in line with a vanilla transaction, a Green/SRI Bond new issue can enhance the issuer's distribution into new funds and new investors.
- Optional rating is given by an extra-financial ratings agency which looks at Environmental, Social and Governance (ESG) policies of the issuer/dedicated segment of the issuer.

### (C) Green Bond Recent Issuance

SRI/Green Bond offerings are becoming increasingly popular in global bond markets, as illustrated by recent successful insurances

- GDF Suez's Green Bond: €1.2bn at 1.375% 6-year and €1.3bn at 2.375% 12-year (largest Green Bond ever issued)
- Renewable Energy Projects imply conception, construction and installation of renewable energy production (including hydro, geothermal, wind, solar ...)
- Energy Efficiency Projects contribute to a reduction of energy consumption per unit of output (heating and cooling network, co-generation, optimization of building or plant efficiency, systems for energy management)
- EDF's Green Bond : €1.4bn and 2.25% 8-year
- Funds will be allocated to best-in-class renewable energy projects financed by subsidiary EDF Energies Nouvelles.
- Eligible Projects include investment in electricity production from renewable sources such as wind (off-shore and on-shore), photovoltaic, biogas, marine energy, etc.

Historical Green Bond Issuance Volumes



# Green bond financing

## *An opportunity to communicate environmental responsible strategies*

### **(D) Green Bond Process**

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In order to mitigate the potential risk of investor concerns, 4 steps have to be followed to ensure compliance with the Green Bond Principles

- Recommended Green Bond Process
  - *Assemble Team*: Potentially including sustainability and operations personnel in addition to treasury and Investor Relations.
  - *Establish Criteria For Asset / Project Eligibility*: The criteria / use of proceeds should be made publicly available so that they can be considered for buyers' investment decision.
  - *Select Assets / Projects Against the Criteria*: An initial set of assets / projects will typically be chosen and used in the marketing of the offering
  - *Verification / Certification*: A third party such as the Company's auditors or a consultant firm help verify the use of proceeds. This is normally done in the context of the publication of the Annual Results
- Green Bond Principles: Voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the approach for issuance of a Green Bond.
  - *Use of Proceeds*: The issuer should declare eligible Green Project categories in the Use of Proceeds.
  - *Process for Project Evaluation and Selection*: The issuer of a Green Bond should outline the decision-making process it follows to determine the eligibility of an individual investment using Green Bond proceeds.
  - *Management of Proceeds*: Net proceeds of Green Bonds should be moved to a sub-portfolio or otherwise tracked by the issuer.
  - *Reporting*: Issuers should report at least annually on the specific investments made from the Green Bond proceeds.
  - *Issuance*: A variety of ways for issuers to obtain outside input (second party consultation, publicly available reviews and audits, 3rd party, independent verification/certification).

### **(E) Growing Momentum in US Environmental Finance**

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- State Green Banks: Several states (e.g. NY, Connecticut, California, Hawaii) have established green banks or similar entities to facilitate scaling of clean energy and deployment of private capital.
- Cities & Local Governments are taking steps to address climate mitigation and adaptation.
- Obama Administration is pushing hard through Executive actions: one recent action is the United States Environmental Protection Agency (EPA)'s planned regulation of carbon under the Clean Air Act. The EPA is currently drafting rules, state-by-state targets and compliance measures. There are significant pushback / legal challenges.
- High profile engagements and statements, such as Henry Paulson's NYT editorial "The Coming Climate Crash", and Tom Steyer and Bob Rubin supporting "Ceres's Clean Trillion" are rising.
- Number of NGOs, such as Ceres and Interfaith Centre on Corporate Responsibility (ICCR), promote positive campaigns to frame the transition to green as new opportunities.
- Primary non-environmental motivations that help overcome political divisions on environmental issues are: 1) cost savings; 2) job and enterprise development; and, 3) energy security or independence. Some of these issues are being driven by associations such as the BlueGreen Alliance.

# Green bond financing

*An opportunity to communicate environmental responsible strategies*

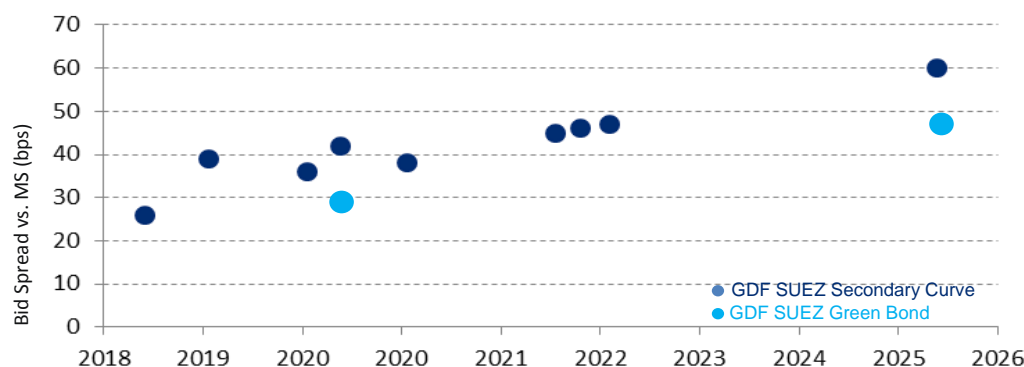
## GDF Suez Case Study: Illustrative charts

On 12 May 2014, GDF SUEZ (A1 st. /A neg.) successfully priced its inaugural Green Bond transaction. The offering consists of a dual-tranche 6-year / 12-year for a total principal amount of 2.5 billion euros, representing the largest Green Bond ever issued.

### Summary Termsheet

<b>Issuer</b>	GDF SUEZ SA	
<b>Rating</b>	A1 (stable outlook) / A (negative outlook)	
<b>Format</b>	Senior, Unsecured, RegS	
<b>Trade Date</b>	12 May 2014	
<b>Settlement Date</b>	19 May 2014	
	6-Year Tranche	12-Year Tranche
<b>Tranche Size</b>	€1,200 million	€1,300 million
<b>Maturity Date</b>	19 May 2020	19 May 2026
<b>Coupon (an.)</b>	1.375%	2.375%
<b>Initial Price Thoughts</b>	MS+50 area	MS+70 area
<b>Guidance</b>	MS+45 ar. (+/- 3 bps, price in range)	MS+60/65 (price in range)
<b>Reoffer Spread</b>	MS+42 bps / Bund+84.1 bps	MS+60 bps / Bund+105.6 bps
<b>Reoffer Price</b>	99.345%	98.494%
<b>Orderbook</b>	ca. €3.5bn	ca. €4bn
<b>Docs &amp; Denoms</b>	EMTN / French Law / €100k+100k	
<b>Listing</b>	Paris Stock Exchange	
<b>Use of Proceeds</b>	Finance Renewable Energy projects and Energy Efficiency projects, in line with the Green Bond framework developed by Vigeo	

### Relative Value Analysis



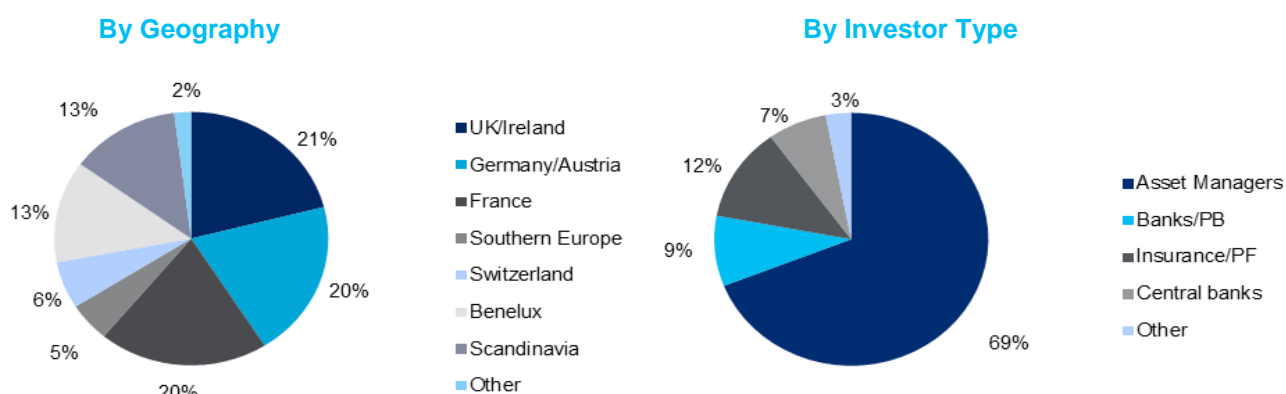
# Green bond financing

*An opportunity to communicate environmental responsible strategies*

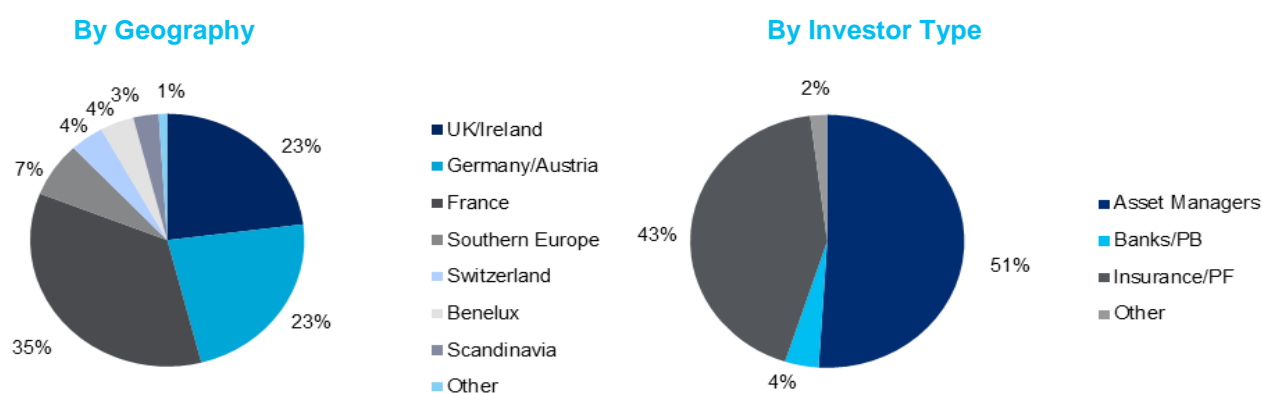
## GDF Suez Case Study: Illustrative chart

The very high quality orderbook comprised over 500 orders in aggregate representing a total demand of ca. €7.5bn. A particular highlight was the geographical breadth of the top 15 orders on the 6-year tranche. As expected for an issuer of this credit quality, French investors took the bulk of the 12-year paper, followed by UK and German accounts. Strong demand came from investors focused on environmental and socially responsible investments who bought 64% of the issue.

### Allocation Statistics on The 6-Year Tranche



### Allocation Statistics on The 12-Year Tranche



## 41. Low carbon finance

### *Investing for a green economy*

Company: Novethic

#### **(A) Overview**

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Transition to a green economy requires additional investments as well as a reallocation of existing financing flows. According to the World Economic Forum (2013), US\$ 0.7 trillion would be required annually for clean energy infrastructure, sustainable transport, energy efficiency and forestry to help the transition towards a low carbon economy. Institutional investors have a key role to play by integrating these challenges into their investment decisions, and in September 2014, 358 investors representing more than \$24 trillion in assets, signed the Global Investor Statement on Climate Change in which they committed to address the topic.

#### **(B) Key trends**

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Main strategies are twofold. First, leading investors start reducing carbon emissions from their investment portfolios, by divesting from fossil fuels companies and by selecting less carbon intensive assets. Second, they increase their allocation in green assets, such as renewable energy projects, clean technology equities and green bonds, a new type of bonds whose proceeds are dedicated to projects with environmental benefits. Among the 185 European asset owners surveyed by Novethic in 2014 on their responsible investment practices, 24% had invested in green assets during the year and 10% had implemented a low carbon investment strategy.



# Low carbon finance

## *Investing for a green economy*

### **(C) Examples of financing green assets**

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#### Zurich Insurance (Swiss)

- In November 2013, Zurich Insurance committed to invest \$1billion in green bonds from public institutions such as World Bank and other development finance institutions. By July 2014, the insurance company had doubled its commitment to \$2 billion. In November 2014, previously-earned \$400 million were already being invested in green bond funds.

#### Environment Agency Pension Fund (UK)

- The pension fund aims to have 25% of its portfolio invested in low carbon assets by 2015. As at 31<sup>st</sup> of March 2014, 13% (£285m) is specifically invested into clean technologies- this figure rises to 24% (£558m) when including broader sustainable themed investments. Since 2008, the local government pension fund has reduced the overall carbon footprint of its portfolio by 39%.

#### APG (Netherlands)

- In 2013, the Dutch pension fund manager reported to have invested approximately €15.5 billion in sustainability investments through clean themed equities and bonds, green infrastructure and real estate. This represents approximately 4.5% of its total invested capital. For the last two years, APG has doubled its investments in sustainable real estate up to €11 billion. In September 2014, the investor committed to double its investments in renewable energy from 1 to €2 billion within three years.

### **(D) Major roadblocks and first policy recommendations**

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There are several barriers to the shift towards a green finance.

- Regarding the reduction of the carbon intensity of portfolios, methods for carbon emissions measurement are still at an early stage, and there is no general consensus on the way to go.
- Regarding the financing of green assets, main roadblocks include the uncertain regulatory context, the investment status of some pension funds not authorized to invest in real assets and project complexity. In addition, investors highlight that few investment proposals meet their quality requirements.

