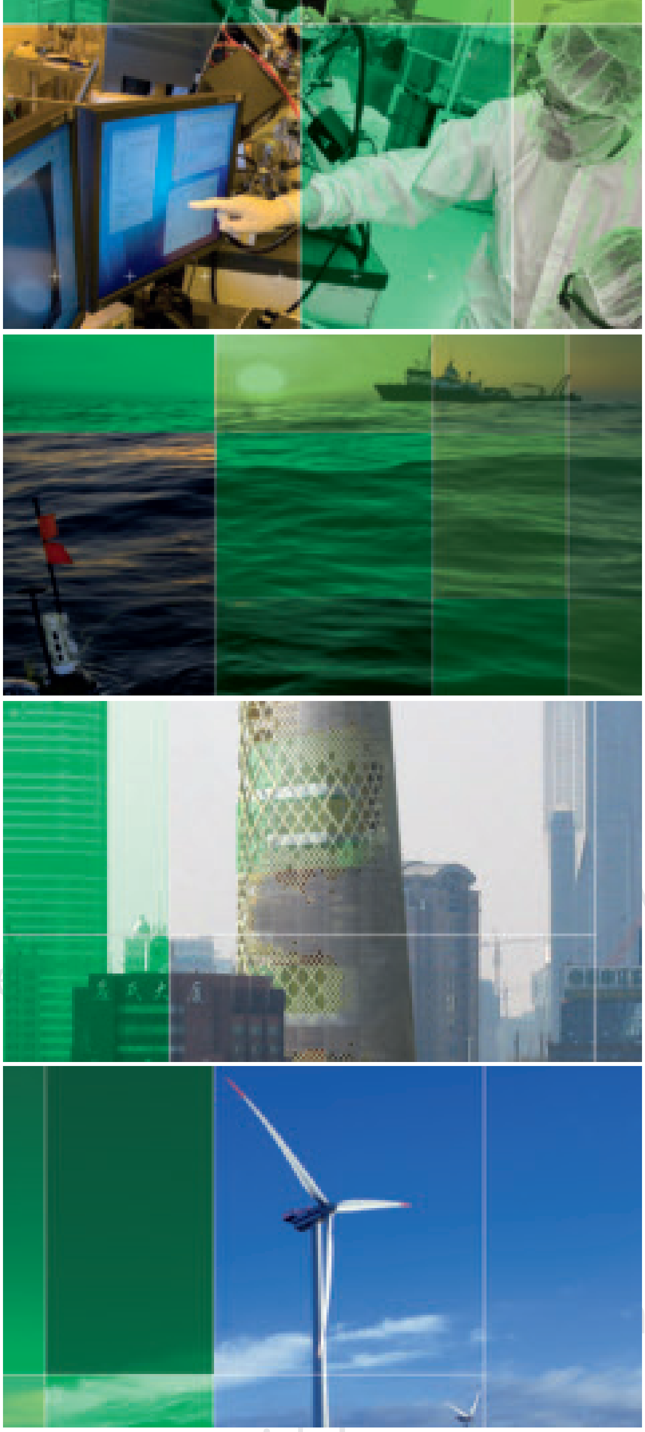
DEDICATED TO MAKING A DIFFERENCE

# Innovating for green growth

## Drivers of private sector RD&D

World Business Council for Sustainable Development



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y=e^sinx
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# Purpose

By 2050, the world's population will have increased to 9 billion, with most of the growth in developing countries. Increasing urbanization and efforts to combat poverty will lead to rapid energy and infrastructure growth demand in these countries. While this offers a huge growth opportunity for business, it also presents companies with the challenge to address the climate change. Businesses understand that an unsustainable world is not a good place for doing business.

The world needs business as a committed solution provider to meet future energy and climate challenges. Business is the main source of innovation, solutions and financing for the growth required, and it must continue to play a strong role in the future climate regime. This requires accelerated innovation, collaboration and implementation of low-carbon solutions. It also requires greater collaboration across business sectors and between business, government, academia and civil society.

Companies and governments recognize that a 'green race' is underway. This is a race fuelled by concerns for energy security and the need to manage resource scarcity. It reflects the constraints imposed by both climate change and the current economic situation that encourages cost savings through efficiency improvement.

Companies want to gain a competitive advantage in future markets and need to anticipate regulatory regimes and demand by consumers. Much has already been done in the absence of price signals and climate regulations, but more can be done with efficient policies.

Companies recognize collaboration can help to develop breakthrough technologies and are thus partnering in order to strengthen their capabilities by sharing risk, know-how and capital costs. On their side, governments are also partnering with business to build new infrastructure, scale up financing for technology development and promote pre-competitive research.

The World Business Council for Sustainable Development (WBCSD) has a track record for facilitating collaboration between companies and promoting best practice sharing. In this publication, WBCSD members share their understanding of the environmental challenges at stake and the role of the private sector in low-carbon technology research, development and demonstration (RD&D). The report presents drivers of private sector RD&D and explains how governments can leverage these by introducing policies that redirect private sector investment. The report also contains case studies from WBCSD members showcasing collaborations between companies, academia and the public sector on RD&D.

## Key findings

For business, investment in research, development and demonstration (RD&D) for low-carbon technologies is motivated by the need to be profitable. This type of investment requires stability in demand and regulation.

Innovation in low-carbon technologies, particularly energy-related technologies, has generally received lower incentives than other sectors. There are various explanations:

- Low-carbon technologies are often more expensive than conventional technologies, especially when there is no carbon value or when fossil fuels are subsidized.
- Often, the large-scale investment required for energy innovation (not focused on product differentiation) cannot be tackled by individual companies.
- It takes time for low-carbon technologies to reach commercial maturity and compete with conventional technologies.

Competition between companies and the use of market mechanisms has a track record of driving RD&D investment. However, the urgent need for climate change mitigation and the characteristics of the energy market requires public policies in order to accelerate the innovation scale-up. Greater rewards and incentives create more innovation

**Photo**: Nanofabrication Lab

**Greater Investment in RD&D** will deliver the energy technologies capable of competing in the market without subsidies. Since current GHG-free energy is not affordable at scale, breakthroughs in technology, fueled by RD&D investments, are essential to bring costs down and deliver scalable energy systems. Business experience, gathered from the case studies presented here, indicate the elements that can accelerate RD&D of low-carbon technologies:

1 **Long-term policy frameworks** generate confidence for RD&D investment and can mitigate some of the new technology risks. These include emission-reduction objectives or commitments and public policies that support these.

2 **A value for carbon is essential to accelerate low-carbon technology development**. A value of carbon can be established explicitly (e.g. via cap and trade or carbon tax) or implicitly (e.g. via standards). Countries that do not impose carbon costs are unlikely to stimulate their markets to deliver the technologies in the long term.

3 **Public funding should be oriented toward addressing existing RD&D risks.** Public policies (such as feed-in tariffs), carbon markets, free trade, and harmonization of regulation can create large local markets for cleaner technologies and attract private investment in RD&D. Different policies are required to address different RD&D risks and different national circumstances (such as driving the cost of a technology down, filling an infrastructure gap or mitigating the risks of technology development).

4 **Intellectual Property Rights (IPR) protection** is critical to ensure a return on large RD&D investments, and to compensate for technologies that would otherwise not become commercialized. An appropriate IPR regime is a strong incentive for private sector investment in RD&D.

5 **Competitive RD&D can deliver** the best technology at the lowest cost for differentiated products or services. Markets are efficient in selecting the best technologies to meet a given goal. Governments should avoid selecting technologies, as this can create technological lock-in, reduce flexibility and crowd-out or disincentivize investors.

6 **A well-trained workforce** is essential for successful RD&D. The public sector has a role in building and supporting mathematics, science and engineering education as a foundation for future talent and RD&D breakthroughs that can attract private sector investment.

7 **RD&D infrastructure** is necessary in countries to conduct tests and laboratory experiments. Human capital and RD&D infrastructure require long-term experience and cannot be created ad-hoc for specific projects. Not all countries have the same capabilities to develop breakthrough technologies.

8 **Dialogue and cooperation between public research institutions and the private sector** can provide opportunities to develop new technologies.

9 **Streamlined public R&D programms could enhance output.** Reducing the time between the conception of an idea and deployment should be a priority for public RD&D programs; for example, by allowing fast decision-making in the allocation of public funds through public private partnerships. Reducing the heavy administrative burden could leverage more innovative results from the money spent.

10 **Collaborative RD&D** can complement competitive RD&D when: technologies are long way from commercialization; supporting infrastructure is needed; standardization can lower the costs; or cross-sectoral knowledge is required.

**Photo**: Carbon Capture & Storage, Numerical simulation of geologic carbon sequestration

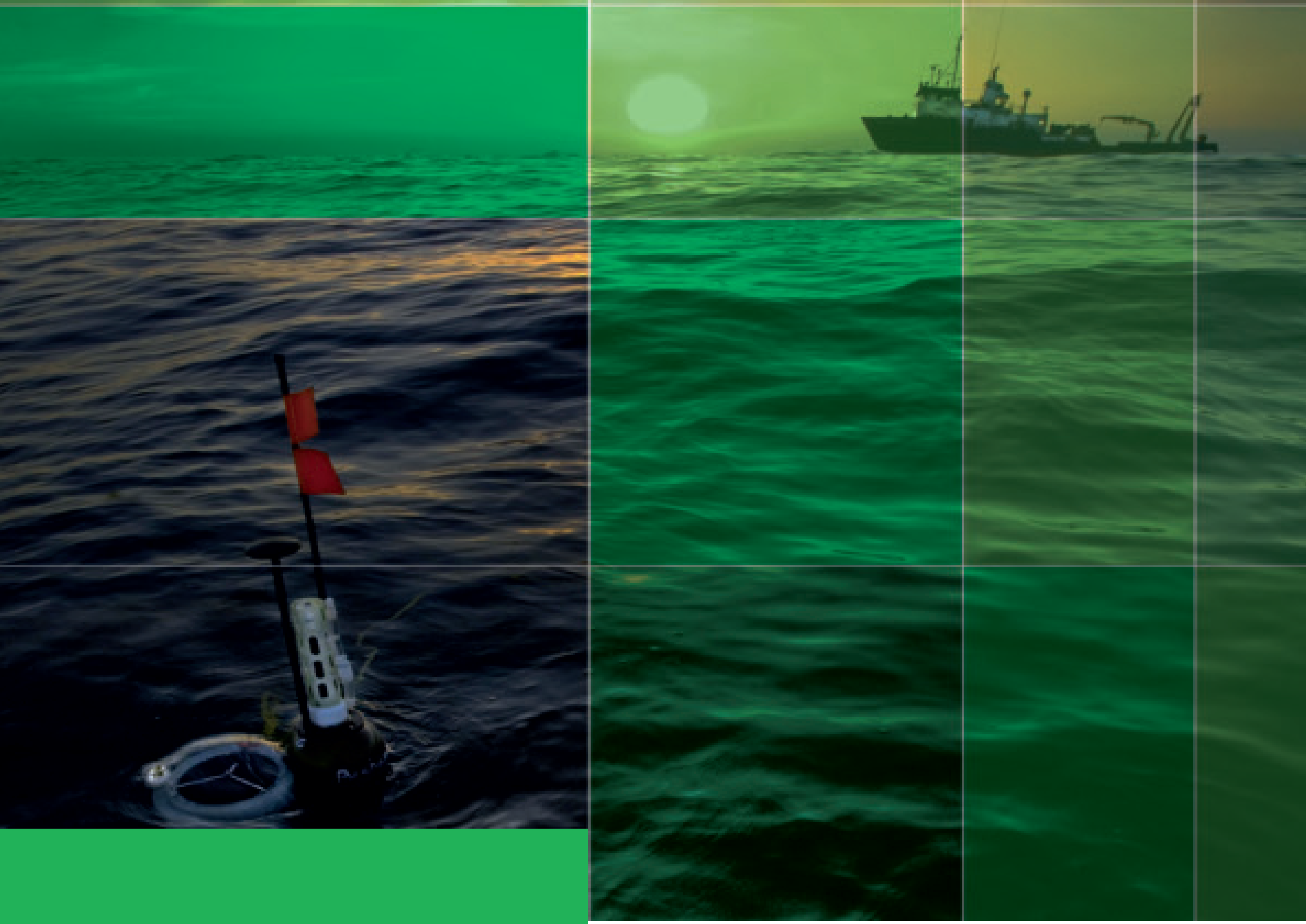


**Photo**: Autonomous Observations of the Ocean Biological Carbon Pump

# Framing the challenge

## The environmental challenges at stake

Expanding economies, growing populations and unsustainable patterns of energy supply and use could lead to an increase in global GHG emissions, incompatible with stabilization objectives. The Intergovernmental Panel on Climate Change (IPCC) has concluded that reductions of at least 50% in global $CO_2$ emissions compared to 2000 levels will be necessary by 2050 in order to prevent dangerous climate change. Concerns over energy security and the volatility of oil prices contribute to a demand for less fossil fuels in the energy mix. Achieving this goal will require a wider diffusion of existing low-carbon technologies as well as RD&D investment to improve existing low-carbon technologies and processes, and to produce new ones.

The International Energy Agency (IEA) 2010 Energy Technology Perspectives (ETP) estimates that implementing the BLUE Map scenario (reducing $CO_2$ emissions by 50% from 2007 levels by 2050) will require investments of approximately USD 750 billion per year by 2030, and over USD 1.6 trillion per year from 2030 to 2050. The estimates for RD&D expenditure are not consistently monitored, given the uncertainty of the innovation process and the difficulty to measure, but the IEA suggests the difference between current and required RD&D investments will amount to approximately USD 40-90 billion annually.

Given the scale of the challenge, robust long-term signals, effective regulatory frameworks, supportive market conditions and a value for carbon will be key to encouraging private sector investment. Slow capital stock turnover and long lead time for the development of new technologies require action and policies in order to stimulate low-carbon RD&D.

## Several technologies must be developed in parallel to meet the stabilization challenge

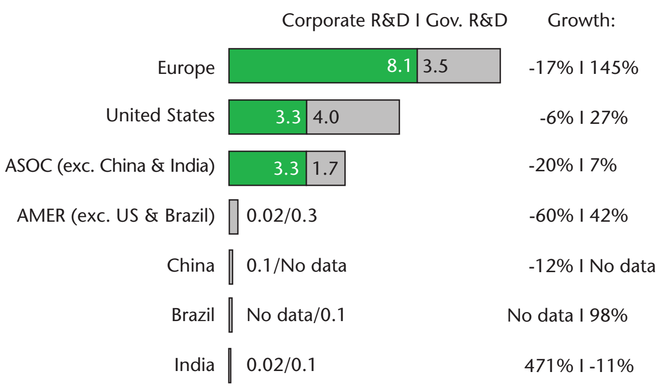
WBCSD companies believe that a wide portfolio of technologies should be developed in parallel, not sequentially, to diversify risks and avoid future lock-in of specific technologies. RD&D is needed for both breakthrough technologies and incremental improvements to existing technologies. The IEA BLUE Map scenario considers various technology options to achieve a 50% reduction in energy-related $CO_2$. These technologies are diverse and at different stages of maturity; they have different carbon-mitigation potential, and they require different policy responses.

The private sector will deliver the technologies that will help achieve the necessary emission reductions, but government policies will influence the speed and levels of investment.

## The private sector has a key role in low-carbon RD&D technology

Business currently conducts around 65% of overall RD&D and funds over 55% of annual RD&D investment. The share of total business RD&D investment is normally correlated to a country's economic and technological development. In OECD countries, more than 60% of all RD&D activities are carried out by business, whilst in developing countries it ranges from a high private share in countries like Brazil, Mexico, Chile, South Korea, Malaysia and China to high government participation in India, Indonesia, Vietnam, most African and Central American countries.[1]

Figure 1: Corporate and government RD&D investment by region (2009) and growth rate (2008) USD Bn




**Source:** UNEP, Bloomberg, SEFI (2010) Global trends in sustainable energy investment 2010

Data on business spending on clean energy technologies is not systematically monitored. Data suggests that investments in RD&D are correlated to business prospects. Global RD&D spending estimates on clean energy technology show a 2% growth rate in 2009, up to USD 24.6 billion.[2] The private sector participated globally with 60% of this amount, down from 73% in the previous year as a result of the global recession. Participation varies across countries: the private sector accounts for the majority of European RD&D spending (70%) whereas in the United States, private RD&D funding is much lower (46%) and also less than in other sectors.

Business focuses its efforts mainly on the commercial development of technologies, improving existing products and developing breakthrough technologies into commercial offerings. Universities and other public sector bodies tend to be more active in basic research. However, companies are also involved in basic research in order to ensure that it is aligned with their strategic and market needs.

Investment in RD&D is linked to management of uncertainty and risk. Private financing is more easily secured in the later stages of technological maturity, when the commercial potential is higher and more imminent.

## The emerging economies have an increasing role in climate change innovation

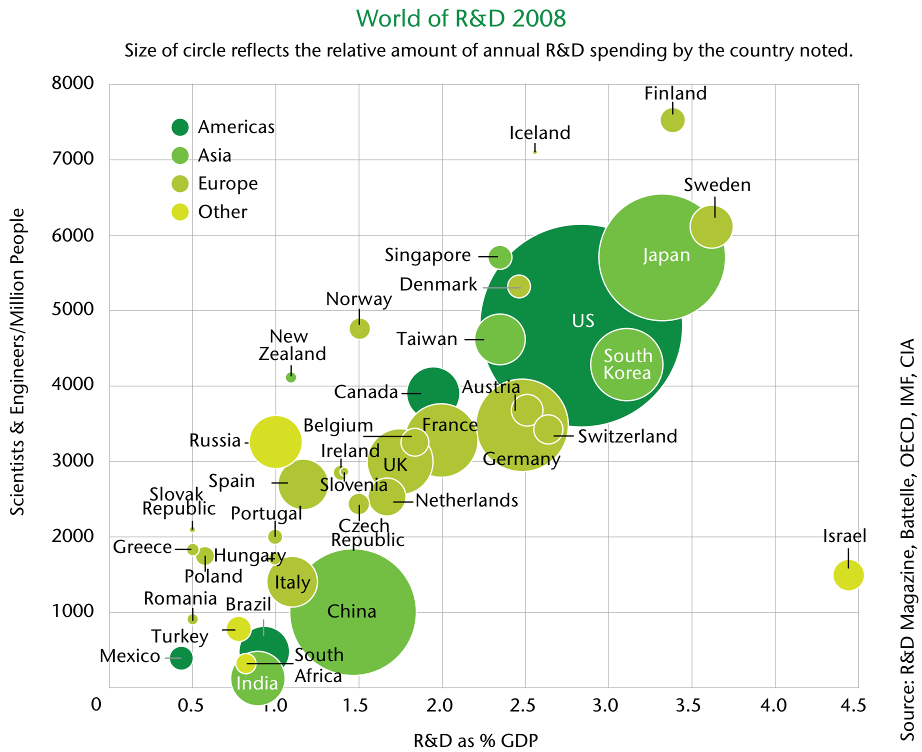
Global RD&D has been traditionally focused on a few industrialized countries, with developing countries lacking the ability to generate cutting-edge innovation. However, this paradigm is changing as a group of dynamic emerging economies are moving from passive technology recipients to innovation leaders. Emerging market companies not only provide highly competitive products and services to their own markets, but also compete internationally.

OECD multinational companies are increasingly investing in emerging markets, with 70% of global growth expected to come from those markets. Investment not only involves low-cost production, but also knowledge-intensive facilities. Companies listed on the Fortune 500 have ninety eight R&D facilities in China and sixty three in India. Economic and commercial factors, such as market size, and the quality of human capital, are driving these investments.

1 UNESCO Institute for Statistics (2009) *A global perspective on Research and Development*

2 UNEP, Bloomberg, SEFI (2010) *Global trends in sustainable energy investment 2010 - Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency*

Figure 2: R&D intensities and number of scientists and engineers per million people




RD&D is growing more rapidly in emerging economies (4% in 2010) than in the US (3.5%) and Europe (0.5%).[3] This trend is fuelled by increased spending by European and US industrial companies in new RD&D facilities in Asia, and through foreign direct investment (FDI).

Although detailed RD&D spending data in energy and climate change technologies does not exist, it can be inferred from patent data which is strongly correlated to RD&D expenditure. Climate change patents are mainly concentrated in three countries (Japan, Germany and USA), but emerging countries (China, South Korea, Russia or Brazil) are rapidly increasing their share.[4]

## Current RD&D investment is insufficient

No single technology can achieve the full emission reduction potential in any sector. A portfolio of technology options is needed, capable of deployment in various geographical, economic and other circumstances. Some of these technologies exist today and others are in development. The urgency of the emissions reduction challenge is such that investment needs to increase significantly in order to accelerate the development and deployment of newer, cleaner technologies. This will be particularly important in the developing world, where access to electricity is pressing. Table 1 summarizes the global RD&D spending gaps estimated by the IEA, as well as the main priorities for each of the required technologies.

**Photo**: Solar development, India

3 Batelle and R&D Magazine (2010) *Global R&D Funding Forecast*
4 Copenhagen Economics (2009) Are IPR a barrier to the transfer of climate change technology?

Table 1: IEA global spending gaps and priorities in low-carbon RD&D

| Technology | Gap (billion USD) | Main RD&D priorities |
|---|---|---|
| Advanced vehicles | 21-43 | • Vehicle efficiency RD&D, including lightweight materials, advanced thermal combustion engine (ICE)-based power trains and onboard diagnostics<br>• Efficiency improvements through new nano-materials<br>• Basic research<br>• Battery cost reduction to achieve EV break-even cost with ICEs<br>• Improving production processes |
| Bioenergy | 1-2 | • Cost-effective conversion of cellulose-rich biomass to usable energy<br>• Sustainable bioenergy cycles<br>• Methodologies and standards for long-term sustainable performance |
| Carbon Capture and Storage | 8-17 | • Reduce the energy penalty associated with $CO_2$ capture<br>• Application of $CO_2$ capture at scale and with reduced capital costs<br>• Optimization of integration, particularly for retrofit applications to achieve $CO_2$ capture rates above 85%<br>• Improve understanding of how $CO_2$ pipeline systems will evolve over time, based on knowledge of $CO_2$ sources and $CO_2$ storage sites<br>• Improved models to advance global understanding of the capacity and injectivity of deep saline formations and the efficacy of different geological media to achieve long-term secure storage<br>• Capture of $CO_2$ from biomass combustion<br>• Novel uses of captured $CO_2$ (e.g. production of algae from $CO_2$ for biofuels).<br>• $CO_2$ capture at industrial facilities. |
| Cleaner, high-efficiency coal technologies | 0.5-2 | • Combustion improvements<br>• Integrated coal gasification combined cycle (IGCC) |
| Nuclear energy | 0 | • Nuclear fission energy, including Generation IV plants<br>• Improved sustainability, economics, proliferation resistance, safety and reliability<br>• Design and build pumps, processes, materials and components for the international fusion device |
| Offshore Wind | 2-3 | • Stronger, lighter materials to enable larger rotors and improved tensile strength<br>• Design of dedicated offshore wind turbines<br>• Advanced sub-surface structures<br>• Use of superconductor wires to reduce transmission losses<br>• Development of advanced wind forecasting models |
| Smart grids | 5-11 | • Improved component and system integration methods<br>• Superconducting wires and devices, storage technology, power conversion and communication technology;<br>• End-use interaction and communication<br>• System and data security<br>• Large-scale demonstration pilots<br>• Viable, safe, cost-effective off-grid energy storage |
| Solar energy | 1-3 | • Improved efficiency for crystalline silicon PV technologies and automation of manufacturing to reduce costs as companies scale up production.<br>• Thin film PV: increased improving device structure, large area deposition techniques, interconnection and manufacturing<br>• System level: improve the product requirements for building integration and minimize the environmental impacts of very large-scale PV deployment<br>• CSP: include increasing system efficiency through higher process temperatures, reducing material consumption and automating operations<br>• Solar heating and cooling: development of compact seasonal heat storage; innovation in collector design, heat storage, cooling devices and advanced materials |
| Energy efficiency in buildings | 4-9 (only industry) | • Improve buildings-related technologies, particularly their integration and system optimization in different applications<br>• Hybrid systems (e.g. combined solar-thermal heat pumps systems)<br>• For major economies, integration of building technologies into low-cost retrofits, as most of the savings potential is in existing building stock<br>• Adapt building designs and practices to local building norms and climates |

**Source:** Global gap analysis in clean energy RD&D, IEA (2010)

**Photo:** Hypergreen Project, future building, Lafarge

# Drivers of private sector investment in RD&D

Companies invest in RD&D to create new or improved products for their customers and to stay ahead of their competitors. Companies expect to recover initial investment through the sale of commercial products.

Most RD&D drivers for low-carbon technologies are similar to those in other sectors. However, low-carbon RD&D has a distinct need for strong signals from the public sector towards a low carbon economy. The main drivers for private sector investment in low-carbon RD&D are:

- Companies want to **gain a competitive advantage** in future markets and anticipate regulations and demand by consumers.
- **An accelerating demand for new technologies.** Growing demand signals that RD&D investments can generate returns. This provides greater opportunities for customer feedback, which in turn enhances product development and cost reduction.
- **Long-term policy signals.** High capital costs for RD&D in many technologies mean that stable regulations are required to ensure long-term demand. Although there is public support at a national level through stimulus plans or national targets, the uncertainty and slow progress of the international climate change negotiations discourage long-term investment.
- An **enabling environment for RD&D**, building on a highly competitive private sector. Competition can be promoted by a legal framework including antitrust, intellectual property protection and support for public open standards. A highly competitive environment encourages innovation and cost reduction, as companies want to stay ahead of their competitors.
- **A vibrant science and technology sector**. Basic research facilities can attract a broad range of businesses, offering opportunities for cross-sectoral research and collaboration between disciplines. This will require the combination of knowledge and expertise of heavy engineering (e.g. turbines and forgings) as well as new chemical compounds or electronic components. A regional or local hub of science and technology expertise can be a powerful incentive to host RD&D or product development facilities in the same vicinity. This could offer opportunities for research partnerships, and also a source of skilled and scientifically trained employees.
- **Trained workforce**. An educated workforce is essential for successful RD&D in low-carbon technologies. There is currently a shortage of science and engineering graduates in specific technologies of RD&D. Developing an educated workforce in the areas highlighted in table 1 provides companies with the opportunities to match employee skills with demands, and to lead the way in green growth.

## Business understanding of low-carbon RD&D

The end goal of low-carbon technology RD&D is to produce goods and services with less energy and greenhouse gases, principally carbon. This can be achieved through RD&D that creates new technologies (breakthrough innovation), improves the performance or functionality of existing technologies (incremental innovation), or reduces the cost of existing low-carbon technologies.

Private sector resources are mainly focused on developing, deploying and preparing technologies for market launch.

Figure 3: RD&D stages

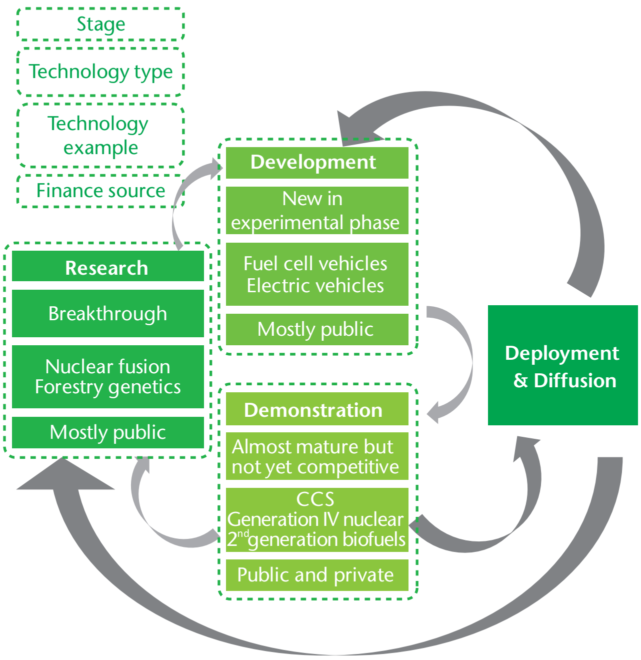



Figure 3 illustrates the stages of the innovation chain. This is not a linear process, but a set of iterative innovations. Basic research is embedded in the phases of the RD&D process, directly as part of the technology, or indirectly through education of scientists and researchers.

Depending on the sector and on the goods and services provided, companies' RD&D differs enormously. In general, businesses continuously produce incremental RD&D because knowledge is accumulated through the use and sale of these technologies or products and services. Private innovation is intensive after commercialization as technologies adapt to local circumstances. The ability to learn from market experience is crucial in the innovation process.

**Photo**: Offshore Wind turbines, Horns Reef, Denmark, Vestas

## Bridging the demonstration gap

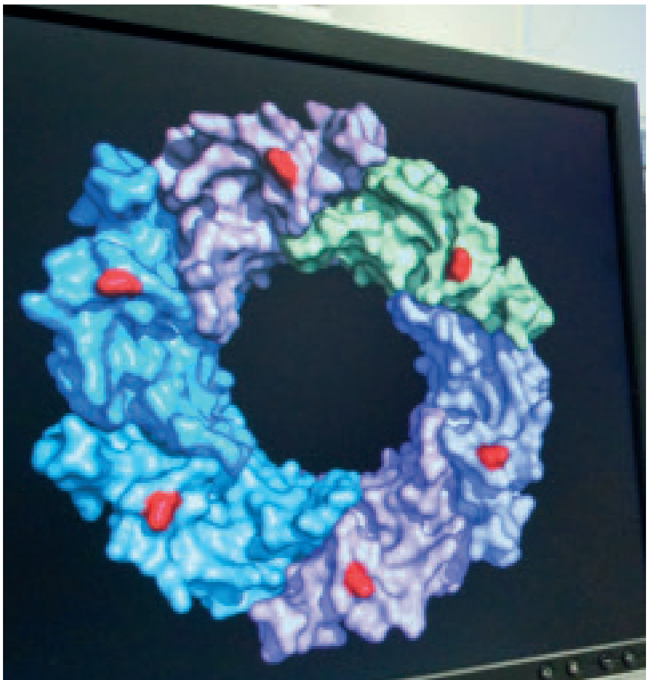
Financing needs vary throughout each of these stages, and are generally more intensive at the deployment and diffusion stages. Private funding is more readily available when there is a short-term commercial prospect. At the intermediate stages, however, and particularly at the demonstration phase, financing is much harder to raise. This is known as the "valley of death". The gap in financing occurs because commercialization is not immediate, because commercial and technical risks are perceived as being too great for private investors. There are, however, alternatives to bridge this gap.

Diverse public policies can "push" demonstration of new technologies (see table 2).

Carbon prices can "pull" the development of new technologies, due to the fact that commercial competitiveness can be achieved more quickly, thus leading to increased diffusion and cost reduction.

At the other extreme, subsidies for incumbent technologies such as fossil fuels, lower their respective costs, thus delaying progress and conferring an unjustified competitive advantage over low-carbon alternatives.

Finally, venture capital firms have played an important role in supporting innovation in the information communication technology (ICT) and biotechnology industries. Venture investments in alternative energy have boomed in the last few years, showing a five-fold increase from 2004 to 2007, responding to the rising cost of energy and climate change mitigation policies. However, venture funds tend to be a cyclical, rigid and lagging form of response. During boom periods they may over-fund particular sectors, which lead to a decline in their effectiveness, while during downturns, good companies may go under-funded. Venture capital has a powerful but inconsistent effect on innovation.



## Intellectual Property Rights

Intellectual Property Rights (IPR) provide confidence to companies to invest in and finance technology development and encourage international cooperation and expansion, as well as the transfer and deployment of inventions at home and abroad. Analysts have recognized that IPR safeguards are essential to technology development and the dissemination of knowledge.

IPR are a key driver of investment in RD&D, innovation and dissemination by:

- Allowing innovators to realize the value of successful RD&D investments (recognizing that many RD&D programs fail) and stimulating investment in innovation that might not otherwise occur, both in the developed and developing world;
- Providing companies with a means to distinguish their products from those of their competitors;
- Encouraging technological vibrancy by providing the commercial and economic incentives and assurances necessary for firms and innovators to share technology and know-how.

IPR portfolios tend to be diverse, ensuring that no single company holds all the patents or proprietary rights to a particular product or solution. Competition amongst and between clean technologies, and across clean technology sectors, is intense, giving users a broad choice at highly competitive prices, and allowing the benefits of innovation to flow to users worldwide. The gap between patent protection in developed and developing countries is narrowing.

A strong IPR system drives and enables technology dissemination and deployment, as well as encouraging and supporting the growth of endogenous capacity.

**Photo**: A Tailorable Nanotube

# How RD&D public policies complement private sector action

**Photo**: Smart transport system

Different businesses approach new markets in different ways, but building on the key drivers for private investment in RD&D, there are some basic conditions that will help attract private investment. These can be created through appropriate public policies:

- **Creating demand for new low carbon technologies and products**. Government policies play a key role in building new markets for cleaner technologies. Policies that discourage emissions or pollution (such as establishing a value for carbon, or regulations that set permissible emission levels), or those that encourage low carbon options (such as tax credits, or portfolio standards) can build market potential and attract companies across the supply chain, from component manufacturers to consumer retailers. Before making significant investments, companies need reassurance that a market exists for their offering. Government policies that indicate sustained support (whether political, financial or regulatory) can be a powerful motivator.
- **Promoting a vibrant public sector program of basic science and technology can produce breakthroughs resulting in tomorrow's commercial technologies.** This kind of public funding attracts private sector investment and collaboration as it offers companies opportunities to jointly develop new products.
- **Strengthening legal frameworks**. Companies are incentivized to invest when a sound legal framework exists to promote competition and provide a basis for planning operations and protecting assets. Common rules and standardized regulations and practices across a region help companies reduce their operating costs, and attract investment across the whole region. Similarly, the reduction and removal of administrative hurdles helps to lower the cost of business operations. Collaborative technology development relies, in particular, on strong and clear rules for the protection of IPR, and the assurance that it can be effectively enforced.

## The urgent need for RD&D justifies public sector support

The timeframe for new energy technologies to reach commercial maturity and compete with conventional technologies can be long. The time required to achieve competitive parity with conventional technologies differs by technology type. For example, according to the IEA, solar PV is expected to reach competitive parity with the power grid by 2020 in many regions. This is almost forty years after the first PV megawatt-scale power station started operations[5]. Onshore wind power is already competitive in some regions. However, in this case too,it has taken around forty years to achieve competitiveness since the time when the first large commercial wind turbines were developed[6]. The urgent need to address climate change demands public intervention in order to accelerate the upscale of new technologies.

## Governments can help reduce or manage RD&D investment risks

The development of new technologies presents several risks that discourage private sector investment. Government policies can help reduce or manage these risks in some cases. Typically, these risks include:

- **Commercial risks**. They include ownership of assets and liabilities; risk and revenue sharing; contractual and operational responsibilities; IPR. A clear legal framework and effective enforcement will help in managing these risks.
- **Regulatory risks**. The absence of specific legal frameworks covering emission controls (e.g. liabilities, performance standards) or access to infrastructure, presents a risk for business. Standardized rules and regulations across regions can help to expand markets, reduce risks and lower entry costs for companies.
- **Political risk**. Companies will look for assurance of political stability and indications that government policies will prevail for a sustained period of time and will not be subject to frequent or extreme changes of direction.
- **Absence of infrastructure**. Companies will look for Government indications of intent to invest in infrastructure where it is lacking (e.g. development of ports, roads or pipelines) and will seek assurances for this before investing.
- **RD&D infrastructure**. Companies need assurances before planning the invetment strategy in RD&D infrastructure (e.g. human capital, education, universities,national labs, testing facilities, or regional partners).

## The energy sector presents chronic underinvestment in RD&D

There is acknowledgement that there has been chronic underinvestment in RD&D for the energy sector, particularly for low carbon technologies. The IEA estimates this could range from between forty to ninety USD billion annually. The energy sector presents lower innovation intensity than other sectors such as ICT and pharmaceuticals. There are two market failures that undermine the level of RD&D:

- **Environmental externalities**. Climate friendly technologies are often more expensive than traditional ones, and even more so when there is no market value for carbon, or there are subsidies for fossil fuels;
- **Public good nature of knowledge and infrastructures**. RD&D leads to knowledge spillovers that benefit the public as a whole, and not just the innovator, unless it is protected by IPRs. Equally, the public benefit of some infrastructures necessary for climate change technologies is higher than the private benefit; therefore individual companies have lacked an incentive to invest in them.

Low carbon technology RD&D involves very different sectors, and it is difficult to generalize. In the energy sector, lower investment in innovation can be explained, to a great extent, by the large capital investment and long timescales required to develop new technologies. Also, innovation is not focused on product differentiation (as can often be seen in the ICT or pharmaceutical sectors) but in delivering the same product with higher efficiency and lower environmental cost. This kind of innovation presents a weaker incentive than product-based innovation, without long-term economic incentives.

There are also barriers to the development of new energy technologies from limited first-mover advantage, low energy prices, and widely deployed and optimized incumbent technologies. These barriers can be too great to overcome without support from the public sector.

Until continued “learning-by-doing” makes renewable technologies competitive, or more fossil fuel scarcity leads to substantial price increases of these conventional energy sources, the main incentives for low-carbon innovation in the energy sector will depend upon government policies to internalize carbon costs, eliminate subsidies to fossil fuels and promote energy security. Even though these are less powerful incentives than market-driven forces, business values public policies that are transparent, broad and equitable, measured and flexible, as basic principles and pre-requisites.

5 IEA/OCDE (2010). Technology roadmap Solar Photovoltaic Energy
6 IEA/OECD (2009). Technology roadmap Wind Energy

## Technology policies

Policies are normally classified as "technology push" measures; when the influence the supply of new knowledge, and "market pull" measures; when they influence the demand for innovation.

- **Technology push** is necessary because advances in scientific understanding determine the rate and direction of innovation and public support to basic research and demonstration programs. It also reduces the cost and risk to the private sector of producing innovation. These advances might lead to breakthrough technologies or processes; however, this kind of research can lead to non-profitable innovation, given the market failures mentioned before.
- **Market-pull** policies are necessary because increasing market demand creates opportunities for companies to invest in innovation. They provide returns for successful innovation, and reduce the cost of new low carbon technologies. However, market pull policies without a knowledge base or capacity to absorb the technology may not lead to the most effective use of public resources, or to the selection of the most appropriate technology.

A combination of technology push and market pull policies would optimize private sector action. Table 2 shows some of the policies that can incentivize business RD&D by strengthening its drivers, preventing its externalities and helping overcome the barriers.

Table 2: Public policies to address barriers to climate change RD&D

<table>
<tr><th>Barriers</th><th>Domestic policies</th><th>International policies</th></tr>
<tr><td>Widely deployed and optimized incumbent technologies</td><td colspan="2">Standards and regulations (biofuels blending, energy efficiency, BAT)<br>Energy intensity targets- sectoral approaches<br>Carbon markets Public procurement</td></tr>
<tr><td>Uncertainty of demand</td><td>Feed in tariffs<br>Fiscal incentives<br>Renewable energy obligations<br>Removal of subsidies to fossil fuels<br>Taxes to competing technologies<br>Carbon taxes</td><td></td></tr>
<tr><td rowspan="2">High up-front capital costs<br><br>Limited finance for demonstration</td><td colspan="2">Public investments in RD&D infrastructure<br>Government funding of demonstration projects<br>Direct subsidies to RD&D<br>Government sponsored RD&D, national laboratories<br>Promote collaborative RD&D, including PPP to share financial burden and risks<br>Loan softening/loan guarantees</td></tr>
<tr><td>RD&D tax credits<br>Emerging technology reverse action mechanism<br>National/state funded or run venture capitalists</td><td></td></tr>
<tr><td>Public good nature of knowledge<br>Limited first mover advantage</td><td colspan="2">Public investments in RD&D infrastructure IPR protection<br>Government sponsored RD&D<br>PPP to share finance, risk and management effort between public and private actors<br>Public subsidies to RD&D Knowledge exchange between public and private institutions<br>Public investment in human capital</td></tr>
<tr><td>Low energy prices<br><br>Environmental externalities make fossil fuel alternatives cheaper</td><td colspan="2">Carbon markets</td></tr>
<tr><td>Low energy prices<br><br>Environmental externalities make fossil fuel alternatives cheaper</td><td>Carbon taxes<br>Remove subsidies to fossil fuels<br>Fiscal incentives</td><td></td></tr>
<tr><td>Low-end use product differentiation (commodities)</td><td colspan="2">Standards and regulations (biofuels blending, energy efficiency, BAT)<br>Energy intensity targets- sectoral approaches Public procurement</td></tr>
<tr><td>High complexity and technical risk of low carbon alternatives</td><td>Public investment in capacity building<br>Promote collaborative RD&D, including PPP to share knowledge and risks<br>Efficacy insurance with publicly guaranteed or funded reinsurance pools</td><td></td></tr>
</table>

**Legend:** technology push and market pull

**BOX 1 Public funding of low-carbon technologies RD&D in the European Union**

Public RD&D investment in low carbon technologies in the EU accounts for 44% of total RD&D. Member States public funding is higher than public funding from the EU[8].

There is no unified European program for fostering low carbon technologies, with the exception of fusion-related research. Pan-European cooperation is limited, and synergies between Member States in the development of new energy technologies have not been fully exploited. Furthermore, RD&D acivities within Member States are often fragmented, due to the complexity created by the involvement of various ministries and agencies in the management of different parts of national programs. To address this lack of coordination, the EU has established the Strategic Energy Technology Plan (SET-Plan). Different sources of funding are considered, both from public and private sectors, at national and EU level.

The Community Framework Research Program and EURATOM Framework Program are the key sources of RD&D financing on energy technologies at EU level. Other smaller scale funding schemes are Intelligent Energy Europe, the Cohesion Policy funds and Trans-European Network's "Energy".

**BOX 2 Federal funding of low-carbon technologies RD&D in the United States[9]**

The US has been pursuing its federal Climate Change Technology Program (CCTP) since 2006 to push climate-friendly technologies into US and international markets. The program is a multi-agency planning and coordinating entity, led by the Department of Energy, whose purpose is to accelerate the development and deployment of technologies aiming to reduce, avoid, or capture and store greenhouse gas emissions. CCTP conducts analysis, provides strategic direction, and makes recommendations to strengthen the federal portfolio of investments in related research and development (RD&D) across more than a dozen participating agencies. It proposes policy options that address barriers to greater technology diffusion and adoption in the marketplace, and works with international entities to promote RD&D cooperation and collaboration with governments of other countries.

Additionally, the American Recovery and Reinvestment Act has funded clean energy investments to encourage use of smart grids, home weatherization projects, green federal buildings,as well as state and local renewable energy and energy efficiency.The act also funds capacity building, and projects such as batteries to store energy .

Nuclear energy RD&D represents the largest component of federal energy spending, followed by basic energy research. The remaining amount is divided equally among research in fossil fuels technology, renewables and energy efficiency. The overall focus of publicly funded low carbon energy RD&D in the US is the support of basic energy science, at the expense,however, of more applied energy technology development.

8 European Commission (2009). RD&D investment in the priority technologies of the European Strategic Energy Technology Plan. COM (2009) 519 final. Brussels, 7.10.2009.

9 Dooley, J. (2008). U.S. Federal Investments in Energy RD&D: 1961-2008. Energy, Pacific Northwest National Laboratory.

**Photo**: NexGen Cyber Innovation and Technology Center

# The role of collaborative RD&D to fill the gaps

Companies of all sizes have consistently made use of partnerships and collaboration when entering new markets or developing new technologies. Partnering with local players and experts can complement and strengthen a company's capabilities, in particular in the energy and climate field.

Collaborative RD&D could fill gaps in climate change and energy RD&D by allowing different actors to share risks, knowledge and capital costs. Collaborative RD&D has several dimensions: national or international; sectoral or cross-sectoral; coordination between private companies, or with public institutions. The main benefit of collaboration is an increase in the efficiency of RD&D efforts,thus accelerating innovation and diffusion. Each combination serves different purposes and has diverse challenges.

## Public private partnerships

Traditionally, public private partnerships (PPP) have been defined as the involvement of the private sector, in the form of management expertise and/or financial contributions, in government projects (e.g. management of a metro system). There is, however, no single definition of PPP. These vary by sector, by geographical situation and purpose of the PPP (see box 3). In the context of low carbon energy technology RD&D, the IEA has defined PPP's as public-private institutions that pool funds for a variety of investments. These include infrastructure projects, initial capital or guarantees, as part of a consortium to fund major investments, loans, equity or venture capital to companies prepared to bring demonstrated technologies to commercial maturity.

Common drivers for the creation of a PPP are the need to build infrastructure, to scale up large financing needs, to share knowledge and also risk from the counterpart. A PPP on RD&D usually promotes pre-competitive research, as companies are more reluctant to collaborate on near-to-market research, owing to the sensitivity of proprietary information. In the area of low carbon technologies, PPP can be a major facilitator, given the complexity of the technologies involved, the levels of capital required, and the common need for cross-sectoral knowledge.

International collaboration with governments at the demonstration stage is beneficial because it enables the testing of new technologies in a wide spectrum of boundary conditions; it also encourages the broad sharing of test results. Furthermore, international collaboration could enhance standard setting and facilitate efforts in RD&D in the adoption of technologies to differing local regulations

Collaboration between companies and government at a national (or regional) level can support alignment of technology roadmaps across different sectors. For example, automobile and electricity generation industries will most probably need to collaborate with governments to develop not only the electric vehicles technology but also the regulatory framework that will accompany the development and operation of any new grid infrastructure.

## Collaborative RD&D is not the 'silver bullet' for low carbon technologies

Collaborative RD&D is not the only solution to current underinvestment in climate change RD&D. Competitive RD&D is the preferred route for business.

Collaboration is already underway in many areas of low carbon technology, as is illustrated in the case studies.Collaborative RD&D is not the only solution to current underinvestment in climate change RD&D. Competitive RD&D is often the preferred route for business. Collaborative and competitive RD&D are needed to tackle the climate change challenge.

Collaboration often involves government, academia andcompanies. An important aspect in the development of breakthrough innovations is that the knowdledge boundaries between them should be erased, allowing the three groups to interact and develop mutual understanding of key findings and issues. Succesful collaboration builds on sharing an understanding of the different mental models, languages and values of the three groups.

Some areas where collaborative RD&D is the preferred option include:

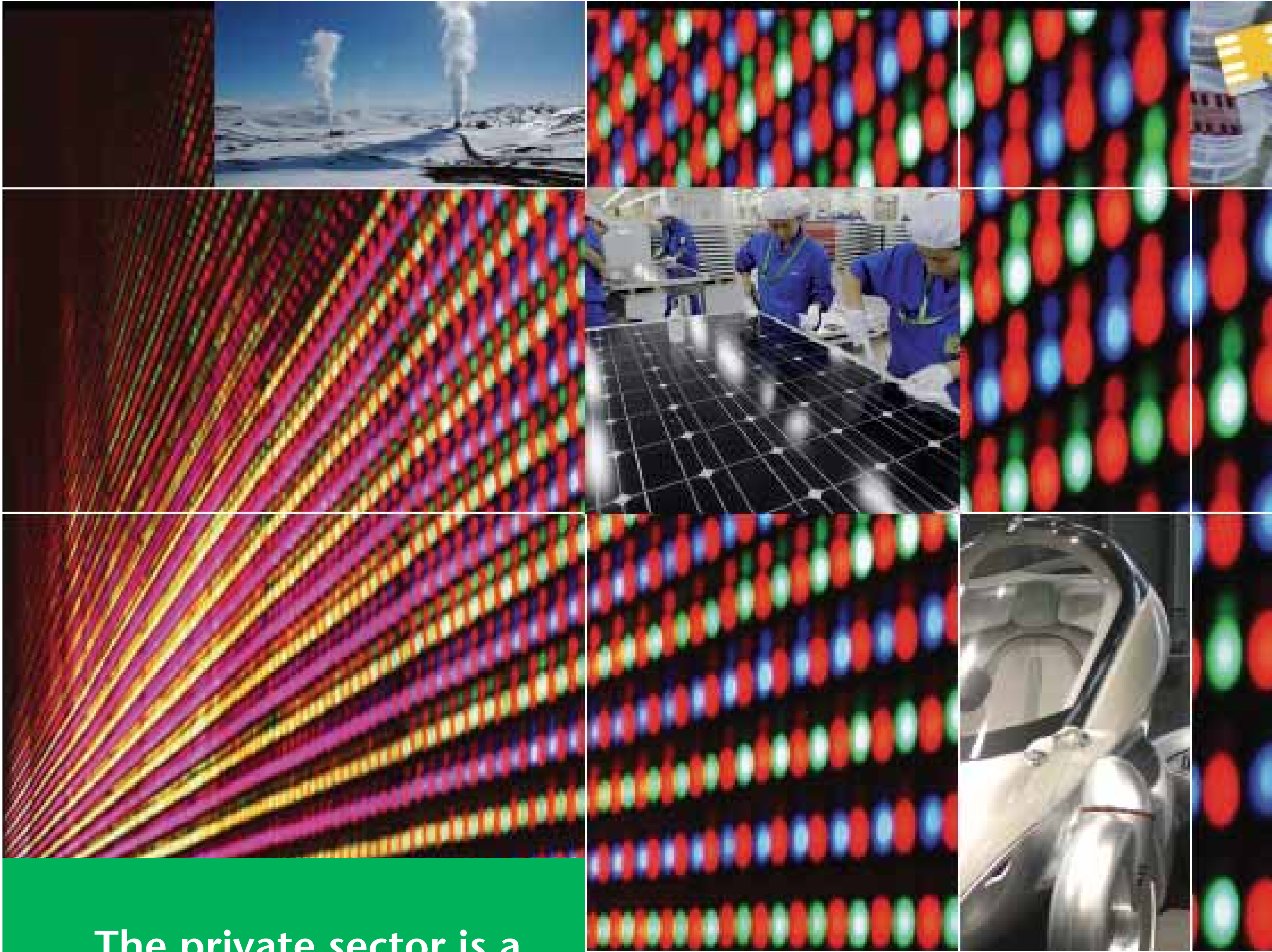
- **Technologies far from commercialization**. When technologies approach the stage of commercialization, competitive RD&D can be more appropriate as firms compete on cost, performance and speed in order to reach the market and acquire a competitive advantage.
- **Significant knowledge and infrastructure spillover across companies**. Company investment can also benefit competitors (creating "free riders"), and this can lead to underinvestment. However, when the scale and risk of RD&D activity are huge and there is a possibility of substantial benefi t from spillover, RD&D collaboration can be a good option. For example, investment in smart grid development or power supply networks for electric vehicles.
- **Infrastructure development in new markets. In developing countries**, collaboration in infrastructure development is particularly important for breakthrough technologies (e.g. batteries or ICT) , as they can "leapfrog" older infrastructure settings and avoid the high cost of retrofi tting. For example, smart grids could accommodate a wider range of new and renewable types of generation and offer much faster access to energy in developing countries.
- **Sectors providing commodities.** Collaborative RD&D is more suitable for sectors delivering commodities such as electricity, than for industries providing differentiated products, such as automobiles. Competition drives the automobile sector to continuously improve the performance of their products and reduce costs.For this reason, collaborative RD&D between competitors which goes beyond basic research faces strategic barriers. The electricity sector provides a homogenous product, and collaboration can be an incentive to invest in lower carbon alternatives.
- **Cross-sector collaboration**. This kind of collaboration benefits from expertise in different sectors for the development of new products. For example, combining ICT and power transmission with distribution expertise in the development of smart grids, or geological, chemical and power generation expertise in CCS, is obviously beneficial.
- **Mitigating risks in the "valley of death"**. RD&D collaboration is particularly important in low-carbon technologies during the "valley of death" period when there is a shortage of cash flow between demonstration and deployment. Sharing risks through PPP could be a way forward. Collaboration can take different forms and involve different actors, for example: technology centers, clustering and hubs, and support for universities and research institutions. At multinational level, such collaboration can deliver economies of scale, pooling regional resources to make better use of limited public funds.

**BOX 3 Public private partnerships have different meanings**

In the EU, PPP has traditionally involved infrastructure projects in sectors such as transport, public health, education and national security. The private company normally finances, constructs, renovates, manages or maintains infrastructure, or it can provide a public service. In return, the company is paid over a number of years for the cost of construction and the operation of the service, either through charges paid by users, or by payments from the public authority, or by a combination of both. More recently, the EU has applied the PPP model to RD&D projects by means of of Joint Technology Initiatives originating from the need of the public sector for private funding and know-how, as well as the distribution of risks, between the public and private partners.

The US has a long history of RD&D in PPP, and a flexible understanding of what it entails. PPP involve cooperative RD&D in industry, universities, and government laboratories. They facilitate technology transfer from the research laboratory to the market, in support of both public agency mission and technology-based regional or national economic growth. PPP structures are diverse (joint funding, collaborative activities, or procurement policies) and range from formal RD&D agreements between industrial companies and government laboratories, to research or science park, to programs targeted for small firms and/or early-stage technologies. In the US, federal laboratories play a key role in the national innovation system, for public services such as defense, health and energy, and also as a source for industrial knowledge. Public and private sectors collaborate through cooperative research and development agreements (CRADAs) through which federal laboratories share personnel, services, or facilities (but not funds) as part of a joint RD&D project which has the potential to promote industrial innovation.

The concept of PPP is more recent in China, where it is understood as the provision of public facilities and services by the private sector. China has focused PPP on short-term return and lacks a spirit of long-term partnership.



# The private sector is a source of continuous innovation

Companies invest in RD&D to gain a competitive advantage and create new or improved products for their customers that can help them develop and stay ahead of their competitors. Companies make investment decisions in anticipation of, or in conjunction with, the regulatory regime and customer demand.

In this publication we present ten business cases that present RD&D investment in the power sector, electric vehicles, the glass industry, biofuel conversion and heat pumps. In the power sector, the case studies present RD&D in technologies both in generation (hydropower technologies, carbon capture and storage and integrated coal gasification combined cycle) and distribution (smart grids).

The case studies describe RD&D activity, the drivers for these investments and the public policies that enhance them. Most importantly, they emphasize the value of collaboration in a competitive environment. Almost all the cases involve some collaboration; with companies, equipment manufacturers, research institutions, government and customers. They describe how the collaboration took place, the main challenges, how these were overcome and the next steps to follow.

## Business Cases

ALSTOM

# Power generation: Hydro

Environmental objective: Renewable energy use and energy efficiency

Country: India

## Alstom global hydropower technology center in Vadodara, India

The Indian hydrological conditions, with high silt content of hydro resources in the Himalayan region, needed to adapt and upgrade turbines to withstand high levels of abrasion.

In November 2008, located at Alstom's existing Vadodara hydro manufacturing site in Gujarat state, the Global Technology Center was inaugurated. The Vadodara site employs around 800 people in a range of technical and managerial roles and focuses on the particular technical needs of this market. The site includes:

- A manufacturing facility, equipped for manufacturing new stationary components, repairing and servicing rotors and assembling turbines and generators of medium and large hydro units;
- A thermal service workshop providing a range of services, e.g. high- speed balancing of rotating equipment, blading/de-blading, welding, casing repairs, rotor straightening, rotor rewinds, insulation changes. It is the only private sector site in India to have a speed-balancing tunnel.
- A technical laboratory to carry out diagnostics and develop innovative integrated products and technologies for the Indian and other regional markets. In particular, the Vadodara laboratory has developed a scale-model test laboratory, to enable research into abrasion effects on turbine blades in hydropower facilities.

## What are the drivers for this RD&D activity?

The project was driven by the need to innovate in a competitive market and provide a product tailored to India. A number of factors were key to the project's success:

- **Demand**: India is the world's biggest market for Pelton turbines (a turbine similar to a water wheel that extracts energy from moving water).
- **Availability of hydro resources** with challenging hydrological conditions that are applicable to other parts of the world.
- Well-developed **infrastructure** with transport links, essential to the logistics of moving heavy machinery.
- **Favorable policy conditions for power projects**: India's 2003 Electricity Act restructured the industry to encourage private sector participation in developing and operating power generation facilities.
- **Human capital**: Availability of a large base of highly-skilled and flexible local engineers and scientists. In the past five years, Alstom India has recruited approximately 400 graduates from all over the country and has links with leading Indian engineering colleges for internships, technical collaborations, sponsorships, scholarships and industrial visits as well as recruitment.

## Which public policies had the greatest impact on the project?

The Indian Electricity Act in 2003 restructured the industry, gave states the power to set their own electricity tariffs and required them to define renewable portfolio standards. The national government also implemented measures to support renewable power, including fiscal incentives such as tax exemptions. India's Eleventh Five-Year Plan (2007-2012) targeted capacity additions of almost 80GW, of which nearly 20% would be hydropower. The state of Gujarat has encouraged private sector participation in the power sector from an early stage. The government endorsed the Gujarat Electricity Industry Act in May 2003 to reorganize the electricity sector and establish an Electricity Regulatory Commission to regulate the industry, set tariffs and other charges as well as aligning tariffs with supply costs. It developed a system of power purchase agreements with independent power producers, encouraging the use of cogeneration, new and renewable sources and the development of smaller power projects. As a result, in February 2010, Gujarat had 11,711 MW of available capacity with additions by 2012 of 7,048 MW, sufficient

to meet the projected peak demand for 2012 of 14,347 MW. In addition, the state created an extensive power distribution and transmission network, with about 880 sub-stations, across a 31,000 km$^2$ network.

For equipment manufacturers like Alstom, this favorable policy environment for power projects signaled a strong interest from the government to partner with business in expanding access to electricity and creating a sound infrastructure for the state in the long term.

## Measuring success and planning next steps

The Vadodara manufacturing site has drawn lessons from a number of technological developments, such as a 500 MW hydropower project on the Teesta River in the Sikkim region, or other hydropower plants currently under installation: Lower Jurala (6 x 40 MW Bulb & generators), Chamera (3 x 77 MW Francis and generators), Uri-II (4 x 60 MW Francis), Chuzachen (2 x 55 MW Francis) and Subansiri (8 x 250 MW Francis and generators).

The experience gained from large-scale deployment, and the challenging characteristics of Indian hydro resources, has allowed the Vadodara site to become a global hub for hydropower R&D, exporting beyond the Indian market. In January 2010, the site produced its largest-to-date Kaplan runner (similar to an airplane propeller), weighing 78 tons, for a power project in Uganda. This is one of the most complex components of hydropower generation and is a turbine with propeller-style adjustable blades that are rotated by high-pressure hydraulic oil. The largest turbines have to be individually designed and manufactured in order to operate at maximum efficiency.

BASF
The Chemical Company

# Power generation: Carbon Capture and Storage (CCS)

Environmental objective: $CO_2$ capture, reduce energy and solvent use

Partners: RWE, LINDE

Country: Germany

## Collaborative Research, Development and Demonstration (RD&D) in CCS

In 2007 BASF, RWE Power and the Linde Group joined forces to develop and test a new process for carbon capture from combustion gases in coal-fired power plants under real operating conditions. The new technology, called $CO_2$ scrubbing, could capture 90% of the $CO_2$ from combustion gases. The captured $CO_2$ could then be stored underground, although this is not part of the project.

Since 2010, newly-developed BASF solvents have undergone a 6 to 8 month-testing for separating $CO_2$ from flue gas in a pilot plant at RWE's lignite-fired power station near Cologne (Germany). Initial test results suggest that this innovative technology including new chemical solvents can capture 7.2 t $CO_2$ per day (equivalent to 0.5 MWe) and reduce energy input in the carbon capture process by about 20% when compared to processes commonly used today. The new solvents also feature superior oxygen stability, which reduces solvent consumption significantly. This project is particularly relevant because RD&D activities that reduce energy consumption associated with $CO_2$ capture are one of the main priorities to fill the RD&D gaps identified by the International Energy Agency.

## Which are the drivers for this collaborative RD&D activity?

The main driver for this collaborative RD&D activity was the need to increase the energy efficiency of CCS in order to reduce the costs of the technology compared to that which was available. The availability of public funding, as well as other favorable public policies, highlight the societal need for this technology and thereby reduce the market risk for the partners involved.

## Which public policies had the greatest impact on the project?

Public policies were key at the start of the project. In particular, the availability of public funding for RD&D and the 2020 European Union energy and climate strategy (20% cut in emissions, 20% reduction in energy consumption, 20% of final energy consumed coming from renewable resources by 2020), which also contains signals favoring clean coal.

However, the business case for an RD&D project on a regulatory-driven technology like CCS requires a long-term target (2030, 2050). In this respect, the unspecific outcomes of the climate negotiations increase the uncertainty for RD&D projects, and even hamper RD&D.

At the EU level, funding for CCS demonstration projects can be provided through the European Energy Program for Recovery (EEPR). Out of the 12 CCS projects submitted to the EEPR, six were accepted and will receive an overall funding of € 1 billion. The BASF demonstration project did not directly receive EU funds, but was granted €4 million by the German Federal Ministry of Economics and Technology.

## Description of the collaborative process

This project involves the cooperation of three companies from different sectors: RWE power offers the power generation expertise to test the newly developed carbon capture process in the pilot plant; BASF provides process know-how and chemical expertise; and LINDE is responsible for pilot plant engineering and construction, as well as conceptual scale-up of the process.

Considering the complexity of the technology and high capital costs, RD&D activities are best shared amongst partners with common objectives and complementary expertise. To develop cost-effective, efficient and safe CCS projects, partners have to combine their know-how on power generation, engineering, gas processing and chemistry. Often, partnerships are already formed during the laboratory-stage of RD&D, long before the first pilot plant is set up.

## What were the main challenges of the collaboration and how were they overcome?

The main challenges have been coordinating activities, allocating Intellectual Property Rights to partners and adapting to different working and communication styles. In order to overcome these challenges, it was important to clearly define roles and responsibilities from the start to build trust between the partners.

## Measuring success and planning next steps

Monitoring the success of collaborative RD&D projects is necessary. For example, the BASF Phase Gate Process proved to be successful in both managing the project and the portfolio. Innovation projects go through five phases, from the moment the idea is generated to the market launch, thereby making the decision-making processes more transparent.

Next steps after the successful implementation of the new technology on the pilot plant-scale are the application in large-scale demonstration power plants. First demonstration plants are scheduled for 2015, and $CO_2$ capture is expected to be used commercially in coal-fired power stations by 2020. This technology should allow more than 90% of the carbon dioxide contained in the flue gas of a power plant to be captured for subsequent sub-surface storage or chemical transformation, for example, in fertilizers.

AMERICAN ELECTRIC POWER

# Power generation: Carbon Capture and Storage (CCS)

Environmental objective: $CO_2$ capture, reduce energy and solvent use

Partners: Equipment manufacturers, Department of Energy, Universities

Country: United States

## Carbon capture and sequestration demonstration project

The scope of this project is the design, construction, and initial operation of the chilled ammonia process (CAP), which is expected to capture approximately 90% of the carbon dioxide from a 235 megawatt electric (MWe) slipstream from the 1300 MWe APCo Mountaineer power plant, located along the Ohio River in New Haven, West Virginia. The captured $CO_2$ will be treated, compressed, and transported by pipeline to an injection site located near the capture facility. The entire amount of captured $CO_2$ will be injected and permanently stored in saline formations approximately 1.5 miles below the surface of the earth.

The project is positioned as a world-leading effort, pushing CCS technology through demonstration and deployment of advanced technology on a large scale and on an aggressive timeline (commercial operation will begin in 2015). This project will be the first integrated $CO_2$ capture, transport, and saline reservoir sequestration effort at commercial scale. Public sector grants in most countries are not likely to be made before the completion of this project.

The knowledge acquired from this project will allow AEP to integrate CCS into new units and to retrofit the existing coal-fired and, if necessary, its natural gas-fired fleet to comply with future $CO_2$ emission reduction requirements.

## What are the drivers for this RD&D activity?

The main driver is to commercialize carbon emission reduction technologies that can be affordably used with existing coal-fired and natural gas-fired generating plants and new facilities in anticipation of climate change policies requiring lower emissions. In this context, the technical and economic objectives of this project are:

- To design, procure, and install equipment capable of 90% $CO_2$ capture efficiency and storing 1.5 million tons of $CO_2$ per year, which would make it the largest power plant $CO_2$ saline injection system. This is essential to optimize equipment performance, demonstrate commercial scale viability of carbon dioxide capture, and monitor permanent $CO_2$ storage in deep saline reservoirs
- To validate reservoir simulation models based on monitoring data from injecting $CO_2$ into the geologic formations
- To complete the project within the budget determined during Phase I
- To integrate the heat requirements for the system into the existing power plant cycle
- To demonstrate the large-scale use of shockwave technology compression systems for $CO_2$ compression and liquefaction
- To begin initial operation of $CO_2$ capture and storage equipment no later than the third quarter of 2015

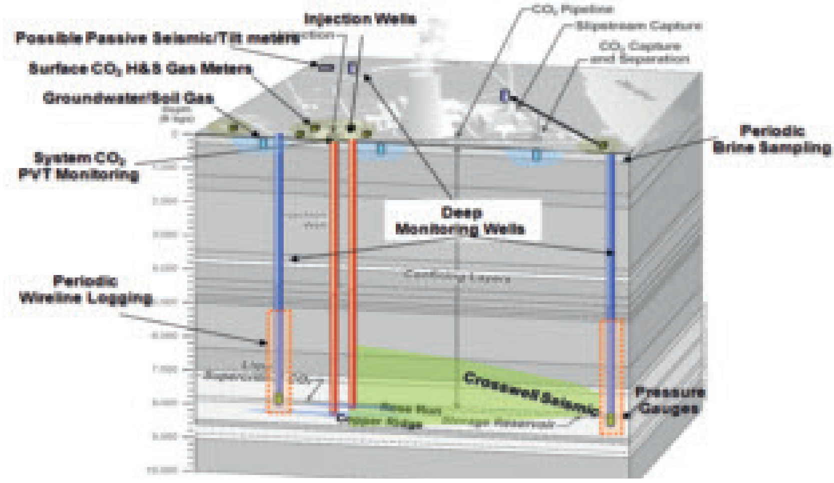
## Which public policies had the greatest impact on the project?

There are currently are no requirements from United States legislation or EPA regulation to reduce $CO_2$ emissions from electric generating power plants in the US. However, in anticipation of public policies, the Congress authorized the US Department of Energy (DOE) to provide funding for the development and demonstration of technologies that would be commercialized in advance of such reduction requirements.

In particular, this project is part of an AEP contract with the DOE for a Clean Coal Power Initiative (CCPI). In December 2009, the DOE made an announcement of its intent to award USD 334 million in support of the AEP project, representing the maximum-allowable 50% government cost share for this program. The US DOE was able to support qualifying projects for nearly USD 1 billion.

## Description of the collaborative process

The project team, as proposed in the CCPI grant application, brings together a world-class group of experts




with a common goal to commercialize CCS on power plants. Alstom is the world's number one provider of environmental control systems. AEP is the largest coal consumer in the Western hemisphere. Schlumberger and Battelle represent the world leaders in geology and sequestration expertise. The Geologic Experts Advisory Team is comprised of representatives from prestigious universities, research groups, and government organizations, with substantial knowledge in geology and sequestration-related fields.

This project builds on experience of capturing $CO_2$ at smaller scale projects, all funded by the private sector, that provide a robust data set and the technical foundation for scaling-up to the proposed capture and injection of approximately 1.5 million tons of $CO_2$ per year. The storage will be designed and optimized by Battelle, whilst managing several other sequestration projects: preliminary site characterization, subsurface characterization, monitoring and injection, well design, drilling and completion, baseline monitoring, compression and pipeline construction, system operation and post-injection monitoring.

The multiple storage wells are expected to have enough injection overcapacity that, if one system is down for maintenance or repair, the other wells can accommodate the entire $CO_2$ stream from the capture process. The $CO_2$ from the Mountaineer generating unit will be compressed and transported by pipeline to multiple saline storage sites, all within an estimated 12 miles of the power plant. The Geological Team under contract with AEP includes Schlumberger, Battelle, Lawrence-Livermore National Laboratory, Massachusetts Institute of Technology, The Ohio State University, West Virginia University, University of Texas, Ohio Geological Survey, West Virginia Geological Survey, CONSOL, and the West Virginia Division of Energy.

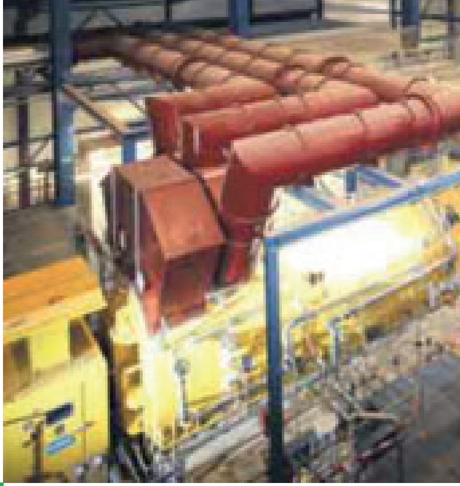
There is currently a 20 MW PVF project in the site that incorporates most of the components and activities needed for the proposed demonstration facility. Consequently it serves as a crucial stepping-stone for this project, and will greatly enhance the likelihood of success of the demonstration project. The scale-up to a 235 MWe plant provides opportunities to handle new technical and nontechnical challenges, including $CO_2$ transport outside the plant property, storage rights, use of multiple injection sites in the area, further evaluation of emerging monitoring technologies, and injection of commercial-scale quantities of $CO_2$.

The uniqueness of this project lies in that it builds upon years of work, in a very deliberate and systematic manner, to characterize the regional geology and validate all characterization findings at a sequentially larger scale. The proposed project will also help validate some of the regional mapping and assessment work being carried out under the DOE-funded Midwestern Regional Carbon Sequestration Partnership program operated by Battelle.

Finally, this project will be designed, installed, and operated as a fully-integrated commercial-scale system and will serve as a template for other similar facilities in other parts of the world.

## What were the main challenges of the collaboration and how were they overcome?

The scale-up of this project requires many competencies to be aligned and synchronized in order to succeed. Well-defined US DOE deliverables and team project management, including a clear understanding by all partners of the project goals and their roles, is helping partners to exceed in their individual contributions.



# Power generation: Integrated Coal Gasification Combined Cycle (IGCC)

**Environmental objective:** Reduce GHG emissions and improve energy efficiency

**Partners:** Power generation companies and the Central Research Institute for Electric Power Industry (CRIEPI)

**Country:** Japan

## Integrated Coal Gasification Combined Cycle (IGCC)

Combining emission reductions with energy security requires the creation of an optimal mix of energy sources. As coal is a globally-abundant fuel source available at stable prices, high-efficiency coal-fired power generation technologies will be an essential part of the energy mix.

IGCC aims at higher efficiency than conventionally coal-fired plants by integrating coal gasification with combined cycle power generation technology. The main benefits of this technology are: thermal efficiency improvement; feedstock flexibility; lower air pollutant emissions; lower slag volume and potential reutilization and lower water needs. Further benefits of IGCC can be expected when it is combined with CCS. In the case of IGCC, pre-combustion $CO_2$ capture is expected to consume less energy compared to post-combustion.

## What are the drivers for this RD&D activity?

The impacts of two oil shocks led Japan to move from its heavy dependence on oil as an energy source. METI (Ministry of Economy, Trading and Industry) pushed for IGCC as an indispensable technology to maintain national energy security. The first national project was initiated in 1986 by nine Japanese electric power utilities that developed an IGCC technology using air-feed design instead of the oxygen-feed design used in the United States (the former is generally expected to achieve better thermal efficiency than the latter).

## Which public policies had the greatest impact on the project?

The IGCC project in Japan has gone through three phases:

- Phase 1: 1986-1996, R&D of a pilot plant (200 ton/day)
- Phase 2: 1997-1998, feasibility study for a demonstration plant
- Phase 3: 1999-present, building and testing a demonstration plant (250 MW)

Public sector participation has been important to the success of the project because of the long-term nature and large budget needed for completion. METI funded 90% of Phase 1, via the New Energy and Industrial Technology Development Organization (NEDO). Although METI contributed less in subsequent phases, it supported the project through subsidies.

## Description of the collaborative process

The Japanese IGCC R&D project has been a collaborative effort between nine Japanese utility companies, the Electric Power Development Co and the Central Research Institute for Electric Power Industry (CRIEPI). A pilot plant project was run from 1986 to 1996 under the public agency NEDO.

Mitsubishi Heavy Industry, Ltd. developed the technology and the electric power utility companies were in charge of operations. CRIEPI joined to deal with basic research regarding burning characteristics of various coals and similar issues.

The Clean Coal Power R&D Co. Ltd. was created in 2001 to conduct the demonstration project (design, construction and operation). This project will provide the necessary data for the construction of commercial plants. The demonstration plant is currently operating successfully.

## What were the main challenges of the collaboration and how were they overcome?

During Phase 2, a feasibility study revealed that a demonstration project was necessary to bring the IGCC technology to a commercial stage, and that USD 1 billion was needed. METI provided 30% of this budget. However, the electric power utility companies were undecided on their commitment to invest such amounts in the IGCC technology. At that time, the thermal efficiency of liquefied natural gas thermal stations had been highly improved and dependence on oil greatly reduced. TEPCO led discussions, convinced that IGCC was necessary for Japan, and agreed to support the demonstration project. TEPCO has covered most of the expenses (representing about 80%

of the private sector burden), leading to the start of the demonstration project in 1999.

## Measuring success and planning next steps

The demonstration project has been successful and most of the targets have been achieved. Thermal efficiency of 40.6% (higher heating value) and very low SOx and NOx emission levels (each being 0-4.1 ppm and 3.4-4.8 ppm) have been achieved.

Mitsubishi Heavy Industries Ltd. is now trying to export the IGCC technology to China and Intellectual Property Rights will be a pre-requisite the diffusion of the technology.

AMERICAN ELECTRIC POWER

# Power generation: Smart grids

Environmental objective: Improve energy efficiency and reduce GHG emissions

Partners: GE, Batelle, Department of Energy, Ohio government, commercial partners and collaborators

Country:
Northeast central Ohio (US)

## AEP gridSMART℠ demonstration project: A community-based approach to favoring smart energy use in the country

AEP's gridSMART℠ demonstration project will integrate commercially available products, new technologies, new products and services within a single, secure, two-way communication network between the utility and its consumers. This closely coupled, multivendor solution integrates field technologies for network communications, advanced metering, distribution grid operation, cyber security, storage, alternative energy and consumer service products, using a comprehensive enterprise software system. This project will demonstrate the impact of a fully functional smart grid on the power utility, its consumers and society.

This project in northeast central Ohio will **demonstrate the potential benefits of concentrated investments in advanced grid technologies on a regional grid. In particular, the project** will:

- Improve distribution system efficiency and reliability
- Reduce energy consumption, peak demand, consumer cost, and fossil fuel emissions
- Link the smart grid project to the Pennsylvania Jersey Maryland (PJM) Power Pool's ancillary services market
- Integrate emerging storage resources into the existing grid to improve system performance
- Develop a prototype that assesses the workforce skills needed

The project should **facilitate integration of smart grid technologies into existing electric networks to improve system performance, power flow control, and reliability**. Finally, the project should **determine best practices in implementing smart grid technologies in the region**.

## What are the drivers for this RD&D activity?

The main driver is to gain a competitive advantage in the development of smart grid solutions. This will be achieved by building a secure, interoperable and integrated smart grid infrastructure in northeast central Ohio; attracting, educating and retaining consumers in innovative business models that provide tools and information to reduce cost, consumption, and peak demand; providing the US government with information to evaluate technology and preferred smart grid business models to be extended nationally.

This demonstration project will test technology viability, quantify costs and benefits, and validate new business models for smart grid, at a scale that can be readily adapted and replicated around the country.

## Which public policies had the greatest impact on the project?

This project was funded, in part, by the American Recovery and Reinvestment Act of 2009, with the objective of enabling smart grid capabilities on the electric system as soon as possible. The Department of Energy (DOE) issued a competitive Funding Opportunity Announcement for Smart Grid Demonstration Grants. The grants provide half of qualifying smart grid investments to support the manufacturing, purchasing and installation of smart grid devices and related technologies for immediate commercial use in electric system and customer-side applications. AEP Ohio and its partners received approval of their application for approximately USD 75 million.

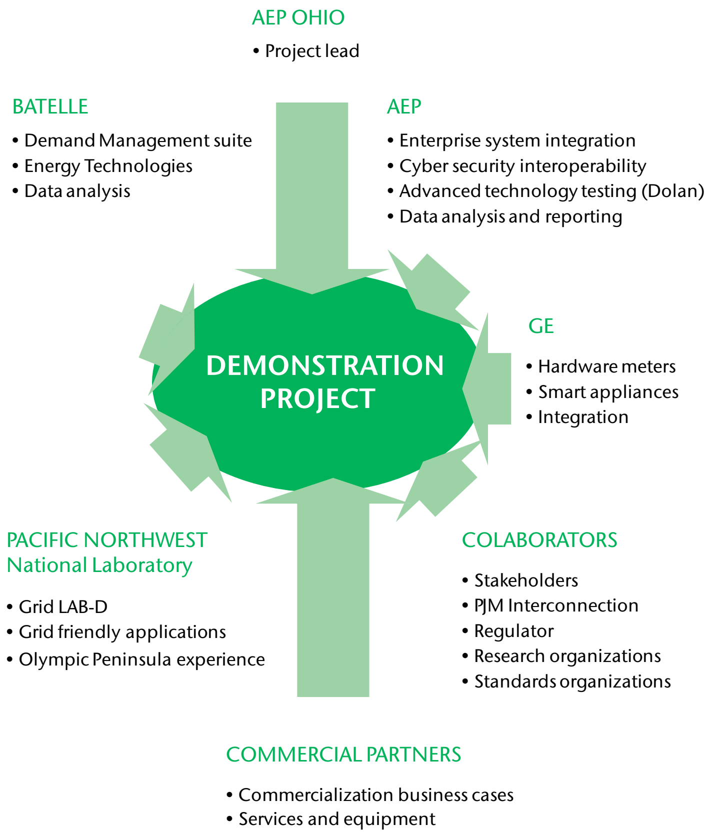
In addition, the state of Ohio passed a bill that allows utilities to modernize the infrastructure, and provides recovery of costs and a reasonable rate of return on such investments. The law established annual energy and demand reduction targets to be implemented by the Public Utilities Commission of Ohio. The Ohio authorities granted the recovery of investment costs in AEP's gridSMARTSM demonstration project.

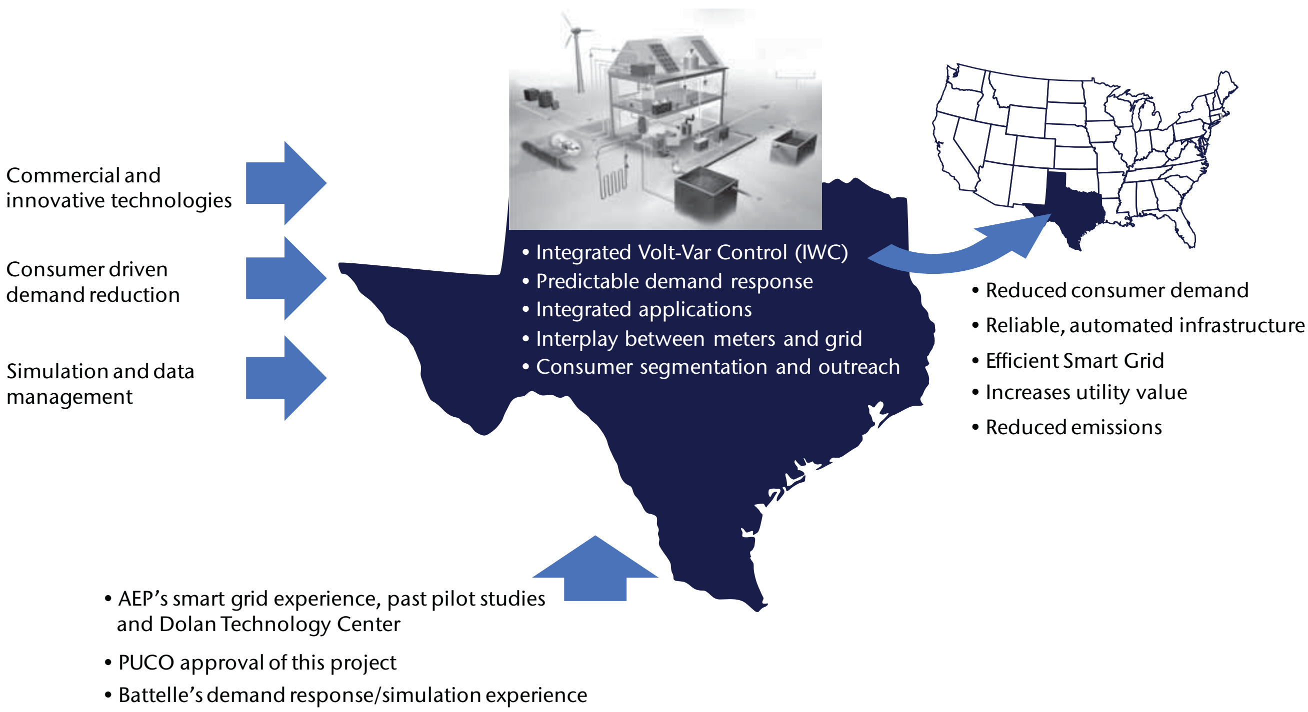
## Description of the collaborative RD&D process

AEP Ohio is the prime contractor, leading an integrated team to execute the project with AEP, Battelle (also managing the Pacific Northwest National Lab), and General Electric. Commercial partners, including Silver Spring Networks, S&C Electric Company, PCS Utilidata, and Lockheed Martin, are proving equipment and participating in the project implementation.

Project collaborators include the Public Utility Commission of Ohio, the Electric Power Research Institute, the National Institute of Standards and Technology, the Ohio Consumers' Counsel, and the PJM Regional Transmission Organization.

This complex project requires the timely coordination of numerous parties on policy, financial, regulatory, technical, and work management issues. To address these challenges, the project team is using vigorous project management practices and business processes.



# Transport: electric vehicles

**Environmental objective:** Reduce $CO_2$, improve energy efficiency

**Partners:** Dutch government, fleet owners, suppliers

**Country:** The Netherlands

## Dutch Consortium for the Tender of Electric Cars

The Dutch Consortium for the Tender of Electric Cars (DC-TEC), chaired by TNT, aims to purchase 3,000 electric vehicles (EVs) with the same functionality as non-electric vehicles and with the same cost through their life cycle. The first delivery of vehicles will be in 2011.

The Consortium consists of 25 blue-chip organizations and government bodies in The Netherlands that have combined their efforts to design and execute a tender for approximately 3,000 vehicles. The specifications include two types of passenger vehicles and two types of utility vehicles. These will have the same functionality as conventional vehicles.

The participants' goal is to create a business case where the cost of EVs is financially neutral compared to their existing fleet by pooling their purchasing power. Participants that joined the initiative will benefit from zero emissions vehicles, greater energy efficiency and become pioneers for EVs in the Netherlands.

An EU public tender process is planned to begin in the third quarter of 2010 until the end of the year. All major EV suppliers have been invited, and delivery of the first EVs is expected for 2011.

The project illustrates the importance and value of collaboration between consumers and also with the public sector during the early demonstration phase of products. The Consortium approach enables potential buyers to bundle demand and share first-mover risk. This sends signals to EV manufacturers to further invest in R&D at the demonstration phase, which will support cost reduction and achieve financial neutrality with respect to conventional vehicles.

RD&D in advanced vehicles is lagging, and presents one of the largest gaps between current spending and estimated needs, according to the International Energy Agency. Building large-scale battery production and knowledge could help reduce battery cost and achieve EV break-even cost when compared against conventional vehicles.

## What are the drivers for this RD&D activity?

This collaboration has four goals:

1. To foster demand for electric vehicles, helping to position The Netherlands as a pioneer in electric mobility.
2. To create an open, cross-industry platform to significantly reduce barriers to EV procurement and ensure that the best possible product is supplied at an affordable price.
3. To disseminate knowledge and encourage policy makers to establish operational boundary conditions that equal or exceed existing internal combustion engine vehicles.
4. To support adoption of electric mobility by the broader public and auto industry.

## Which public policies had the greatest impact on the project?

Participation of the public sector provided three significant contributions:

1. Direct subsidies. The Dutch government contributed nearly 50% of the total process cost (Euro 300,000) and had a seat on the project steering board, which is the main decision-maker. This gave the government direct access to the information and the opportunity to understand at first hand the main challenges in the adoption of EVs.
2. Participation in the Consortium through public procurement. This helped to create economies of scale and reduce the final cost for all participants. Public sector institutions are planning to buy 24% of the procured vehicles confirmed to date.
3. Roll-out of a charging infrastructure together with the energy sector. Infrastructure development and collaboration between the electricity industry and the public sector is an important enabler for the roll-out of electric vehicle fleets.

## Description of the collaborative process

The collaborative process was started by two companies and one NGO who wanted to speed up implementation of EVs and break the vicious circle in which everyone was caught. Each actor was waiting for the other to take the first step: fleet owners were waiting for product availability; manufacturers were waiting for demand, and were also expecting government support. The Dutch Consortium was created to break the deadlock by giving a clear signal that there is a strong demand for these vehicles, thereby incentivizing suppliers to start supplying vehicles and creating a platform from which industry could initiate discussion with governments TNT was one of the two companies, and is the chair of the Consortium. Today, the Consortium is comprised of 33 private companies and public institution including the Ministry of Transport, the cities of Amsterdam and Rotterdam, and the province of Friesland.

The main objectives of the collaboration were to obtain funding, to share and reduce costs and to increase the impact of the initiative by establishing one large-scale effort instead of many small efforts.

The collaboration is facilitated by a small project organization, supported by professional consultants and legal experts. Half the funding comes from the government, which is also one of the largest participants in the Consortium.

Success is measured by the number of vehicles committed to tender and the level to which financial neutrality will be achieved, compared to conventional vehicles.

## What were the main challenges of the collaboration and how were they overcome?

The main challenges were to ensure effective communication and to align the interests of the 30+ participants.

- Although the Consortium set itself the goal of reaching cost neutrality and parity with conventional vehicles, the business case differed for each company, depending on use patterns.
- Some companies had clear commercial interests; others had operational interests. Therefore some had a greater interest in the branding opportunities.
- The vehicle specifications differed from company to company, so had to be narrowed down to a single set of requirements per vehicle type.

There was also a challenge in the tendering process. Companies are generally looking for speed and efficiency, whilst governments are looking for clarity, openness and transparency in a tender procedure. The governance structure and good communication within the Consortium helped to overcome many of these barriers.

TEPCO

# Transport: Electric vehicles

**Environmental objective:** Reduce GHG emissions

**Partners:** Power utilities, car manufacturers and engineering companies producing chargers

**Country:** Japan, European Union, North America

## Standardization of electric vehicle infrastructure through development of a fast-charging technology

TEPCO is involved in the development of a standard technology for fast electric vehicle (EV) charging, the "CHAdeMO" charger (standing for "CHArge and Move"). The technology has been developed in collaboration with several auto manufacturers. Electricity utilities worldwide have joined the project through the CHAdeMO Association.

TEPCO has a low-carbon power generation mix, with 80% of its electricity coming from nuclear, hydro and natural gas. The company has placed an ambitious voluntary emission factor target of 330 g $CO_2$/kWh. TEPCO's low-carbon intensity will allow emission reductions of 75% in Tokyo's transport sector by switching from fossil fuel to electric vehicles, and an estimated reduction of 21% across the entire Japanese transport sector.

The main advantages of CHAdeMO technology are: safety; no impact on battery lifetime; no impact on power grid; reasonable total costs (vehicle and infrastructure); and availability of EVs and quick chargers already on the market.

CHAdeMO chargers are based on direct current (DC) which makes it easy for drivers in urban areas to recharge at any time. The availability of a number of DC fast chargers in urban areas eliminates driving-range anxiety. The use of DC charges also relieves households from having to upgrade their alternating current (AC) outlet and does not cause additional costs to the existing low-voltage grid. However, AC normal chargers continue to be the most common charging method, with many accessible outlets. AC can also be used for slow charging (e.g. at night). From the perspective of power utilities, the most cost-efficient and useful charging infrastructure should include both AC and DC charging.

## What are the drivers for this RD&D activity?

TEPCO does not generate direct revenue from the development of the CHAdeMO charger, which is completely patent-free. Moreover, TEPCO does not produce nor sell any products related to this technology. The company's revenue comes solely from selling electricity to the Tokyo metropolitan area. However, it is interested in the development and dissemination of electric vehicles, which would offer a large emission reduction potential in Tokyo's transport sector and increase its electricity business.

There are a number of reasons for this interest.

- First, with an ambitious environmental corporate philosophy, TEPCO has set high emission reduction targets. It has moved from a 'supply side approach' to reduce carbon emissions to a 'demand side approach' or 'switch' that aims to reduce $CO_2$ emissions of users, by changing the energy source from fossil fuels to low-carbon electricity.
- Secondly, dissemination of EV technology would involve higher electricity sales and generate higher profits and growth for TEPCO. Wider dissemination of EV benefits all businesses in the power and automobile sectors. The R&D project is not driven by immediate profit gains, but by the prospect of a stable future demand. The technology developed has been licensed, free of charge, to any automakers or charger manufactures around the world who will join the CHAdeMO Association.
- Finally, the early establishment of globally-accepted standards is expected to enhance user-friendliness (users are able to apply the same charger to every EV, regardless of the manufacturer) and, as a consequence, lead to broader spread of the CHAdeMO charger.

## Which public policies had the greatest impact on the project?

CHAdeMo is a private, international organization. Although there were no government subsidies for this R&D project, the Japanese government signaled its interest in low-carbon development which, in turn, assured the partners a future demand. In particular, the government plans to give subsidies to those who purchase an EV or a CHAdeMO

charger. In an effort to develop environmentally-friendly cities, some local governments, such as the Kanagawa prefecture, also have a strong interest in introducing EVs and chargers. These public sector actions can support the initial installation of new products. In Europe, policy makers are also increasingly favorable to this technology.

## Description of the collaborative process

Collaboration is essential for the development of common standards in the EV business. Cross-sectoral expertise is required, involving power utilities, car manufacturers and engineering firms producing chargers. Individual action would lead to variety of standards that would make it impossible to create a common charging infrastructure for EV drivers. Previous efforts to disseminate electric vehicles have failed for two main reasons: a lack of standardization and a lack of fast charging technology. With the advent of lithium ion batteries and fast-charging CHAdeMO technology, these barriers can be overcome. The CHAdeMO Association was established in March 2010 to promote standardization of fast-charging infrastructure.

R&D in CHAdeMO technology was conducted by TEPCO, Subaru and Mitsubishi. The organization has grown internationally and anticipates on an increasing number of members from North America and Europe, including electricity utilities, automakers and engineering firms. ENEL, ENDESA, ABB, Bosch, PSA Peugeot, Think, AeroVironment, AkerWade were all founding CHAdeMO members. Currently, the list has grown to include more auto manufacturers, charger makers and power companies in Asia, Europe and North America.

## What were the main challenges of the collaboration and how were they overcome?

At the early stage of the project, decision-makers in companies were conservative due to a negative image about EV arising from previous failures. Therefore TEPCO looked for an auto manufacturer partner who would agree to develop an EV. While most auto manufacturers were hesitant to deal with EV, Subaru and Mitsubishi decided to support TEPCO's proposal and collaborate. TEPCO had analyzed previous failures of EV and concluded that one of the key issues was the lack of a quick charger. Once new EVs and a quick charger were successfully demonstrated, other sectors became convinced that these products could offer a solution for reducing $CO_2$ in the transport sector. TEPCO expanded the partners to establish the CHAdeMO Association.

## Measuring success and planning next steps

After three years of testing at TEPCO, electric vehicles equipped with the CHAdeMO protocol were launched on the market in 2009 by Subaru and Mitsubishi. TEPCO's servicing fleets served as the test-bed for the technology, and in particular helped to identify the optimal location of DC chargers, knowing that drivers become anxious when far from a charger. Ultimately, this anxiety can lead to lower mobility.

Nissan and Peugeot will provide EV with this standard in 2010. As more automakers use DC chargers, their mass production could bring down the price, from USD 35,000 to USD 20,000.

The future success of EV depends on whether fast-charging infrastructure is correctly built. In Japan today, there are more than 250 DC fast chargers, but there are plans to increase the number to 5,000 by 2020.

# Industry: Glass melting technology

Environmental objective: Reduce GHG emissions, improve energy efficiency

Partners: Glass companies, New Energy and Industrial Technology Development Organization, Universities

Country: Japan

## Innovative energy-efficiency glass melting process technology

AGC (Asahi Glass Co., Ltd.) has participated in the development of an innovative glass melting technology which could drastically reduce the energy required. The glass production industry is energy-intensive and consumes more than 70% of the total energy in the glass melting process. This new technology has the potential of achieving large energy savings in the glass industry, which contributes to meeting the global goal of GHG emission reductions.

The traditional process of melting materials (such as silica sand and soda ash) is done with fuel oil to keep the large melting tank at the high temperatures for many hours required to manufacture homogenous glass without bubbles.

This new technology involves bringing granulated raw materials, made by spray dry methods, into a very high-temperature environment, produced with an oxygen combustion burner and/or plasma. The process changes the granulated materials to glass instantly.

The technology is called 'in-flight melting'. The melting is completed within the very short time of the flight, and the melting energy required is reduced dramatically (figure 1). Estimates suggest that the energy required for glass melting with this technology could be up to almost 50% of the average energy required for melting most kinds of glass in Japan.

## What are the drivers for this RD&D activity?

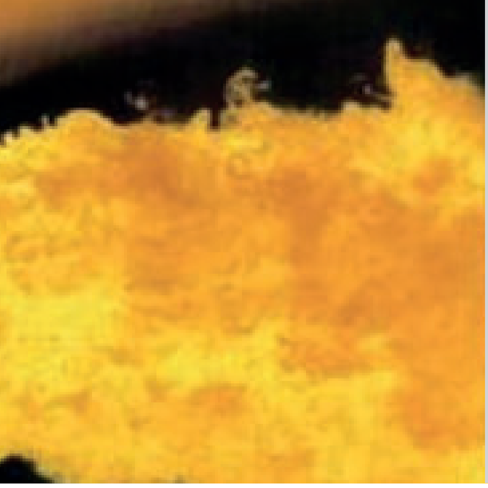
Almost all mass glass production (sheet glass, glass bottles, glass fibre, CRT (cathode-ray tube) glass and flat display glass sheets) is produced using the continuous melting furnace technology, first developed in 1860. For 150 years, this technology has been incrementally improved, allowing for better energy efficiency. However, concerns over climate change and recent peaks in oil prices have created incentives for a revolutionary innovation that dramatically improves energy efficiency in the glass industry.

This new, efficient technology had to be compatible with the demand of high-quality special glass products, which requires that melted glass is maintained at high temperatures for a long time to homogenize it and avoid the formation of bubbles. The new, efficient technology allows high-quality standards by improving heating efficiency and reducing high-temperature hold time.

## Which public policies had the greatest impact on the project?

Several public policies made AGC's RD&D project possible:

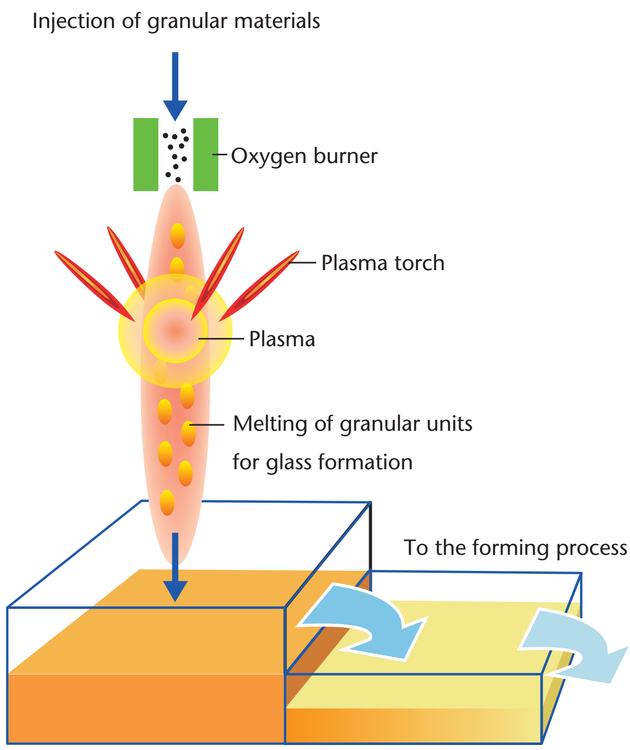
- Public sector subsidies for basic research. The project builds on the results of previous academic industrial research and was performed by NEDO (New Energy and Industrial Technology Development Organization). NEDO is Japan's public management organization which promotes research and development, as well as the dissemination of industrial, energy and environmental technologies. AGC has been participated in the project from the start.
- Best—practice sharing. NEDO provided a platform for industry-academia-government collaboration for innovation, which is essential for a basic research project, and provides a sophisticated management of knowledge. This is part of NEDO´s mission to explore new technology seeds, support applied research and fund mid- to long-term national projects, which are all at the basis of Japanese industrial competitiveness.
- NEDO's financial support. All the financial resources for this project were provided by NEDO. The selection of projects takes into consideration the need for technology, a clear purpose for research and expected outcomes. NEDO's support had a significant impact in this technology.
- Energy efficiency standards set by the Japanese government are an incentive for continuous improvement in energy performance of production processes.
- Protection of Intellectual Property Rights is essential for the future technology diffusion in emerging countries.



## Description of the collaborative process

Innovation in the glass melting process requires various technology developments and resources. Further, it requires cooperation between government, academia and industry. The project involved collaboration with ten institutes during the first two years, and with five institutes in the third year. The process technology working group in the Glass Industry Conference of Japan (GIC) coordinated the project with three laboratories of the Tokyo Institute of Technology; AGC, TOYO GLASS Co., Ltd., the National Institute for Material Science, New Glass Forum, and the Tokyo University of Science, HOYA CORPORATION, HIKARI GLASS Co., Ltd. and Central Glass Co., Ltd. all participated in this project and conducted the R&D activity with their best technology potential.

Figure 1: Illustration of in-flight melting



MEADWESTVACO Weyerhaeuser

# Forestry: Integrated wood-based biofuel

**Environmental objective:** Reduce $CO_2$, improve energy efficiency, renewable use

**Partners:** US government, 7 universities, 2 suppliers, 7 pulp companies

**Country:** United States

## Value Prior to Pulping R&D program

The Value Prior to Pulping (VPP) program, managed by Agenda 2020, is a collaborative effort between industry, including MeadWestvaco Corporation and Weyerhaeuser and 5 other pulp companies, and 13 research organizations. The VPP program is now completing the research and development phase, and is ready for commercial-scale demonstration.

The VPP program aims to extract hemicelluloses from wood chips before pulping, and to convert the extract to ethanol, butanol, and other value-added chemicals. Hemicelluloses represent about 15-30% of natural wood biomass by weight and are water-soluble, medium-length polymeric chains of five and six carbon sugars. These sugar-based wood components (which would otherwise be burned for their fuel value) are transformed into higher-value liquid transportation fuels (ethanol and butanol) and acetic acid. The resulting liquor which is burned to recover inorganic chemicals – has higher energy value enabling more energy-efficient liquor concentration and combustion processes. Low-grade heat and steam, that would probably be wasted in a traditional pulp mill, are used in the bio-refinery process of converting the sugars to alcohols.

Producing biofuels in a process integrated with an existing pulp mill offers significant advantages for efficiency and energy consumption, relative to a stand-alone bio-refinery. It does not require additional wood to be harvested and brought to the pulp mill either.

In line with the International Energy Agency's analysis on R&D gaps, this project is particularly relevant because the most important breakthrough for bio-energy is expected to come from cost-effective conversion of cellulose-rich biomass (found in wood, grass and agricultural residues) to usable energy.

## What are the drivers for this RD&D activity?

R&D was driven by profit-seeking business decisions and an appropriate set of supportive public policies. Participating companies see the project as an opportunity to create new revenue streams from products made in the existing plants. However, there are still no commercially-operating facilities using this technology and supportive public policies were needed.

## Which public policies had the greatest impact on the project?

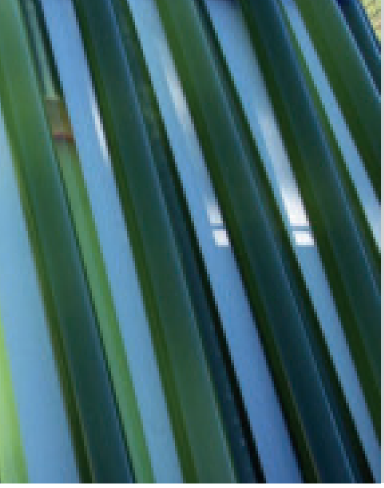
The US public sector has contributed to the feasibility of this R&D project through investment in R&D infrastructure, public subsidies, renewable energy portfolios and renewable fuel standards regulations. The R&D for the VPP program was undertaken in the US largely because more than one-third of the project funds were obtained from the US government, and significant expertise in the underlying technologies was available in US research institutions.

## Description of the collaborative process

The collaboration was motivated by a desire to benefit from partners' experience and know-how, obtain funding, share costs and mitigate risks.

The collaboration brought together the complementary expertise of the different participants. The project concept emerged after a technology road-mapping activity. The concept of converting a wood component to a liquid transportation fuel, in parallel with existing pulp mill processes as a way to add economic value to a pulp and paper mill attracted interest from many companies. The concept, aligned with other initiatives from the US government, was likely to attract financial support, which it did. The collaboration amongst research institutions developed because each of the seven universities or government laboratories involved had specific expertise to bring to the table.

The program's steering committee (formed by the seven pulp and paper companies) provided oversight and ensured that research providers performed as expected. Project management was provided by Agenda 2020 Technology Alliance, and accounting and fiduciary services by a non-profit organization.



The collaboration lasted five years. Two years (2006-07) were required to define the concept and scope of work for the R&D phase. This was funded partially by the US government, and lasted three years (2008-2010).

## What were the main challenges of the collaboration and how were they overcome?

The main challenges arose from the coordination of activities, ensuring effective communication among the multiple groups, and clarifying Intellectual Property Rights (IPRs) and other project outcomes.

- Communication challenges were resolved through effective project coordination. Each party prepared a detailed work plan, list of tasks, budget, responsibilities and contributions.
- An open process for selecting providers of R&D services ensured that the most qualified individuals were selected.
- Regular steering committee meetings guided the work and ensured compliance with the work plan.
- An intellectual property and non-disclosure agreement was signed at the beginning of the program to prevent IPR-sharing issues.
- New companies were incentivized to join, due to favorable conditions in terms of intellectual property. The possibility of adding new partners to the program should be agreed transparently.
- As for the sharing of other products and services, an early agreement concerning the value of in-kind contributions to the program is necessary.

## Measuring success and planning next steps

Building on the success of the VPP program, Agenda 2020 is initiating new collaborative projects. Some examples include a project to convert hemicelluloses in a pulp mill to butanol, jet fuel and value-added chemicals. Another case is a full-scale demonstration of VPP technology to validate the economic benefits of producing biofuels in an integrated pulp and paper operation. Looking to the future, 'open innovation' and approaches that improve the capabilities and methods for connecting basic science with industrial needs will be useful in further collaborative projects. This is a good example of the concept of 'boundary spanners', where the partners benefit from the exchange between research communities and the industrial companies, and the development of mutual understanding of key findings and issues.

# Residential: Hot water supply

Environmental objective: Energy efficiency and GHG emission reduction

Partners: DENSO, Central Research Institute for Electric Power Industry (CRIEPI)

Country: Japan

## Development of a $CO_2$ heat pump water heater 'ECOCUTE'

Energy efficiency in the supply of hot water has the potential to achieve large emission reductions in Japan. Demand for hot water accounts for 30% of residential energy consumption and 90% of this demand is met by direct combustion of fossil fuels. TEPCO, in collaboration with DENSO, a private component manufacturer, and CRIEPI, a public research institute, is developing a high-performance heat pump water heater to tap into this emission reduction potential.

The heat pump water heater (HPWH) consists of a heat pump that uses heat from ambient air and electricity to deliver hot water. This device can save 30% of the primary energy when compared with a gas-fired water heater. The heat pump avoids the use of fluorocarbons that damage the ozone layer, and HFCs, which are alternative refrigerants with large global warming potential (GWP). Instead, it uses $CO_2$, a natural refrigerant as a 'sustainable refrigerant' because it is nontoxic, nonflammable, has no ozone-depletion potential and has smaller global warming potential. The world's first $CO_2$ heat pump water heater was commercialized as 'ECOCUTE' in May 2001.

## What are the drivers for this RD&D activity?

This project was driven by the commercial interest of TEPCO. The sales department identified the potential to use natural refrigerants for air-conditioning systems. After starting a dialogue with CRIEPI to discuss the technical feasibility of such a system, scientists concluded that $CO_2$ is a better refrigerant for hot water supply. TEPCO analyzed the technical and commercial feasibility of a $CO_2$ heat pump water heater and a collaborative development project started in 1998, involving DENSO as the components manufacturer. Research at CRIEPI was fundamental, given the limited experience on using $CO_2$ as a refrigerant.

An open dialogue between research centers and private companies, in a country with a functioning national innovation system, is a strong driver of RD&D in energy and climate change technologies.

## Which public policies had the greatest impact on the project?

The project is a good example of the interaction between technology-push and market-pull policies to spur RD&D in energy and climate change technologies. Energy efficiency standards, public subsidies, as well as increasing fossil fuel prices, have created a demand for efficient household equipment in Japan. Even though the heat pump has low running costs, public subsidies were required, due to the high initial costs.

The technological knowledge base provided by CRIEPI was necessary to identify the best technology to meet the demand. Public funding of basic research was essential to develop the project.

## Description of the collaborative process

The R&D collaborative project took place between 1998 and 2001. The three participants had complementary expertise, and tasks for each of them were clearly defined from the start:

- TEPCO developed the concept for the commercial product
- DENSO undertook the R&D of the heat pump components
- CRIEPI performed basic research on the use of $CO_2$ as a refrigerant and evaluated the prototype

## What were the main challenges of the collaboration and how were they overcome?

Although the collaboration ran smoothly, a first technical challenge occurred. A new compressor had to be developed because $CO_2$ refrigerant required very high pressure for high performance. To confirm the feasibility of the development of such a compressor, TEPCO's R&D group worked on the matter immediately, despite the need to make budget available in the middle of the fiscal year. This prompt action was important to drive progress.

## Measuring success and planning next steps

The following criteria have been used to evaluate success of RD&D development:

- **Technical**. Success of the prototype was evaluated in terms of its coefficient of performance (COP), measuring output per electrical input. Many field tests were conducted, and results showed that the system was able to produce hot water over 90°C from a heat source temperature of -15°C.
- **Commercial**. 'ECOCUTE' has spread steadily since it was launched in 2001, covering 13% of the water heater market for residential use and 5% of households. 'ECOCUTE' sales were 2 million units in 2009.
- **Environmental**. If 'ECOCUTE' (with COP 3) was installed in all dwellings in Japan, $CO_2$ emissions would be reduced by 5.9 million tons (1.9% of all emissions in Japan) and if performance improved (to COP 4), the emission reduction would equal 7.2 million tons (2.3% of Japanese emissions).
- **Reputation**. Success can also be measured by the number of awards received by the $CO_2$ heat water pump since its launch. For instance, it has received the 11th Nikkei Global Environment Technology Award; the Energy Conservation Grand Prize of the Energy Conservation Center; the US EPA Climate Protection Award 2002; the Technical Prize of the Japan Society of Mechanical Engineer; the Copper Center Prize; and the 100 Eco-Tech Award.

On the commercial side, next steps include the wider dissemination of 'ECOCUTE' in the residential sector and in companies. On the technical side, the target is to achieve higher temperatures with lower heat source temperatures.

Now that 'ECOCUTE' has demonstrated that it clearly reduces $CO_2$, it can be disseminated worldwide. In the US, the Electric Power Research Institute (EPRI) is testing its performance and informing widely on its impacts. There is still a perception that a water heater using heat pump technology is expensive and that it takes many years to recover initial investment. To overcome this perception, the Japanese government has provided subsidies, and TEPCO has offered a price system suitable for the financial capabilities for a range of different 'ECOCUTE' users.

## About **WBCSD**

The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 36 countries and 22 major industrial sectors. We also benefit from a global network of 60 national and regional business councils and partner organizations.

Our mission is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

Our objectives include:

Business Leadership – to be a leading business advocate on sustainable development;

Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development;

The Business Case – to develop and promote the business case for sustainable development;

Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members;

Global Outreach – to contribute to a sustainable future for developing nations and nations in transition.

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