FACT SHEET

Research and development and technological innovation

Key points

- ***Technological innovation and its deployment will be central pillars that enable countries to achieve low carbon green growth.***
- ***Developing and deploying innovative technologies that enhance energy efficiency and promote the use of new energy sources will be essential to overcome current energy challenges and to achieve a low-carbon development path.***
- ***Governments must take the lead by developing a national framework on R&D, institutions and financing that creates an enabling environment for technological innovation to flourish.***

R&D and technological innovation explained

Research and development (R&D) is the process of discovering new technologies that can change and improve the way we live, produce and consume or fine-tuning what is already in the works. Recent examples of technological breakthroughs that have brought transformative changes to our society are the Internet and the associated information and communication technologies. Technological innovation is especially critical for solving environmental challenges.

But innovation does not occur in a vacuum. The innovation chain must be supported by government policies, financing, institutions and the participation of the business sector, academia and civil society. At the same time it must be sensitive to the demands and needs of society. In terms of low carbon green growth, innovations should contribute to promoting the eco-efficiency and the development efforts of countries.

How they works

The role of technology

Low-carbon technology is a major driver in enabling countries to reduce their carbon emissions, stabilize atmospheric greenhouse gas concentrations, limit the temperature increase to less than 2° C and make the transition to low carbon green growth. Without the development, deployment and commercialization of such technologies, it will be difficult for countries to cut the greenhouse gas emissions to reach the global target of halving CO_2 emissions by 2050. Although technological breakthroughs will be crucial for reducing CO_2 emissions, for some developing countries, innovative indigenous applications of existing technologies may be more relevant due to their social and economic conditions. Some of the areas in which technological innovation will need to take place are in the power sector, transport, buildings and industry. For instance, carbon capture and storage technologies are projected to contribute 20 per cent of the global emission reductions by 2050.[1] Nonetheless, in developing countries, governments will need to drive the introduction of low-carbon technologies under a long-term vision.

The role of national policy frameworks to promote technological innovations

Governments will be critical for developing a comprehensive national policy framework and sector-based policy frameworks (technology, energy, innovation, industry, climate change mitigation and adaptation) that

[1] Shane Tomlinson, *Breaking the Climate Deadlock: Technology for a Low Carbon Future* (London, The Office of Tony Blair and The Climate Group, 2009). Available from www.theclimategroup.org/_assets/files/Technology_for_a_low_carbon_future_full_report.pdf (accessed 28 July 2011).

embrace a mix of policy measures or regulations that create enabling conditions and a level competing field for low-carbon technologies. These national frameworks can map out technological priorities and identify the level and types of government support in consideration of the national context, including investment and incentive schemes that are required for these technologies along the innovation chain, such as R&D in the commercialization phase.

Another important area in terms of partnerships is identifying how governments can work together with the private sector so that technologies can avoid being trapped in the "valley of death".[2] Depending on the country context, these issues can also be addressed through sector policies, such as national industrial policies. In some countries, technology roadmaps are developed to specify the time-bound actions and steps that need to be taken by the government, research institutions and the private sector.

National policy frameworks are also important to define the role of government support and to allow the government to close the time and cost gaps, especially in terms of basic research as well as for those technologies at the early stages of development that require huge amounts of upfront investments and financial risks that the private sector is not able to support.

Low-carbon technologies and the innovation chain

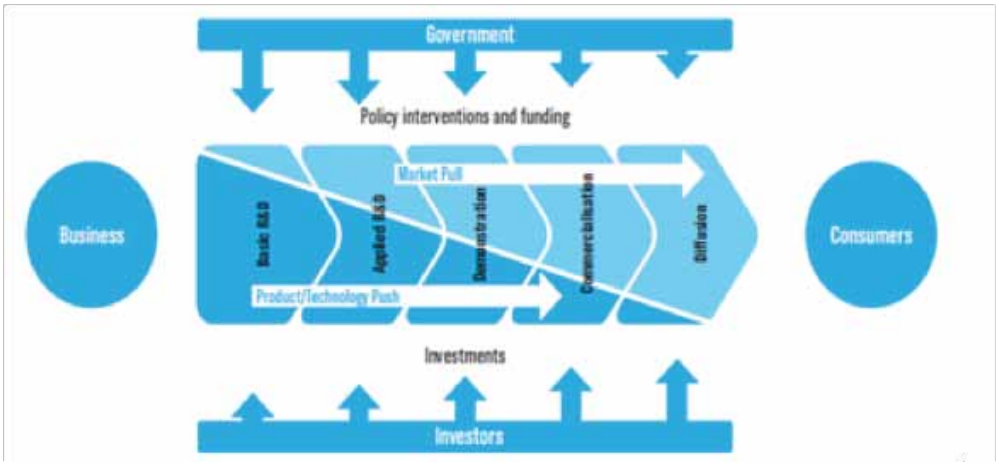
There is no one technology that will be the silver bullet for reducing CO_2 emissions and for achieving low carbon green growth. A combination of technological options will need to be introduced in various sectors. Not only should efforts be directed towards developing breakthrough technologies but also towards making incremental improvements to existing technologies, such as improving energy efficiency or undertaking innovations on application and use.

Many low-carbon technologies are in different stages of development within the innovation chain. Accordingly, the support that is required by the government will differ, depending on the stages and maturity of the respective technologies. Figure 1 depicts the five stages of the innovation chain: basic R&D, applied R&D, demonstration, commercialization and diffusion.

In the early stages of technological development, governments will have a bigger responsibility in terms of prioritizing, implementing policy measures and providing financial support for the technology options. In these early stages, government support is crucial, especially in filling the cost and time gaps, because the investment volume is huge and the returns are long term. For the private sector, the investment risks are too high at this stage. In the later stages of the innovation chain in which the technologies are more mature and close to commercialization, the private sector will have greater involvement. Government-funded R&D should also support or stimulate efforts by the private sector.

[2] "Valley of death" refers to the phase in the R&D chain in which technologies do not successfully reach the commercialization stage because they lacked support and investment (public funding, private investment or public-private partnerships) in the demonstration and deployment stages.

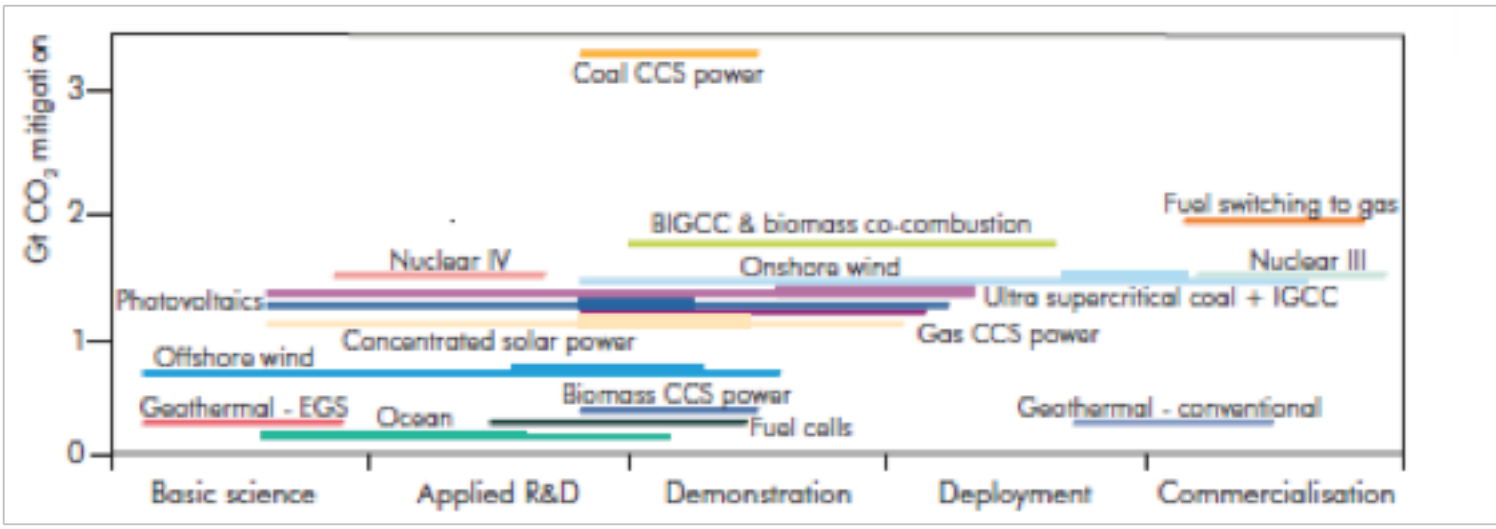
Figure 1: Innovation chain



Source: Shane Tomlinson, *Breaking the Deadlock: Technology for a Low Carbon Future* (London, the Office of Tony Blair and the Climate Group, 2009). Available from www.theclimategroup.org/_assets/files/Technology_for_a_low_carbon_future_full_report.pdf (accessed 28 July 2011).

Some of the biggest advances in low-carbon technologies have been in the area of renewable energy. Some that are near maturity are wind, solar PV and biofuels, which are in the technology demonstration and deployment phases. Figure 2 depicts the development stages of power-generating technologies along the innovation chain. To reach the deployment and commercialization stages requires market pull. Some of the emerging technologies that require the technology push under government-driven policy interventions and financing include carbon capture and storage (CCS), smart grids and hydrogen fuel cells. In addition to government support during the technology push phase, further assistance will be required in the commercialization and diffusion stages. Some technologies, however, may never reach the commercialization phase due to lack of support and investment (public funding and private investment) in the demonstration and deployment stages (valley of death).

Figure 2: Near-term development priorities for power-generating technologies



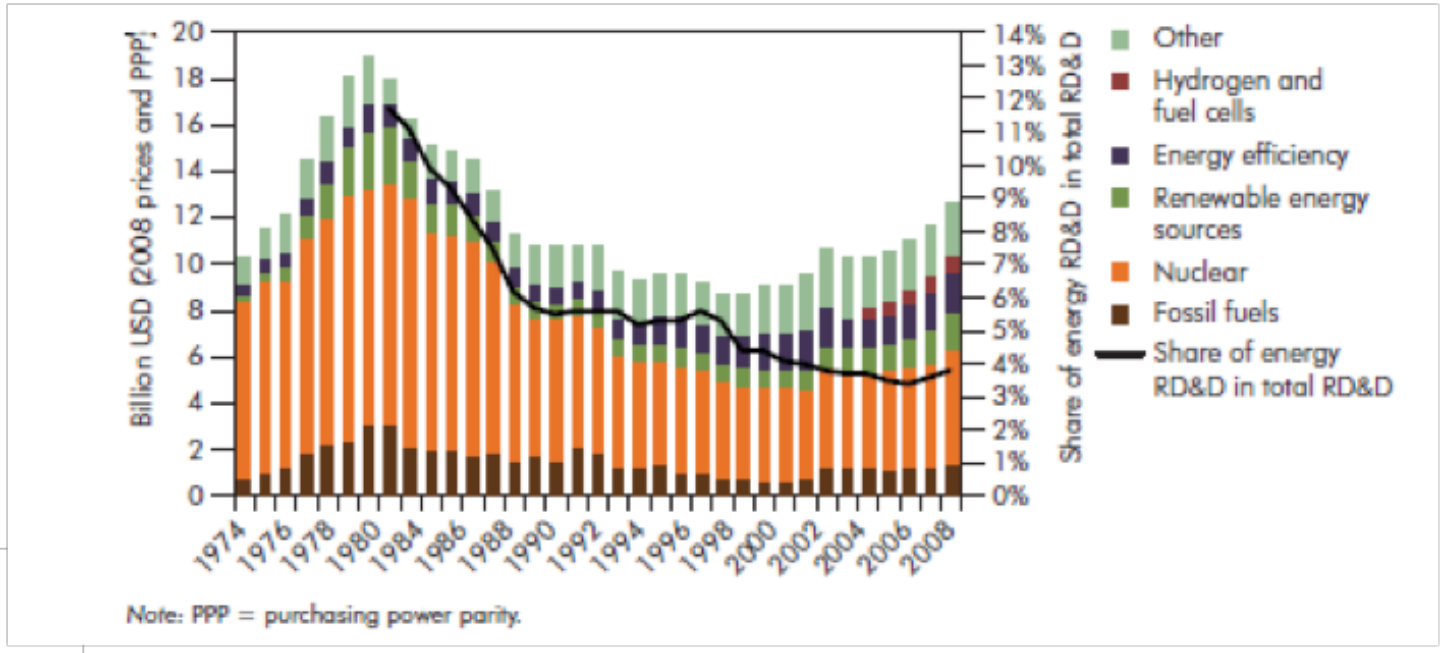
Notes: 1) Near-term indicates the next 10 to 15 years; 2) CO2 emission mitigation as laid out in the International Energy Agency's BLUE Map scenario relative to the baseline scenario
Source: International Energy Agency, *Energy Technology Perspective 2008* (Paris, 2008). Available from www.iea.org/w/bookshop/add.aspx?id=330 (accessed 15 February 2012).

The trends in public energy-related R&D

Governments have to take the upper hand in expediting public R&D through policies and financing schemes for accelerating low-carbon technological innovation. Funding towards public R&D has been allocated to a variety of parties, including public research institutes, laboratories and universities. Many of the breakthrough technologies, such as the Apollo space and nuclear energy programmes, have been government driven, particularly in the United States. Europe, Republic of Korea, Japan and more recently China have also concentrated efforts on public R&D for developing technologies for specific objectives.

There has been a decline in public energy-related R&D budgets in the 1990s (US$19 billion in 1980 to US$8 billion in 1997) in the International Energy Agency member countries in response to the difficulties of the nuclear industries and the decline of oil prices from 1985 to 2002.[3] However, since 1998, there is an evident upward trend in government expenditures on energy research, development and demonstration; in 2008, expenditure was around US$12 billion.[4] The share of energy research, development and demonstration in total RD&D, which had been declining in IEA member countries, appears to be on the rise again since 2006.[5]

Figure 3: Government RD&D expenditure in IEA member countries, 1974–2008



Source: International Energy Agency, *Energy Technology Perspective 2010* (Paris, 2010). Available from www.iea.org/Textbase/nppdf/free/2010/etp2010_part2.pdf (accessed 15 February 2012).

Figure 4 depicts that the share of government R&D devoted to improving environmental challenges is also low compared to total government budget for R&D. This indicates there is still a large need for governments to strengthen and invest in R&D efforts to address the environmental challenges that have the potential to hamper economic growth.[6]

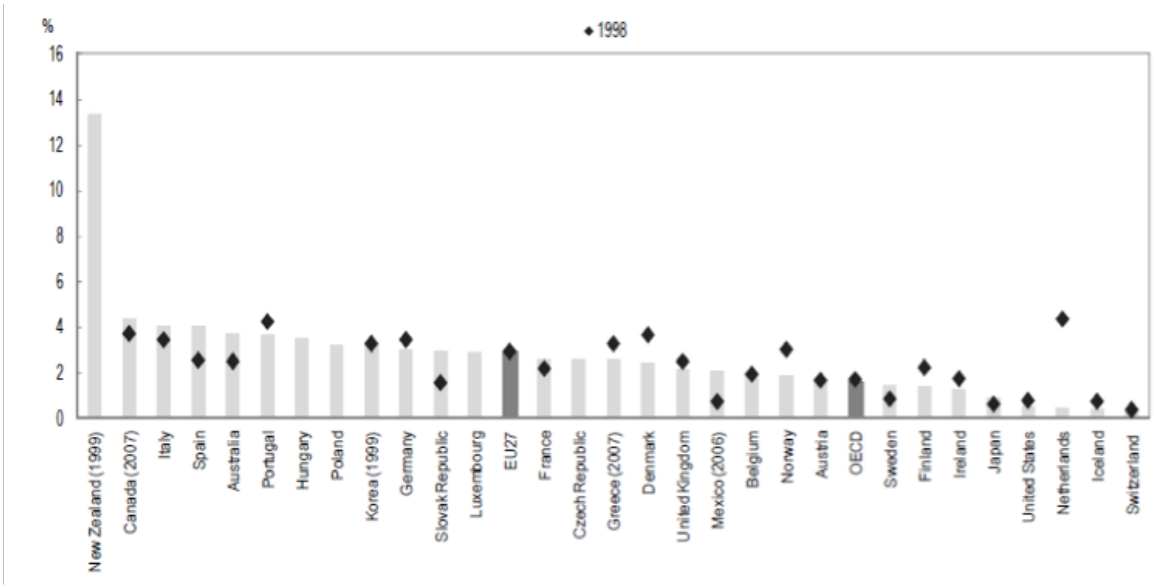
[3] International Energy Agency, *Energy Technology Perspective 2010* (Paris, 2010). Available from www.iea.org/Textbase/nppdf/free/2010/etp2010_part2.pdf (accessed 15 February 2012).

[4] ibid.

[5] ibid.

[6] Organization for Economic Co-operation and Development, *Green Growth Studies: Fostering Innovation for Green Growth* (Paris, 2011). Available from www.oecd-ilibrary.org/science-and-technology/fostering-innovation-for-green-growth_9789264119925-en (accessed 15 February 2012).

Figure 4: Government budget devoted to control and care for the environment, 1998–2008



Source: Organization for Economic Co-operation and Development, *Green Growth Studies: Fostering Innovation for Green Growth* (Paris, 2011). Available from www.oecd-ilibrary.org/science-and-technology/fostering-innovation-for-green-growth_9789264119925-en (accessed 15 February 2012).

In recent years, developing countries have also been active in spurring their own energy-related technology innovations – thus going against conventional thinking that technology is developed elsewhere and merely transferred to developing countries.[7] For example, according to the United Nations Department of Economic and Social Affairs, the combined energy R&D budget of Brazil, China, India, Mexico, Russian Federation and South Africa was about US$19 billion (in PPP terms), which was higher than the total public energy R&D budget of all of the IEA countries (estimated at US$12.7 billion in PPP terms) (table 1).

Table 1: Public and private spending on energy-related RD&D in selected emerging economies and the United States, 2004–2008a

Millions of 2008 US$ at PPP							
	Fossil (including CCS)	**Nuclear (including fusion)**	**Electricity, transmission, distribution and storage**	**Renewable energy sources**	**Energy efficiency**	**Energy technologies (unspecified)**	**Total**
China	7 044	19	--	--	161	5 885	**14 772**
Brazil	1 246	8[b]	122[b]	46[b]	46[b]	196	**1 664**
Russian Federation	430	--	22[b]	14[b]	25[b]	553	**1 045**
India	800	965[b]	35[b]	57[b]	--	--	**1 857**
Mexico	140	32[b]	79[b]	--	263[c]	19[c]	**534**
South Africa	164	164	26[c]	7[c]	--	9[b]	**370**
Subtotal	**9 624**	**>1 187**	**>285**	**>124**	**>497**	**>6 662**	**>18 580**
United States	1 821	804	319[b]	699[b]	525[b]	2510	**6 678**

a: Most recent year available.
b: Government only.
c: Private sector only.
Source: United Nations Department of Economic and Social Affairs, *World Economic and Social Survey 2011: The Great Green Technological Transformation* (New York, 2011). Available from www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf (accessed 19 March 2012).

[7] United Nations Department of Economic and Social Affairs, *World Economic and Social Survey 2011: The Great Green Technological Transformation* (New York, 2011). Available from www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf (accessed 19 March 2012).

Strengths of promoting R&D and technological innovation

- **Addresses environmental challenges.** Technological innovation of low-carbon technologies, including breakthrough technologies, can provide cost-effective solutions for addressing environmental challenges. At the same time, it can also address development goals and improve the quality of life by improving access to energy and safe drinking water, including for the rural poor.
- **Drives economic growth.** New technologies can lead to the creation of new business and investment opportunities and generate employment opportunities. With the increasing resource constraints and volatile fossil fuel prices impacting energy security issues, it is assumed that there will be higher demand for low-carbon technologies, products and services.
- **Strengthens national technology and innovation capacities.** Governments need to establish and strengthen the national innovation and science and technology base, including the institutionalization of national innovation systems and the human resource base. In the long term, this can lead to better capabilities to undertake innovations beyond technology transfer and adoption. Strengthening the innovation systems also means strengthening school curricula, especially in the areas of math and science, as well as setting up university courses that boost the knowledge base and the skills that are necessary to establish a capable workforce.
- **Strengthens indigenous innovation capacity for developing technologies applicable to the local context.** Technology transfer may strengthen the general technological absorption and application capacity, which can induce the expansion of the indigenous innovation capacity required to meet local conditions and needs.

Box 1: Grameen Shakti and promoting innovation at the local level

The Grameen Shakti, a subsidiary organization of the Grameen Bank, installed over 100,000 solar home systems under a programme of the Infrastructure Development Company Limited (a financial institution set up by the Government of Bangladesh), financed by the World Bank. Initially, all components of the solar home system were imported. Today, most of the components of the system are produced domestically. As a result of conducting their own indigenous research and development, Grameen Shakti has been successful in domestically producing 70 per cent of the compartments, excluding only the solar panels and batteries.[8] This has helped to save costs and to produce innovative technologies based on local needs, thus creating new business opportunities.[9] In addition, the deep-cycle batteries are now produced domestically by Rahimafrooz Renewable Energy Ltd (formerly Rahimafooz Batteries).[10] Recently, Rahimafrooz set up a solar panel assembly plant in Bangladesh with technical support from a company overseas.[11] The solar photovoltaic panels and tube lights are still imported.

Challenges for promoting R&D and technological innovation

- **Absence of national frameworks that promote R&D and technological innovation.** Without a national innovation or industrial strategy, there are no clear short- to long-term policy and price signals for raising the demand for green technology and motivating investors to make the necessary investment decisions.

[8] Dipal Chandra Barua, "Grameen Shakti (energy): Innovative use of micro-credit, market & social forces, government policy to bringing green energy & business opportunities to the rural areas in Bangladesh". PowerPoint presentation at the ESCAP Third Green Growth Policy Dialogue: The Greening of Business and the Environment as a Business Opportunity, Bangkok, 5-7 June 2007. Available from www.greengrowth.org/download/green-business-pub/The_Policy_Dialogue/Programme/Day1/Topic3/Mr_Dipal_Chandra_Barua.pdf (accessed 25 July 2011).

[9] United Nations Department of Economic and Social Affairs, *World Economic and Social Survey 2011: The Great Green Technological Transformation* (New York, 2011). Available from www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf (accessed 19 March 2012).

[10] ibid.

[11] Sohel Parvez, "Rahimafrooz to Set Up Solar Panel Assembling Plant", *The Daily Star*, June 24, 2009. Available from www.thedailystar.net/newDesign/news-details.php?nid=93896 (accessed 2 March 2012).

- **Lack of demand for low-carbon technologies due to market failures.** Market failures that do not incorporate the environmental externalities will not provide the necessary incentives for private sector and consumers to shift their preference towards developing, adopting and purchasing green technology, products and services.
- **Lack of finance directed towards funding national R&D efforts.** R&D efforts for low-carbon technologies require huge investments and the current levels of public financing are not sufficient, even in industrialized countries. According to the International Energy Agency, there is a shortfall of about US$40–$90 billion in public sector low-carbon energy technology spending (currently, it is about US$10 billion) to achieve the goal of 50 per cent CO_2 emissions reduction by 2050.[12]
- **Lack of innovation capacity.** Developing countries lack the human resources and public institutional capacity to undertake R&D for low-carbon technologies. This is also the case for private companies, including small and medium-sized companies.
- **Regulatory barriers for enabling technological transfer to developing countries.** Developing countries may lack appropriate trade and investment policies, intellectual property rights and enforcement measures.

Implementing strategies

Set national goals: Governments need to set national innovation and science and technology targets and goals in national economic and development plans or in low-carbon development plans, which can be further elaborated in specific national energy strategies, climate change strategies, national environment strategies, national science, technology, innovation and R&D strategies, national educational strategies or technology roadmaps. The key is consistency among the various plans and strategies. There must also be consistency among the various sector policy frameworks.

Construct long-, medium- and short-term innovation policies within a national development framework: Governments can take a number of approaches to strengthen the R&D phase that is targeted towards the development of low-carbon technology development through clear and consistent strategies and policy direction. The role of the public-private sector partnerships can also be incorporated into these policy frameworks. The national policy must attempt to minimize uncertainty so that the private sector can complement or prepare to take part in certain stages of the innovation chain, for instance in the later stages of the innovation chain. Such efforts of the government and private sector may lead to creating new growth engines that can generate business opportunities and employment.

Develop an investment plan: Governments need to develop an investment plan and roadmaps with clearly defined outputs to accompany the national policy frameworks. In particular, specifications have to be given for the public financial support that will be extended by the government for specific interventions and actions along the innovation chain. R&D strategies and innovation programmes should also be designed with consideration of how to coordinate and complement the efforts and investments of the private sector.

Select strategic and core technologies and provide concentrated government support: Some countries may choose to identify and concentrate on a technological priority area for creating future niche and competitive markets. Although there are different views on such policy approaches, many countries have taken this track as part of their industrial and technological strategies, such as the Republic of Korea, China and Japan. These policies have allowed technological advancements that have led to the strengthening of their national competitiveness.

Some analysts believe that "picking winners" may distort the market. Thus a broad array of technologies, to the greatest extent possible, can be selected for support as part of achieving national goals. For some developing countries, experiences from East Asia may not be relevant at this time of their development stage. In such cases, countries can concentrate on how to adopt and improve existing technologies and develop the pathways for

[12] Organization for Economic Co-operation and Development, *Green Growth Studies: Fostering Innovation for Green Growth* (Paris, 2011). Available from www.oecd-ilibrary.org/science-and-technology/fostering-innovation-for-green-growth_9789264119925-en (accessed 15 February 2012).

deployment and commercialization, which in the future may eventually reduce costs in renewable energy, energy efficiency and associated infrastructure, based on the country context and demands.

National frameworks for R&D and technology innovation in the Asia-Pacific region

In China, the R&D and innovation goals and targets have been incorporated into the National Plan for Economic and Social Development and more detailed and long-term goals have been woven into China's medium- and long-term science and technology plans (box 3). In the Republic of Korea, the Five-Year Green Growth Plan provides R&D policy direction and goals. More focused policies and investment plans were included in the Republic of Korea's Green Technology R&D Plan (box 4).

Box 2: China's R&D strategies within its national policy frameworks

In China, the Twelfth Five-Year Plan (2011–2015) set short-term targets as part of its innovation policies, which included R&D expenditure to account for 2.2 per cent of GDP and for the research pace to hit a level of 3.3 patents per 10,000 inhabitants by 2015.[13] Along with these targets, there are policies to support, strengthen and promote seven strategic and emerging industries: i) energy saving and environmental protection, ii) next-generation information technology, iii) biotechnology, iv) high-end manufacturing, v) new energy, vi) new materials and vii) clean energy vehicles.

Such innovation strategies coupled with industrial policies and investments constitute the basis for developing a new growth engine by developing and deploying green technologies as well as greening the existing industries, all of which will help China transition towards a low-carbon economy.[14]

The Chinese Science and Technology National Plan released in 2006 (15-year plan) provides medium-term policy direction on the quality and quantity of China's R&D and innovation efforts up to 2020. This plan reflects the Chinese Government's determination to become an innovative nation by 2020 and a world leader in the science and technology field by 2050. The plan specifies four targets: i) invest 2.5 per cent of GDP in R&D, ii) reduce China's dependence on foreign technologies to 30 per cent, iii) increase the contribution of technology to economic growth to 60 per cent and iv) rank in the world's top-five countries in patents granted and citations used in international science papers. The plan also enumerates five strategic focuses that include develop technology in energy, water resources and environmental protection and strengthen R&D in basic science and in cutting-edge technology.[15]

Polices to stimulate private sector R&D and investment from the Chinese medium- to long-term science and technology plan (2006)[16]

Preferential tax treatment

- Accelerate implementation of consumption VAT to allow for capital expenditure deduction
- Accelerate depreciation of R&D apparatus and facilities
- Increase deduction of R&D expenses from taxable income
- Offer favourable tax policies, including favourable taxation terms for venture capital to promote the development of new products, technologies and high-tech enterprises
- Offer preferential tax policies for R&D-focused small and medium-sized enterprises
- Support the establishment of overseas R&D centres.

[13] The number of invention patents per 10,000 inhabitants here refers to the granted domestic patents, not the total. It indicates the patent values and nation's market controlling capacity. State Intellectual Property Office of China, "*What is the meaning of '3.3'?*", May 13, 2011 [in Chinese]. Available from www.sipo.gov.cn/mtjj/2011/201105/t20110513_604228.html (accessed 1 March 2012).

[14] Deborah Seligsohn and Angel Hsu, "How Does China's 12 Year Five-Year Plan Address Energy and the Environment?", *Climate, Energy & Transport News of World Resource Institute*, March 7, 2011. Available from www.wri.org/stories/2011/03/how-does-chinas-twelfth-five-year-plan-address-energy-and-environment (accessed 1 September 2011).

[15] Xiamei Tan and Zhao Gang, "An Emerging Revolution: Clean Technology Research, Development and Innovation in China", WRI Working Paper, p.6 (Washington D.C., 2009). Available from pdf.wri.org/working_papers/an_emerging_revolution.pdf (accessed 19 July 2011).

[16] ibid., p.6.

Favourable financing polices

- Provide loans to R&D-focused enterprises, and finance their import and exports
- Encourage commercial banks to provide loans based on government guarantees and discounted interest rates
- Encourage venture capital investment with government funding and commercial loans
- Create favourable environment for R&D enterprises to go public in overseas stock exchanges
- Establish technology-oriented financing platforms
- Provide special funding for the absorption, digestion and re-innovation of imported technologies.

Government procurement policies

- Require local governments to purchase domestically innovated products and technologies
- Extend financial support to enterprises that purchase domestically innovated products and technologies
- Establish technical standards through government purchases of domestically innovated products and technologies.

Source: Xiamei Tan and Zhao Gang, "An Emerging Revolution: Clean Technology Research, Development and Innovation in China", World Resources Institute Working Paper (Washington, D.C., 2009). Available from pdf.wri.org/working_papers/an_emerging_revolution.pdf (accessed 19 July 2011).

Box 3: Republic of Korea's R&D strategies within its national policy frameworks

One of the three major policy objectives in the Republic of Korea's Five-Year Green Growth Plan[17] is "creating new engines for economic growth", which is accompanied by four policy directions: i) develop green technologies, ii) green existing industries and promote green industries, iii) advance the industrial structure and iv) engineer a structural basis for the green economy.

Specific policies on R&D have been incorporated for the development of green technologies, which entail such goals as expanding green R&D investment, establishing an effective green R&D system, boosting green technology transfer and commercialization, expanding green R&D infrastructure, vitalizing international cooperation for green R&D and promoting green technology industries as new growth engines. In line with the Five-Year Green Growth Plan, a Green Technology R&D Plan[18] was developed in 2009 to assess government-driven R&D and develop investment plans for relevant ministries that include the Ministry of Knowledge and Economy, Ministry of Land, Transport and Maritime Affairs, the Ministry of Food, Agriculture, Forestry and Fisheries and the Ministry of Health and Welfare. The funds allocated for green technology R&D have been growing over the past few years, with more than 70 per cent now allotted to 27 core technologies.

Table 2: Republic of Korea's Investment plan for green technology R&D (unit: trillion won)

Year	2008	2009	2010	2011	2012
Green technology R&D	1.4	1.9	2.2	2.5	2.8
27 core technology R&D (portion in overall green technology, %)	1.0 (71.7)	1.4 (72)	1.7 (77.3)	2.0 (80)	2.3 (82)

Source: Republic of Korea, *National Green Technology R&D Plan* (Seoul, National Science & Technology Commission, 2009).

[17] Republic of Korea, *National Strategy for Green Growth and Five-Year Plan* (Seoul, Presidential Committee on Green Growth, 2009). Available from www.greengrowth.go.kr/?page_id=2450 (accessed 10 August 2011).

[18] Republic of Korea, *National Green Technology R & D Plan* (Seoul, National Science & Technology Commission, 2009).

Investment plans and financing policies to support the innovation chain

National policy must be supported by sufficient public funds to achieve national innovation goals. Public funds will need to be allocated for R&D as well as for implementing a mix of incentives and regulatory policies that will boost the innovation, deployment and commercialization stages of the innovation chain. Many governments put together an investment plan to budget and map out how government funds will be allocated and dispersed to support specific policy goals and measures.

Specific government intervention and support along the innovation chain will be needed early on for funding R&D programmes, demonstration projects and then scaling up what works best. During the later stages of the innovation chain, such as in the technological diffusion and deployment phases, the private sector may require support to minimize its risks and to stimulate private sector investment.

Box 4: Selected economic and financing policies to stimulate innovation

On the supply push side:
- Direct R&D funding for various organizations and institutions specializing in research, such as public research organizations, universities and the private sector
- Tax incentives and subsidies to promote R&D in the private sector
- Financing arrangements, such as preferential or concessional loans and guarantees.

On the market pull side to influence consumers and purchasing decisions:
- Government procurement to create or support a market for specific technologies
- Regulations and standards
- Tax incentives and subsidies.

Countries such as China, as previously pointed out, have developed a medium- to long-term science and technology plan outlining the specific policy measures and programmes to achieve its targets as well as in the five-year plans for economic and social development. The plan also indicates the specific incentives and financial and procurement measures to support private sector innovation efforts and domestically innovated products.

There are several bilateral and multilateral financing funds targeted towards technology transfers that developing countries can access, such as the Special Climate Change Fund and the Clean Development Mechanism under the UNFCCC and the Climate Investment Fund under the World Bank (box 6).

Box 5: Multilateral financing mechanisms

For developing countries, financial support can be accessed through multilateral and bilateral funds intended for the demonstration, deployment and transfer of low-carbon technologies. There is, for example, the Special Climate Change Fund under the UNFCCC, which is operated by the Global Environment Facility and was established in 2001 to support, including, adaptation and technology transfer projects and programmes. The technology transfer programme focuses on "the transfer of environmentally sustainable technologies, concentrating on, but not limited to, technologies to reduce emissions or atmospheric concentrations of greenhouse gases, in line with the recommendations from the national communications, technology assessments (TNAs) and other relevant information".[19] Activities such as implementing the results of technology needs assessments, dissemination of technology information, capacity building for technology transfer and facilitating enabling environments can be supported through the fund.

[19] The Global Environment Facility, *Accessing Resources Under the Special Climate Change Fund* (Washington, D.C., 2011). Available from www.thegef.org/gef/sites/thegef.org/files/publication/23470_SCCF.pdf (accessed 12 March 2012).

The other funding mechanisms are the Clean Technology Fund (CTF)[20] and the Strategic Climate Fund under the World Bank's Climate Investment Fund. The CTF promotes scaled-up financing for demonstration, deployment and transfer of low-carbon technologies with significant potential for long-term greenhouse gas emissions savings. The CTF finances programmes in 12 countries and one region. The focal areas of work are the power sector, transport sector and energy efficiency. The Strategic Climate Fund is an overarching framework to support three targeted programmes: the Forest Investment Programme, the Pilot Programme for Climate Resilience and the Programme for Scaling-up Renewable Energy in Low-Income Countries, with dedicated funding to pilot new approaches that have the potential for scaling up transformational action aimed at a specific climate change challenge or sector-based responses.

Institutional mechanisms

Many countries have established a dedicated agency or ministry that is responsible for overseeing the development of policies. Such a body ensures that there is policy coherence among the various sector-based policies, ministries and agencies, such as the ministry or agency of science and technology and the ministries for industry, education and finance. R&D programmes require inter-ministerial and cross-sector coordination and collaboration across ministries and research institutes, and thus a funding agency is an effective way to ensure consistency.

An inter-ministerial mechanism can affect how well policies are developed, implemented and monitored. They must be entrusted with a certain degree of authority and responsibility. Cross-ministerial coordination may encounter challenges. Depending on the economic and political circumstances, policy directions need to be reviewed and adjusted accordingly. The institutional arrangements will determine how public funds are secured and allocated throughout the innovation chain. The capacity of inter-ministerial mechanisms to resolve these challenging tasks will be crucial for a successful implementation of programmes that will lead to the achievement of national goals and targets.

In terms of publicly funded innovation programmes at the national level, a national innovation system or centre can prove to be a powerful institution, building the foundation and knowledge base for R&D and innovations as well as promoting the deployment and commercialization of low-carbon technologies.

Box 6: The National Innovation Agency of Thailand

Thailand's National Innovation Agency (NIA) was established by the Ministry of Science and Technology in 2003 by combining two funds, the Innovation Development Fund and the Revolving Fund of Research and Technology Development. It is an independent organization under the supervision of the National Innovation Board.

The NIA works to accelerate national innovation capacity, promote an innovation culture, create awareness of innovation at all levels (in industry, organizations and the public sector) and develop the National Innovation Ecosystem. The NIA is a central unit that coordinates networking of different organizations from a variety of fields. It mainly focuses on using knowledge management to achieve innovation, which can be a driving force towards improving the quality of life and the national competitiveness.

Over the past few years, the NIA has tried to build a system that can promote national innovation systems by providing both technical and financial support. From 2006 to 2010, the NIA invested in a total of 520 innovation projects.[21] It has established two development programmes, a strategic innovation programme focusing on bioplastics and the organic agriculture industry and the sector-industry innovation programme focusing on bio-business, eco-industry and design and solutions.

Sources: Thailand, National Innovation Agency website "About NIA" (2010). Available from www.nia.or.th/en/index.php?page=aboutus_background (accessed 12 February 2012); and Thailand, National Innovation Agency website "NIA Perspective" (2010). Available from www.nia.or.th/2009/publicmedia/downloads/NIA_Per_10.pdf (accessed 12 February 2012).

[20] The Climate Investment Funds website "*Clean Technology Fund*". Available from www.climateinvestmentfunds.org/cif/node/2 (accessed 12 March 2011).

[21] Thailand, National Innovation Agency website "NIA Perspective" (2010). Available from www.nia.or.th/2009/publicmedia/downloads/NIA_Per_10.pdf (accessed 9 February 2012).

Public-private partnerships

Partnership building with the private sector will be integral to the technological development and commercialization stages, especially in creating new markets and ensuring an enabling business environment for technology deployment.

Some R&D programmes are products of partnerships among the public and private sectors. Governments need to take up projects that are high risk and require large investment over the long term, which may be difficult for the private sector to embrace alone. Public-private partnerships can reduce the risks and make the hurdles seem feasible.

Partnerships with the private sector can include:

- Collaborative research, joint conferences and seminars and policies that encourage the mobility of researchers between the public and private sectors.[22]
- Cooperative R&D agreements that allow government entities to work with the private sector, academia and other organizations.
- Industry consortia, in which businesses work together with funding and support provided by the government, which may reduce R&D costs and increase R&D efficiency.[23]

Box 7: Shanghai International Business Incubator

With approval of China's Ministry of Science and Technology, the Shanghai International Business Incubator (SHIBI) was established in 1997. Following the organization model of One Incubator, Several Bases, the SHIBI built six incubation bases (research centres), including a headquarters in the Shanghai Technology Innovation Center.

The SHIBI provides an innovative environment and services for domestic and overseas small and medium-sized businesses and functions as a unit that coordinates national and international organizations. To promote international exchange and cooperation, it organizes training programmes and information exchange sessions and works closely with many organizations within and outside of China, including in France, Japan, Republic of Korea, Russian Federation and the United Kingdom. It has helped Chinese students to establish their own technology business by sharing information and experiences with international enterprises, institutions, R&D centres and companies. It plans to continue offering workshops and seminars for information consultation, matching of partners, market reviews and new technological product distribution and thus stokes technological cooperation between China, other Asian countries and the rest of the world.

Sources: Wang Rong, *Shanghai Hi-tech Business Incubator Network: Networking, Internalization and Professionalization* (Shanghai, Shanghai Technology Innovation Center, undated). Available from www.aspa.or.kr/files/webzinevol.10_050907/050907_ASPA%20paper15_eg.htm (accessed 12 February 2012); and Shanghai Technology Innovation Center website "About SHIB" (2005). Available from www.incubator.sh.cn/en/aboutshibi.asp (accessed 12 February 2012).

Box 8: The Innovation Centre for Micro, Small and Medium Enterprises, Indonesia

Although micro, small and medium-sized enterprises (MSME) in Indonesia have made a significant contribution to the country's economic development, they lack modernized technology, facilities and management skills. To address these issues and propose solutions for a better future, the MSME Innovation Center was established in 2008 by decrees from the president and the coordinator minister for economics; it is an initiative with the Agency for Assessment and Application of Technology.

[22] United Nations Department of Economic and Social Affairs, *World Economic and Social Survey 2011: The Great Green Technological Transformation* (New York, United Nations, 2011). Available from www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf (accessed 19 March 2012).

[23] United Nations Department of Economic and Social Affairs, *Climate Change: Technology Development and Technology Transfer.* Background paper prepared for the Beijing High-level Conference on Climate Change: Technology Development and Technology Transfer, Beijing, 7 - 8 November 2008. Available from www.un.org/esa/sustdev/sdissues/energy/op/beijing_hlccc_nov08/back_paper.pdf (accessed 2 March 2012).

The MSME Innovation Centre was set up to strengthen existing enterprises and generate new enterprises that are more competitive in process, products and services.

The MSME Innovation Centre functions as a platform for coordinating and creating synergies among the three components of innovation: research institutes, industry and government (including organizations). The Innovation Centre works with all major research, developmental and educational institutions that provide assistance in the areas of technology, capacity development, business network development and access to finance or markets. The centre facilitates the sharing of information among research institutions, industry and policymakers.

Sources: Utama H. Padmadinata, "The Importance of SME Innovation Center in Indonesia SME Condition in Indonesia", *APEC SME Briefing*, December 21, 2007. Available from www.apec-smeic.org/newsletter/newsletter_read.jsp?SEQ=387 (accessed 12 February 2012); and Organisation for Economic Co-operation and Development, *SMEs, Entrepreneurship and Innovation*, OECD Studies on SMEs and Entrepreneurship Series (Paris, 2010). Available www.keepeek.com/Digital-Asset-Management/oecd/industry-and-services/smes-entrepreneurship-and-innovation_9789264080355-en (accessed 12 February 2012).

Complementary measures

Complementary measures can assist in securing public finances to stimulate green innovation, including R&D. Environmental taxes, carbon pricing and the phasing out of perverse subsidies can spur innovation efforts and create new markets, but it also enables governments to generate funds that can be redirected to support innovation efforts. Without the introduction of such policy measures, existing brown technologies and infrastructure will be locked in because it will be more costly to invest in and introduce green innovations. Such market mechanisms as cap-and-trade schemes not only encourage the private sector to invest in low-carbon innovation and infrastructure, but it generates capital for further innovation efforts.

For innovation to flourish, other complementary measures require investment in human resources development and strengthening academic institutions and their research efforts, which is the basic foundation for reinforcing the national capacity in terms of knowledge and technical skills. Without the availability of capable human resources, challenges will arise in managing and operating the green technologies – let alone carrying out innovative research.

Box 9: The new growth strategy and science and technology policies in Japan

In December 2009, the Basic Policies of the New Growth Strategy of Japan was approved by the cabinet. In June 2010, the cabinet then approved a more detailed document, the New Growth Strategy Blueprint for Revitalizing the Economy. It provides measures for pursuing a strong economy, fiscal budget and social welfare system, with a target of boosting growth of more than 2 per cent on average and reducing the unemployment rate to 3 per cent by 2020. To achieve these goals, the strategy identifies seven focus areas (green innovation, life innovation, Asian economy, tourism and regional development, science and technology and ICT, human resources and employment and financial sector) and proposes 21 projects. One of the seven focal areas is the "Strategy for becoming an environment and energy power through green innovation", which puts the innovation of green technologies at the heart of the country's growth strategy. Specific policies to back up the strategy include promoting renewable energy use, technological development and innovation, energy-saving and energy-efficiency products, low-carbon investments and green tax reform. The environment and energy priority areas alone are expected to create new environment-related markets worth more than 50 trillion yen and 1.4 new environment-related jobs by 2020 and reduce 1.3 billion tonnes of CO2 equivalent by using Japanese private sector technology.

The science and technology focus area is considered as a "platform for supporting growth" to push Japan forward as a world leader in green innovations by 2020. Proposals include increasing the number of universities and research institutions, providing support to technological innovation, including R&D, to small- and medium-sized enterprises and increase public- and private-sector investment in R&D to more than 4 per cent of GDP.

Based on the New Growth Strategy and the Blueprint Strategy, the cabinet approved the Fourth Science and Technology Basic Plan in August 2011. One of its pillars aims to strengthen green innovation in order to "realize the world's most advanced low-carbon society by identifying trends in de-fossil fuel that many countries are developing competitively as a key to future growth. Such promotion is expected to facilitate further innovation of environmental/energy technologies, in which Japan has strengths, and promote the reform of social systems and institutions."[24]

The earthquake and tsunami disaster of March 2011 greatly impacted the Japanese economy, sending the country into further recession. The environmental disaster of the Fukushima nuclear plant forced the Government to review and revise its growth strategy as well as the national energy strategy. As a result, in December 2011 the cabinet approved the Basic Strategy for Rebirth of Japan, which is a roadmap to recovery from the aftermath of the earthquake to revitalize the economy towards economic growth in the short term. To create new industries and markets in response to a changing environment, the short-term high-priority projects include removing barriers to green growth and conducting joint R&D research through partnerships. A new medium- to long-term strategy on energy and the environment will also be developed as one of the central drivers for growth and will be based on the new science and technology frameworks and global warming countermeasures. Regarding international cooperation, Japan will encourage the dissemination of Japanese low-carbon technologies. In 2012, the Government will further develop the Strategy for Rebirth of Japan, providing medium- to long-term specifics.

Sources: Japan, *The New Growth Strategy* (Basic Policies) Toward a Radiant Japan (Tokyo, Ministry of Economy, Trade and Industry, 2009). Available from www.meti.go.jp/english/policy/economy/growth/report20091230.pdf (accessed 1 March 2012); Japan; *The New Growth Strategy Blueprint for Revitalizing Japan* (Tokyo, Ministry of Economy, Trade and Industry, 2010). Available from www.meti.go.jp/english/policy/economy/growth/report20091230.pdf (accessed 1 March 2012); Japan, *Japan's Science and Technology Basic Policy Report* (Tokyo, Council for Science and Technology Policy, 2010), p.6. Available from www8.cao.go.jp/cstp/english/basic/4th-BasicPolicy.pdf (accessed 1 March 2012); and Japan, Strategy for Rebirth of Japan, Cabinet decision, December 24, 2011. Available from www.npu.go.jp/policy/pdf/20120127/20120127_en1.pdf (accessed 13 February 2012).

Further reading

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[24] Japan, *Japan's Science and Technology Basic Policy Report* (Tokyo, Council for Science and Technology Policy, 2010), p.6. Available from www8.cao.go.jp/cstp/english/basic/4th-BasicPolicy.pdf (accessed 1 March 2012).