E3G

Low Carbon Technology Cooperation

A Framework for EU-China Dialogue

Aleyn Smith-Gillespie

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Third Generation Environmentalism Ltd (E3G)
4th floor, In Tuition House
210 Borough High Street
London SE1 1JX
Tel: +44 (0)20 7234 9880
Fax: +44 (0)20 7234 0851
www.e3g.org

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Acronyms and Abbreviations

BAU	Business-as-usual
CAS	China Academy of Sciences
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CECIC	China Energy Conservation Investment Corporation
CHP	Combined Heat and Power
CSP	Concentrating Solar Power
CWER	Danish Consortium for Wind Energy Research
DWIA	Danish Wind Industry Association
EC	European Commission
EERA	European Energy Research Alliance
EII	European Industrial Initiative
ELC	Enhanced Low Carbon
ERI	Energy Research Institute
ETI	Energy Technologies Institute
EU	European Union
EV	Electric Vehicle
FDI	Foreign Direct Investment
GHG	Greenhouse Gas
GW	Gigawatt
IGCC	Integrated Gasification Combined Cycle
IP	Intellectual Property
IPR	Intellectual Property Rights

JV	Joint Venture
LC	Low Carbon
LCTIDZ	Low Carbon Technology and Investment Demonstration Zone
LNG	Liquefied Natural Gas
MTCE	Metric Tonnes of Coal Equivalent
NDRC	National Development and Reform Commission
NGCC	Natural Gas Combined Cycle
PV	Solar Photovoltaic
R&D	Research & Development
RD&D	Research, Development and Demonstration
SET-Plan	Strategic Energy Technology Plan
SME	Small and Medium Enterprises
TNA	Technology Needs Assessment
TW·h	Terawatt hour
UNFCCC	United National Framework Convention on Climate Change
WOFE	Wholly-owned Foreign Enterprise

Executive Summary

International cooperation for developing and diffusing low carbon technologies is a core element of the global effort to mitigate climate change. As both a leading supplier and user of low carbon technologies, the EU has an important stake in this process. China equally has a crucial role to play as an important emitter of greenhouse gases (GHG) as well as being a manufacturing hub and an emerging technology provider and driver of cost reduction.

This paper focuses on the opportunities for technology cooperation between the EU and China, specifically in the area of low carbon technologies for mitigation. The frameworks and approach defined in this paper can also be applied to the development and diffusion of technologies for adaptation. Furthermore, while the discussion focuses on the EU-China relationship, the findings of this paper can inform the broader debate on technology cooperation in the international climate change negotiations.

The focus in the international negotiations is on technology transfer from developed to developing countries. Europe remains at the cutting of edge of innovation and diffusion of many low carbon technologies and much of the analysis in this paper focuses on opportunities to share best practice with China.[1] However it must be recognised that China is ahead of Europe in some areas (e.g. local diffusion of solar water heaters) and catching up fast in others. The future will increasingly be about a two-way flow of ideas and investment and joint R&D of new technologies.

A final caveat: this paper focuses on the specific role of technology in driving the low carbon transition. However this transition also depends on broader lifestyle changes and other forms of "social innovation" such as better urban planning. EU-China exchanges of best practice across this broader agenda must also flow both ways.

Opportunities for 'win-win' cooperation

From the EU's perspective, technology cooperation with China presents a number of opportunities:

[1] Lee et al. (2009)

> Access to China's market, with associated benefits to the EU economy and job creation

> Benefit to technology end-users and acceleration of low carbon transition in the EU due to China's influence on cost reduction through localisation of manufacturing and making the technology market more competitive

> Acceleration of new technology development by pooling resources and capabilities, leveraging China's growing know-how and emerging role as a supplier of technology

> Facilitating low carbon development in China provides global benefits in the effort to mitigate the impact of climate change

Similarly, from China's perspective cooperation with the EU offers important benefits:

> Access to leading-edge technology to meet climate change mitigation and adaptation objectives

> Socio-economic development through job creation driven by FDI, exports, and development of a domestic low carbon market

> Technological development through spill-over effects of international science and technology cooperation

The challenge of intellectual property rights (IPR) in technology cooperation

The sharing and protection of IPR is an important issue in the context of technology cooperation and a sensitive topic in international negotiations. Solutions needed to be designed on a case-by-case basis depending on the technology in question and the importance of IP relative to other factors that encourage or discourage diffusion (e.g. manufacturing costs and tacit know-how). In all cases the challenge is to achieve the dual objective of ensuring that

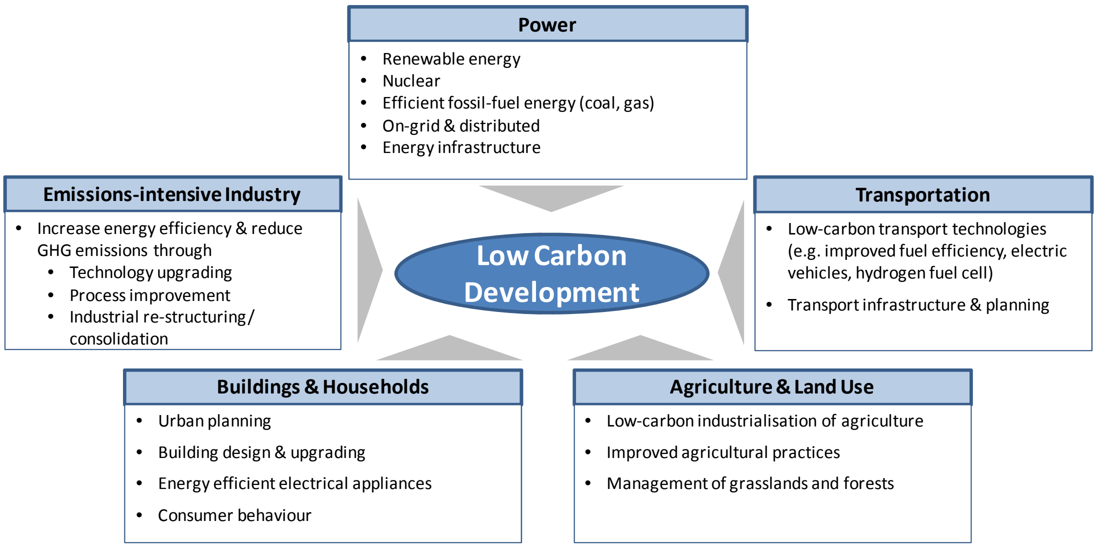
> innovation continues – hence the interests of current and future IP owners need to be properly addressed; and

> diffusion is effective – available technology must reach those who need it at the speed and scale required to meet the challenge

China's technology needs

Recognising the importance of the low carbon and 'green' economy to its social, economic and energy security objectives, China has begun to establish a comprehensive set of policies and regulations to promote the development and uptake of low carbon technology. Progress will require concerted action across five key areas (Figure 0.1).

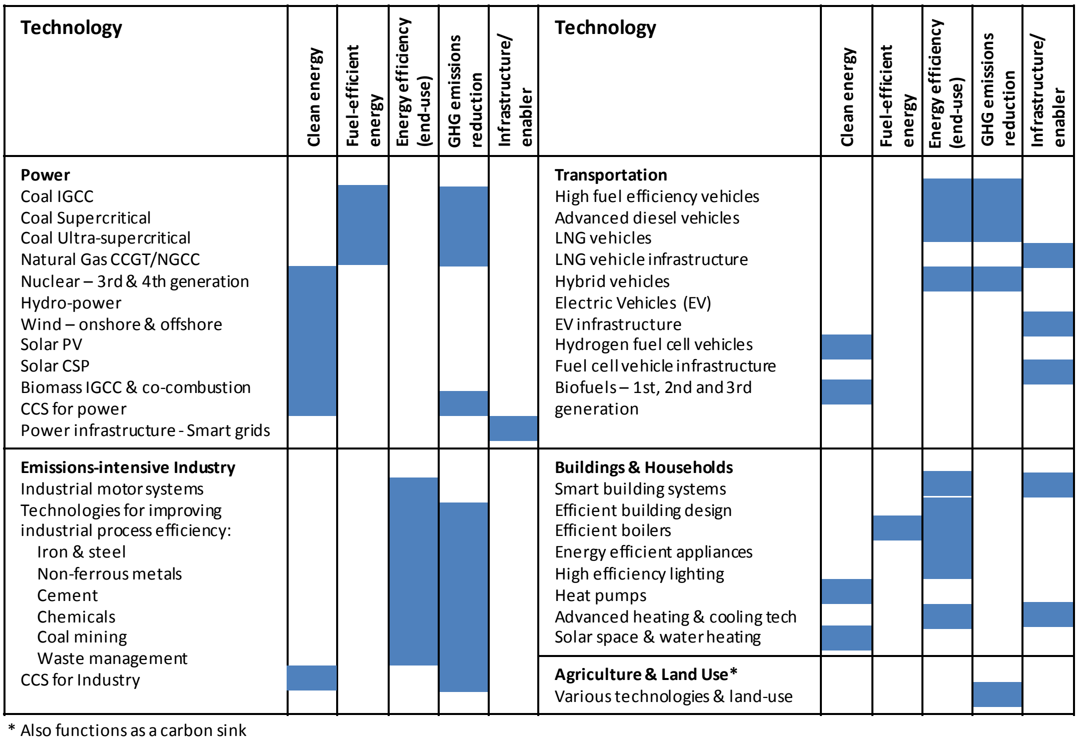
Figure 0.1 Key sectors and activities needed to drive low carbon development



Source: E3G analysis

Figure 0.2 summarises the key technologies relevant to each of the above sectors, and the major 'levers' they act on to deliver low carbon development. In the short-term, accelerating the deployment of low carbon technologies in the power sector will play a critical role in achieving Chinese carbon intensity targets in 2020 and beyond. This will require changes to the electrical grid infrastructure as well as efforts to monitor and manage electricity demand.

Figure 0.2 Selected key technologies for low carbon development



Source: E3G analysis

Framing the opportunities for cooperation

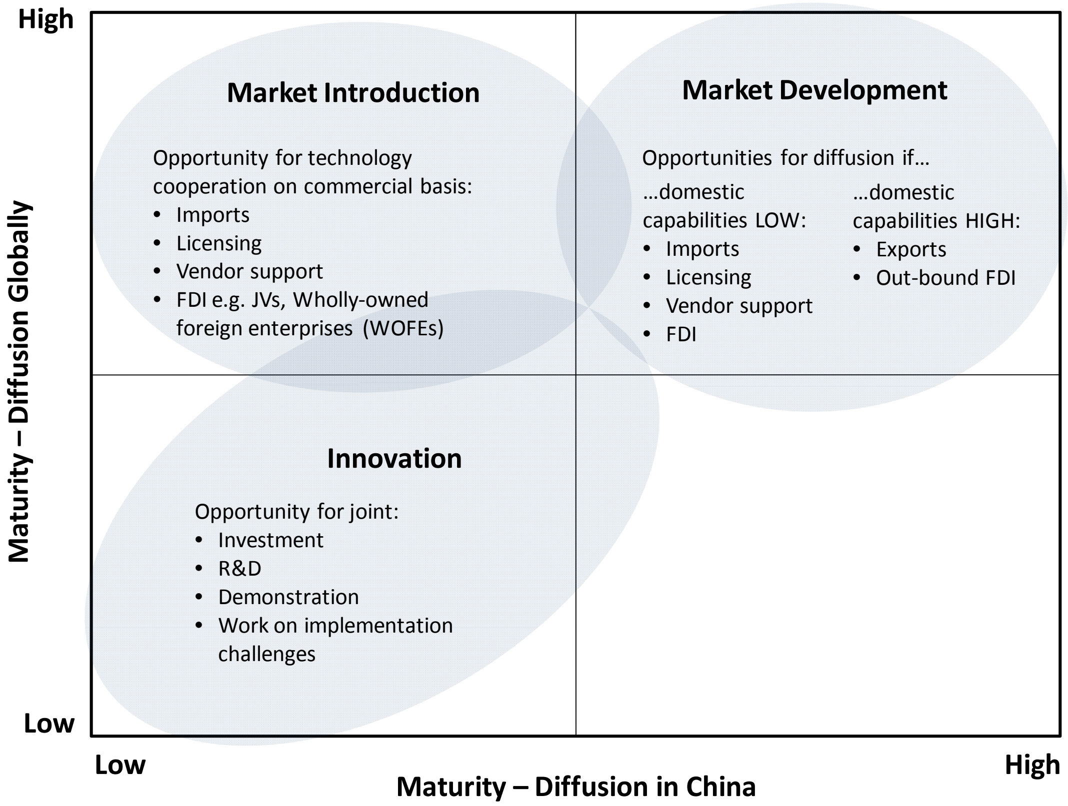
While the range of technologies that China needs to adopt and diffuse across its key sectors is vast, it is possible to group these into three areas for the purpose of discussing cooperation opportunities with the EU (Figure 0.3):

> Innovation – Opportunity to jointly accelerate new and emerging technologies towards eventual commercialisation

> Market introduction – Opportunity to facilitate China's access to mature technologies

> Market development – Opportunity to drive down costs of low carbon technologies, supporting their diffusion in China and globally

Figure 0.3 Potential areas of cooperation between China and global technology leaders[2]



Source: E3G analysis

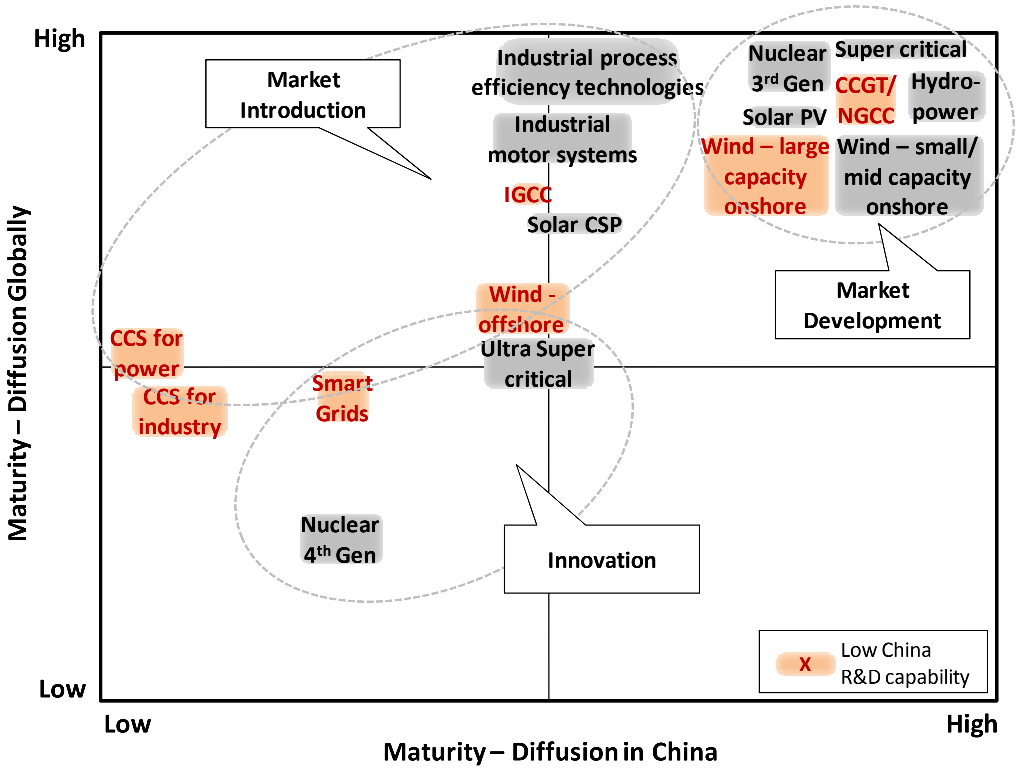
By applying the above framework to key low carbon technologies in the energy and emissions-intensive industry sectors (Figure 0.4), the transport sector (Figures 0.5) and the buildings and households sector (Figures 0.6) a view emerges of potential areas of cooperation. This highlights a number of emerging technologies in which China is at a similar stage of development compared to the global level, or where the global maturity of technologies provides opportunities for co-investment and co-development with China.

The remaining technologies fall within the Market Introduction and Market Development areas, in which the role of government in technology development is relatively low, and transactions will mainly occur among private companies. Opportunities in this case will mainly be driven by commercial channels for

[2] As noted as the start of the paper, Market Introduction could also happen in Europe for technologies that are more mature in China, e.g. solar water heaters or electric bicycles.

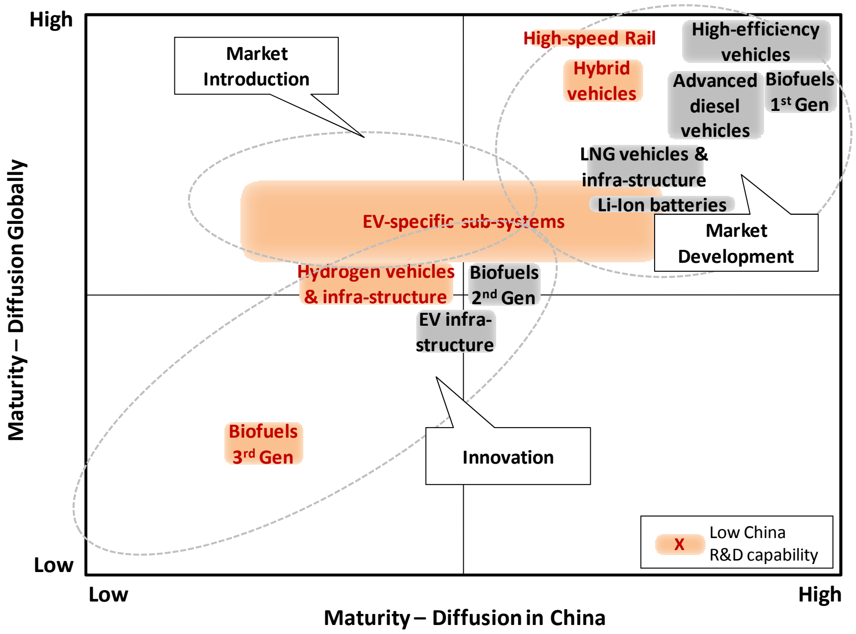
technology acquisition and transfer described above, while governments should provide an enabling environment to facilitate this.

Figure 0.4 Example of opportunities within the energy and industry sectors



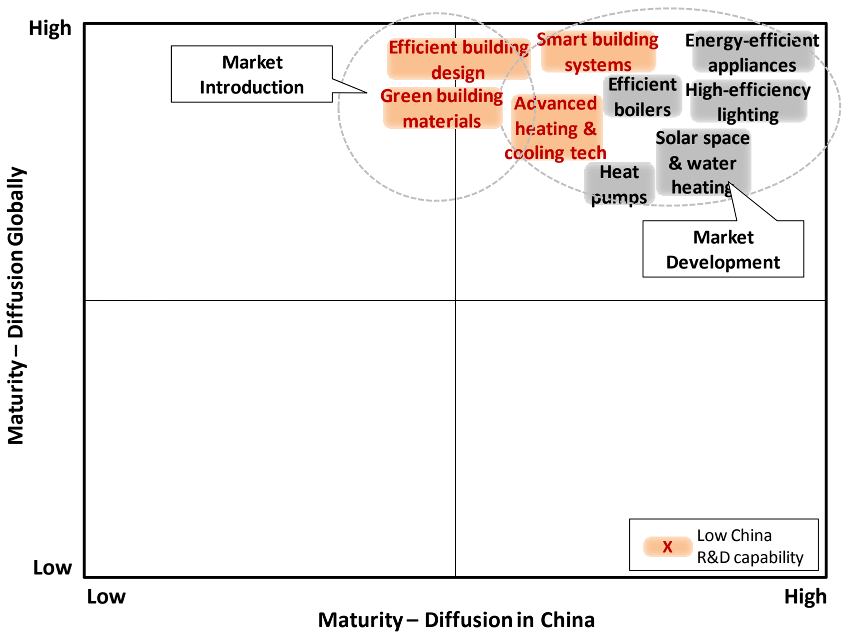
Source: E3G analysis

Figure 0.5 Opportunities within the transport sector



Source: E3G analysis

Figure 0.6 Opportunities within the buildings and households sector



Source: E3G analysis

Lessons from EU Experience

By examining EU capabilities as well as case studies and examples of how low carbon technologies have been developed, introduced into the market and broadly diffused, we draw ten key insights and lessons that are relevant to the three areas of cooperation defined above.

Innovation-focused opportunities

1. **The EU and China have very similar technology development agendas, providing opportunities for joint initiatives based on existing R&D platforms**

The EU and China have common interests in developing and commercialising new and emerging technologies, ranging from specific projects and initiatives (e.g. at university level) to large-scale programmes.

Mechanisms for cooperation in large-scale programmes have not yet been developed, however these can leverage existing platforms for public-private cooperation such as the SET-Plan's European Industrial Initiatives. Smaller-scale cooperation models such as Innovation China-UK (ICUK) provide practical lessons on how to develop effective win-win opportunities between EU and Chinese research institutions.

2. **Well-designed IPR management regimes can create the right conditions for collaborative R&D in the EU and China**

Despite the fact that IPR is a contentious issue in global climate change negotiations, EU and Chinese organisations are successfully using models to share and protect IP, enabling joint development and commercialisation of technologies.

Effective cooperation requires an IPR framework that is clear, but flexible enough to accommodate the rights and interests of the various parties involved. To be effective, a process of technology cooperation needs to be based on

> Clear rules that lay out the responsibilities and rights of different participants

> A governance process for agreeing the terms of cooperation and handling issues as they arise

3. Corporate R&D can be a mechanism for joint innovation between European and Chinese institutions when interests are aligned

Localisation of corporate R&D can provide commercial as well as knowledge spill-over benefits to foreign and local partners. Attracting the localisation of foreign corporate R&D requires investment in local capabilities and expertise, support for the domestic low carbon technology market, and implementation of policies and regulations that encourage companies to locate IP development activities in China.

4. Implementation of joint R&D initiatives requires 'hands-on' facilitation as well as incentives for joint commitment to ensure success

While identifying common areas of interest is relatively easy, making joint R&D collaboration work is very difficult. Specific challenges include:

- Cultural and language barriers
- Different systems of governance and funding in the research sector
- Lack of knowledge on where relevant expertise lies across a vast range of organisations
- Different expectations on the roles, responsibilities and benefits of cooperation

In order to overcome these challenges, a mechanism needs to be established to proactively facilitate communication and address issues as they arise through all stages of the process. This requires strong institutional and governance arrangements, as well as a strong team that is able to bridge the inevitable cultural, knowledge and process gaps.

Market introduction-focused opportunities

5. Technology access through commercial channels needs to be supported through market incentives

Mature low carbon technologies are accessible by Chinese companies through a number of commercial channels.

For manufacturers of low carbon technologies, this includes purchasing and/or licensing of core components and sub-systems when local technology isn't available (e.g. several domestic wind turbine manufacturers).

For users of low carbon technology such as companies in emissions-intensive industries, importing key plant and equipment is an option for upgrading and modernising their production processes. This can however represent a substantial expense to local firms that do not have the financial resources for this type of investment -- a particular challenge for small and medium-sized enterprises in China given their limited access to capital. Technology adoption is therefore often driven as a parallel effect of industry re-structuring, modernisation, and FDI.

Broad adoption of technologies by Chinese end-users will require a mixture of regulatory and financial incentives and support, which can be a focus of EU-China collaboration.

6. Acquiring technology through outbound FDI is an option for Chinese companies

In a similar way to companies in developed countries, Chinese enterprises are increasingly looking to invest abroad in order to acquire technology and enter new markets. This is both an opportunity for introducing technology into China, as well as a means to make the low carbon market more competitive.

At the government level, EU-China cooperation in this area should ensure market openness and transaction efficiency for mergers and acquisitions (in both directions).

7. Commercialisation of new technologies can be achieved through effective public-private cooperation and management of IPR issues

Public-private partnerships can provide effective structures for overcoming barriers to technology implementation and pushing broad diffusion beyond early adopters. Enabling several organisations to pool complementary expertise and capabilities can help to address cost-drivers and technical issues. IPR issues will also need to be managed to ensure effective collaboration, as discussed in Point 2 above.

Market development-focused opportunities

8. Investment in local capabilities and development of the local value chain is needed to promote diffusion in China and globally

EU experience has shown that development of a low carbon industry requires a mixture of private sector entrepreneurialism as well as public sector support in R&D and other areas to enable industry to grow and develop.

Chinese industry is now approaching the point in several areas of low carbon technology where further development requires deepening links between industry players in the supply chain as well as with the domestic research community. Growing local capabilities in R&D (both basic and applied) and engineering and management talent is crucial, and will have positive impacts on innovation and market development opportunities. This can, for example, take the form of local centres of technology excellence, coupled with mechanisms to diffuse know-how and IP developed within them.

EU-China cooperation can help develop local capabilities, as well as build links between industry in Europe and China. This will create opportunities for technology buyers and suppliers and help drive innovation and diffusion of low carbon technology in both regions.

9. FDI and open markets play important roles in continued diffusion of mature technologies

For China to continue developing its low carbon technology market, it needs to remain an attractive place for EU and other foreign companies to invest and do business. This provides domestic buyers with the choice they need, as well as spurring the improvement of local product quality and industry capabilities. Attracting high value-added FDI (i.e. beyond assembly) is particularly important for China given the eventual spill-over effects for its own industry as talent grows and flows between foreign-owned companies or JVs and local companies.

10. Establishing comprehensive performance standards for low carbon technology enables effective implementation and drives diffusion

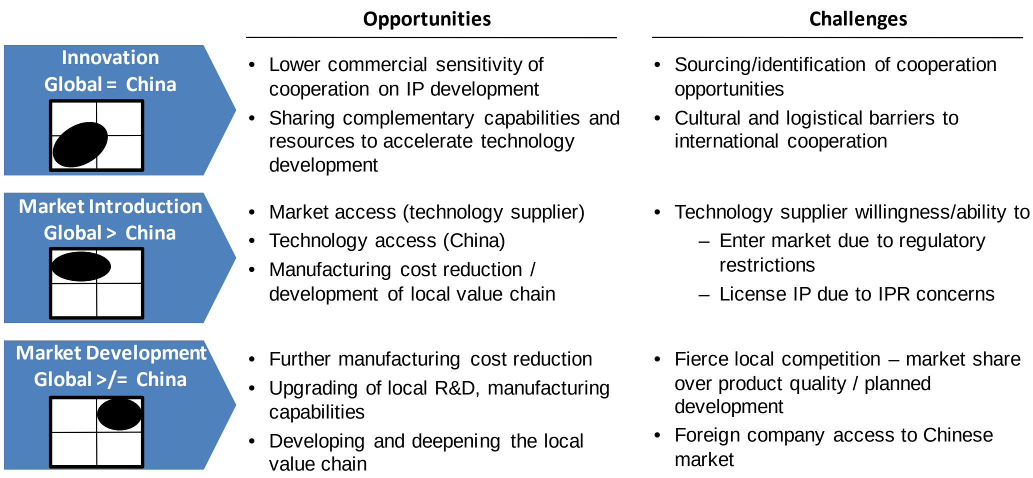
The harmonisation and implementation of low carbon standards within the EU has established a strong market incentive for industry that will drive technology development and diffusion.

Similarly, cooperation between the EU and China on performance standards relevant to energy efficiency and GHG emissions is mutually beneficial for the long-term development of the low carbon economy in both regions. The EU and China should continue to grow their engagement in this area, and position themselves as global leaders.

Models of cooperation

EU-China cooperation on low carbon technology can yield a number of win-win opportunities. Defining opportunities into three areas (innovation, market introduction, and market development) distinguishes the different requirements of each area and enables a more focused discussion of the key challenges.

Figure 0.7 Opportunities and challenges for cooperation



Source: E3G analysis

Depending on the area of cooperation, requirements can be defined around five key issues: technology and IP; financing; local capabilities; infrastructure; and regulations and policy.

Table 0.1 Key requirements for innovation-focused cooperation

Area	Requirements

Technology / IP	> Effective IPR management regime needed to address
	  > Sharing/exchange of complementary IP
	  > Joint creation of new IP and subsequent licensing/commercialisation
	  > Cooperation with private sector to commercialise technology

Financing	> Funding required for speculative activities of high technology risk > Mechanism required for identifying promising RD&D and allocating funds based on priorities
Local capabilities	> Qualified scientists and engineers > Standardisation and certification processes > IPR management for innovation and commercialisation
Infrastructure	> R&D infrastructure and facilities > Testing facilities > Proximity to centres of technology excellence
Regulations & policy	> Incentives for localisation of R&D (e.g. tax breaks) > Effective IP protection laws and enforcement > Strategic policies and integrated programmes for planning and coordinating R&D

Table 0.2 Key requirements for market introduction-focused cooperation

Area	Requirements
Technology / IP	> Mechanism to effectively and efficiently identify sources of technology, assessing suitability and negotiating agreements with IP providers > Effective and cost-efficient channels for accessing technology: imports, licensing > Effective IP protection regime providing guarantees to technology suppliers
Financing	> Financing market introduction activities for new technology > Funding of market uptake to address cost barriers for technology users (e.g. zero/low interest loans) > Provision of project finance for large infrastructure projects (e.g. power plants)
Local capabilities	> Engineering/technical skills to absorb and implement new technologies > IPR management for licensing and protecting IP
Infrastructure	> Electrical grid and transport/logistics infrastructure needed to implement large energy projects (e.g. wind farms, power plants) > Development of industry zones for new/emerging technology (facilitates future development and 'seeds' the creation of industry clusters)
Regulations & policy	> Policy targets and regulations (e.g. pollution regulations, renewable energy targets) > Effective IP protection laws and enforcement > Market incentives to drive uptake

Table 0.3 Key requirements for market development-focused cooperation

Area	Requirements
Technology / IP	> Effective IP protection regime providing guarantees to technology suppliers (domestic and foreign)
Financing	> Funding of local capacity-building > Funding market uptake (e.g. preferential loans, subsidies, feed-in tariffs)
Local capabilities	> Applied R&D for technology improvement > Manufacturing and systems integration > Marketing/sales and channel development > Management (planning, control, financial)
Infrastructure	> Development of industry networks and clusters to support localisation of supply chain (e.g. high-tech zones for low-carbon industries > Electrical grid infrastructure needed to implement new energy technologies
Regulations & policy	> Product performance standards (e.g. energy efficiency standards) > Policy targets and regulations (e.g. pollution regulations, renewable energy targets) > Effective IP protection laws and enforcement > Market incentives to drive uptake > Policies encouraging FDI and localisation of value chain

Potential models for EU-China cooperation

EU-China technology cooperation can take a number of forms depending on the area of focus, and the scope of requirements it seeks to address. It can also concentrate on a single technology field, or a portfolio of technologies. Nevertheless, some broad models can be considered based on the different objectives.

The key objective of innovation-focused opportunities is to **accelerate the development and commercialisation of new technologies**. This could be achieved through:

> Joint RD&D programmes and initiatives

> EU funding and support of Chinese innovation

The objective of market introduction-focused opportunities is to **enable relevant technologies to be identified and adopted in China**. This can be achieved by:

> Facilitating the licensing of technologies to Chinese companies

> Facilitating the entry of EU companies with innovative technologies into China

The objective of market development-focused opportunities is to **deepen capabilities and localisation of value chains in China in order to drive down technology costs and promote diffusion – globally and in China**. Potential models include:

> Development and harmonisation of policies, regulations and standards

> Attracting high value-added FDI and developing linkages with Chinese industry

Making it work – key success factors

Whatever the model employed, experience has highlighted three factors that are important to the success of any initiative:

Frameworks for managing and protecting IPR must be fit-for-purpose

The management and protection of IPR is a contentious issue within the international negotiations. It is clear that tackling climate change will require the protection of incentives for future innovation while accelerating the diffusion of low carbon technologies. At a practical level, companies and institutions have already developed models that enable them to successfully work together. The key is to ensure that responsibilities and relevant processes are clear and agreed upfront.

Incentives for joint collaboration need to be built into relationships

While collaborative agreements set the framework for a relationship, creating the right incentives is the key to success. A common means of doing this is through joint and equal investment by the partners involved, so that they have the same stake in the risks and benefits of the venture, and are encouraged to work towards the same outcomes. Joint ownership can however also create challenges in a relationship that need to be addressed through clear and agreed governance and decision-making processes.

The right level of institutional and organisational support needs to be provided

When the structure for cooperation is complex or the scope for problems arising due to communication, cultural issues or knowledge-gaps is large, an adequate support structure is essential. At the core of this structure should be a strong team that has the experience, knowledge and resources needed to address issues as they arise.

1 EU-China Technology Cooperation – Opportunities and Challenges

International cooperation for developing and diffusing low carbon technologies is a core element of the global effort to mitigate climate change. Cooperation enables existing technologies to be improved and new ones to be brought to market faster. It also accelerates the adoption of new technology by end users by improving access and reducing costs. As both a leading supplier and user of low carbon technologies, the EU has an important stake in this process. China equally has a crucial role to play as an important emitter of greenhouse gases (GHG), as well being a manufacturing hub and an emerging technology provider.

Both developing and developed countries have made detailed proposals on potential mechanisms that could be used to enable and accelerate access to key technologies[3]. These include inputs from China (as part of a G77 submission), as well as the European Union (EU). Key issues under discussion in the UNFCCC technology negotiations include:

> Joint research & development (R&D)

> Intellectual property rights (IPR)

> Financing

> Performance assessment

> Institutional arrangements

This paper focuses on low carbon technology cooperation between the EU and China. However, the themes and practical examples discussed can also inform the broader international debate on technology transfer for mitigating and adapting to climate change.

[3] Seligsohn et al. (2009)

The focus in the international negotiations is on technology transfer from developed to developing countries. Europe remains at the cutting of edge of innovation and diffusion of many low carbon technologies and much of the analysis in this paper focuses on opportunities to share best practice with China.[4] However it must be recognised that China is ahead of Europe in some areas (e.g. local diffusion of solar water heaters) and catching up fast in others. The future will increasingly be about a two-way flow of ideas and investment and joint R&D of new technologies.

A final caveat: this paper focuses on the specific role of technology in driving the low carbon transition. However this transition also depends on broader lifestyle changes and other forms of "social innovation" such as better urban planning. EU-China exchanges of best practice across this broader agenda must also flow both ways.

This chapter gives an overview of the opportunities and challenges to low carbon technology cooperation. Chapter 2 looks at China's technology needs by examining the scale and nature of change required, and defining a framework for understanding cooperation dynamics for different types of technologies. Chapter 3 draws lessons on technology development and cooperation mechanisms by discussing examples and case studies of EU experience and developments in China. Building on the previous chapters, Chapter 4 proposes high-level models for EU-China technology cooperation.

EU-China cooperation can produce a number of 'win-win' outcomes

From the EU's perspective, technology cooperation with China presents a number of opportunities:

> Access to China's market, with associated benefits to the EU economy and job creation

> Benefit to technology end-users and acceleration of low carbon transition in the EU due to China's influence on cost reduction through localisation of manufacturing and making the technology market more competitive

> Acceleration of new technology development by pooling resources and capabilities, leveraging China's growing know-how and emerging role as a supplier of technology

[4] Lee et al. (2009)

- Facilitating low carbon development in China provides global benefits in the effort to mitigate the impact of climate change

Similarly, from China's perspective cooperating with the EU also yields important benefits:

- Access to leading-edge technology to meet climate change mitigation and adaptation objectives
- Socio-economic development through job creation driven by FDI, exports, and the development of its own low carbon market
- Technological development through spill-over effects of international science and technology cooperation

Nevertheless, a number of challenges remain in fostering closer cooperation which need to be addressed. For both parties, this includes issues of market access and protectionism. EU-specific concerns also include IPR protection (discussed further below) and restrictions on EU companies' models of operating within the country, such as local content requirements. From China's perspective, an important preoccupation is to build up local capabilities and localise the technology value chain. Concerns on both sides may be valid, however the focus of this paper is on seizing the 'win-win' opportunities and 'growing the low carbon economic pie' for mutual benefit.

IPR management needs to achieve the dual objective of protecting the incentive to innovate and promoting diffusion of key technologies

The sharing of IPR as a means to promote technology diffusion is an important point in the debate on technology transfer. This paper does not take a specific position on this, but acknowledges that a dual objective needs to be fulfilled to ensure that

- innovation continues – hence the interests of current and future IP owners need to be properly addressed; and
- diffusion is effective – available technology must reach those who need it at the speed and scale required to meet the challenge

In the context of this debate, it is important to note that IP ownership is an important factor, but not the only one that impacts diffusion. For mature technologies, costs associated with manufacturing as well as service (e.g. maintenance and operation of plants) can be barriers to market adoption. Tacit know-how and capabilities also play an important role. Unlike other sectors such as pharmaceuticals, having the blueprint (or formula) may be a relatively small element in enabling technology to be reproduced.

IP for mature technologies is owned by companies, rather than governments. Developing mechanisms and incentives for technology transfer should therefore take into account private sector interests and ways of working. This includes using the range of commercial channels through which technology can be introduced into new markets, such as imports, licensing, and attracting FDI to localise manufacturing and R&D. These issues are examined in later chapters.

2 China's Low carbon Technology Needs

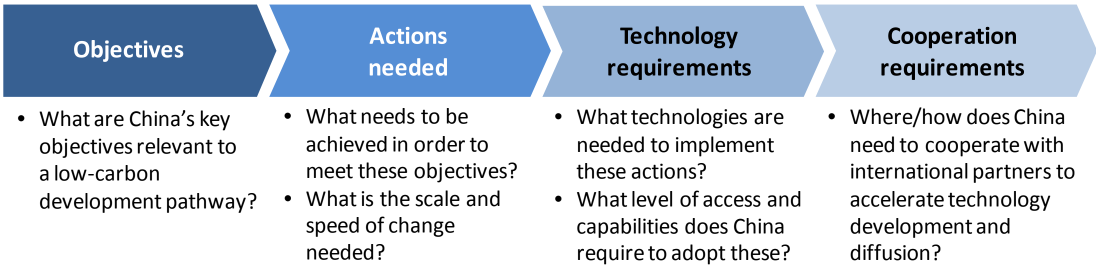
This chapter presents a view of China's low carbon technology priorities based on the country's own development objectives and its role within the global response to climate change. The first section presents the approach for defining China's technology needs. This is followed by an assessment of China's position with respect to key low carbon technologies, drawing conclusions on potential areas for international cooperation. The final section addresses some of the key challenges in meeting China's low carbon development objectives.

China is already engaged in developing an updated Technology Needs Assessment (TNA) in line with the process recommended by the UNFCCC. This chapter does not attempt to reproduce the detailed and in-depth effort of the TNA, or to pre-empt the results. Rather, it provides a framework for discussing technology cooperation models based on a high-level analysis of China's low carbon technology needs and priorities.

Defining China's low carbon technology priorities

An assessment of China's technology needs must begin with an understanding of its objectives with respect to low carbon development and the actions required to meeting these objectives. Figure 2.1 summarises the analytical framework used in this paper.

Figure 2.1 Assessing technology development and cooperation requirements



Source: E3G analysis

China is in the process of developing its long-term strategy for addressing the opportunities and challenges of climate change and low carbon development.

Key elements of this strategy are embedded within a number of government policies and plans, as shown in Table 2.1.

Table 2.1 Selected key policies and regulations related to China's low carbon development agenda

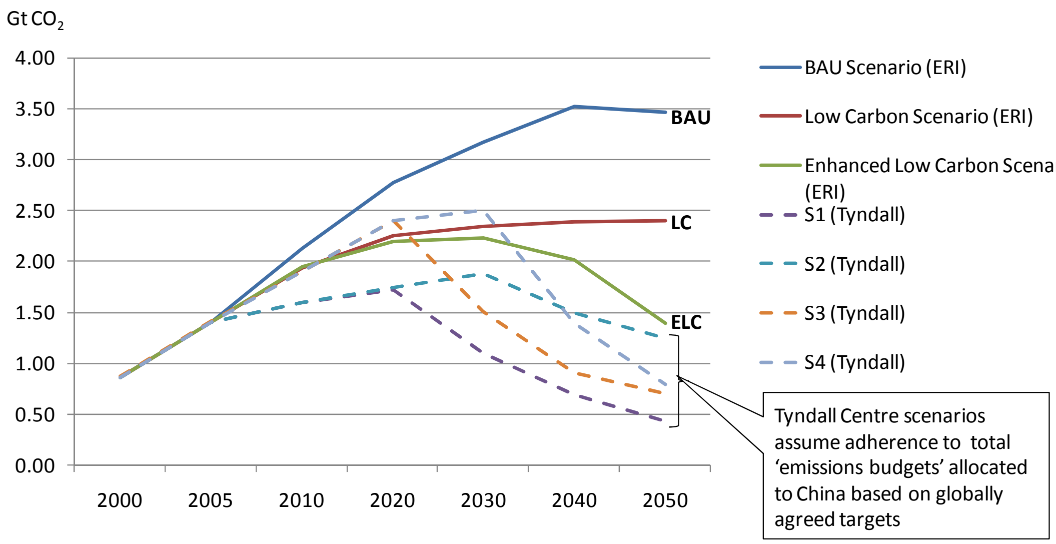
Policies & regulations	Key objectives
Medium and Long-term Science & Technology Development Programme (2006-2020)	> Defines key areas of research and development for the 2006-2020 period, including specific low-carbon technologies covering the following sectors: > Power (including coal, renewable energy and nuclear, as well related infrastructure such as smart grids) > Industry (energy efficiency) > Transportation (low-carbon vehicles and public transport) > Urban planning and buildings (energy efficiency, building design and related technologies) > Prescribes R&D investment in all areas required for innovation and development of these technologies such as design, manufacturing, and the development of advanced materials, key components and systems.
11th Five Year Plan (2005-2010)	> Cut energy consumption per unit of GDP by 20% > Cut major pollutant emissions by 10%, including reduction of 360 M tonnes of SO_2
Medium and Long-term Energy Conservation Plan (2004-2020)	> Coal consumption of coal-fired power generation should drop to 360g/kWh by 2010, and 320g/kWh by 2020
Renewable Energy Law (2007)	> Renewable energy share of China's primary energy demand should increase from 8% in 2006 to 15% in 2020 by meeting several targets for electricity generated from hydropower, wind, biomass, nuclear power and solar power

Furthermore, the Chinese government has begun to formulate new targets on reducing energy and carbon intensity, which will be incorporated within the country's 12th Five Year Plan[5]. The government has announced that this will include a reduction in carbon intensity of up to 45% by 2020.

In addition to current policies, China is beginning to establish a long-term view of its GHG emissions based on a number of critical development and technology choices it will need to take within the next five to ten years.

The Energy Research Institute (ERI), under the Chinese government's National Development and Reform Commission (NDRC) recently published a set of development scenarios and associated emissions profiles spanning the period until 2050[6]. A further study carried out by the University of Sussex and the Tyndall Centre for Climate Change Research provides an alternative external view of potential development paths and GHG emissions profiles[7]. The projected emissions profiles of both these studies are shown below.

Figure 2.2 CO2 emissions from fossil fuels in China (Gigatonnes of CO2)



Source: ERI; Tyndall Centre; E3G analysis

5 China Daily (2009)
6 Jiang K. J. et al. (2009)
7 Wang T. and Watson J. (2009)

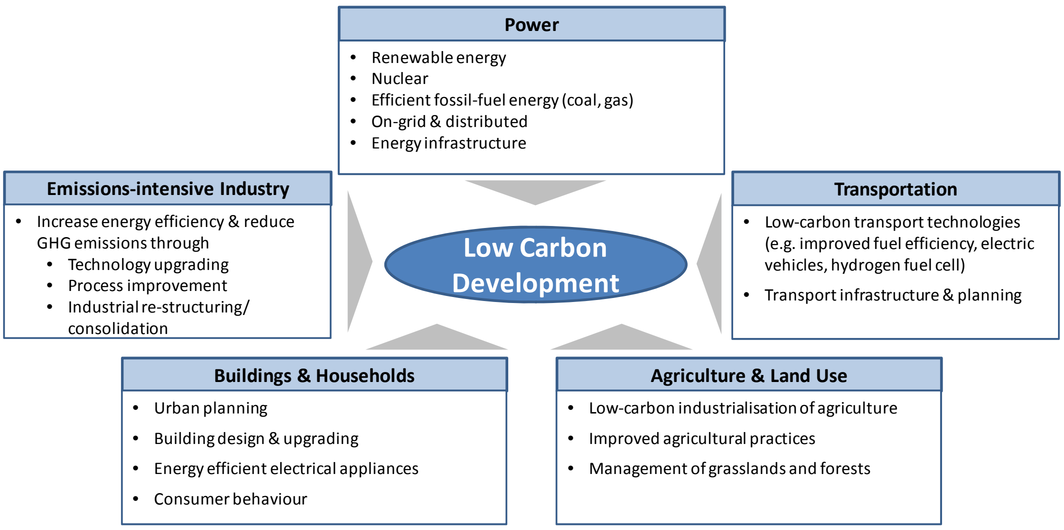
The ERI's Business-as-usual (BAU) scenario assumes the continued implementation of current policies referred to above. This is the baseline against which more ambitious low carbon development pathways are compared, as illustrated by the 'Low Carbon' (LC) and 'Enhanced Low Carbon' (ELC) scenarios. The Enhanced Low Carbon scenario in particular assumes greater use of Carbon Capture and Storage (CCS). The Tyndall Centre scenarios take a more top-down view, assuming China's adherence to an overall 'carbon budget' based on a global allocation across countries.

Unless otherwise indicated, the data and analyses shown below to illustrate the scale of change required are based on ERI's projections. These present the latest and most detailed study from a Chinese government organisation on possible development pathways and associated emissions projections.

China needs to implement a comprehensive set of technologies across various sectors in order to follow a low carbon development pathway[8]

In order to address its low carbon development objectives, China needs to take concrete actions across five key sectors, summarised in Figure 2.3.

Figure 2.3 Key sectors and areas of action needed to drive low carbon development



Source: E3G analysis

[8] Discussion of China's low carbon technology priorities and development pathways in this document is based on the Chinese government's current position and analysis by ERI. This includes the use of higher efficiency fossil fuel power generation (coal and natural gas) as well as nuclear power. It does not necessarily represent E3G's endorsement of any particular form of technology.

The net result of these activities would be a decrease of over 20% in total primary energy needs for the Enhanced Low Carbon scenario by 2050 compared to BAU (Figure 2.4), as well as a significant increase in power generated from renewable and 'cleaner' energy sources (Figures Figure 2.5 -
Figure 2.7). Specifically, for the Enhanced Low Carbon scenario, this includes:

> Significant increase in installed capacity of renewable energy: four-fold increase by 2020 (498GW) and eight-fold increase by 2050 (1,012GW) relative to 2005 levels (124GW), of which hydropower and wind power are the largest components

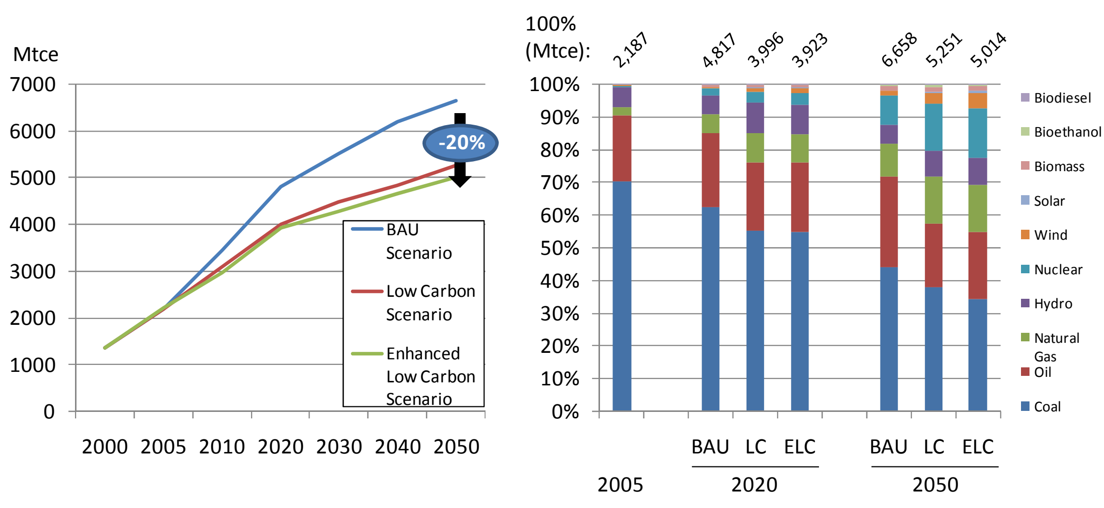
> Major increase in nuclear power installed capacity: from 9GW in 2005, to 69GW in 2020 and 388GW in 2050

> Increase in natural gas power installed capacity: from over 2GW in 2005, to 66GW in 2020 and 205GW in 2050

> Increasing penetration of more efficient coal-burning technologies (including super-critical, ultra-super-critical and IGCC), aiming at 40% penetration by 2020, and close to 100% penetration by 2050

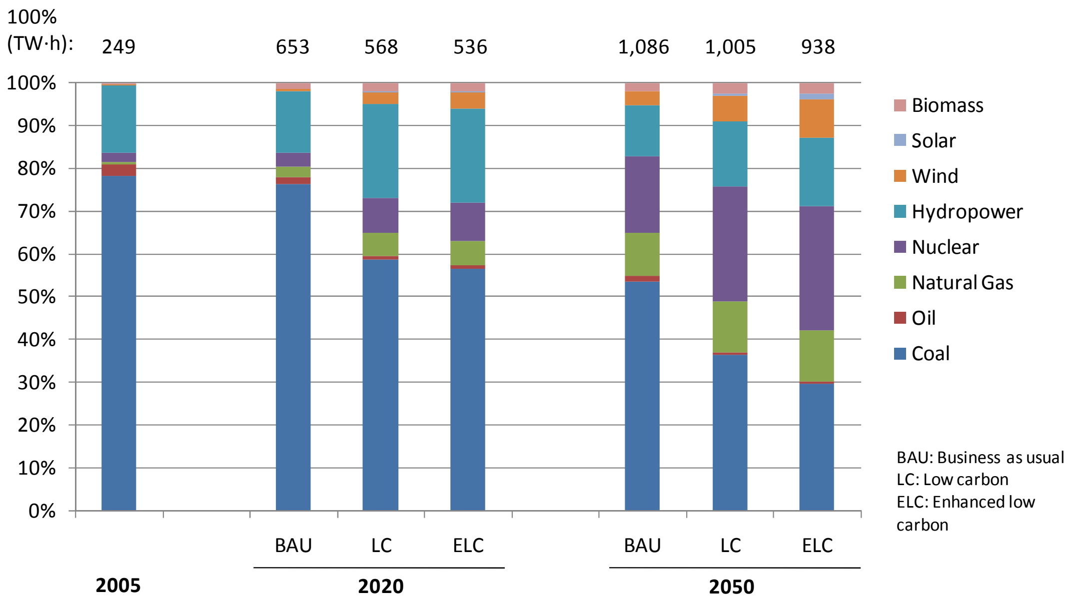
The projected net result will be to achieve close to 40% of power generated from nuclear and renewable energy by 2020, and nearly 60% by 2050 (Figure 2.5).

Figure 2.4 Primary energy needs projections and mix



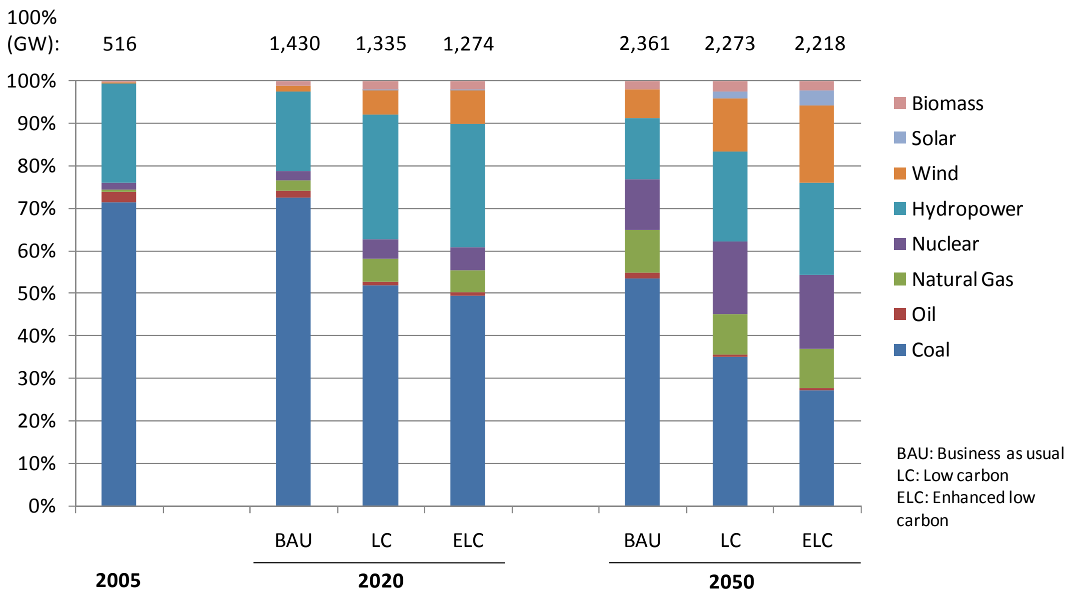
Source: ERI, E3G analysis

Figure 2.5 Power generated by source



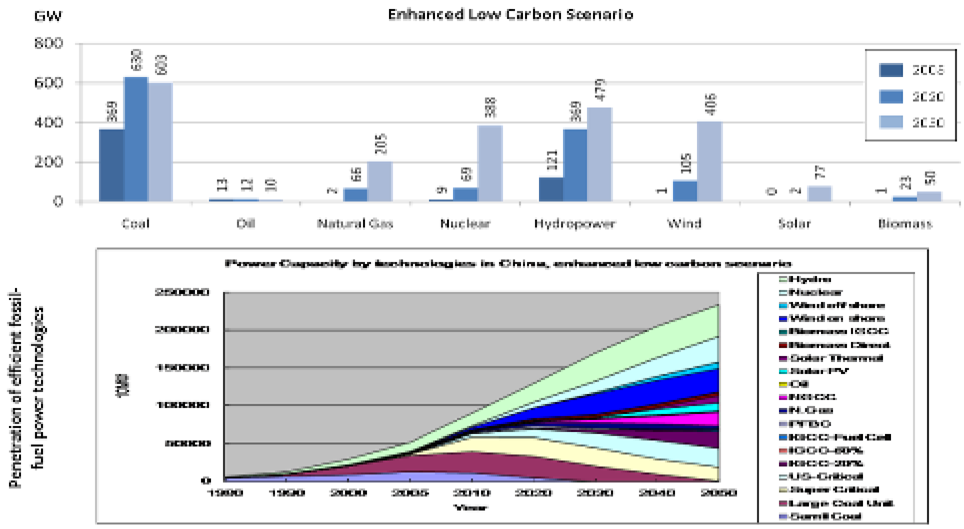
Source: ERI, E3G analysis

Figure 2.6 Installed power capacity by source



Source: ERI, E3G analysis

Figure 2.7 Installed power capacity – Enhanced Low Carbon



Source: ERI, E3G analysis

Additional reductions in greenhouse gases would be achieved by changing certain industrial production technologies (e.g. cement and iron), as well as by using CCS in the power and industry sector. CCS is not expected to become commercially available prior to 2020, but it contribute up to around 15% of total CO_2 emissions reduction in China post-2020 under certain scenarios[9].

Significant investment in low carbon technologies will need to be made over the next decade especially to avoid 'lock-in' to a higher carbon pathway. This is due to the long lifespan of investments made today in plants, buildings and infrastructure and the increased difficulty and high costs of retrofitting lower carbon solutions later.

[9] McKinsey & Co (2009)

Opportunities for cooperation

In order to meet its objectives, China needs to adopt and diffuse a number of low carbon technologies for which it has varying levels of access and capabilities

Preliminary assessments of low carbon technologies relevant to China are well documented [10]. Some of the major technologies and their benefits are summarised in Figure 2.8, segmented by sector.

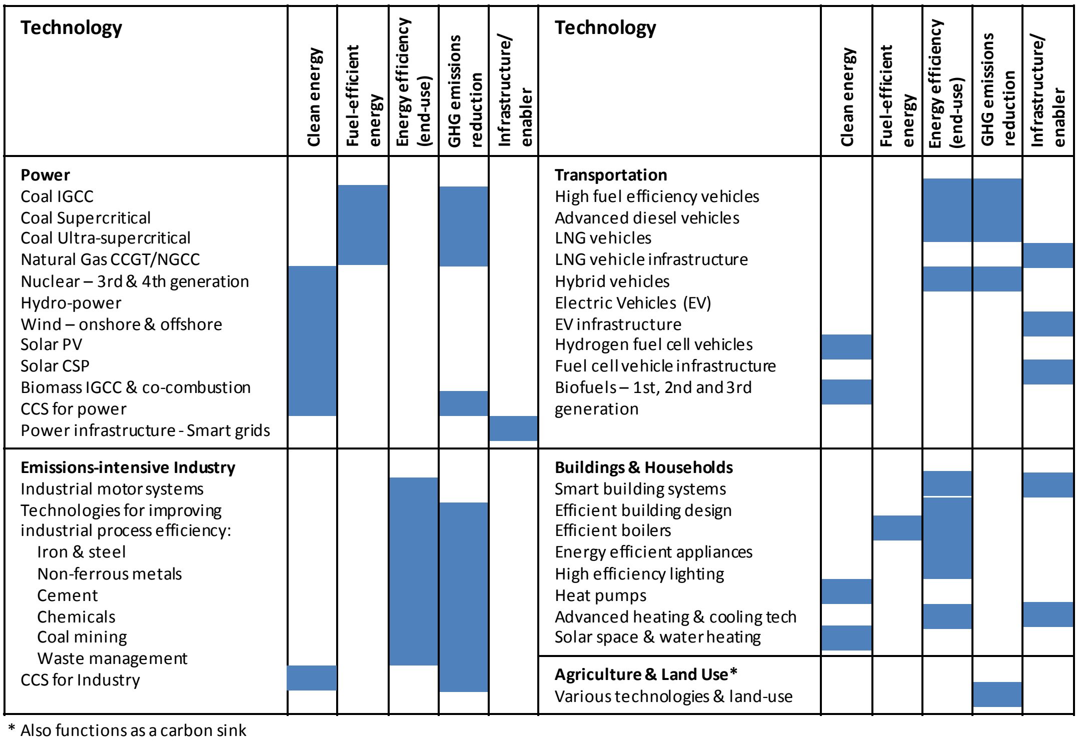
China's domestic capabilities with respect to these technologies and their level of diffusion within the country vary significantly. This presents important opportunities for international cooperation, which will be driven by:

- The gap between the technology's maturity and diffusion within leading markets (e.g. the EU), compared to the situation in China
- China's level of R&D, manufacturing and implementation/systems integration capabilities (where relevant) with respect to a given technology

These two issues determine China's access to low carbon technologies, and its ability to absorb and diffuse them.

[10] Jiang K.J. et al. (2009); The Climate Group (2009); Wang T. and Watson J. (2009); McKinsey & Co (2009): China Medium and Long-term Science and Technology Development Programme

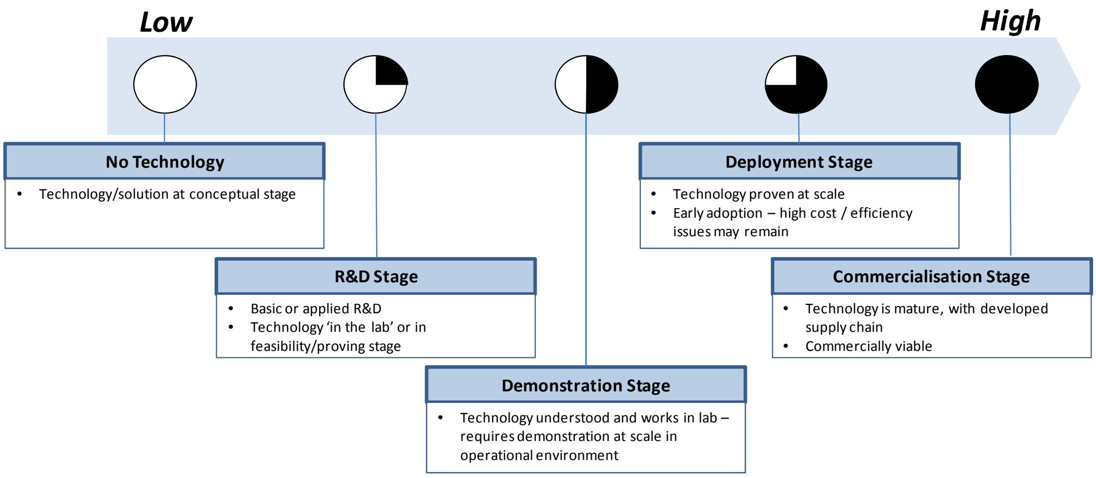
Figure 2.8 Selected key technologies for low carbon development



Source: E3G analysis

The level of a technology's maturity and diffusion within a market can be classified along five stages (Figure 2.9). It should be noted that, with respect to China, technology may reach the commercialisation stage through imports and FDI-driven manufacturing without necessarily building domestic R&D capabilities. Although this provides initial access to technologies, local capabilities need to be improved to drive further diffusion, as discussed later.

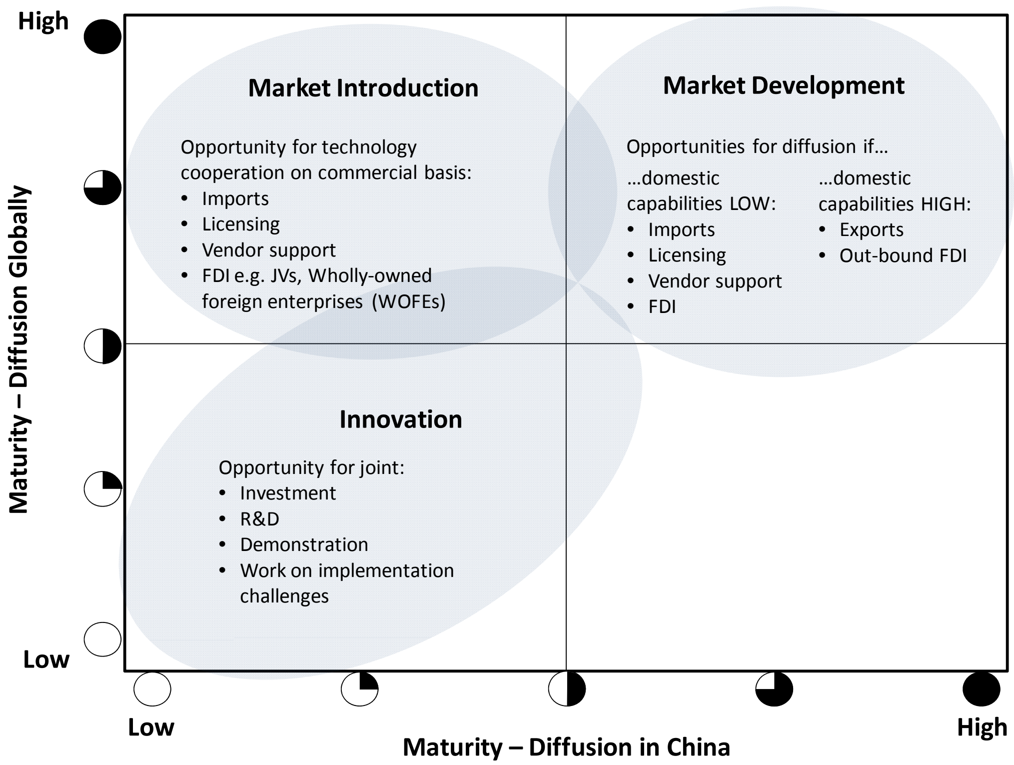
Figure 2.9 Low carbon technology maturity-diffusion stages



Source: E3G analysis

By assessing where the above low carbon technologies fall along this scale within China compared with global leaders, it is possible to distinguish three broad types of opportunities that EU-China cooperation can address (Figure 2.10): innovation; market introduction; and market development.

Figure 2.10 Areas of cooperation between China and global technology leaders[11]



Source: E3G analysis

In the Innovation area, technologies are at similar levels of maturity in China compared with global leaders. In this situation, there could be a common interest in joint development and cooperation to overcome financial and technical barriers to technology development and deployment. **The key opportunity of cooperation here is to accelerate technologies towards eventual commercialisation**. Examples include:

> Joint R&D and co-investment in early stage technologies (often involving a degree of government support as well as private sector participation)

> Initiatives to overcome technical barriers to deployment (usually between a consortium of companies and may also include research bodies)

Where China lags significantly compared to the global level, **the key opportunity of cooperation is to facilitate China's access to this**

[11] As noted as the start of the paper, Market Introduction could also happen in Europe for technologies that are more mature in China, e.g. solar water heaters or electric bicycles.

technology (Market Introduction). This can be achieved through a variety of channels such as imports, licensing, foreign direct investment in local manufacturing facilities (either JV or wholly-owned) and building domestic capabilities through technical support from foreign manufacturing equipment and component vendors.

Where a technology is mature and commercially available both globally and in China (Market Development), some or all of this technology will typically be manufactured in China. Nevertheless, in some cases China may have relatively low design and R&D capabilities (for example if key components or sub-systems are imported, or if Chinese manufacturing focuses on low value-added assembly). The opportunity here is to continue driving down costs through competition or by moving relevant parts of the value chain to China. Although domestic versus foreign ownership of core technology IP is not necessarily a key cost driver, improving local technology know-how is important. **Driving down costs of low carbon technologies will in turn support their widespread diffusion in China and globally**.

Viewing low carbon technologies within this framework enables a clearer understanding of China's requirements with respect to technology access, development and eventual diffusion/commercialisation. It also differentiates between the different types of cooperation that China needs to engage in. Figure 2.11 summarises some of the opportunities and challenges for international technology cooperation within each area.

Figure 2.11 Opportunities and challenges for cooperation

	Opportunities	Challenges
Innovation Global = China	• Lower commercial sensitivity of cooperation on IP development • Sharing complementary capabilities and resources to accelerate technology development	• Sourcing/identification of cooperation opportunities • Cultural and logistical barriers to international cooperation
Market Introduction Global > China	• Market access (technology supplier) • Technology access (China) • Manufacturing cost reduction / development of local value chain	• Technology supplier willingness/ability to – Enter market due to regulatory restrictions – License IP due to IPR concerns
Market Development Global >/= China	• Further manufacturing cost reduction • Upgrading of local R&D, manufacturing capabilities • Developing and deepening the local value chain	• Fierce local competition – market share over product quality / planned development • Foreign company access to Chinese market

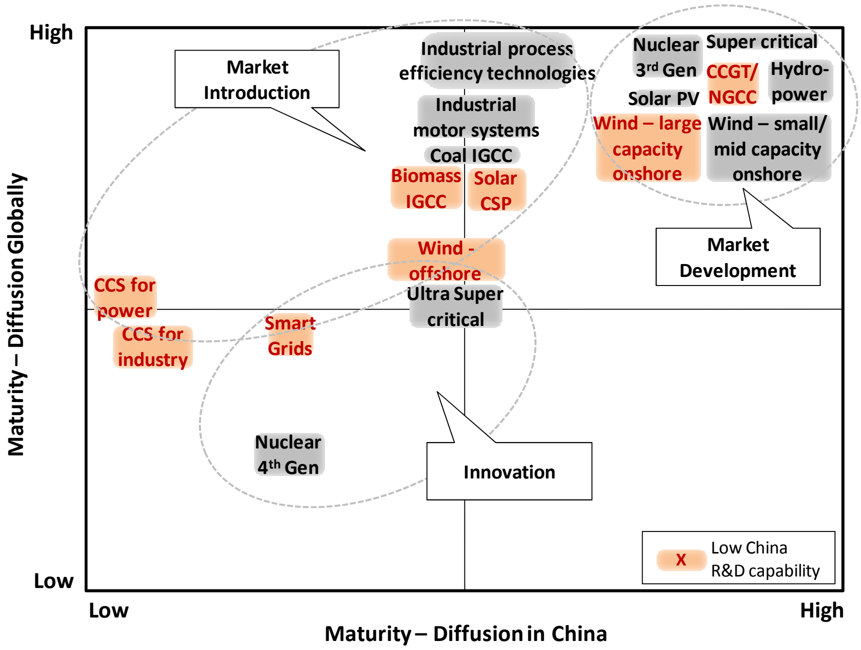
Source: E3G analysis

A number of low carbon technologies can be focal points for collaboration with China on development and commercialisation

By applying the above framework to the key low carbon technologies identified in Figure 2.8, a view emerges of potential areas of cooperation (Figures 2.12 to 2.14). This highlights a number of emerging technologies in which China is at a similar stage of development compared to the global level, or where the global maturity of technologies provides opportunities for co-investment and co-development with China.

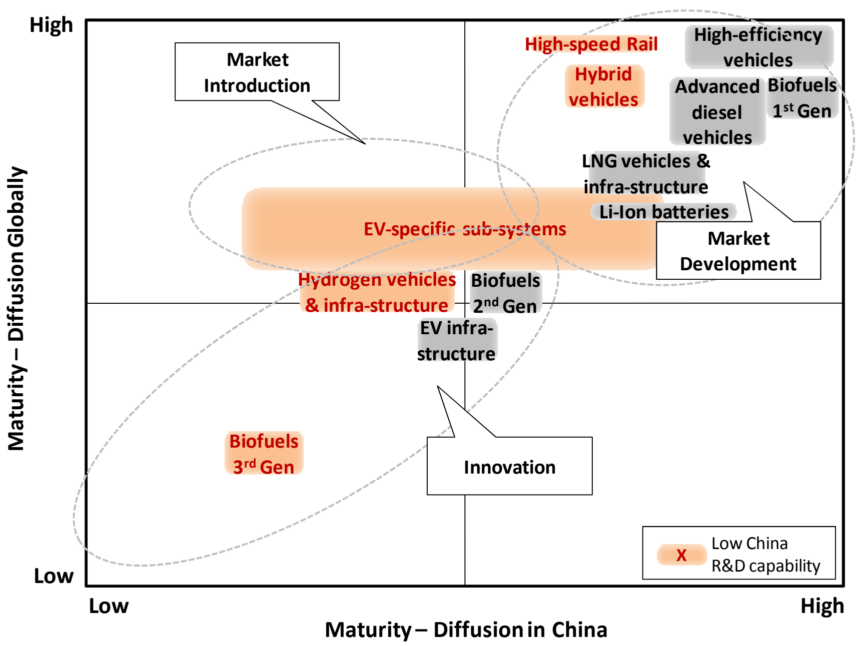
The remaining technologies fall within the Market Introduction and Market Development areas, in which the role of government in technology development is relatively low, and transactions will mainly occur among private companies. Opportunities in this case will mainly be driven by commercial channels for technology acquisition and transfer described above, while governments should provide an enabling environment to facilitate this.

Figure 2.12 Opportunities within the energy and industry sectors



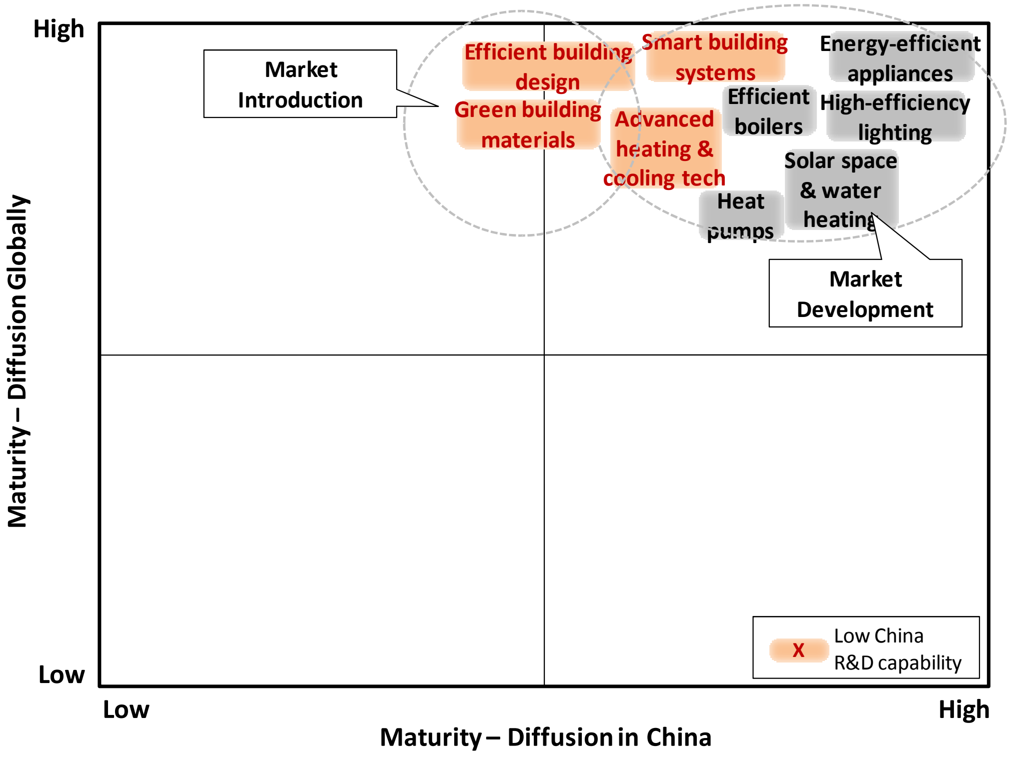
Source: E3G analysis

Figure 2.13 Opportunities within the transport sector



Source: E3G analysis

Figure 2.14 Opportunities within the buildings and households sector



Source: E3G analysis

Addressing China's technology needs

The cost of adopting and deploying low carbon technologies to achieve significant change compared with 'business as usual' will be substantial. Estimates place this figure at up to EUR 150-200 billion on average per year in incremental costs until 2030, and could reach 1.5-2.5% of China's GDP by that year[12].

A substantial amount of this cost will need to be offset by savings from increased energy efficiency to make this a realistic proposition. Investments will also need to include direct international financing of technology development and deployment. The share coming from government compared with the private sector will depend on the nature of cooperation along the technology innovation chain, from research to commercialisation.

[12] McKinsey & Co (2009)

Acquiring low carbon technologies is only one of several issues impacting the speed and scale of change needed to meet China's objectives. Further challenges are summarised in Table 2.2. Addressing these will require adequate resources, strong institutions, and targeted policies and regulations – all potential areas for international cooperation.

Table 2.2 Challenges to development and diffusion of low carbon technologies

Challenges	Issues	Enablers
Market risk (market demand / uptake)	> Product/solution cost > Lack of awareness > End-user behaviour	> Subsidies > Drive to localise manufacturing > Clear policies, regulations and communication
Technology risk	> Unproven technology (for immature technologies)	> Co-development > Co-investment
Domestic capabilities for technology absorption & diffusion	> R&D > Testing and certification > Manufacturing > Implementation/ systems integration	> Government-funded technology centres of excellence (Science & Technology infrastructure) > Attracting localisation of foreign corporate R&D > International R&D collaboration > Localisation of manufacturing > Joint-bidding for supply contracts
Infrastructure	> Quality and flexibility of electricity grid	> Infrastructure investment from local/international suppliers

Source: E3G analysis

3 Lessons from EU Low carbon Technology Development and Cooperation Experience

The EU has a long track record of developing low carbon technologies and markets. The purpose of this Chapter is to draw lessons from the EU's experience – both within Europe as well as with China. This will be done by examining selected examples and case studies relating to the key areas of cooperation identified in Chapter 2, namely: innovation, market introduction, and market development.

Innovation: Technology development and platforms for R&D cooperation

Development of new technologies and improvements on current low carbon solutions will be important drivers of future emissions reductions, particularly in the energy and transport sectors.

Large-scale low carbon R&D efforts face similar challenges globally, notably:

- Financial constraints and competing budget priorities of governments
- Limited resources and capabilities
- High levels of technology risk and uncertainty of outcomes
- Need for integrated strategic planning to coordinate numerous activities and achieve scale and impact

In order to address these issues, the EU has established the Strategic Energy Technology Plan, or SET-Plan, as a pan-European approach to low carbon R&D[13]. The purpose is to provide strategic direction and effectively coordinate the efforts of public and private sector players in order to achieve specific targets.

[13] The SET-Plan is part of the EU's Energy and Climate Change policy framework, and has been adopted as part of the EU's overall Energy and Climate Package.

China faces similar issues while also needing to reinforce its science and technology innovation infrastructure to meet the challenges of developing and absorbing new low carbon technologies[14]. China's Medium-to-Long Term Science & Technology Plan and other low carbon development policies referred to in Chapter 2 commit the country to developing low carbon technologies and expertise across several of the same priority sectors as in the EU SET-Plan.

The EU's SET-Plan provides a useful model for large-scale public-private technology development and is a potential platform for cooperation with China

The SET-Plan is a new model of cooperation, based on a collective approach to research, development and demonstration (RD&D) planning and implementation. The objective is to take a number of separate RD&D initiatives that were previously funded through independent national and EU-level programmes, and manage them through an integrated process.

At the core of the SET-Plan are a number of European Industrial Initiatives (EIIs) bringing together industry, the research community and government institutions (Member States and EC), into public-private partnerships. The EIIs are focused on accelerating the development of new technologies in specific areas, as shown in Figure 3.1 below.

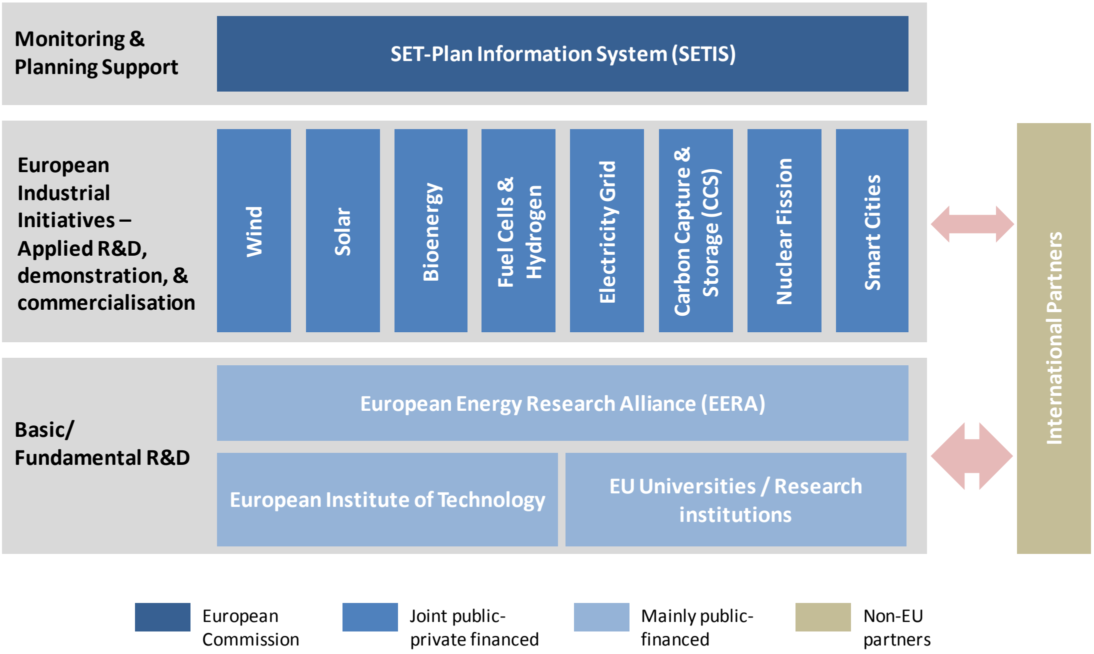
Underpinning the EIIs is a programme of fundamental research coordinated by the European Energy Research Alliance (EERA) which interfaces with key institutions in the EU research community.

Industry participation and funding is an important component of the EIIs, particularly for technologies that are close to commercialisation. Industry also has the opportunity to link with more basic R&D coordinated by the EERA, although funding will mainly be supported by public sector sources due to the more speculative nature of research at this level.

The SET-Plan presents an opportunity for strategic cooperation between the EU and international partners (including China). The opportunity is highest for areas where additional scale and complementary capabilities can help accelerate the development of technologies.

[14] OECD (2008)

Figure 3.1 Overview of the EU Strategic Energy Technology Plan (SET-Plan)



Source: European Commission; E3G analysis

Other mechanisms for cooperation that are integrated with the SET-Plan are the EU's Framework Programmes for Research, Technological Development and Demonstration activities. These are long-running programmes that that have traditionally been used to direct EU-level RD&D funding. The current Framework Programme (FP7) runs over the 2007-2013 period, and has earmarked €1.9 billion for environment-related RD&D (including climate change) and €2.35 billion for energy. Both budget lines are open for application by non-EU members, and China has begun engaging with the EU research community through these programmes.

A potential issue impacting technology cooperation will be the commercial sensitivity of the technology and know-how being developed. This will be greatest for technologies at higher levels of maturity that are close to commercialisation. This may therefore present a barrier for cooperation on certain activities within the Industrial Initiatives above. Nevertheless, this can be addressed through clear 'protect and share' IP arrangements, examples of which are discussed below.

Clear and agreed rules for IP management and protection support effective technology cooperation; co-investment also ensures equal stakes in a successful outcome

Issues surrounding IPR protection can become a barrier to innovation and cooperation if not properly managed. This is a particular challenge for the research community when technologies are at the stage of moving out of the lab and being developed for commercial applications.

In the EU, academic and research institutions are relatively familiar with the commercial value of IP. At times however this has become a stumbling block when they have tried to work with industry in order to commercialise innovations[15]. In China, the notion of IP protection in the academic and research community has not yet become as prominent, although this is gradually changing. The way in which some EU countries have tackled IP issues arising from R&D activities therefore holds valuable lessons.

The UK is an example of how an IPR regime has been developed to overcome IP protection issues, facilitating transfer of technology to industry and subsequent commercialisation. In 2004, an initiative involving the UK Intellectual Property Office developed a standardised set of model IPR agreements (also called 'Lambert Agreements') with the purpose of encouraging collaboration between universities and industry. The model agreements offer a spectrum of options around ownership and rights to use IP, designed to address the interests of different partners, including scope of licensing, scope of IP ownership (based on financial contribution by each party), and the rights of the academic institution to publish.

The type of IPR regime described above provides a potential framework for R&D cooperation between the EU and China. An example based on this model is Innovation China UK (ICUK), an organisation facilitating R&D cooperation between UK and Chinese research institutions across a range of areas, including low carbon technologies. This example is discussed in the case study below.

[15] HM Treasury (2003)

Box 1: Innovation China UK (ICUK) – Public-public international R&D cooperation

Innovation China UK (ICUK) was established in 2007 as the first UK-China partnership in the area of applied research. It has since then become one of the most successful initiatives in Europe of its kind, establishing a number of joint research projects with Chinese counterparts.

ICUK identifies technologies with commercial potential being developed by UK universities that would benefit from collaboration with leading Chinese institutions. The objective is to bring together parties from both countries that provide a complementary set of knowledge and capabilities in order to move a technology out of the lab and into the commercial space.

One of the crucial roles played by ICUK is to facilitate communication and 'match-making' between UK and Chinese institutions. This is enabled by the organisation's core UK team that mainly consists of Chinese professionals with deep subject-areas experience as well as experience of working within the Chinese research system during part of their careers.

ICUK has developed a two-stage model of funding cooperation initiatives:

> Partnership Awards are given to UK institutions to establish a working relationship with the Chinese partner by jointly exploring commercial feasibility and opportunities for the technology in question

> Proof-of-concept Awards may then be provided to take the technology to the prototype stage where it can be presented for commercialisation by an industry partner. Award of funds by ICUK is conditional on the Chinese counterpart receiving matching funding

The principle of matching funding for Proof-of-concept Awards provides each side with an equal stake in the joint initiatives and a guaranteed level of support to conduct the necessary activities.

As part of the funding process, both the UK and Chinese counterparts sign a Commercialization Partnership Agreement which clearly states each party's responsibilities with respect to research effort, commercialization activities, and the sharing of IPR. The core principle is that all IP arising from the collaboration is equally shared by the UK and Chinese institutions. The specific format of the agreements is flexible, and has used similar principles to those of Lambert Agreements.

Participation from industry is encouraged, but in this particular model industry sponsors do not have rights over IP arising from this collaboration in order to provide maximum flexibility as to choice of commercialisation routes. However industry partners can be given preferential access to results and have 'first refusal' over any licensing opportunities.

Over the two years since the initiative's creation, funding for over 30 'proof of concept' projects have been awarded, with over £2M in matching funds raised from Chinese sources. Results include the filing of 10 patents to date, and joint publication of numerous papers to disseminate R&D results and provide recognition to the participating institutions.

Private sector-led R&D cooperation on low carbon technologies can be promoted where corporate objectives are aligned with local capabilities and market conditions

Technology companies need to invest in R&D in order to remain competitive and support future growth. This tends to be in the 'applied' end of the R&D scale, where the link between technology and market applications is relatively clear, or where existing technologies need to be adapted for new markets. The SET-Plan's Industrial Initiatives discussed above seek to leverage private sector R&D investment, which in the EU reached over €1.6 billion for key low carbon technology areas in 2007[16]. Similarly, China has the opportunity to attract corporate R&D and enable Chinese research organisations to work with global low carbon technology leaders.

Companies localise R&D in new markets for a number of reasons, including:

> Need to develop or adapt products for specific local market requirements – locating R&D capabilities close to customers makes sense when the scale of the opportunity warrants it

> Access to talent – technology-focused firms with sufficient resources will seek the best talent globally

> Access to technology and know-how – similarly to accessing talent, companies will seek to locate R&D 'outposts' close to technology clusters as a means to absorb know-how and input into their R&D agenda

Concurrently, R&D localisation is enabled if

> local institutions have the relevant talent and capabilities attracting companies to recruit and collaborate

[16] European Commission (2009a). Low carbon technology areas include: hydrogen and fuel cells; wind energy; photovoltaics; concentrating solar power; carbon capture an d storage; biofuels; and smart grids

> government support and local market demand justify the investment

> local regulatory frameworks and institutions enable effective management and protection of IP arising from local R&D activities

A number of companies manufacturing products relevant to China's low carbon needs have begun to establish local R&D centres in China within high-tech development zones[17]. Corporate R&D localisation presents an opportunity, both for EU firms (for the reasons discussed above), as well as for Chinese counterparts to upgrade their capabilities and contribute to technology development at the global level. A case study of BP's experience in China is presented below.

Box 2: BP China – Public-private international R&D cooperation

Over the past decade, BP has been developing a range of interests in alternative energy and clean fossil fuel technology in response to global market and policy developments. BP Alternative Energy is currently active in several fields including wind power, solar PV, hydrogen power, advanced biofuels, and CCS. It has developed relationships with key players in countries that are either important markets for these areas, or have a strong technological base in them.

BP employs a range of technology collaboration models as part of its ongoing effort to improve and discover new technologies and processes that are core to its business, or are likely to be so in the future. This includes BP's Universities Programme, which collaborates with leading academic institutions globally in several areas, including alternative and clean energy. For example, significant US partnerships include

> USD 25 million funding over five years to the Massachusetts Institute of Technology (MIT) for research undertaken by the MIT Energy Initiative

> USD 500 million funding for a partnership between Berkeley University, Lawrence Berkeley National Laboratory, and the University of Illinois, establishing the Energy Biosciences Institute (EBI) to focus on advanced biofuels

BP's approach to collaborative R&D varies case-by-case, and is tailored to the risks inherent in developing technologies at different stages of maturity, as well

[17] E3G (2009)

as the level of internal versus external talent and capabilities. For example, in new and emerging areas where technology risk is high and the nature of investment is more speculative, collaboration will tend to be more open and less restrictive in order to share knowledge and pool resources from a variety of sources. The company has also been building a corporate venturing team to create insights and options in new areas with high disruptive potential.

BP's involvement in China dates back to the 1970's when it began licensing technology for chemical processing to Chinese companies.

In 2001 BP began to look to China as a potential source of technology that would be relevant to its business. This resulted in the establishment of the "Clean Energy: Facing the Future" programme in collaboration with the Dalian Institute of Chemical Physics (DICP), an institute of the Chinese Academy of Sciences (CAS), and Tsinghua University. The programme has received USD 1 million per year in BP funding for several areas of basic research in clean energy technologies. Outcomes include assisting the commercialisation of an ethanol processing technology relevant to biofuels.

In 2008, BP strengthened its relationship with CAS through a joint venture in which both have roughly equal stakes (49% BP, 51% CAS) – the Clean Energy Commercialisation Centre, based in Shanghai (Shanghai Bi Ke).

The centre's initial focus is in the commercialisation of lower emissions coal technology – an area of relevance to the Chinese market and in which CAS has existing expertise. The JV leverages CAS' access to IP within its own institutions as well as being an access point for other research organisations in China seeking to commercialise their IP. In this model, it is intended that technology suppliers maintain their rights on the original IP, while the JV company has rights over any new IP arising from commercialisation efforts. The JV and original IP suppliers are expected to share financial benefits through pre-agreed arrangements. Through this relationship, BP has the opportunity to access new technologies at an early stage and may provide support for developing commercialisation routes. In the same way, Chinese companies have similar opportunities if they co-invest in development and commercialisation activities.

As part of its R&D relationships, BP has provided its global expertise in IPR management and technology cooperation models. For instance, BP provided capacity-building support to DICP and CAS more generally, local IP suppliers and other partners to enable the activities to effectively develop and protect IP as it progresses towards commercialisation. This includes not only IPR management and protection, but also advice on the range of capabilities needed to provide a technology licensing service to partners (e.g. technical support and commercial guarantees).

BP also established a strong relationship with China Environment Fund (CEF), a leading venture capital group focused on clean energy solutions. China is fast becoming a hotbed of cleantech innovation in many sectors (e.g. solar, e-vehicles). The CEF relationship and the portfolio of companies they are invested in, provides BP with an excellent window on the fast evolving landscape and ability to spot trends and opportunities early.

Market Introduction: Commercialising new technologies and creating new markets

A key area for cooperation between the EU and China is introducing relatively mature low carbon technologies that are not yet widely deployed within China. Several commercial channels can be used for this purpose, as outlined in Table 3.1 below.

Table 3.1 Commercial channels for technology transfer

Channel	Description
Import	Chinese end-users purchase technology (e.g. equipment or plant) from foreign vendor. The vendor may also provide additional services to build/install, maintain and operate it.
Vendor and supplier support	Chinese companies may develop local manufacturing capabilities through support from vendors and suppliers. Vendors can provide manufacturing equipment and know-how for optimising processes. Foreign suppliers may provide key components, modules or sub-systems where local manufacturers do not have the technology or capabilities to manufacture these.
Technology licensing	A foreign technology supplier may license IP to a local JV or a Chinese company to manufacture and/or sell a technology. Licensing agreements can include requirements on IP protection, as well as guarantees to local manufacturers regarding technology support, licensing period, and level of exclusivity.
Foreign direct investment – Inbound	Foreign companies may establish local manufacturing capabilities, either as wholly-owned foreign enterprises (WOFEs) or joint ventures (JVs) with local partners. The rationale for investing in local manufacturing may be driven by the foreign company's desire to reduce costs, or to adhere to government 'local content' requirements. Foreign companies may also establish local sales and distribution operations as part of the import channel (as WOFEs or JVs).
Foreign direct investment – Outbound	Chinese companies may purchase foreign firms, in the process acquiring proprietary technology as well as R&D, design and manufacturing capabilities, brand equity, and sales/distribution channels.

Source: E3G analysis

As discussed in Chapter 2, there is potential for several key low carbon technologies to be introduced and further deployed in China in the energy, emissions-intensive industry, transportation, and buildings and households sectors.

In the emissions-intensive industry sector, EU companies have been involved in introducing advanced industrial process technologies into China enabling local companies to increase energy efficiency and reduce GHG emissions. In the cement, chemicals, and iron & steel industries, this has been particularly driven by localisation of manufacturing plants utilising advanced technologies, or selling plant and equipment to Chinese companies. This is illustrated by companies such as Lafarge (cement) and BASF (chemicals) locating plants with efficient process technologies in China. The case study below discusses Lafarge's experience in China.

Box 3: Introduction of low carbon technologies in the Chinese cement industry

Lafarge is the largest manufacturer of cement globally, and is also one of the largest manufacturers of other key materials for the building industry. Lafarge's activity in China began in 1994 with the establishment of a JV in cement (Chinefarge). After acquiring a controlling stake in a JV with Shui-On, Lafarge is now one of the top cement manufacturers in China. The company's operations in China mainly serve the domestic Chinese market. Table 3.2 summarises Lafarge's activities across its four businesses in China.

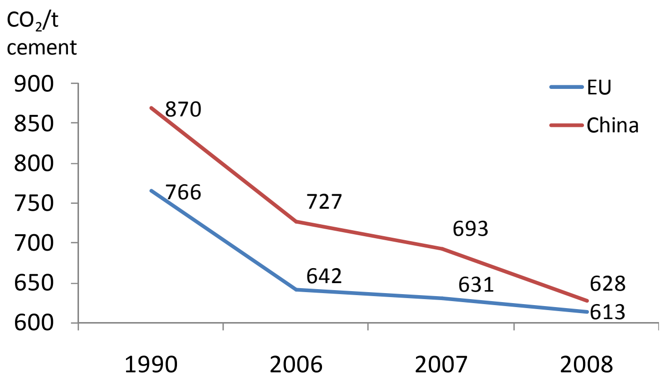
Table 3.2 Lafarge operations in China

Business	Facilities
Cement	17 plants across Beijing and provinces of Sichuan, Yunnan, Chongqing and Guizhou
Aggregates & concrete	1 readymix concrete plant in Beijing
Roofing	6 concrete roof tile plants in Sanshui, Shaoxing, Beijing, Nanjing, Qingdao, and Chengdu
Gypsum	3 plasterboard plants in Shanghai and Chongqing

Source: Lafarge

Lafarge has reduced CO_2 emissions from its China plants by modernising operations and investing in new technology. After the merger with Shui-On's China business in 2005, Lafarge closed 38 old kiln lines, replacing these with eight new lines at a cost of RMB 3.6 billion (over €400 million). This has enabled Lafarge to deliver a 20% decrease in CO_2 emissions per tonne of cement produced in its Chinese plants since 2005 – with current performance close to parity with EU levels (Figure 3.2).

Figure 3.2 CO2 emissions reduction from Lafarge cement operations in China and the EU



Source: Lafarge (2008)

One of the drivers for this improvement has been the implementation of waste heat recovery systems installed in Lafarge's Nanshan, Gongxiang and Kaiyuan plants, each costing RMB 60-90 million (€7-10 million). This investment has reduced emissions at each plant by 70-90 thousand tonnes of CO_2 per year. In addition, most of Lafarge's plants are adapted to the use of alternative raw materials, such as the use of waste gypsum from coal-fired power plants.

Lafarge's investments in China are aligned with its own cost and operational efficiency requirements and are part of an overall drive to rationalise and modernise its operations. This illustrates how the introduction of modern technology, in conjunction with industry restructuring, can lead to energy efficiency improvements and GHG emission reductions.

Introduction of low carbon technologies in the Chinese iron & steel industry

In the iron and steel sector, a number of EU companies have also transferred energy-efficient and low carbon technologies to Chinese steel companies. For example, Siemens recently signed a contract with Maanshan Iron & Steel Company Ltd. (Masteel) to install a Meros (Maximized Emission Reduction Of Sintering) plant at the company's facility in Anhui province. This will enable reduction of sulphur dioxide emissions, as well as other pollutants. In other cases, technology suppliers from the UK, Germany, Denmark, Sweden, Italy and

Switzerland have transferred technologies to 11 of the top 30 Chinese steel producers through the CDM mechanism (Table 3.3).

Table 3.3 Selected technologies transferred by EU companies to Chinese steel manufacturers (2007-2009)

Technology Transferred	Technology Source
Coke Dry Quenching (CDQ) Waste Heat Recovery	> 22 CDM projects in the steel sector
Blast Furnace Gas Combined Cycle Power Plant	> Annex 1 countries involved: UK, Germany, Denmark, Sweden, Italy, Switzerland, Japan
Sinter Machine Waste Heat Recovery	
Waste Saturated Steam Recovery and Generation	

Source: E3G analysis

Significant progress is needed to enable Chinese industry to adopt new technologies. Given the substantial cost, adoption will be driven by government regulations and financial support, as well as industry-wide dynamics underway in certain sectors of the Chinese economy (e.g. restructuring and consolidation of inefficient companies).

Acquiring technology through outbound FDI

Chinese firms are increasingly able to scout for and acquire foreign companies in order to gain access to technology and foreign markets. On the one hand, large Chinese corporations have the financial clout to execute acquisitions either through their own funds, financial backing from the Chinese government, or participation of local and foreign private equity investors. On the other, the global financial crisis has opened up opportunities to buy firms that are struggling or whose market capitalisations have been depressed.

An example of outbound FDI is Goldwind, the leading Chinese manufacturer of wind turbines that acquired a stake in a German company Vensys AG, described below.

Box 4: Outbound FDI – Technology acquisition by Chinese wind manufacturers

In 2008, Xinjiang Goldwind Science & Technology Co. (Goldwind) acquired a 70% stake for €41 million in Vensys AG, a German wind turbine manufacturer that previously licensed technology to Goldwind. The purchase enabled Goldwind to acquire core IP in direct-drive turbine technology, as well as IP in converters and variable propeller systems owned by a Vensys subsidiary.

Future development plans include building a €5 million wind turbine manufacturing plant in Germany through the acquired company, providing a further foothold for Goldwind in the European market.

The Vensys acquisition has enabled Goldwind to internalise core technology as well as gaining a strategic advantage on competitors that also licensed technology from Vensys. It will also enable Goldwind to build its capability for offering higher-capacity wind turbines.

Deployment of new energy technologies – Experience in the EU

The EU also has experience in driving the deployment and commercialisation of low carbon technologies in areas that are less mature. Public-private initiatives and private-sector consortia have been established to jointly address common technology implementation issues and accelerate commercialisation. An example of this is in the area of offshore wind, where several major companies have joined forces under the umbrella of an initiative partly funded by government. This is discussed in the case study below.

Box 5: Technology commercialisation through collaboration – ETI's offshore wind initiative

The Energy Technologies Institute (ETI) is a public-private initiative funded 50:50 by the UK Government and its Industry Members. Member companies provide matching funds and have a seat at the ETI Board. They currently include EDF, E.on, Rolls Royce, Caterpillar, Shell and BP. ETI projects focus on existing technologies where proof of concept already exists, and takes these to large-scale demonstration. The objective is to make technology ready for full-scale commercialisation by private sector, and be eligible for separate follow-on funding targeted at technology diffusion (e.g. through other government organisations and programmes). Technologies and sectors within the ETI's remit include offshore wind, marine energy, carbon capture and storage (CCS), transport, energy networks, distributed energy, and buildings.

Cooperation and IPR management model

ETI manages the process for allocating and using IP arising from projects. Project participants enter into a Technology Contract with ETI which governs how IP issues arising from project deliverables are dealt with. These are adapted to fit the needs of particular projects, and address issues such as: ownership of arising IP; participants' rights to exploit arising IP; and licensing of pre-existing IP required to conduct projects and exploit arising IP derived from it.

Royalty-free 7-year licences are granted to ETI Industry Members. Similar rights are granted to other project participants depending on the proportion of financial contribution they bring to each project.

After a 7-year period, licences become non-exclusive, and revert to an agreed mechanism to enable continued exploitation of the IP. University participants in projects generally have the right to use arising IP for academic, non-commercial purposes.

Accelerating offshore wind technology

ETI and the UK's Carbon Trust jointly launched a £40M programme in 2007 to cut the costs of offshore wind power and accelerate its deployment around the UK. A number of energy companies are involved as part of this programme, including DONG Energy (Denmark), Airtricity Developments (UK), RWE Innogy (Germany), ScottishPower Renewables (UK) and StatoilHydro (Norway). The programme's goals are to:

> Reduce the cost of offshore wind energy to at least the prevailing least-cost wholesale price of electricity

> Increase yields to 97- 98% or better, equivalent to onshore wind

> Reduce risks related to technical uncertainties, enabling wind farms to be financed in a manner equivalent to onshore wind

> Reduce technical barriers to large-scale offshore wind deployment

The ETI offshore wind programme is funding projects in the following areas:

> Design and demonstration of novel offshore systems, including technologies that are fundamentally different to those currently being deployed. This

includes offshore-specific wind turbine designs and systems for deep-water installation

> Improvements to existing technologies, to enable large-scale deployment and improve wind farm design, construction (e.g. foundation structures), operation (e.g. access methods), and reliability

> Supporting studies on other issues critical to deployment, e.g. mapping offshore wind resources, improved environmental impact assessment methods and construction health and safety

Market Development: Diffusion of mature technologies, deepening capabilities and riding down the learning curve

A number of low carbon technologies have reached the commercialisation stage in China, and are accessible to the local market in the same way as they are in the EU and globally. These include super-critical coal power, solar photovoltaics, nuclear (3rd generation), on-shore wind power and other technologies discussed in Chapter 2.

Many of these technologies reached the Chinese market through the commercial channels described in Table 3.1 above. Although China has access to these, there remains a significant opportunity for both foreign and Chinese firms to drive further sales and diffusion of these mature technologies. In particular, cost reduction through further localisation of manufacturing (e.g. beyond simple assembly of parts) is an important factor. Other aspects impacting the level of market uptake and diffusion are regulatory requirements, customer awareness, and direct or indirect government subsidies to incentivise the purchase of low carbon products and services.

Furthermore, two key areas of public-private cooperation that are important for market development are the strengthening of domestic industry and research capabilities, and establishing technology performance standards (e.g. energy efficiency). These are discussed in more detail below.

Developing a mature domestic industry requires investment in local capabilities

Deepening local capabilities is key to improving cost, quality, and reliability of technology, and providing value-added services such as systems integration, maintenance and operation (where relevant). The challenge of doing so is illustrated by the development of the Chinese wind power equipment industry.

While international wind turbine manufacturers such as Vestas, Nordex and RE Power originally entered the Chinese market as the main suppliers to wind farm operators, Chinese firms such as Goldwind now dominate with 60% market share[18]. Drivers of this shift towards local suppliers include government local content requirements and market access issues, prompting multinationals to set up manufacturing operations and JVs in China. In addition, licensing of core technologies to local manufacturers by European and US companies has also been a key factor in developing a domestic manufacturing base, as illustrated in Table 3.4. In some cases, Chinese companies have also obtained technology through acquiring foreign companies (as discussed in

[18] Wind Energy Update (2009)

Box 4 above).

Table 3.4 Selected examples of wind technology licensing to China

Supplier	Country	Licensee	Technology
RE Power	Germany	Goldwind, Dongfang Electric, A-Power	Turbine
Fuhlander Corporation	Germany	Baoding	Turbine
Nordex	Germany	Xian	Turbine
Jacob	Germany	Goldwind	Turbine
Norwin	Denmark	A-Power	Turbine
GE	USA	China High Speed Transmission	Gearbox

Source: Wind Energy Update

Although local turbine manufacturers dominate the Chinese market, their products are not yet on par with foreign companies in terms of quality, reliability, longevity and design. Furthermore, Chinese companies do not yet have the capabilities to manufacture large capacity wind turbines needed for optimal power generation in high-wind conditions. From the perspective of China's energy objectives, these issues may impact the quality of wind power generation. From the perspective of the domestic industry's competitiveness, this will present challenges as Chinese buyers become more discerning and market-oriented in their purchasing criteria.

Although specific to the wind industry, similar issues can arise in other technology sectors as China develops its domestic low carbon market. In order to address these, China must develop local capabilities across the value chain from technology development through to manufacturing and systems integration. The case study below of how Denmark has developed and sustained its wind industry is a good illustration of the type of actions that can be taken.

Deepening and strengthening local capabilities is an opportunity for China as well as for foreign companies and buyers of technology. For example, this will provide EU industry with the opportunity to draw upon local expertise and low-cost manufacturing capacity. Driving down the cost of low carbon technology is of global benefit given the level of investment needed to meet climate change targets. In China, this requires relatively open markets so that it remains an attractive place for foreign investment, and to ensure that competition is driven by quality as well as cost.

Box 6: Denmark's Wind Industry – Growing and deepening an industry value chain

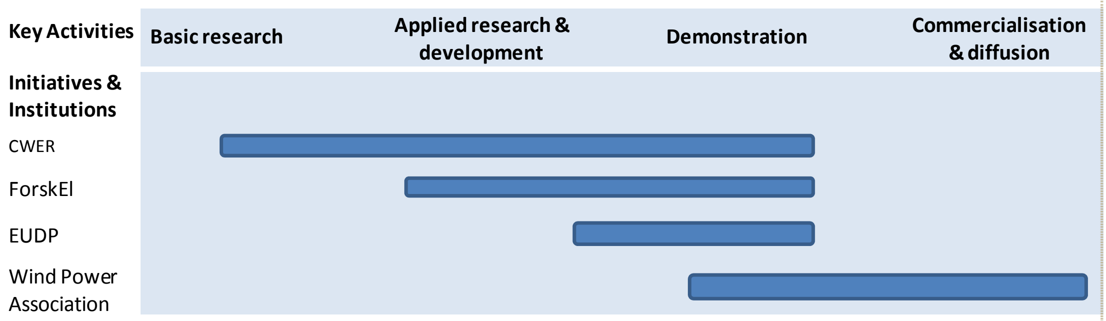
The development of the Danish wind power industry has been characterised by close collaboration between the public and private sector in research, development and demonstration.

Government-backed R&D provides the initial know-how and continues ensuring technological spill-over to industry

The government-funded Risø National Laboratory was instrumental in the early years of large-scale wind turbine technology development (1970s and 1980s) in providing the research infrastructure and technical expertise (e.g. for R&D and standards development) that enabled the technology to become fully deployable domestically and internationally. In effect, the laboratory functioned as a technology service facility at the time when individual companies did not have the resources to undertake significant R&D themselves. The Danish Energy Authority has been a key source of public sector co-financing for a number of R&D projects between the Risø National Laboratory and Danish producers of wind turbines.

Two other government-backed programmes also serve as funding channels for RD&D in wind as well as other low carbon technologies – the ForskEL Programme and the Energy Technology Development and Demonstration Programme (EUDP). Figure 3.3 summarises the activities of these and other key players in the Danish wind technology value chain.

Figure 3.3 Key technology cooperation players in the Danish wind and low carbon industry



With growth of the sector, the focus of government support for technology development has expanded from R&D to encompass education and development of technical talent

The Danish Consortium for Wind Energy Research (CWER) was established in 2002 with funding from the Danish Energy Authority's Energy Research

Programme, to have responsibility for coordinating most of the wind energy-related research in Denmark, as well as providing education and technical consulting services. CWER brings together a core of basic and applied R&D and education capability with participation of the Risø National Laboratory and other academic and research institutions. CWER plays a central role in supporting technological development to maintain leadership in wind and growing the engineering talent pool needed by industry.

Supporting technological development to maintain leadership in wind

The Consortium is focused on delivering technological and economic outcomes from its activities that directly benefit the industry. These include:

> Continued cost reduction (e.g. turbine design and construction)

> Developing technology to ensure reliability, construction and maintenance of offshore wind farms

> Better integration of wind energy into the power grid

> Developing the key technical sciences underpinning wind energy development (e.g. blade aerodynamics, structural design and materials)

Developing and growing the engineering talent pool needed by industry

The Danish government and industry are jointly addressing the human resource requirements needed to sustain technological leadership in the wind sector. Key issues identified include the need for training a larger number of qualified engineers; continuous technical training of industry staff; and greater integration of research within education programmes.

CWER and the Danish Wind Industry Association (DWIA) are addressing the talent shortage in two ways. Firstly, DWIA is spearheading an awareness campaign targeted at engineering students. In parallel, CWER is leading an effort to ensure that new knowledge developed through R&D is fed back into national-level higher education institutions. The purpose is to promote the development of centres of competence with sufficient critical mass to sustain world-class education and research programmes.

CWER has been used as a model for collaboration between research institutes and universities and has inspired similar structures within other European countries. One outcome has been the development of a European network – the European Academy of Wind Energy – in which CWER is the Danish node.

Cooperation mechanisms enable key public and industry players to work towards a common agenda, develop a thriving industrial value chain, and enable continuous technological improvement

Megavind Partnership

The 'Megavind' partnership was established in 2006 to strengthen public-private cooperation between government, businesses, research institutions, and venture capital. The Partnership is responsible for defining a common agenda for research, development and demonstration to guide and inform the work conducted by all major technology players.

Vindkraftnet Innovation Network for SMEs

'Vindkrafnet' was set up with funding from the Danish Ministry of Science, Technology and Innovation as a networking forum for SMEs and R&D institutions in the wind technology and components sector. The purpose is to reinforce the wind technology value chain by providing the following benefits:

> 'Matchmaking' between SMEs and the research community

> Learning and knowledge-sharing including courses, workshops, seminars targeted at wind industry players

> Dissemination of information on relevant technology developments

Both the Megavind and Vindkraftnet are hosted by the Danish Wind Industry Association.

Centre for Wind Turbine Components

In order to improve the quality and reliability of wind turbines, component suppliers need to better understand how their products behave within harsh operational environments. Improving component performance is crucial to delivering the increasing efficiency and lower maintenance costs demanded by the industry.

Given that SME component suppliers do not have the resources to develop new test methods and carry out necessary tests themselves, a dedicated knowledge centre has been proposed to serve their needs. The centre will include turbine test beds where performance data can be gathered, and new testing methods developed.

Jointly establishing rigorous performance standards for low carbon technology expands the market for both Chinese and foreign companies, and drives diffusion

Over recent years, the European Commission has worked extensively with industry to establish performance standards for a range of products and technologies that are sold and used within the EU. This includes standards that aim to reduce carbon emissions and improve energy efficiency, of which a selection are summarised in Table 3.5.

Given that the EU is China's largest export market, EU standards are influencing the development of China's own performance standards related to low carbon. For example, the EU invited China as an observer in the process of setting standards for energy using appliances under the Ecodesign Directive, fostering dialogue and exchange of best practice on this topic.

EU performance standards on carbon emissions and energy efficiency are some of the most stringent globally, as they are driven by the EU's own climate change targets. Cooperation between the EU and China on harmonising standards will expand the market for low carbon technology and drive diffusion by enabling greater trade opportunities between the two regions.

Table 3.5 Selected EU regulation for low carbon performance standards

Standard	Description
European Union Eco-design Directive (2005)	The EU has adopted a directive that requires certain standards of energy efficiency to be met by all equipment that uses, generates, transfers or measures energy. This includes consumer goods (e.g. boilers, water heaters, computers, televisions) as well as industrial products (e.g. transformers, industrial fans and industrial furnaces). The European Commission is extending the scope of the directive to include other products which do not consume energy, but which impact on energy consumption such as windows, insulation materials or water-using devices such as shower heads or taps.
Energy Performance of Buildings Directive (2002)	The directive applies to residential and office buildings, and stipulates minimum requirements with regards to energy performance of new and existing buildings, ensuring the certification of their energy performance and requiring the regular inspection of boilers and air conditioning systems in buildings.
Proposal on CO_2 emission limits on new vehicles	The Commission is proposing to set a CO_2 emission limit on vehicle manufacturers for new cars registered in the European Union in order to achieve the average objective of 130 g CO_2/km. If this is exceeded, the manufacturer concerned will be liable for financial penalties. The regulation would come into effect from 2012 onwards.

Source: European Commission

It is important for the EU and China cooperate in a positive way in the context of developments in other major markets (e.g. the US and Japan). This should avoid working towards a 'lowest common denominator' in performance standards, but instead realise the opportunity that standards can help position

EU and Chinese industry as global market leaders while achieving environmental benefits.

Insights for EU-China technology cooperation

EU experience in technology development and diffusion highlights several insights that are relevant to EU-China cooperation as well as the broader debate on technology transfer. These are summarised below based on the focus of cooperation.

Innovation-focused opportunities

1. The EU and China have very similar technology development agendas, providing opportunities for joint initiatives based on existing R&D platforms
2. Well-designed IPR management regimes can create the right conditions for collaborative R&D in the EU and China.
3. Corporate R&D can be a mechanism for joint innovation between European and Chinese institutions when interests are aligned
4. Implementation of joint R&D initiatives requires 'hands-on' facilitation as well as incentives for joint commitment to ensure success

Market introduction-focused opportunities

5. Technology access through commercial channels needs to be supported through market incentives
6. Acquiring technology through outbound FDI is an option for Chinese companies
7. Commercialisation of new technologies can be achieved through effective public-private cooperation and management of IPR issues

Market development-focused opportunities

8. Investment in local capabilities and development of the local value chain is needed to promote diffusion in China and globally

9. FDI and open markets play important roles in continued diffusion of mature technologies
10. Establishing comprehensive performance standards for low carbon technology drives diffusion

Each of these lessons is discussed in further detail below, and are inputs to the discussion of EU-China cooperation models in the next Chapter.

1. **The EU and China have very similar technology development agendas, providing opportunities for joint initiatives based on existing R&D platforms**

The EU and China have common interests in developing and commercialising new and emerging technologies, ranging from specific projects and initiatives (e.g. at a university) to large-scale programmes.

Mechanisms for cooperation in large-scale programmes have not yet been developed, however these can leverage existing platforms for public-private cooperation such as the SET-Plan's European Industrial Initiatives. Smaller-scale cooperation models such as ICUK provide practical lessons on how to develop effective win-win opportunities between EU and Chinese research institutions.

2. **Well-designed IPR management regimes can create the right conditions for collaborative R&D in the EU and China.**

Despite the fact that IPR is a contentious issue in global climate change negotiations, EU and Chinese organisations are successfully using models to share and protect IP, enabling joint development and commercialisation of technologies. This ranges from public-public cooperation (e.g. ICUK model of collaboration between UK and Chinese research institutions), to public-private collaboration (e.g. the JV between BP and the Chinese Academy of Sciences) and private sector consortia.

Effective cooperation requires an IPR framework that is clear, but flexible enough to accommodate the rights and interests of the various parties involved. To be effective, a process of technology cooperation needs to be based on

> Clear rules that lay out the responsibilities and rights of different participants

- A governance process for agreeing the terms of cooperation and handling issues as they arise

The rules and governance process may need to be adapted depending on the context and objectives of cooperation, and the types of parties involved. The use of government funding, as opposed to private funding, will also determine the balance of power in IPR issues.

3. Corporate R&D can be a mechanism for joint innovation between European and Chinese institutions when interests are aligned

Localisation of corporate R&D can provide commercial as well as knowledge spill-over benefits to foreign and local partners. For instance the BP-CAS joint venture enables BP to access local technology expertise on a commercial basis that is relevant to its core business. Similarly, the Chinese Academy of Sciences (BP's JV partner) has developed capabilities for technology commercialisation such as IPR management and managing licensing arrangements. This has also benefited the broader Chinese research community by creating an established channel and centre of expertise enabling commercialisation and diffusion of technologies.

Attracting the localisation of foreign corporate R&D requires investment in local capabilities and expertise, support for the domestic low carbon technology market, and implementation of policies and regulations that encourage companies to locate IP development activities in China.

4. Implementation of joint R&D initiatives requires 'hands-on' facilitation as well as incentives for joint commitment to ensure success

While identifying common areas of interest is relatively easy, making joint R&D collaboration work is very difficult. Specific challenges include:

- Cultural and language barriers
- Different systems of governance and funding in the research sector
- Lack of knowledge on where relevant expertise lies across a vast range of organisations
- Different expectations on the roles, responsibilities and benefits of cooperation

In order to overcome these challenges, a mechanism needs to be established to proactively facilitate communication and address issues as they arise through all stages of the process. This requires strong institutional and governance arrangements, as well as a strong team that is able to bridge the inevitable cultural, knowledge and process gaps. ICUK provides a concrete example of the value added to R&D cooperation through effective facilitation and coordination.

Collaboration is also facilitated by giving parties equal stakes in the relationship to ensure that incentives for success are aligned. This can be achieved through establishing joint-ownership of R&D initiatives as well as joint rights to the IP and benefits arising from them.

5. Technology access through commercial channels needs to be supported through market incentives

Mature low carbon technologies are accessible by Chinese companies through a number of commercial channels.

For manufacturers of low carbon technologies, this includes purchasing and/or licensing of core components and sub-systems when local technology isn't available (e.g. several domestic wind turbine manufacturers).

For users of low carbon technology such as companies in emissions-intensive industries, importing key plant and equipment is an option for upgrading and modernising their production processes. This can however represent a substantial expense to local firms that do not have the financial resources for this type of investment – a particular challenge for small and medium-sized enterprises in China given their limited access to capital. Technology adoption is therefore often driven as a parallel effect of industry re-structuring, modernisation, and FDI.

Broad adoption of technologies by Chinese end-users will therefore require a mixture of regulatory and financial incentives and support, which can be a focus of EU-China collaboration.

6. Acquiring technology through outbound FDI is an option for Chinese companies

In a similar way to companies in developed countries, Chinese enterprises are increasingly looking to invest abroad in order to acquire technology and enter new markets. This is both an opportunity for introducing technology into China, as well as a means to make the low carbon market more competitive.

At the government level, EU-China cooperation in this area should ensure market openness and transaction efficiency for mergers and acquisitions (in both directions).

7. Commercialisation of new technologies can be achieved through effective public-private cooperation and management of IPR issues

Public-private partnerships can provide effective structures for overcoming barriers to technology implementation and pushing broad diffusion beyond early adopters. Enabling several organisations to pool complementary expertise and capabilities can help to address cost-drivers and technical issues. IPR issues will also need to be managed to ensure effective collaboration, as discussed in Point 2 above.

8. Investment in local capabilities and development of the local value chain is needed to promote diffusion in China and globally

EU experience has shown that development of a low carbon industry requires a mixture of private sector entrepreneurialism as well as public sector support in R&D and other areas enabling industry to grow and develop.

Chinese industry is now approaching the point in several areas of low carbon technology where further development requires deepening links between industry players in the supply chain as well as with the domestic research community. Growing local capabilities in R&D (both basic and applied) and engineering and management talent is crucial, and will have positive impacts on innovation and market development opportunities. This can, for example, take the form of local centres of technology excellence, coupled with mechanisms to diffuse know-how and IP developed within them.

9. FDI and open markets play important roles in continued diffusion of mature technologies

For China and Europe to continue developing their low carbon technology markets, they need to remain attractive places for foreign companies to invest and do business. This provides domestic buyers with the choice they need, as well as spurring the improvement of local product quality and industry capabilities. Attracting high value-added FDI (i.e. beyond assembly) is particularly important for China given the eventual spill-over effects for its own industry as talent grows and flows between foreign-owned companies or JVs and local companies.

10. Establishing comprehensive performance standards for low carbon technology drives diffusion

The harmonisation and implementation of low carbon standards within the EU has established a strong market incentive for industry that will drive technology development and diffusion.

Similarly, cooperation between the EU and China on performance standards relevant to energy efficiency and GHG emissions is mutually beneficial for the long-term development of the low carbon economy in both regions. The EU and China should continue to grow their engagement in this area, and position themselves as global leaders.

4 EU-China Models for Collaboration

As discussed in Chapters 1 and 2, EU-China cooperation on low carbon technology can yield a number of win-win opportunities. Specifically, these can be grouped into three areas: innovation, market introduction, and market development. This is based on the maturity level of different technologies and the relative capabilities of China versus the EU (and other technology leaders).

Breaking down cooperation opportunities into these areas helps in understanding the common issues and requirements faced by public and private sector players. This enables discussion of cooperation to be more focused on key challenges in each area.

Chapter 3 provided a view of how EU experience has addressed the different areas of cooperation through examples and case studies within Europe as well as those involving China. Based on this, we have drawn insights and lessons that can be applied to cooperation models between the EU and China.

Cooperation requirements

Depending on the stage of technology maturity, EU-China initiatives will need to take into account different sets of stakeholders, each with different interests and ways of working, as well as cultural and organisational differences that can pose practical challenges to collaboration. These differences have implications for the way in which IP is developed and owned, the source of risk (technology, market, or commercial), and capability requirements to deliver change. This in turn will shape the way collaborative relationships are managed, and the relative roles and importance of public and private sector organisations, as illustrated in Figure 4.1.

Figure 4.1 Impact of technology maturity on cooperation dynamics

	Technology Maturity: Low	Technology Maturity: High	Implications for Cooperation
Key Players & Stakeholders	• Mainly academic & research institutions • Some private sector participation: directly through applied R&D; indirectly through sponsorship of R&D activities	• Mainly commercial enterprises • Some participation of independent research institutions (e.g. standardisation; incremental performance improvement)	• Key organisations to involve in technology cooperation
IP Creation & Ownership	• IP mainly created by academic and research institutions	• IP mainly held by companies	• Level of commercial sensitivity • Determines channels for technology sharing/ acquisition
Source of Risk	• High level of technology risk (will it work?) • Uncertain commercial potential (will the market buy it?) • 'portfolio approach' to manage risk	• Low technology risk (technology is 'proven') • Low-to-high market risk, depending on stage of market adoption and enabling factors (e.g. government policies)	• Focus of public sector support & financing vs. private sector responsibility
Capability requirements	• Technology innovation for breakthroughs and adaptation/extension of technology	• Engineering • Manufacturing & supply chains • Marketing/sales and channel development • Management (planning, control, financial)	• Focus of support for capability building

Source: E3G analysis

Depending on the area of cooperation, requirements can be defined around five key issues: technology and IP; financing; local capabilities; infrastructure; and government regulations and policy. These are summarised in the tables below.

Table 4.1 Key requirements for innovation-focused cooperation

Area	Requirements

Technology / IP	> Effective IPR management regime needed to address
	  > Sharing/exchange of complementary IP
	  > Joint creation of new IP and subsequent licensing/commercialisation
	  > Cooperation with private sector to commercialise technology

Financing	> Funding required for speculative activities of high technology risk > Mechanism required for identifying promising RD&D and allocating funds based on priorities
Local capabilities	> Qualified scientists and engineers > Standardisation and certification processes > IPR management for innovation and commercialisation
Infrastructure	> R&D infrastructure and facilities > Testing facilities > Proximity to centres of technology excellence
Regulations & policy	> Incentives for localisation of R&D (e.g. tax breaks) > Effective IP protection laws and enforcement > Strategic policies and integrated programmes for planning and coordinating R&D

Table 4.2 Key requirements for market introduction-focused cooperation

Area	Requirements
Technology / IP	> Mechanism to effectively and efficiently identify sources of technology, assessing suitability and negotiating agreements with IP providers > Effective and cost-efficient channels for accessing technology: imports, licensing > Effective IP protection regime providing guarantees to technology suppliers
Financing	> Financing market introduction activities for new technology > Funding of market uptake to address cost barriers for technology users (e.g. zero/low interest loans) > Provision of project finance for large infrastructure projects (e.g. power plants)
Local capabilities	> Engineering/technical skills to absorb and implement new technologies > IPR management for licensing and protecting IP
Infrastructure	> Electrical grid and transport/logistics infrastructure needed to implement large energy projects (e.g. wind farms, power plants) > Development of industry zones for new/emerging technology (facilitates future development and 'seeds' the creation of industry clusters)
Regulations & policy	> Policy targets and regulations (e.g. pollution regulations, renewable energy targets) > Effective IP protection laws and enforcement > Market incentives to drive uptake

Table 4.3 Key requirements for market development-focused cooperation

Area	Requirements
Technology / IP	> Effective IP protection regime providing guarantees to technology suppliers (domestic and foreign)
Financing	> Funding of local capacity-building > Funding market uptake (e.g. preferential loans, subsidies, feed-in tariffs)
Local capabilities	> Applied R&D for technology improvement > Manufacturing and systems integration > Marketing/sales and channel development > Management (planning, control, financial)
Infrastructure	> Development of industry networks and clusters to support localisation of supply chain (e.g. high-tech zones for low-carbon industries > Electrical grid infrastructure needed to implement new energy technologies
Regulations & policy	> Product performance standards (e.g. energy efficiency standards) > Policy targets and regulations (e.g. pollution regulations, renewable energy targets) > Effective IP protection laws and enforcement > Market incentives to drive uptake > Policies encouraging FDI and localisation of value chain

Potential models for EU-China cooperation

EU-China technology cooperation can take a number of forms depending on the area of focus (innovation, market introduction, market development), and the scope of requirements it seeks to address (defined above). It can also be focused on a single technology field, or a portfolio of technologies.

Innovation-focused cooperation models

The key objective of innovation-focused opportunities is to accelerate the development and commercialisation of new technologies. This could be achieved through the following types of EU-China collaboration:

> Joint RD&D programmes and initiatives

> EU funding and support of Chinese innovation

Joint RD&D programmes and initiatives

The EU and China can jointly fund initiatives to develop specific technologies, drawing on each other's areas of strength and complementary capabilities. This can enable China to gain joint ownership of IP in core technologies, while also enabling the EU to benefit by sharing costs and speeding development and commercialisation. Chinese institutions could, for example, link up with existing EU-wide R&D platforms or develop relationships with specific institutions.

Whichever precise model is chosen, relationships involving co-development of technology will require an appropriate level of support and coordination to overcome the complexities of international cooperation.

EU funding and support of Chinese innovation

Instead of co-development, the EU can act as a partner by co-investing in China-based institutions developing technology or enterprises wishing to commercialise new technology. This could involve establishing a centre providing grants for targeted R&D projects, or seed funding for start-up enterprises or university spin-offs.

An example of this model is the Carbon Trust in the UK, which provides grants for applied R&D as well as investing in start-ups and helping them obtain follow-on funding from venture capital investors. The Carbon Trust has recently entered into a JV partnership with the China Energy Conservation Investment Corporation (CECIC) to apply a similar model in China.

This model can also be delivered through a form of FDI, such as the BP-CAS Clean Energy Commercialisation Centre discussed in Chapter 3. EU government support could take the form of co-funding specific projects through this type of vehicle.

A reverse situation of Chinese funding for EU-based RD&D initiatives could also be envisaged if the opportunity arises.

Market introduction-focused cooperation models

The objective of market introduction-focused opportunities is to enable relevant technologies to be identified and adopted in China. This can be achieved in a number of ways, such as:

> Facilitating the licensing of technologies to Chinese companies

> Facilitating the entry of EU companies with innovative technologies into China

Facilitating the licensing of technologies to Chinese companies

An intermediary could be established with the purpose of identifying relevant technologies across the EU and facilitating their licensing to Chinese companies.

The organisation would act as a single point of contact for both EU IP suppliers and potential Chinese licensees. This would enable it to build a base of knowledge and experience in managing the IP licensing process, including evaluation of candidate technologies and negotiation of licensing agreements. It could also play a role in managing and monitoring the enforcement of license terms and IPR guarantees in China (in conjunction with relevant Chinese organisations).

It would also be able to apply a form of 'collective bargaining' on behalf of Chinese industry, enabling it to negotiate favourable terms while also giving EU technology suppliers a valuable and accessible channel to the Chinese market.

Facilitating the entry of EU companies with innovative technologies into China

A number of SMEs based in the EU have developed new and promising technologies, but do not have the resources of larger companies and multinationals to expand into the Chinese market. A centre could be established to act as an incubator specifically for low carbon technology companies, providing them with resources and a base from which to do business in China. By developing local expertise as well as linkages with key Chinese institutions and companies, the centre could provide significant value to EU companies and facilitate technology diffusion in China.

The centre could be funded in a number of ways. A possible model is illustrated by the UK's Carbon Trust JV with CECIC (discussed above). The JV provides funding for business ventures in China, giving both the Carbon Trust and CECIC a joint stake in their success.

Market development-focused cooperation models

The objective of market development-focused opportunities is to deepen capabilities and localisation of value chains in China in order drive down technology costs and promote diffusion – globally and in China. Potential models include:

> Development and harmonisation of policies, regulations and standards

> Attracting high value-added FDI and developing linkages with Chinese industry

Development and harmonisation of policies, regulations and standards

A significant amount of cooperation between the EU and China can be done at the policy level to encourage the development of low carbon markets in both regions. Developing common product standards (e.g. on energy efficiency) is a way of growing the overall market and opportunities for EU and Chinese companies. The EU can also share its rich experience in policy and regulatory development, which can be facilitated through exchanges between relevant EU Directorates and/or Member State governments and Chinese ministries.

Attracting high value-added FDI and developing linkages with Chinese industry

In order to both develop local capabilities and attract FDI in targeted areas, EU-China cooperation can focus on establishing geographically-based initiatives that focus on developing a specific low carbon industry or driving adoption of low carbon technologies.

An example is the proposed creation of 'Low Carbon Technology and Investment Demonstration Zones' (LCTIDZs), centred on industrial and technology development zones in specific locations. The LCTIDZ concept is an integrated model of EU-China cooperation that includes the following objectives:

- Facilitating technology upgrading of local industry, and accelerating joint development of new technologies
- Working with the business community to build a "protect and share" IPR regime that can facilitate rapid and large-scale diffusion of low carbon technology
- Identifying and establishing innovative mechanisms and financial instruments to help both Chinese and European enterprises, in particular SMEs, to overcome barriers to innovation

The LCTIDZ would respond and be adapted to the specific needs of different geographies (e.g. heavy industry in western and central provinces, compared with high-tech industry in coastal urban zones). It could also seek to leverage and develop local capabilities for technology development. Initially funded and supported through public-private partnerships, this would in turn encourage further investment from the EU and Chinese private sectors. The LCTIDZ model is also appropriate for addressing market introduction opportunities where the focus is on bringing new technologies into China.

Making it work – key success factors

Whatever the model employed, experience has highlighted three factors that are important to the success of any initiative:

> Frameworks for managing and protecting IPR must be fit-for-purpose

> Incentives for joint collaboration need to be built into relationships

> The right level of institutional and organisational support needs to be provided

Fit-for-purpose IPR management

The management and protection of IPR is a contentious issue within the international negotiations. It is clear that tackling climate change will require the protection of incentives for future innovation while accelerating the diffusion of low carbon technologies. At a practical level, companies and institutions have already developed models that enable them to successfully work together. The key is to ensure that responsibilities and relevant processes are clear and agreed upfront.

Incentivising success

While collaborative agreements set the framework for a relationship, creating the right incentives is the key to success. A common means of doing this is through joint and equal investment by the partners involved, so that they have the same stake in the risks and benefits of the venture, and are encouraged to work towards the same outcomes. Joint ownership can however also create challenges in a relationship that need to be addressed through clear and agreed governance and decision-making processes.

Providing a support structure

When the structure for cooperation is complex or the scope for problems arising due to communication, cultural issues or knowledge-gaps is large, an adequate support structure is essential. At the core of this structure should be a strong team that has the experience, knowledge and resources needed to address issues as they arise.

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