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Advancing technology transfer for climate change mitigation: considerations for technology orientated agreements promoting energy efficiency and carbon capture and storage (CCS)

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Advancing technology transfer for climate change mitigation

Considerations for technology orientated agreements promoting energy efficiency and carbon capture and storage (CCS)

IIIEE Report 2009:3

Carl Dalhammar | Philip Peck | Naoko Tojo | Luis Mundaca | Lena Neij

INTERNATIONAL INSTITUTE FOR INDUSTRIAL ENVIRONMENTAL ECONOMICS AT LUND UNIVERSITY



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Executive Summary

Introduction

The role of technology and technology transfer have emerged as key issues in recent climate change negotiations. The technologies required for greenhouse gas (GHG) reductions have been largely identified for both the short and long term, and deployment scales required to mitigate climate change have been analyzed. However a key issue remains – that of rapidly progressing such technologies from niche applications in a limited number of countries, to widespread deployment so as to displace incumbent high-carbon technology systems.

With the emerging focus on technologies as part of the solution to climate change mitigation, there is a growing interest in how international technology-oriented agreements (TOAs) can become a key synergising element within future climate regimes and how technology transfer can be advanced. It is widely held that future agreements addressing climate-friendly technologies can take various forms and include different activities and measures, including:

- (i) knowledge sharing and coordination;
- (ii) research development and demonstration (RD & D) activities;
- (iii) technology transfer, and;
- (iv) technology deployment mandates, standards, and incentives.

Effective capacity building efforts focused on technical and institutional capacity to effectively engage in technology transfer and other TOA activities are crucial, especially in developing countries. However, current funding mechanisms, such as the Clean Development Mechanism (CDM) and the Global Environmental Facility (GEF) cannot, in their current forms, deliver technology transfer at the pace required, and their contribution to capacity-building efforts are limited.

The purpose of this research project, commissioned by the Swedish Environmental protection Agency, is to increase the knowledge about critical (pre)conditions for effective technology oriented treaties. The study has addressed the promotion of technology transfer in two areas:

- 1) Carbon capture and storage (CCS) technologies, with a focus upon technology status implications, technology availability,

and the significance of capacity-related issues for large scale implementation;

2) Technical applications for energy efficiency within the building sector, including:

- i) building envelopes, and materials, mechanical services, and lighting systems; building services (e.g. climate control, lighting etc.);
- ii) domestic appliances.

Technology agreements: linked to a post-Kyoto agreement?

Whether relevant TOAs and supporting structures should be pursued within or outside the UNFCCC is a key issue. The main arguments for establishing technology-specific agreement(s) under the UNFCCC are firstly that the associated mechanisms, and notably the Carbon Market, can support technology policies, and secondly that the establishment of additional funds for technology transfer under the UNFCCC can constitute a stimulus for developing countries to initiate technology policies and undertake mitigation actions. With the main focus of developing countries being on economic development, it may be crucial to add further incentives in order to increase the attractiveness of the climate regime.

However, there are several factors indicating that some technology oriented agreements may fit best outside the UNFCCC/(post-)Kyoto framework. Indeed, experiences with multilateral environmental agreements (MEAs) indicate that modest approaches, limited in both subject matter and scope tend to work best. A further argument for keeping a framework technology agreement, or several technology oriented agreements, outside the UNFCCC/Kyoto framework is that that their inclusion adds to the already immense complexity of negotiations. This has the potential to contribute to the climate regime being even more difficult to grasp. Many actors consider parallel arenas for climate change negotiations as a positive development, and it is often stressed that initiatives coming from outside the UNFCCC bear with them the potential for importation over time.

The initiation of TOAs outside the UNFCCC also means that much of the bureaucracy and lengthy procedures associated with many components of that system can be avoided. The main problem with keeping important initiatives outside the UNFCCC framework is that such developments may increase fragmentation of climate efforts. Many developing countries have already expressed concern that

important future developments will take place outside UNFCCC negotiations.

Regardless of whether inside or outside, the complexity of the climate negotiations and the controversy surrounding some elements of technology transfer make it very difficult for the climate regime and the UNFCCC mechanisms to deal with the vital aspects of technology transfer. Moreover, a fundamental scepticism exists among many actors towards the ability of UNFCCC and its related mechanisms to drive technology transfer. As such, resolution requires reform of the UNFCCC system, and the addition of new components, but also the pursuit of technology objectives outside the UNFCCC framework.

Technology diffusion should therefore be pursued both inside and outside the scope of the post-Kyoto framework.

Carbon capture and storage (CCS)

CCS is not a single technology or system; it has both a number of different components and a significant number of potential system combinations. An analysis of existing CCS-related TOAs and similar initiatives were made in the project. The analysis suggests that there is no 'all-encompassing TOA' to promote the transfer of technologies along the entire CCS system chain. Rather, different TOAs are very likely needed to address different components of the system. Differing forms of agreement, coordination or collaboration may even be required to address various aspects of the same components of a single technology (e.g. addressing hardware, software, or institutional aspects). The nature of each component largely frames the challenges that CCS-related TOAs face.

Due to the pre-commercialization phase of CCS technology systems, most TOA efforts are observed in the areas of: *knowledge sharing and co-ordination* and *RD&D activities*. Furthermore, 'enabling environment' parameters – a central item examined in the study – were found to be extensively addressed by ongoing activities that can be placed within the sphere of TOA initiatives. However, such activities are largely 'precursors to technology transfer' rather than transfer of technologies *per se*. Moreover, these activities are largely conducted between industrialized countries at this point in time.

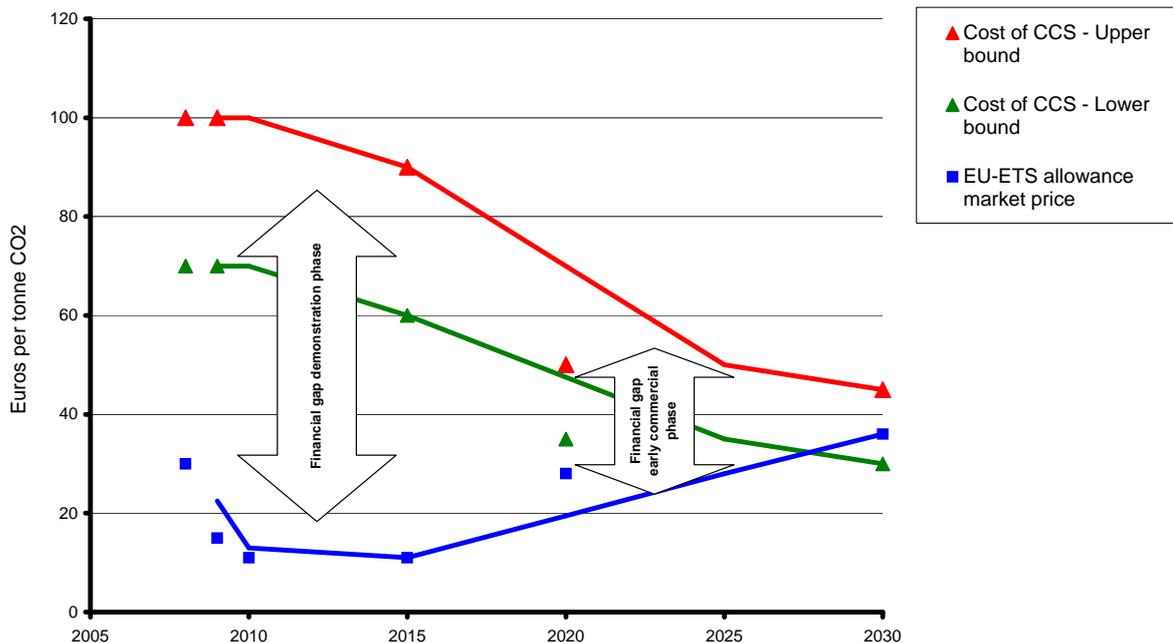
Given current policy and market conditions, carbon markets appear marginal or inadequate for sole support of CCS applications (especially industrial-scale demonstration plants) to economic viability. There appears to be a need for (potentially

significant) additional support. Examination of the different estimated cost ranges for CCS technologies, and current and future EU-ETS allowance price projections, reveals a significant financial carbon crediting gap for CCS projects (cf. Figure).

This finance shortfall can hamper or delay the commercialization of such systems and thus exacerbate challenges in achieving scale economies. The current uncertainty surrounding climate policy (and thus carbon markets) thus also poses a significant barrier to the establishment of market confidence for early movers in the European market. This also reinforces belief that incentives additional to the Carbon Market will be required if CCS is to become financially viable for the targeted industrial sectors.

The analysis does find that a number of CCS components are both sufficiently mature to be 'transferred' – and sufficiently 'certain to be needed'. However, when the CCS technological system is viewed as a whole, this analysis indicates that it is not yet ready for establishment in industrialized countries, let alone ready for full transfer to the developing world. There remain numerous technical, financial, institutional, social and environmental issues to be addressed and overcome before key stakeholders (e.g. industrialized country utilities) engage at large scale.

The study discusses a number of areas where more international cooperation will be required. These include legal issues, commercial and financial issues, technical issues, and measures that address public acceptance and understanding of CCS technologies. The challenges for inclusion of CCS technologies under the CDM are discussed. While the study does not analyze whether CCS is a appropriate technology for the developing world, some of the special considerations for developing countries are outlined. CCS transfer to the developing world should be considered a medium to long term strategy, but preparations for specific pre-cursors to such transfer need to be made in the short term.



Financial crediting gap for CCS projects in carbon markets during demonstration and early commercialisation phases. Note that average trend lines are also presented (in red for upper bound of CCS costs; in green for lower bound of CCS costs; in blue for EU-ETS allowance price) to better illustrate the estimated cost range for CCS and reveal the financial gap in relation to carbon market price

Energy efficiency in buildings

The building sector accounts for almost 40 per cent of final energy use worldwide. Although energy is used more efficiently over time in many countries, total energy consumption has been increasing. Energy efficiency in buildings is not something that must wait for technological development – much of the potential for energy efficiency in buildings can already be achieved using technical options available on the market. Moreover, the building sector probably has the highest (economic) climate change mitigation potential using commercial technologies and practices. As such, the strategic focus of the building sector in the climate change discussions cannot be ignored.

Despite the great potential and interest in achievement of GHG savings, only a fraction of low cost or even negative cost energy efficiency gains have been achieved. Reasons for low engagement in energy efficiency despite its clear financial benefit can be explained by a number of barriers and market failures. Indeed, there is broad consensus that the primary barrier for energy efficiency has not been the lack of technology, but a poorly functioning market where energy savings are

not accurately valued. While the barriers are often similar in nature for developed and developing countries, some constraints – such as improper implementation and enforcement – are of special importance in developing countries.

While a number of policy instruments exist to promote building energy efficiency, even the most progressive developed countries have achieved limited success. A review of existing international agreements reveals that with the exception of European Union (EU) Directives, there are no identified TOAs for technology deployment mandates, standards, and incentives. This, to some extent, reflects the national character of the building sector. The EU has however enacted a more comprehensive policy package to kick-start the market for energy efficient buildings and provide for consistency and innovation in the construction and building industries.

International cooperation to further improve energy efficiency in buildings can be advanced both within and outside the UNFCCC framework. The CDM has proven to be a largely inappropriate mechanism for addressing the building sector, and only a few building projects have been initiated under its

auspices. For the most part, the economic benefits from CDM projects cannot justify the transaction costs associated with project management, dealing with CDM methodologies, and required monitoring programs. Programmatic CDM has not been the boost hoped for, and the ultimate conclusion is that the CDM in its current form simply does not encourage projects for improved building energy efficiency. While the CDM will probably be reformed, it appears likely that the CDM will never be a suitable instrument for addressing the building sector. Transaction costs for dealing with thousands of structures or households, where no proper baseline or benchmarks are available, are to be compared to projects that target a small number of large production plants, where benchmarks and methodologies exist.

The preferred way forward within the UNFCCC framework appears to be via nationally appropriate mitigation actions (NAMAs). In the report, we propose a straightforward approach, where non-annex I countries may receive funding if presenting credible packages of policy instruments, supportive actions, and evaluation and enforcement mechanisms. Funding should not be given merely for “additional costs”; rather, an effective scheme requires funding for capacity-building efforts. Evaluation of such packages will also need to make use of both qualitative and quantitative approaches. Funds should be provided in phases, to avoid wastage, and to facilitate the reward of high-performing actors. This analysis indicates that such approaches offer a promising way forward, although it is recognised that controversy may arise in several areas.

Outside the UNFCCC framework, we propose a platform for sustainable buildings, which can act as a coordination body for different national and regional initiatives, fund strategically important pilot projects, and deliver key functions related to dissemination of best practices and set-up of networks and educational activities.

Considering the importance of buildings not only as energy users but as providers of basic human needs, and aesthetics, it would seem reasonable to initiate such a platform. If such a platform was indeed created, it should contain the institutional set-up, and the resources, to participate in relevant settings to promote sustainable buildings and related technologies. These settings include:

- the Green Goods negotiations;
- standardisation;
- official development assistance (ODA) funds devoted to infrastructure and

buildings that should preferably incorporate best practices for sustainable buildings, climate-friendly building techniques, and where calculations on investments are based on life cycle costing techniques;

- efforts to strengthen ongoing projects to integrate courses on sustainable design for relevant professions such as architects, building designers, and construction engineers.

Moreover, to complement technology and infrastructure related issues, a policy focused platform could be developed to support policy learning, experiences on best practices and coordination of different policy instruments. It should explore opportunities for working with a variety of different actors.

Energy efficiency of appliances

The electricity consumption of some of the large home appliances, such as refrigerators, freezers and washing machines, is decreasing in OECD countries, despite the increase of per capita ownership and size. The improvement of energy efficiency of individual equipment has mainly been driven by government policies. A rapid increase in the use of a variety of small appliances – namely Information and Communication Technology (ICT) equipment and Consumer Electronics (CE) – and in some countries, of air conditioners, are probably the main reasons for why the overall electricity consumption by appliances has nevertheless increased. The share of electricity used by small appliances has increased and, even taking into account the foreseen energy efficiency measures, electricity consumption by appliances is projected to increase 250 % by 2030.

A number of policy instruments have been implemented to improve the energy efficiency of appliances, including labels, procurement, fiscal measures, subsidies, and mandatory standards. As one example, the Ecodesign Directive was adopted by the EU in 2005. Binding standards for different product groups are set under the directive, through so-called Implementing Measures. Currently, nine implementing measures, setting mandatory energy efficiency standards for nine product groups have been implemented, with additional measures planned for the immediate future. The expected savings from these 9 products groups are 341 TWh, which equals 12% of the electricity consumption of the EU in 2007. This is an indication of the significant potential to cut GHG emissions through

the setting of mandatory energy efficiency standards for appliances.

Unlike buildings for which a diverse and decentralised domestic manufacturing industry exists in virtually all countries in the world, manufacturing of appliances does not take place in all countries. The relevance and the capacity building potential of technology transfer is, at least in the short term, generally higher in cases where domestic manufacturing industry exist in the country. The studies on technology transfer projects in developing countries reveal that market transformation projects can be successful if designed properly and that country-specific factors are crucial and must be taken into account. Such factors include available technologies and capacities in the country, capacity of testing and verification, market surveillance practices, negotiated agreements and the market structure, and the size and structure of the second hand market.

For a number of reasons, specific international agreements dealing with appliances will be very difficult to implement. A number of observations with recommendations for pathways forward are listed below.

- Due to the transferability of standards, it is important that developed countries continue to set stricter standards.
- The recent trend in policymaking to focus more on functions provided than product groups per se should be supported, as this approach will be very important in the future.
- In the case of developing countries, tailor-made solutions are needed to respond to the social, economic, market and political characteristics of the developing country in question.
- Durable mature appliances that end its first life in developed countries or in their domestic market are used as second-hand products by population with lower income. Considering the high initial cost of purchasing new equipment and the basic function these mature appliances (e.g. refrigerators) provide to enhance quality of life, it would not be appropriate to prohibit the sales and use of second-hand mature appliances because of energy efficiency considerations. An ideal situation would be to upgrade the energy efficiency of products when they re-enter the market. Thus, raising awareness of the dealers in second hand market – repairers, reconditioners, refurbishers and the like – and providing them with tools and means for energy efficiency upgrade, could be very effective in improving the situation. Building local capacity to improve the efficiency of the components, to incorporate new components with better efficiency, or to establish manufacturing plants for components could be a fruitful way forward. Schemes for the second hand components could be also considered. However, the less organized structure of second hand markets, as well as the involvement of a large number of informal market actors pose challenges to organize such schemes.
- Importation of second-hand electronics has been highlighted under the context of Basel Convention that deals with the trans-boundary movement of hazardous waste. However, the different dimension of ICT and CE equipment (functions provided, waste problems, bridging of the digital divide, and so on) are often discussed in separate forums and reports, and it could be useful to coordinate different efforts.
- The question can be also raised whether the replacement of less energy efficient products to more efficient ones is always preferable from the life cycle perspective. Essentially the same problem is found in the implementation of EU's Ecodesign Directive where – despite its mentioning of life cycle thinking as a starting point – a strong and narrow focus on the issue of use-phase energy efficiency as well as dismissal of the material and energy use from the production process have been pointed out.
- The main role we see for policies within the UNFCCC framework to enhance energy efficiency of appliances in developing countries is the potential applications of NAMAs, taking into account the special needs required. Funds should be provided to design policies, develop capacity for monitoring and measurement, for participation in international fora for standard-setting etc. Such efforts should be coordinated with other ongoing initiatives that aid developing countries to deal with product standards in order to gain access to global markets.

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LIST OF ABBREVIATIONS

AAU	Assigned Amount Unit
ADB	Asian Development Bank
ASTAE	Asia Alternative Energy Program
BAT	Best Available Techniques
BAU	Business as usual
BTA	Border tax adjustment
CBA	Cost-Benefit Analysis
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CE	Consumer electronics
CER	Certified emission reduction
CGIAR	Consultative Group on International Agricultural Research
COP	Conference of the Parties
EAP	Environmental Action Programme
EC	European Community
ECCP	European Climate Change Programme
Ecodesign Directive	Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products (Previously Directive 2005/32/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European parliament and of the Council)
EEA	European Environmental Agency
EEB	European Environmental Bureau
EEE	Electrical and Electronic Equipment
EFTA	European Free Trade Agreement
EiT	Economies in Transition
ENDS	Europe's Environmental News Service
EPA	Environmental Protection Agency
EPD	Environmental Product Declaration
EPR	Extended Producer Responsibility
ERU	Emission Reduction Unit
ESMAP	Energy Sector Management Assistance Program
ETAP	Environmental Technologies Action Plan
ETSI	European Telecommunications Standards Institute
EU	European Union
EU-ETS	European Union Greenhouse Gas Emission Trading System

EuP	Energy-using Products
EuP Directive	Directive 2005/ 32/ EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/ 42/ EEC and Directives 96/ 57/ EC and 2000/ 55/ EC of the European parliament and of the Council (replaced by Directive 2009/125/EC)
FDI	Foreign Direct Investment
GATT	General Agreement on Tariffs and Trade
GEF	Global Environment Facility
GHG	Greenhouse gas
HVAC	Heating Ventilating Air Conditioning
IEA-IA	International Energy Agency Implementation Agreement
ICT	Information and Communication Technologies
IDB	Inter American Development Bank
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
ITER	International Thermonuclear Experimental Reactor
JI	Joint Implementation
KP	Kyoto Protocol
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCD	Liquid Crystal Display
LDC	Least Developed Country
LCM	Life Cycle Management
MARPOL	International Convention for the Prevention of Pollution from Ships
MEA	Multilateral environmental agreement
MOP	Meeting of the Parties
MRV	Measurable, reportable, verifiable
NAFTA	North American Free Trade Agreement
NAMA	Nationally appropriate mitigation action
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
ODA	Official development assistance
ODS	Ozone Depleting Substance
RD & D	Research development and demonstration
RIA	Regulatory Impact Assessment
RMU	Removal Unit
SD-PAMs	Sustainable Development Policies and Measures
SME	Small and Medium sized Enterprise
SPS Agreement	Agreement on the Application of Sanitary and Phytosanitary Measures

TAP	Technology Action Plan
TEP	Techno-economic paradigm
TBT Agreement	Agreement on Technical Barriers to Trade
TNA	Technology Needs Assessment
TNC	Transnational corporation
TOA	Technology oriented agreement
TRIPS Agreement	Agreement on Trade Related Aspects of Intellectual Property Rights
UK	United Kingdom of Great Britain and Northern Ireland
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
US	United States of America
USEPA	United States Environmental Protection Agency
VAT	Value added tax
WTO	World Trade Organization
WWF	World Wide Fund for Nature

1. INTRODUCTION

1.1 Background

The role of technology and technology transfer has come to the forefront in the climate change policy negotiations. The establishment of the Bali road-map highlighted the role of technology transfer as a key component in any future climate post-Kyoto regime. The necessary technologies required for GHG reductions - in the short and long term - have been largely identified, and the estimated scale of deployment to mitigate climate change has been analyzed (e.g. Stern, 2006; IPCC, 2007; IEA, 2008a; McKinsey, 2008). The question is how to rapidly take these technologies from niche applications, in particular in developing countries, to widespread deployment in order to displace our present high-carbon energy technology systems.

With the emerging focus on technologies as part of the climate solution, there is a growing interest in how international technology-oriented agreements (TOAs) can be a critical element and effective mechanism of any future climate regime and how technology transfer can be furthered (recent contributions include de Coninck et al. 2008; Tomlinson et al. 2008; Depledge 2008; Bazilian et al. 2008; Newell 2008). It has been argued that future agreements addressing climate-friendly technologies can take various forms and include different activities and measures: (i) knowledge sharing and coordination, (ii) research development and demonstration (RD & D) activities, (iii) technology transfer, and (iv) technology deployment mandates, standards, and incentives (De Coninck et al.; 2008). Conceptual details of TOAs are presented in Chapter 2.

Technology cooperation and transfer has always been a key issue for developing countries in the climate negotiations, due to its perceived role in supporting economic and technological development. But international technology cooperation for low carbon technologies is less straightforward than the setting of GHG emission reduction targets; the latter focus on solely targets whereas the former requires actions of various actors and outcomes (Ueno 2006). Thus, while there is a rather established consensus that TOAs are a key part of the solution, there is limited knowledge on the performance of existing technology-specific agreements, and the institutional and market conditions necessary to make TOA an effective contribution to

international climate change policy. Within this context, there is less agreement concerning what specific policies and institutions are best suited to stimulate innovation and diffusion of technologies of the required scale under TOAs. To make things more complex, mounting policy uncertainties associated with any post-Kyoto regime add further complexities to any future climate-friendly TOAs. At the risk of oversimplifying, critical contentious issues shaping the challenges faced by TOAs can be summarized as follows:

- **Funding and equity concerns:** If technology-related measures are to become something more than just a complement to other actions, there is a need to increase both the scale and pace of transfer. Technology transfer on a grand scale however requires substantial funding. It is currently estimated that only a part of that funding can be provided by the Carbon Market ¹, and additional funding sources are required. Furthermore, whereas there is consensus that universal participation is needed to tackle climate change, key contentious discussions converge to mitigation costs and how they should be distributed. Studies show that global abatement costs are both substantial (US\$ 400 billion to 3 trillion) and wildly different across regions depending on, for instance, the allocation method chosen in a global cap-and-trade scheme (e.g. Jacoby et al., 2008). A critical issue here is whether developing countries are to be fully or partially compensated for the costs of mitigation. TOAs can play a key role to compensate the welfare burden on developing countries
- **Governance:** While funding is a central issue, the most significant challenge concerns the governance structure for the efficient provision of funding to relevant undertakings, the build-up of 'enabling environments' in developing countries, and the need for clear, efficient and transparent criteria for singling out relevant projects.

¹ Even an extended Carbon Market cannot provide more than a fraction of the funds required for necessary mitigation and adaptation measures.

Depending on the type of TOAs, the industrialized countries need some guarantees that funds invested will be applied to the desired activities and not dissipated or misappropriated. Any approach is likely to require robust mechanisms for implementation and monitoring. Furthermore, it is argued that a key hurdle in achieving any meaningful post-Kyoto regime lies in the fact that that developed countries are simply not trusted to deliver on their promises (Rajamani, 2009).

- **Institutional and capacity building:** Even in situations where funds are available, there is uncertainty about corresponding human and institutional resources needed in developing countries to adequately and effectively participate in TOAs. It has long been argued that realistic and relevant projects in developing countries may not be realized unless there are investments devoted to the build-up of required technical or institutional capacity among local actors. Further, there is a need to initiate research for adaptation technologies that are crucial for developing countries but where there is little R & D being performed in industrialized/developing countries due to low expected market returns (e.g. drought resistant crops). Some authors claim that there is a need also for mechanisms which aids technology deployment in developing countries in cases where patent holders are resistant to grant licenses for these markets (see e.g. Tomlinson et al. 2008), though this is a disputed issue.
- **Short-term vs. long-term objectives:** If the 2 degree target (i.e. 550ppm CO₂-eq) is to be achieved, the total global emissions of GHG should peak no later than 2020. Such a scenario - realistic or not - in turn implies an urgent need to rapidly reduce GHG emissions. Therefore there is a need to quickly adopt a structure for the transfer and deployment of existing, proven and cost-effective climate-friendly technologies to the main emitters in the industrialized and developing world (e.g. increased deployment of energy efficient technologies). However, the market penetration of already cost-effective technologies is still prevented by a number of market imperfections that have not been reduced or eliminated by existing policy portfolios – both in industrialized and developing countries. In the long-term perspective, there is a need to focus on building up substantive effective frameworks for transfer and implementation

of technologies that are not ready for large-scale use yet but may be needed in the future, such as carbon capture and storage (CCS) technologies.

- **Development and justice issues:** Technology transfer is predominantly viewed as a development issue by some actors in both industrialized and developing countries. It is often seen as big “carrot” for developing countries in the negotiations, offering the promise of development growth. However, there are few or limited signs that the desired bridging of development and climate issues are taking place, neither at the national nor the international level, but rather the opposite (cf. Gleckman 2009; Friedman 2009 for such discussions). To some extent, this is because of the lack of evaluation studies addressing co-benefits or sustainable development performance of climate investments. Furthermore, there are several contentious issues, which make industrialized countries cautious in their approach to technology transfer. One problem raised in current negotiations is that countries whose classification as ‘developing countries’ is disputed, receive greater financial support than deemed equitable (Marr 2009).^{2 3} Furthermore, and from the developing country perspective, there are several reasons to be skeptical towards technology transfer as an engine for development (e.g. Munari 2003; Gupta 2007; Gupta 2009). Examples of concerns are listed below.
 - Risks that much of the additional funding provided for climate assistance will be taken from the official development assistance (ODA) budget. This means that at a time when the quality of ODA projects has - in general - started to improve, money may be taken from ODA and put into climate assistance, where some of the historical mistakes of ODA risk being repeated (Gupta 2009). A related concern is that

² The Bali Action Plan refers to ‘industrialised’ and ‘developing’ country parties, rather than Annex I and non-Annex I parties.

³ For instance, a huge concern among many members of the US Senate is that many proposed climate policies could mean that means are transferred from the US to China; this support to a (current and especially future) ‘competitor’ is often viewed unfavorably (Denish 2009).

some development projects will not be funded because they will contribute to increased GHG emissions.

- ‘Distributive justice’ related concerns: while ODA projects tend to address the poorest layers of the population in developing countries, climate related projects often provide benefits to more well-off economic actors.
 - Risks of the promotion of technologies poorly suited to the needs of the South – which in the worst case may serve to lock-in to energy-intensive lifestyles.
 - Concerns that unless supported by a relevant set of institutions and laws, the import of technology from industrialized countries may require risk burdens that are not linked to satisfactory benefits.⁴
- **Additionality and baselines:** a main aim of TOAs is to encourage technologies that would not have been implemented under a business-as-usual (BAU) scenario (i.e. as depicted by the baseline or counterfactual situation).⁵ In contrast, and driven by the cost-effective evaluation policy criterion, financial mechanisms often and initially target the implementation of ‘no-cost’ and ‘low-cost’ options for climate reduction measures. These types of technologies (e.g. residential efficient technologies) should or may occur in the absence of international intervention. Along these lines, one can hypothesized that some developing countries might refrain from

implementing climate policies because targeted technologies by these policies become by default non-additional and thus might be exempted from any TOAs. They will therefore not be subsidized by developed countries. A main concern is how the additional component of climate-friendly technologies can be ensured or dynamically adjusted if a variety of policy instruments is constantly implemented in the short and long term (affecting the BAU) in developing countries. Additionality underscores the importance of having alternative and credible counterfactual situations.

There are also differing opinions concerning the viability of the technological dimension. In this light, de Coninck et al. (2008:336) state:

“...there is growing recognition that TOAs could play a substantial role in post-2012 international policy discussions. It is less clear...what specific form future TOAs might take, how large a role TOAs might play within an international policy framework, whether their role should be as complements to or substitutes for emissions-based agreements, or how effective they might be in advancing certain international climate-policy objectives.”

Despite the challenges and uncertainties related to TOAs under any climate regime, there are success stories (e.g. of solar PV systems in Africa and India), showing how technology transfer may indeed further support technology diffusion and advance significant development objectives. At all events, the aforementioned points indicate that TOAs will continue to be a controversial issue in the climate change policy negotiations.

1.2 Research objective

While there is a growing body of research devoted to climate-related technology agreements in general, and an increasing number of evaluations of how various instruments (CDM, JI, GEF etc.) have promoted technology transfer (see chapter 3), there are relatively few studies that deal with technology-specific agreements.

The purpose of this research project, which is commissioned by the Swedish Environmental protection Agency, is to increase the knowledge about critical (pre)conditions for the effectiveness of technology oriented treaties - promoting technology transfer - in two areas:

⁴ Such risks may include direct risks (e.g. risks from chemicals in groundwater, toxic waste, and stockpiles of old pesticides that must be treated); risks related to economic investment (scarce resources are devoted to a technology that fits badly in the local context) and; more strategic risks (e.g. increased dependence on patent-holding technology suppliers).

⁵ In the current negotiations, EU has argued that funds should be available for covering additional costs of technology transfer, and not to support projects that would be cost-effective without support, and/or projects that would have happened also in the absence of financial support. Several Chinese CDM projects have been criticized as they would probably have taken place without economic support.

1. Carbon capture and storage (CCS) technologies with a focus upon technology status implications, technology availability and capacity based implications for large scale implementation .
2. Technical applications for energy efficiency within the building sector, including:
 - a) building envelopes and material, building services (e.g. climate control, lighting etc.) and
 - b) domestic appliances, with focus upon the role of legally-based performance standards.

The rationale behind the selected case studies stems from the different aspects. In order to reach the 2-degree target, it is estimated that global CO₂-eq emissions must be reduced by 19 Gigatonnes (Gt) in 2020, and energy-related emissions by 48 Gt approx. by 2050 (see e.g. Tomlinson et al. 2008). While the 2020 target can (in theory) be achieved through the use of proven technologies, such as energy efficient and renewable technologies, reaching targets for 2050 and beyond will most likely require support of new technologies through increased investments in RD & D, the creation of programs for niche technologies, and, possibly, the adoption of IPR-related measures (see e.g. Sanden and Azar 2005; Tomlinson et al. 2008). These measures are necessary in order to reduce costs of emerging technologies, such as CCS technologies. Thus, whereas energy efficiency can play an immediate role, CCS is likely to be play role in the longer run once more cost-effective potentials are used up. Besides these aspects, the two main technologies or case studies analyzed can be considered as two “opposites”, in several ways:

- Whereas the diffusion of energy efficient technologies is being already targeted by international climate policy mechanisms (e.g. Kyoto Flexible Mechanisms), much less can be said for CCS, in which international efforts remain mostly confined to knowledge sharing and RD&D.
- Some energy efficient technologies have very short pay-back time and have negative marginal abatement costs. On

the other hand, CCS - even with expected future costs improvements and refinement of techniques - has relatively high marginal abatement costs (cf. picture 1-2)

- Building of low-carbon or zero buildings, as well as retrofitting of old buildings, are cost-effective instruments for carbon reductions in virtually all parts of the world, although the techniques applied may vary due to differences in building material, local preferences, and climate. CCS on the other hand will - at least in the near future - make (economic) sense in a limited number of regions around the world.
- Promoting low carbon building technologies require the involvement of many actors and policies. But the techniques applied are not controversial, or connected to any major risks. Efficient building technologies are to a large extent established and available on most markets. What is needed is mechanisms to ‘quick-start’ the diffusion of technologies, including policies that paves the way for such market penetration (e.g. building codes) and policies that promotes learning (e.g. demonstration projects and the creation of knowledge brokers). In comparison, CCS technologies are still in the demonstration phase; are connected to known and possibly unknown risks; require new legal frameworks, and; will most likely face strong public resistance.

For these reasons, we can expect that the policies and mechanisms for promoting the two technologies are fundamentally different. However, the questions posed for the two technologies in the context of this study are similar in nature:

- What are the key (potential) determinants that determine the successful diffusion of technologies under a TOAs?
- What kind of policies would support TOAs? How can we make nations interested in pursuing technology-specific policy instruments?

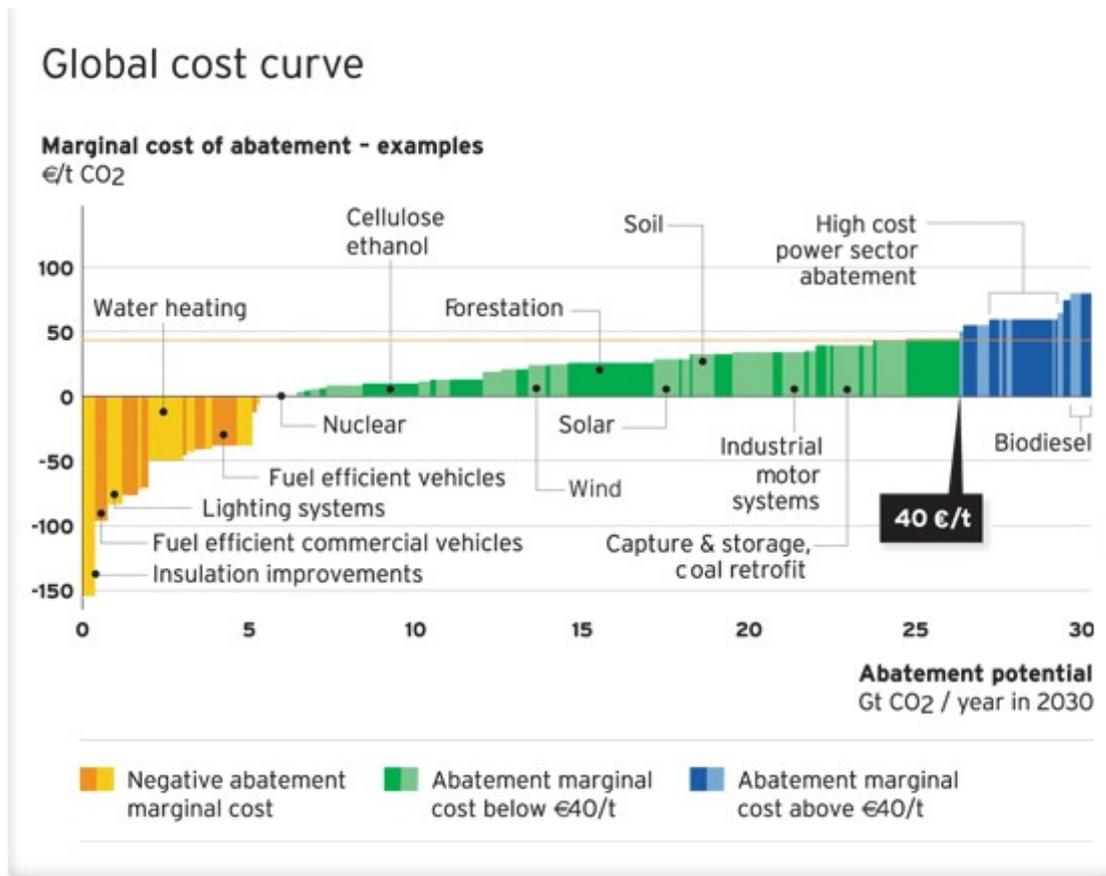


FIGURE 1-1: VATTENFALL/MCKINSEY MACC IN 2030. SOURCE: VATTENFALL, 2007.

- What kind of incentives/policies/other supportive measures should be pursued within the climate regime (in this context the instruments and policies in the Kyoto Protocol and the post-Copenhagen agreement), and what policies/incentives/supportive measures are best pursued outside of the regime? How can the approaches complement each other?

1.3 Methodology and analytical framework

While there are an increasing number of reports devoted to the design of technology oriented agreements in the climate regime, these have very different perspectives, and the solutions advocated vary. Many of the suggestions are influenced by ideology; others propose “optimal” solutions, rather than realistic ones. However, while Bismarck claimed that politics is “the art of the possible”, it is of course impossible to predict the future, and know in advance what is possible or impossible.

In light of the above, we attempt to identify potential ways forward for the chosen technologies, grounding the analysis in:

1. the features and usage of the relevant technologies and related developments, both technological developments and policy developments, e.g. how technology diffusion is promoted through CDM and other instruments;
2. the capacities and support policy mechanisms required to successfully implement the relevant technologies in different regions and settings;
3. literature that deals with technology related issues in the climate regime, most notably literature that provides suggestions for new approaches towards technology transfer;
4. a few additional interviews were made with experts in the respective fields to complement the literature reviews.

An extensive review of peer-reviewed material, books and ‘grey’ literature (i.e. project reports, workshop/seminar presentations, institutional publications, policy statements, etc.) was conducted. Furthermore, information was

gathered during participation at workshops, conferences and other events.

Taking into account the already mentioned critical contentious issues shaping the challenges faced by TOAs, the ‘enabling environment’ approach has been influential as analytical framework to analyze TOAs under this study (see Figure 1-2). In the climate regime discourse the term usually refers to appropriate conditions for the uptake and deployment of low-carbon technologies (Bazilian et al. 2008). This involves policy, market and regulatory conditions, but also people and institutions. The process of strengthening enabling environments is thus tied

to effective governance in general, and the promotion of economic development. Recent literature stresses the importance of working with local entrepreneurs and other local actors which have relevant knowledge about the needs of the local communities in technology oriented projects (Foray 2009.). The achievement of long term GHG emission reduction targets are strongly connected to the build-up of ‘enabling environments’ in developing countries and economies in transition (EIT) - and in some cases also in industrialized countries - in order to build up capacity for large-scale technology transfer (e.g. Bazilian et al. 2008; Tomlinson et al. 2008).

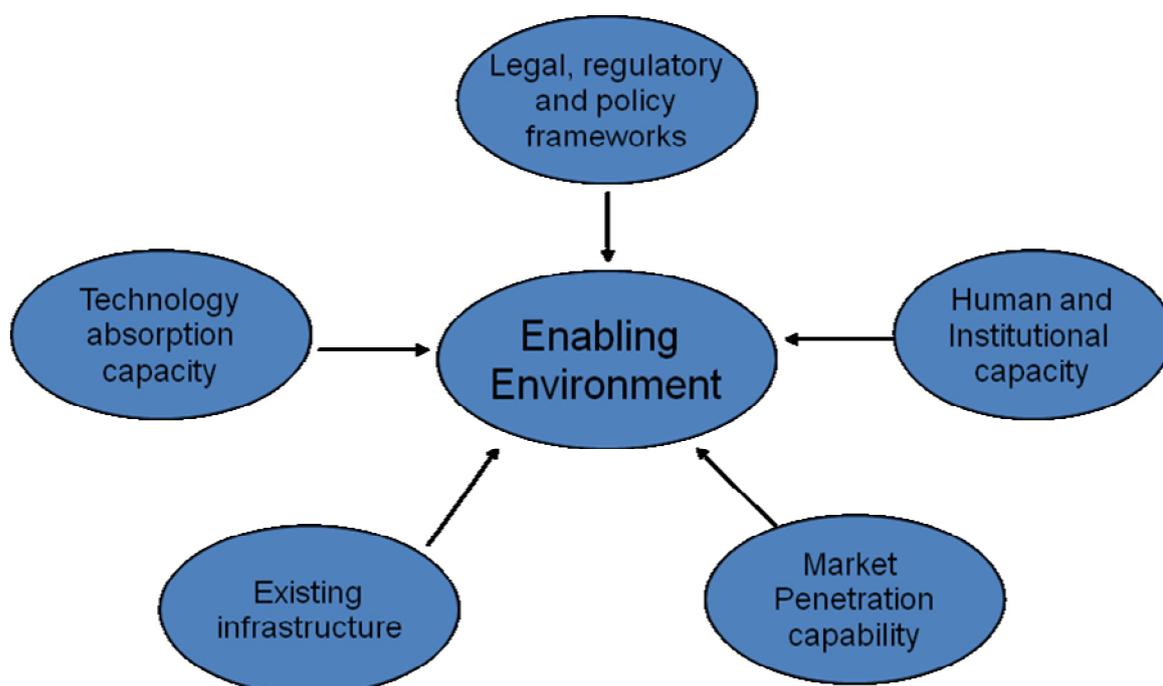


FIGURE 1-1 ENABLING ENVIRONMENTS SCHEMATIC. SOURCE: UNFCCC 2003

‘Enabling environments’ represent key fundamental pillars of technology development, deployment and transfer. Many arguments can be given in this regard. For instance, it is argued that the transfer of technologies comprises integration of human beings, know-how, physical objects and techniques (Karani 2001). Furthermore, the capacity of the workforce in a given country to absorb and apply new technology and know-how is considered a main barrier for a more rapid technology transfer to developing countries (World Bank 2008a). Technology transfer is not only hardware but involves building of human and institutional capacity to handle the technology and the stimulation of awareness among users and other stakeholders (Forsyth 2007; Bazilian et al. 2008). Some authors argue that ‘technology’ is more of a dynamic concept than a static one, as technology is primarily made

up of know-how and the constant use of it (Muntari 2003).

While Figure 1.1 depicts some aspects that may be influenced by policymaking, much attention has been given to the role of factors that are not easy to replicate or stimulate directly through policy measures (Bell and Pavitt, 1993; Bazilian et al. 2008; Tomlinson et al. 2008). These include tacit knowledge⁶ and past learning efforts

⁶ Tacit knowledge is knowledge that can not easily be transferred to another person by written or verbal communication. It is knowledge gathered by experience, often passed down to new people when they enter an organization. In organizational studies, tacit knowledge is considered as an important - sometimes crucial - contributor to sustained competitive advantage in many business sectors. In the case of energy and

of firms and other organizations, the internal organization of firms, investments in human capital and ‘learning by doing’ or ‘learning by R&D’ (cf. Jamasb, 2007), existing supply chains and networks, access to finance, and market structures and competitive pressure. Of importance are also government interventions to correct market failures, and policies that stimulate education R&D and other innovation activities.

1.4 Scope and limitations

There are a growing number of reports proposing frameworks for TOAs for climate-friendly technologies (these are reviewed in chapter 3). It is evident that the proposed suggestions for future technology cooperation depend very much on the background of the authors of the reports, as well as the assumptions made. Different solutions can be considered more or less realistic given the political landscape and current negotiations. In this report we have tried to focus on solutions that could be considered effective *and* politically feasible, though it is of course difficult to know such things in advance.

Besides the technological scope previously addressed (i.e. energy efficiency and CCS), the study focuses on policies pursued mostly outside the scope of any future post-Kyoto climate regime, and some main instruments under the climate regime that are likely to remain (e.g. the CDM) or emerge (e.g. NAMAs) regardless of future development. We have included sectoral CDMs in the analysis because several experts and analysts have recently supported such an approach. Arguments for these choices rely on the following aspects.

The complexities in the current climate negotiations have increased to a point where it is indeed difficult to get an overview of all relevant issues. Copenhagen is likely to constitute a ‘meta-negotiation’ (Depledge 2008) as it must simultaneously deal with a number of complex negotiation strands. The Copenhagen negotiations have three main issues on the agenda: industrialized country mitigation, developing country mitigation and/or actions, and financial and technological support. These strands of negotiations are obviously linked and add complexities and uncertainties to any

low-carbon technologies, tacit knowledge can be of utmost importance in some sectors. In order for ‘laggard’ countries to catch up in some areas, it may not be enough to import technologies, but there is also a need for bringing in experienced people.

future/potential TOAs. Therefore, it would be far too optimistic to expect any details on a future framework for technology transfer. In addition, the details on the design of different instruments, such as a reformed CDM, will probably not be known until the Copenhagen negotiations are finalized. This makes it difficult to focus our analysis and provide concrete recommendations.

Whether relevant TOAs and supporting structures should be pursued within the UNFCCC or outside of it is a key issue. The main arguments for establishing technology-specific agreement(s) under the Copenhagen agreement is that the Carbon Market can support technology policies and most notably that the establishment of additional funds for technology transfers under the UNFCCC can be a potential attraction for developing countries to initiate technology policies, and undertake mitigation actions. Technology transfer fits well into the development agenda. With the main focus of developing countries being on economic development, it may be crucial to add further “carrots” in order to increase the attractiveness of the climate regime. While climate change is often perceived as an environmental issue in developed economies, it is often perceived as a development issue in developing economies.

However, there are *several reasons as to why technology oriented agreements in some cases fit best outside of the UNFCCC/(post-)Kyoto framework*. First of all, our experiences with MEAs are that modest approaches, limited in both subject matter and scope tend to work best (Kellow 2008). The most successful MEAs have often been regional regimes with limited scope (Vogel 1997), perhaps not surprisingly as these have involved fewer parties with similar interests (Kellow 2008). Further, a slow regime-building process, built upon trust and a shared understanding provides a higher chance of success (Young 1994). A further argument for keeping a framework technology agreement, or several technology oriented agreements, outside the UNFCCC/Kyoto framework is that it adds to the already immense complexity of the whole negotiations, making the climate regime even more impossible to grasp (Ueno, 2006). Further, Victor claims that successful regimes tend to involve no more than a dozen negotiating parties; additional members will add a layer of complexity that outweighs the leverage (Victor 2006). Among relevant actors in the climate change discourse, *parallel arenas for climate change negotiations are often seen as something positive, and it is often stressed that initiatives coming from outside the UNFCCC can be imported into the regime over time* (Tippmann

2007). Keeping initiatives outside the UNFCCC can aid in reducing the complexity of the UNFCCC, and avoid dealing with very controversial topics - e.g. crediting of CERs for CCS projects - but at the same time increases the potential for fragmentation of climate efforts, and the risk that beneficial synergies will not be exploited. Many developing countries fear that important future developments will take place outside UNFCCC negotiations. Current outside arenas include the ACP, the G8 and G20 meetings, and various bilateral and multilateral agreements or partnerships. An unfavorable outcome in Copenhagen can give further boost to these developments. In any way, the complexity of the climate negotiations and the controversies surrounding some elements of technology transfer means that the climate regime, and the UNFCCC mechanisms, can hardly deal with all the vital aspects of technology transfer.

Excluded from the main scope of the report are intellectual property rights (IPRs) issues for the main technologies discussed, although IPR issues are discussed at a more general level in the introductory chapters. Further, the report does not propose in any detail how different TOAs could be funded, as funding solutions will to a large extent depend the outcome of ongoing negotiations.

1.5 Structure of the report

The next chapter outlines the conceptual framework of the report, discussing some of the key concepts, including 'technology transfer', and technology oriented agreements (TOAs) before discussing technology governance aspects, i.e. legal and political aspects in current negotiations.

Chapter three reviews the literature on the current state of play regarding technology-related agreements and measures, focusing on the experiences of international technology treaties, and the performance of key mechanisms: CDM, JI, and GEF. It then goes on to analyze the proposals for a strengthened technology regime brought forward in the literature, looking at both proposals for more fundamental agreements, and proposals for reforming/improving the CDM.

Chapter 2-3 provides some background for the case studies in chapter 4 (CCS), 5 (energy efficiency in buildings, and 6 (appliances)

The report ends with some concluding remarks in chapter 7.

2. CONCEPTUAL FRAMEWORK

This Chapter aims to provide a variety of conceptual considerations related to the aspects investigated. As in any research project, this study faced the challenge of making conceptual choices or developing certain terminology. Whereas most of the terms used for the various aspects of this research are not new, endless connotations and interpretations can be found in the reviewed literature.

We first discuss some key terms and concepts, and then discuss some key issues and themes in international governance, focusing on issues of special importance for the climate change regime, and especially technology-related issues.

The chapter provides a background for analyses in later chapters.

2.1 The concept of technology transfer in this report

This analysis follows approaches by the IPCC, the WMO, and others (IPCC, WMO et al. 2000) and defines the term “*technology transfer*” as a “*broad set of processes covering the flows of know-how, experience and equipmentamongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions*”. In this case, the specific motivation for doing so is for the mitigation of climate change. While other ancillary benefits (e.g. economical, socio-developmental, etc.) are recognized, particularly in the case of energy efficiency, they are not addressed specifically in this discussion.

For this discussion, there are a broad suite of areas and subsets of the concept that are worthy to demarcate. Delineation is important to the focus areas of this report (CCS and end use efficiency in buildings) as some areas are more pertinent than others. One can break such definitions down to at least the following subsets:

- **diffusion of technologies** across and within countries;
- **technology cooperation** across and within countries;
- **technology transfer processes between** countries, including **developed, developing** and **transition** economy countries;
- **technology transfer processes amongst** countries, including **developed, developing** and **transition** economy countries;
- the **process of learning to understand, utilize and replicate** technologies;
- the process of building **capacity to choose** technologies and **adapt** them to local conditions;
- the process of building **capacity to integrate** new technologies with indigenous technologies.

While this scope is broader than the treatment of technology transfer in the UNFCCC or of any particular Article of that Convention, it should be noted that the Bali Action Plan has broadened the scope of the technology discussions under the UNFCCC; from focusing historically on technology transfer from industrialized to developing countries to also recognize or address aspects of international collaboration on technology development, deployment and diffusion.

The richness of the topic can also be communicated in different ways. IIASA (2007) for example, provides a useful typology of technology parameters that support discussion of the technology issue:

- ‘*hardware*’: manufactured objects (also referred to as ‘artifacts’);
- ‘*software*’: knowledge required to design, manufacture, and use technology hardware; and
- ‘*orgware*’: institutional settings and rules for the generation of technological knowledge and for the use of technologies.

Functions of Technology Transfer

Of central importance for CCS

Technology transfer processes between developed and developing countries

The process of learning to **understand, utilise and replicate** technologies

Of central importance for Energy Efficiency

The process of learning to **understand, utilise and replicate** technologies

The process of **building capacity to integrate** new technologies with indigenous technologies

Outhred (2008) argues that the importance of the institutional environment is often underestimated, particularly in developing countries where orgware is a major challenge . Outhred also notes the importance of considering not just hardware, but the systems in which they are embedded (i.e. electricity generation and distribution systems, including markets and infrastructure). It may be that discussions of orgware are critical also for the two technology areas addressed within this discussion.

In the case of building efficiency measures, there is significant evidence that the technologies are often reasonably mature, and the application of them requires only moderate knowledge levels. In short, the technologies, and the knowledge to support their application, are generally simple and widely available. Thus a key area suggested by this observation is the rules steering the use of the technologies. It may be that ‘transfer’ of knowledge and capacity to apply firm steering mechanisms is an important area to be pursued.

For CCS on the other hand, while the technologies may not be entirely new or innovative, their application requires a complex and fundamental systemic change – and firm steering mechanisms. Moreover, even if CCS is NOT widely applied in developing countries for two or more decades (a topic discussed later in this report) substantial changes to (power) plant design and build layout probably need to be achieved well within a decade. Further, and as is discussed later in this text, CCS does not have the potential to ‘self-fund’ – thus there may not be immediate ancillary benefits associated with the environmental (climate) service provided.

Taking the theme of intervention in systems of actors, networks, and institutions a little further, Bergek et al. (2008) argue that policy intervention in a number of other areas may be required. They point out that there are several functions that must be fulfilled for a technological innovation system to successfully

deliver. These include development and diffusion of knowledge related to:

- science and technology;
- design and industrial production;
- market development, function and steering;
- logistics systems;
- pathways for actor ‘search’ for market entry and different options within an innovation system;
- entrepreneurial experimentation;
- the social and political understanding and acceptance of technology systems (i.e. ‘legitimation’);
- resource mobilisation (in terms of human capital, financial capital and complementary assets);
- the development and leverage of positive external economies.

This implies that the need to transfer of knowledge, skills, and activities that surround new technological systems go far beyond the technical ‘understanding’ of the technology, and the capacity to use a piece of technology. For the system to deliver its technological promise, the market and the society must be prepared for it.

Thus this discussion underlines the views of the IEA (2001) that “*technology transfer is not simply about the supply and shipment of hardware...*” and seeks to highlight aspects of the complex process of sharing knowledge and adapting technology to meet local conditions. This in turn being critically dependent upon the strengthening of human and technological capacity in developing countries. It is also recognized that the very rapid progress of some countries in industrialization and economic development and the increasingly global spread of technology R&D, demonstration, commercialization, manufacture and deployment add significantly to the complexity of technology transfer discussions.

The subject of this analysis can also be viewed through a Schumpeterian lens that highlights the important effects of political instability, government policies and ‘band-wagon’ effects of the diffusion of new technologies, products, services and markets ...that lead to new techno-economic paradigms’ (TEPs). These are underpinned by changes in the dynamics of the relative cost-structure of all types of production. Once established a TEP becomes a ‘technological regime’ whereby the key technological innovation (that has driven that TEP) is an omnipresent influence in all activities of the economy. A number of observations regarding this are presented in the following text. ‘Bandwagon’ effects do appear to be developing for CCS – one aspect is that they reflect acceptance of the ‘omnipresent’ nature of the coal fired electricity regime to be retrofitted and expectations of expansion of this sector in developing countries. However, a second aspect is that an emerging ‘push’ for CCS is also related to strategic defense of the incumbent industry and recognition that unless CCS is achieved, then the eventual phase-out of coal as a dominant energy carrier may be markedly accelerated (e.g. in developed countries).

CCS represents an expensive ‘add on’ in the short-to-medium term, and a moderately expensive ‘integrated complexity’⁷ in the medium-long-term. While it is being sought to establish a TEP around the technology, it does not appear to have potential to ever provide a more attractive cost-structure of production when compared to the existing technology system. Rather it needs significant early subsidisation, and then a permanently ‘strong’ carbon price to (eventually) pay for the additional costs and drops in efficiency that implementation incurs. As Figure 2-1 indicates, CCS coal retrofit has a positive and relatively high marginal abatement cost.⁸ When viewed in strict economic terms (marginal cost of abatement) it is not a leading technology. It is the ‘fit’ of CCS with the existing system that makes it attractive. In this light, it ‘fits’ with existing (and already planned) energy infrastructure, it presumably has lower transaction costs of implementation (e.g. there

⁷ At present, CCS can be retrofitted to existing facilities at a high cost per unit of carbon stored. With time, the costs of CCS will decrease as it is integrated with more complex facility design, and as scale economies are achieved. It shall however, still involve significant additional cost.

⁸ The figure indicates implementation at a time (during the 2020s) with marginal costs of implementation at slightly under 40€/t of carbon.

are only a limited number of facilities and a limited number of utilities to deal with),⁹ and it has the considerable support of vested interests in the coal sector (fuel), the engineering sector (building of power plants) and the generation sector (electricity).

Energy efficiency measures in buildings are broadly recognized to have a very significant negative marginal abatement cost (see Figure 2-1), however progress has been slow in implementation. No new TEP for building has emerged based on market based dynamics of relative cost-structure of building life cycle performance despite the immediate economic rationality of investment in this sector. This is clearly linked to the common situation that the ‘production’ activity and actors (e.g. ‘construction’ and builders) do not overlap with the areas or actors to whom benefits accrue (owners). Nor is there immediate and tangible payment for provision of environmental services.

⁹ The relative transaction costs associated with CCS may be lower than for many other more decentralised technologies. There is a limited suite of technologies, limited number of sites for injection, a limited number of key actors/constituents, and a relatively small (only thousands) number of power stations and other suitable facilities.

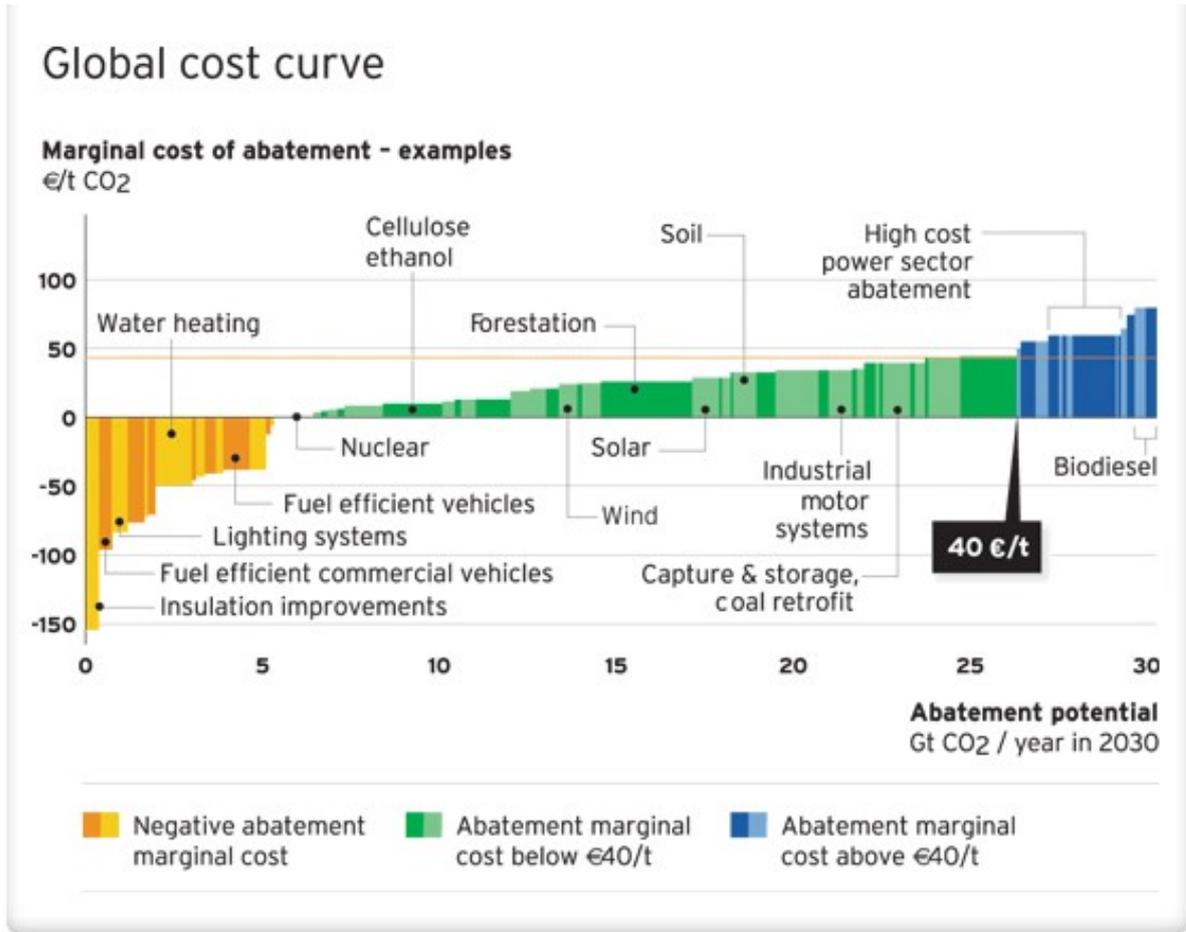


FIGURE 2-1. VATTENFALL/MCKINSEY MACC IN 2030. SOURCE: VATTENFALL, 2007.

An additional point that this discussion must address – but will find difficult to take a clear stance upon – are the dynamics related to the phenomena of ‘technological lock-in’ that appear throughout the CCS debate. On the one hand, CCS is seen in most respected modelling exercises as a pivotal technology for achieving deep reductions in CO₂ emissions. It is also seen as central to actions that can be taken to achieve

meaningful removal of CO₂ from the atmosphere (e.g. related to biomass fired systems fitted with CCS).

Figure 2-2 clearly shows the central importance of CCS and end use efficiency strategies.

On the other hand, many analysts express concern that the huge investments required in

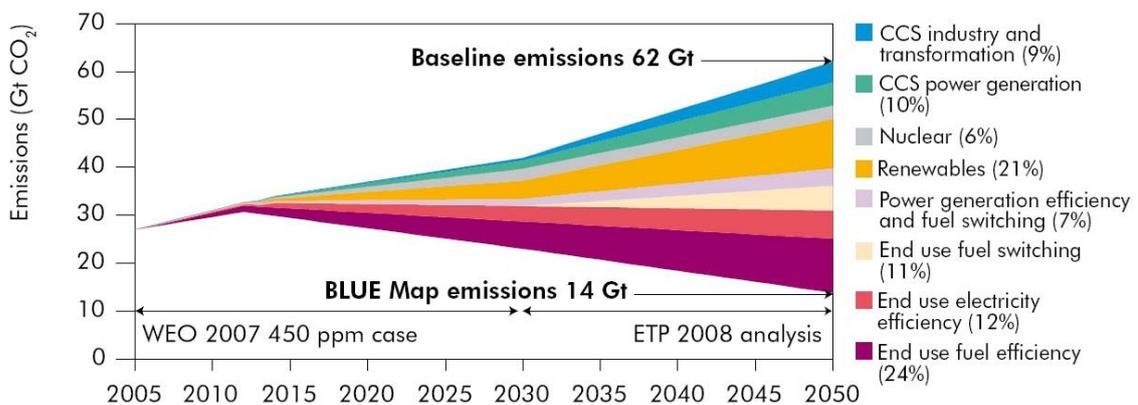


FIGURE 2-2 IEA TECHNOLOGY PORTFOLIO FOR THE BLUE MAP SCENARIO. SOURCE: IEA, 2008.

CCS systems may ‘crowd out’ investments in other worthy technologies.

A self-reinforcing facet of technological change has been referred to as ‘path-dependency’ (David, 1975), ‘technological momentum’ (Hughes, 1983), and ‘technological lock-in’ (Arthur, 1989; and Rosenberg, 1994). Hughes’ focuses on the momentum of the electricity system highlights how system closure may be achieved through: vertical integration of the industry; regulatory capture and stakeholder encouragement of conservative inventions and adoption of technologies that preserve the existing institutional arrangements (Hughes, 1989).

The behaviour of key proponents of CCS (e.g. the coal industry, the coal fired electricity sector, etc.) can already be seen to be demonstrating each of these parameters. In Europe, the 2020 EU Energy and Climate Change package is to provide some €7-12 billion for 10-12 CCS demonstrations across Europe. In the US, the US government is investing more than USD4 billion with some USD7 billion to be supplied by industry.

2.2 Technology-oriented agreements

Whereas most of the terms related to technology transfer are not new, endless connotations and interpretations can be found in the literature. In fact, it did not take much time for the group of researcher to discover that common or no standard definitions for a number of concepts yet exist. To guide this study, we use the definitions given by de Coninck et al. (2008) that differentiate between four main types of agreements:

1. **Knowledge sharing and coordination;** including meeting, planning and information exchange, information about ‘best practice’, coordination and harmonization of research agendas and measurement standards.
2. **Research development and demonstration (RD & D) activities;** including jointly agreed RD & D activities and funding commitments and agreements to expand or enhance domestic RD&D programs.
3. **Technology transfer;** including commitments for technology and project financing, and measures for the facilitation of licensing and patent protection.

4. **Technology deployment mandates, standards, and incentives;** including international agreements encouraging technology deployment through establishing deployment mandates for specific technologies (or groups of technologies), international technology performance standards (e.g. concerning energy efficiency of appliances), or technology deployment incentives (e.g. subsidies for promising technologies or fuels).

In the context of climate negotiations, ‘technology transfer’ tend to refer mainly to the transfer from industrialized to developing countries. As pointed out in literature cases of South-South, and even South-North transfer are becoming more prominent, and will be even more so in the future (Brewer 2008). Still, RD & D activities connected to promising climate technologies in developing countries are mostly located in the large countries¹⁰ with rapidly growing markets – such as Brazil, South Africa, China and India (for examples see e.g. Brewer 2008) – and in the case of patented technologies, patents held by corporations in developing countries can be characterized as innovations (incremental improvements of existing technologies) rather than inventions (see e.g. Barton and Osborne 2007; Tomlinson et al. 2008). The development capacities in most developing countries are still very limited (Hutchison 2006), though there are some obvious exceptions to this rule; China might become a key player - including R&D, commercialization and export - in clean technologies within the next 10-20 years.

Trade and ODA are the main instruments of technology transfer. Technological knowledge, experience, and equipment can be transferred from industrialized to developing countries through various channels, such as export; foreign direct investments (FDI), including joint ventures (JVs); licensing; and imitation (Ueno 2009). The different flows can end up in deployment and diffusion of mitigation technologies, but may also lead to local production of mitigation technologies in developing countries (Ibid.) (cf. figure 2-3).

¹⁰ In the current climate negotiations, several actors would like to change the status of some of these countries, questioning whether they should be labelled as developing countries/Non-Annex I countries, and enjoy some of the associated benefits of their status in the UNFCCC regime.

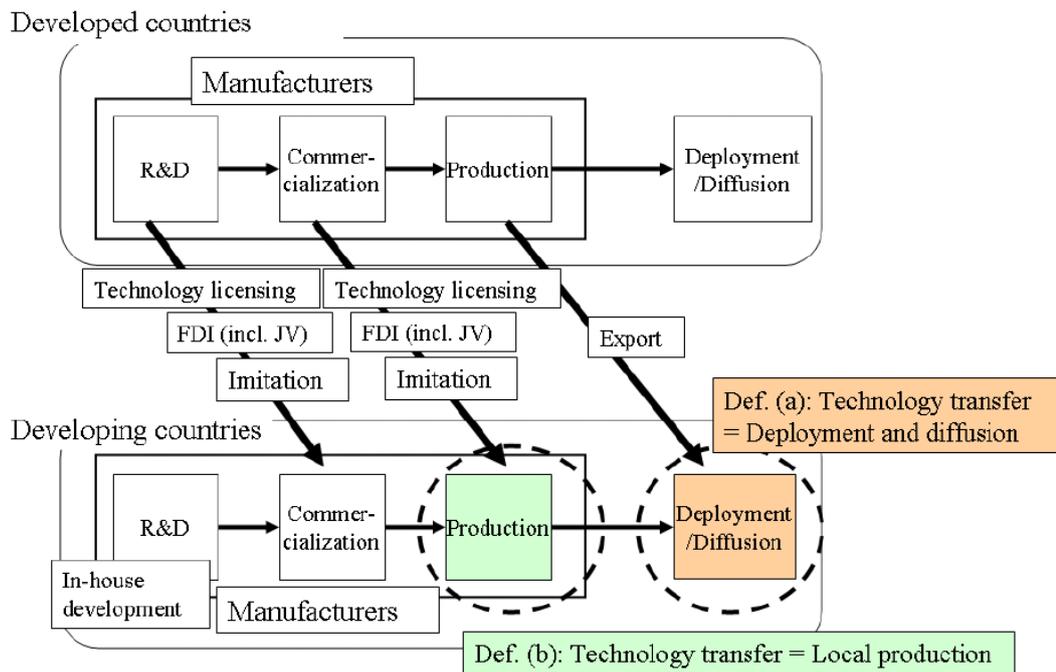


FIGURE 2-3. TECHNOLOGY TRANSFER FLOWS (SOURCE: UENO 2009)

2.3 Bilateral projects

There are currently no existing multilateral treaties that effectively deal with the *transfer of low carbon technologies* from industrialized to developing and EIT countries at a high scale (similar to the Montreal Protocol). Instead, technology transfer has taken place mainly through bilateral projects. There are a vast number of completed, undergoing and planned bilateral projects that aim to stimulate the uptake of energy efficient and renewable energy technologies in developing countries, within or outside the scope of CDM and JI. These are financed by both international and national bodies, and investors include the regional development banks like the Asian Development Bank, the Global Environment Facility (GEF) and domestic bodies such as the USEPA and state aid organizations. These projects may be divided into different categories (Evander et al. 2004):

- *Diffusion of ready, "off-the-shelf" products, which can be directly transferred from industrialized to developing countries* (e.g. light bulbs, refrigerators, wind turbines and solar PV systems);

- *Diffusion of technologies that have been upgraded or industrialized in order to adapt to the context in developing countries* (e.g. upgraded industrial processes, and solar PV systems for household use); this can be done either
 - by manufacturers inside of outside the developing country.
- *Diffusion of technologies from industrialized to developing countries (or from one developing country to another one) and development of a local industry for the further production of technologies;*
- *Projects that promote knowledge transfer and the elimination of barriers for diffusion and development of new energy technologies.*

The two principle mechanisms for promoting technology transfer between countries are international trade and different types of development assistance. Projects implemented under the different instruments that constitute the Carbon Market, such as the CDM and JI, usually include an element of technology transfer, and they provide impetus for different actors to engage in projects which may otherwise not have taken place. In the long run we can expect - or at least hope (see discussion in chapter 2) - that carbon markets will be a key driver for technology development and diffusion, at least if

the price of carbon goes up, but in the short run there is an evident need for more policy interventions, especially in order to meet the 2020 mitigation targets.

2.4 Technology innovation chain

There are numerous theories on technology and innovation, and we will not account for all of these here but attempt to summarize key concepts that guided our analysis. There is some consensus that technology development has four main stages (constituting the so-called innovation chain): R&D¹¹, demonstration, (initial) adoption, and diffusion. R&D entails fundamental research as well as application research, while demonstration tests the technical and commercial feasibility of technologies (e.g. by construction and operation of plants and equipment). Initial adoption entails some market penetration; a stage essential in order to reduce production costs and price, through technology learning and removal of various barriers that hinders diffusion (Ueno 2006). With lower costs and higher social acceptance of a policy, a technology may become competitive and ultimately more commonly diffused. In reality, the boundaries between the different stages in the innovation chain tend to be indistinct.

Government intervention may be required in order to nurture a promising, emerging technology. Different government policies can be applied in different stages of the innovation chain

¹¹ “Research and development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D is a term covering three activities: basic research, applied research, and experimental development.” (OECD Factbook 2008).

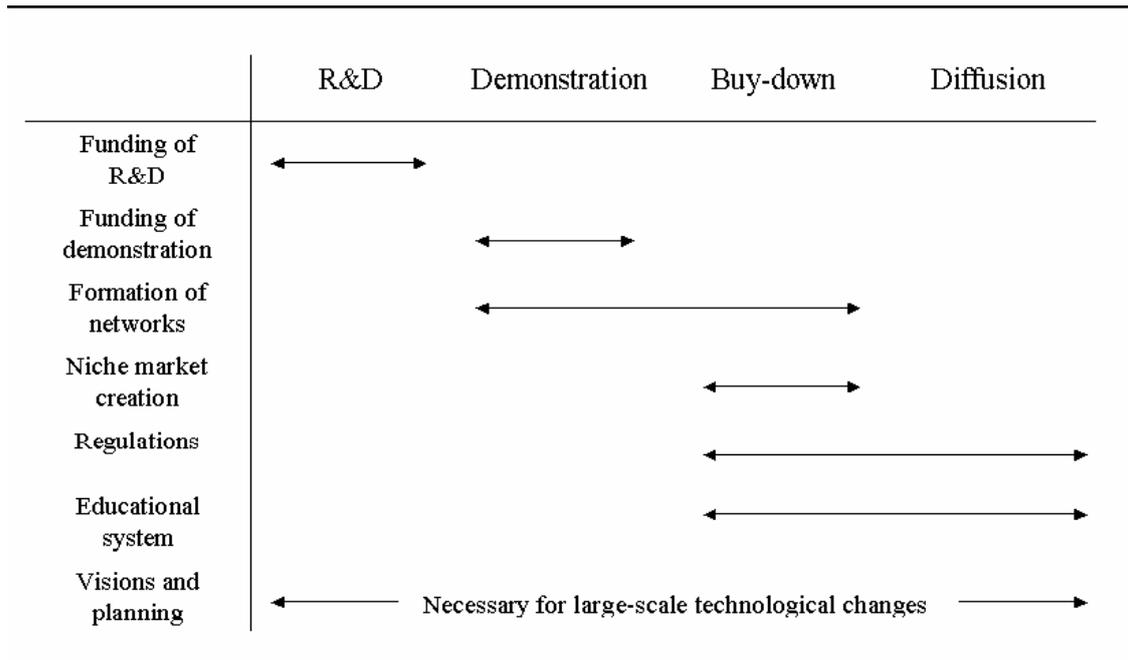


FIGURE 2-4. POLICY INSTRUMENTS FOR ENERGY AND ENVIRONMENTAL TECHNOLOGICAL INNOVATION (SOURCE: UENO 2006)

In the case of energy-efficient products used in households, current policies tend to focus on improving the environmental efficiency of ‘mature’ product groups, where limited invention takes place (e.g. fridges and freezers, TVs, PCs, air conditioners, etc.). Innovation in such products groups is probably best provided through a policy mix that provides incentives for both front-runner and laggards, through a combination of carrots and sticks, cf. figure 2-5. Some instruments (e.g. EU dir. 2005/32/EC and eco-labels¹²) addresses not only energy efficiency but also other environmental life cycle environmental impacts of products, allowing for reasonable trade-offs between different environmental parameters (and costs) in standard-setting.¹³

¹² Note: there is a difference between voluntary eco-labels (which may embrace several environmental parameters such as energy efficiency, recyclability and toxic content, and mandatory energy labels).

¹³ From a regulatory standpoint, not only trade-offs between different environmental parameters and between environmental gains and costs relevant, but also the coordination of various laws addressing the environmental performance of products. For a discussion on the regulatory complexity in an EU context, see van Rossem et al. (2009).

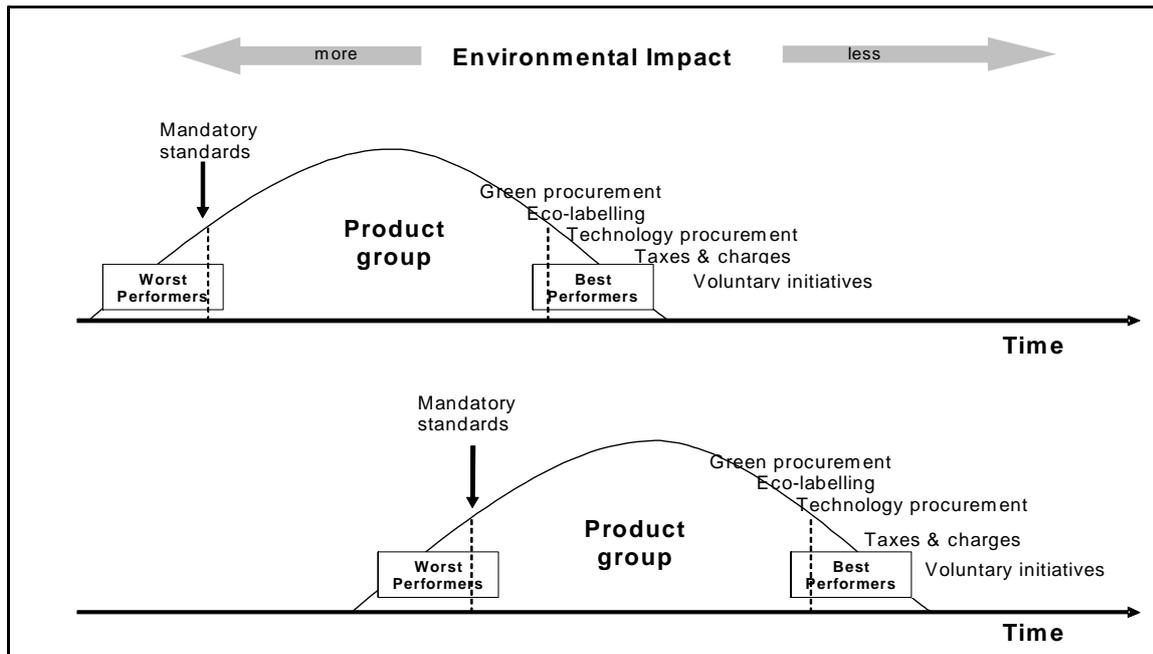


FIGURE 2-5. POLICY INSTRUMENTS AND ENVIRONMENTAL PERFORMANCE OF PRODUCT GROUPS OVER TIME (SOURCE: DALHAMMAR 2007A)

However, while several jurisdictions - including the EU and Japan - has implemented (or are in the process of implementing) product performance standards, what is often missing is a more strategic focus on how different instruments can drive innovation among both forerunners and laggards. For instance, current EU policies will mainly drive innovation among the laggards - thus getting the worst performers off the markets - while instruments that would drive innovation among market leaders are missing (Dalhammar 2007a).

2.5 Technology governance

2.5.1 Technology and policy agendas

Climate change raises serious issues in regard to global environmental justice, and such issues must be dealt with in order to successfully deal with legal, economic and technological dimensions in the long run (Brunnee 2009; Vandenberg et al. 2009); in the long run, developing countries will only commit to options considered 'just', and institutions lacking legitimacy can hardly last. Whereas it may be very hard to define what justice entails in specific contexts, it at least requires that the outcomes are considered as (relatively) fair by the involved parties. According to many analysts, climate negotiations to date have not adequately addressed equity and ethics, in this line Ekman et al. (2008:24) claims:

"...the fundamental principle of equity must underlie the post-2012 climate agreement. Unless developing countries are on board, any attempt at agreement will inevitably fail. An emergency climate stabilization plan does not allow developing countries to go through the same carbon-intensive stages of development as the North. Radical transformations of technology and energy systems are needed. This requires industrialized countries to provide large-scale technological and financial support. The necessary technology transfers are not primarily about generosity – but represent a much needed settlement of a historic debt and a fair sharing of the burden based on the capacity among rich and poor nations. This moral imperative is strengthened by the recognition that a large share of developing country emissions is caused byproducts that are consumed in the industrialized world."

These arguments are indeed well founded, and it implies that industrialized countries should take on large mitigation packages, confess to their historical contribution to climate change, and be prepared to invest considerable funds to technology transfer projects benefitting growth, improved well-being and reduced climate change in developing countries. It is also easy to agree with Tickell (2009), who wants to see a shift in the debate, from a negative discourse on burden sharing to a positive engagement in how to divide the benefits of climate change. Several authors point to the importance of "no-lose" options for developing countries, which would mean that they see opportunities associated with

climate measures rather than restraints on economic developments (e.g. Depledge 2008).

There are however several valid reasons why such a strategy may not be very successful:

- *'Realpolitik' considerations:* Many industrialized countries are not likely to admit any guilt for climate change (and thus continue to bypass the 'common but differentiated responsibilities' principle), nor interested in committing the necessary funds for technology transfer activities. Unless there is reasonable proportionality between funds devoted by different industrialized countries, opportunities for free-riding and associated mistrust are plenty. An additional problem is that the governance mechanisms in some developing countries are considered too insufficient to handle large funds; some of these will be lost through corruption and improper management (Bergström 2009).
- *Time considerations:* In order to reach the 2 degree target, swift and national effective policy measures are necessary.¹⁴ This implies a strategy that focuses on countries and societal sectors associated with high emissions.
- *Past experiences of cooperation:* Past experiences of technology cooperation (see chapter 3) indicate that countries seldom engage in deep cooperation but rather 'information sharing' activities with little pooling of common resources for technology advancement; that domestic interests are the priority, and; that countries tend to transfer domestic funds to common purposes mainly for large, very costly technology projects.

These complexities of international climate policy will increase, not least due to the inevitable, but problematic, need to coordinate/integrate several development and political agendas but also trade and national climate regimes (WTO/UNEP 2009). In the current climate negotiations, EU has taken a rather 'soft' stance, trying to rely on persuasion – and carrots in the terms of financial assistance – rather than more coercive approaches. But there

¹⁴ Some recent reports even indicate that the importance of speed is greater than previously thought.

is little reason to expect that such a strategy will work unless supported also by more 'coercive' approaches. Nilsson et al. (2009), when discussing the role of EU in assisting and inducing emerging economies to make climate-related commitments, states (p.49):

“EU policymakers need to consider sticks as well as carrots – preparing for different scenarios and determine its response for each. An unchartered way forward is to more strongly integrate policies and negotiations across traditionally separate sectors, such as trade, development cooperation and climate change, and develop “policy packages” at the international level much like the EU has done in the energy and chemicals sectors domestically¹⁵

If the Copenhagen outcome is not very successful, a scenario which looks more and more likely, it may sign the dawning of a new agenda. A number of developments are possible, including:

- *Focus on main emitters.* In principle, a rather limited number of parties would cover about 75 % of world GHG emissions, and one potential option is to focus on these actors in order to achieve quicker results (Victor 2006). Main emitters in the developing world include mainly large countries (China, India, South Africa, Brazil, etc.) with

¹⁵ According to Nilsson et al. (2009:4): *“EU commitments to carbon pricing are not mirrored in the near future in the US and in emerging economic powers such as China and India, it cannot be ruled out that a further integration of climate and trade policy is needed, for instance through the application of price adjustments for globally-exposed industries that have high mitigation costs, such as iron & steel, chemicals, and paper & pulp. The principal argument is clear: the core reason for global market liberalisation is to create a level playing field for industries to compete on equal terms. If Europe imposes restrictions and costs on its domestic industries to mitigate climate change, this creates a distortion of the playing field. There is no doubt, from ecological, economic and political perspectives, that greenhouse gas emissions must be priced one way or the other – either at the time of production, distribution or consumption of goods and services. Policy packages reflecting this fundamental insight could be more explicit in Europe’s policies towards multilateral negotiations.”*

reasonable internal capacity to deal with technology-related policies. The key in order to quickly cut emissions is therefore to focus on these countries. Time and resource consuming capacity-building efforts in other developing countries bring about smaller GHG reductions, and it will take time to achieve them; thus they could become less of a priority.

- *More focus on other actors.* The governance structure of countries will determine what solutions that can be considered most appropriate. For instance, in developing countries with high corruption levels and poor governance, it makes sense to provide direct incentives to market actors and local entrepreneurs to engage in carbon projects. In the current ODA discussions, ideas for “bypassing” governments, for instance by creating independent, strong economic entities, are discussed (Hyden 2009).
- *Less dependence on carrots and more reliance on sticks.* It is very likely that the issue border tax adjustments (BTAs) (i.e. tariffs on imports or rebates for exports) will receive more attention after Copenhagen¹⁶. BTAs and other measures such as free emissions allowances, countervailing duties (against ‘de facto’ subsidies in the form of absent carbon restrictions), and anti-dumping duties. While BTAs could be considered trade distortive, and bad policy (cf. Bhagwati and Mavroidis 2007), they have recently gained support from leading economists like Paul Krugman.¹⁷ BTAs serve several important functions: they would reduce the risk for carbon leakage; prevent free-riding of states, and; increase the incentives for joining international agreements and undertake domestic reduction measures. While EU governments have not stressed the possibility of tax recently, in order not to disturb current negotiations, the outcome in Copenhagen could change the attitudes. While the US previously opposed such a tax, the current

administration – as well as the Senate and the Congress – will most likely support it, as the US will most likely implement a cap-and-trade scheme and therefore would like to prevent carbon leakage.

- *More use of technology deployment mandates, standards, and incentives,* including international agreements encouraging technology deployment through establishing deployment mandates for specific technologies (or groups of technologies); international technology performance standards (e.g. concerning energy efficiency of appliances); or technology deployment incentives (e.g. subsidies for promising technologies or fuels). As demonstrated by MARPOL and the Montreal Protocol, technology and performance standards may induce nations to join agreements instead of free riding, because adopting standardized technologies can be more beneficial than not doing so (cf. Barrett 2003; de Coninck et al. 2008).¹⁸ While there are few examples of international environmental agreements of this kind, there are relevant examples within the European Union. Further, EU laws setting standards for energy-efficient products and toxic substances in products tend to be implemented also in other jurisdictions, as these want so safeguard exports (Selin and VanDeveer 2006; Dalhammar 2007a; Dalhammar and van Rossem forthcoming 2009). The vision of an eco-efficient global economy requires front-runners, which come up with new standards and innovative policies, which then are taken up by other countries for different reasons (Jänicke 2005). The EU is currently the main front-runner due to market size and the willingness to regulate. In many cases the European Commission has been forced to adopt stringent standards in order to block national standards which would disturb the functioning of EU’s internal market

¹⁶ There are however severe methodological problems associated with the introduction of BTAs (WTO/UNEP 2009).

¹⁷ See e.g. Krugman, P. (2009). *Fetishizing free trade*. Paul Krugman’s blog, September 11, 2009, accessible through www.nytimes.com.

¹⁸ This is even more obvious in the case of consumer product standards, where the reason for governments to adopt the most stringent standards are economic in nature: standards are enacted in order to meet market requirements in all relevant export markets and safeguard exports from domestic industries, and to improve the environmental knowledge/ performance of domestic industries (Dalhammar 2007a).

(Dalhammar 2007a; 2007b). The EU can continue to act as a standard-setter (cf. Nilsson et al. 2009), but in the future we can expect that different nations will lead the way in different areas.

However, the idea that technology and performance standards may induce nations to join agreements instead of free riding has so far applied only for certain standards and certain countries, as not all countries have the willingness - especially when the implementation of standards are not connected to direct economic benefits - or capacity to implement stringent standards. Poor market surveillance practices in some countries make authorities unable to monitor and prevent low-quality illegal products from flooding the markets and cause consumer mistrust (Evander et al. 2004). One way forward in the international climate efforts is to more strategically push for adoption of technology standards, with special focus on developing countries, where *the adoption of technology standards in combination with credible programs for monitoring and enforcement could be stimulated by funds from industrialized countries*. Such policies would – often in the absence of market demand – “pull” technologies into the market through the provision of strong economic incentives or mandating of their use (de Coninck et al. 2008). While harmonization of standards is not positive under all circumstances¹⁹, many standards are connected with strong social welfare benefits, and may provide “win-win” scenarios as they simultaneously reduce GHG emissions and save money. Standards for energy efficient buildings and energy efficient products offer promises of win-win as they reduce life cycle energy costs, but as they tend to require higher up-front costs, subsidies are often vital.

Ueno (2006) holds that the most effective way to handle complexity associated with international cooperation is to reduce degrees of freedom. He uses the example of reciprocity principles applied in trade regimes, where actions by each country are conditional to counterparts’ actions. A regime that focuses more on standards and technology mandates should probably pursue

¹⁹ It is often held that harmonization at the global level may mean that developing countries must adopt practices and standards of industrialised countries even if these are not appropriate for local conditions (cf. Mayeda 2004; MacDonald 2005), and there are also concerns that standard-setting is an industry-driven process where other actors have limited influence (UNCTAD 2006; Dalhammar and van Rossem 2009).

reciprocity in the sense that funds are strongly dependent on the creation of strong and credible policy packages and, eventually, results.

Among relevant actors in the climate change discourse, *parallel arenas for climate change negotiations are often seen as something positive, and it is often stressed that initiatives coming from outside the UNFCCC can be imported into the regime over time* (Tippmann 2007). Keeping initiatives outside the UNFCCC can aid in reducing the complexity of the UNFCCC, and avoid dealing with very controversial topics - e.g. crediting of CERs for CCS projects - but at the same time increases the potential for fragmentation of climate efforts, and the risk that beneficial synergies will not be exploited. Many developing countries fear that important future developments will take place outside UNFCCC negotiations. Current outside arenas include the ACP, the G8 and G20 meetings, and various bilateral and multilateral agreements or partnerships. An unfavorable outcome in Copenhagen can give further boost to these developments. In any way, the complexity of the climate negotiations and the controversies surrounding some elements of technology transfer means that the climate regime can hardly deal with all the vital aspects of technology transfer.

2.5.2 Furthering technology: The technology paradigm vs. the market based paradigm

A key issue concerns the importance of the technology perspective vs. other perspectives in the climate change discussions. The proponents of a “technology paradigm” sometimes clashes with opponents of the reigning “market-based paradigm” in the climate discourse. The current belief in the market mechanism (the “market-based paradigm”) has several critics. For instance, Jeffrey Sachs has cautioned that we might promote an approach where a lot of talent and time is invested in the engineering of financial instruments of the Carbon Market, an undertaking which does not really solve any social problems and may attract talent, innovation and resources away from more fruitful approaches (Reuters 2008). The analogy with the discussions on the current economic crises is striking, as many university talents in the last decades have engaged in financial engineering rather than traditional engineering.

Another concern, voiced by some authors, is that there is a fatal flaw in the current “market-based paradigm” mindset. In essence, the reason given is that the main premises are incorrect: *no governments are willing to initiate a system*

where the true costs of carbon emissions are internalized in the near and medium future, thus making the tax vs. cap-and-trade debate meaningless; the price signals will never be strong enough to stimulate new technologies on a large scale, regardless of what policy instruments that are chosen as the main strategy (Nordhaus and Shellenberger 2009).

It is therefore proposed that public investments promoting cheaper and cleaner energy, rather than reliance on just price signals (e.g. through taxation or cap-and-trade systems) will be the main solution for reducing emissions (Ibid.). Nordhaus and Shellenberger (2009) propose that we should accept that the price signals will not be adequate, and should instead use revenues from taxes or auctioning to invest in R&D, and deployment and diffusion of technologies. This line of thinking implies a shift away from viewing private interests and markets as the primary drivers of technological innovation, instead focusing on public investment. However, this approach requires significantly more investment than is proposed today. As an example, the proposed Waxman-Markey bill in the US will – if adopted – provides only marginal additions to the current RD & D spending.

Bazilian et al. (2008) discusses whether a more extensive treatment of technology in the climate regime would mark a departure from the current paradigm of market-based instruments. However, given the current discourse, it appears quite unlikely that a technology focus would out-compete the market-based focus and the optimal solution might be that a strong technology framework is industrialized and that it operates in synergy with the main elements of the market-based approach. In this line, Bazilian et al. (2008:46) holds that:

“...the literature on economics, political science, law and policy identifies difficulties of reaching international agreement on emission reductions, and free-rider incentives can provide for an unstable coalition... A self-reinforcing technology framework might provide the reciprocity and solidity that an agreement based on emission reductions alone lacks. As such, the focused treatment of technology should be considered in concert with the more ‘dominant’ paradigm of market-based instruments in international climate policy.”

There is most likely some agreement that if we are to effectively respond to the climate challenge there is a need to raise both public and private investments for innovation and diffusion of low-carbon technologies. Newell (2008:29)

also holds that the two perspectives are complementary:

“Climate technology policy must complement rather than substitute for policies that provide a direct financial incentive for emission mitigation. R&D without market demand for the results would ultimately have limited impact, while market demand-pull without supportive technology policies misses longer-term opportunities for significantly lowering GHG mitigation costs and expanding opportunities for greater GHG mitigation.”

Obviously, in the current situation where there are no - or very limited - markets for climate-friendly technologies in many (if not most) countries, climate policies that set a price on carbon are usually considered the most cost-effective means of encouraging technology deployment (Newell 2008). Further, a price on carbon will stimulate innovation for new carbon-friendly technologies as long as there is some certainty regarding the future policy framework. However, while some writers have a positive view of the RD & D activities in the private sector, it is not likely that the carbon market will do the job without support from various technology oriented policies and measures.

As Sandén and Azar (2005) note, there is an inherent danger in allowing cost-effectiveness to be the main parameter when deciding upon which mitigation measures to apply. Whereas the unconstrained use of flexible mechanisms may be supported by some economists, relying too much on such an approach may lead to an extreme near-term cost-effectiveness where the financially most viable options are pursued, and there is suboptimal investment in new technologies. IEA scenarios also indicate short versus long term issues with promotion of near term cost effective fuel switching to gas, versus longer term investment in CCS and renewables (IEA 2008).

Furthermore, the concept of cost-effectiveness is embedded in efficiency (i.e., maximization of the difference between total social benefits and costs or Pareto potential improvements), which in public policy is often mentioned as the most relevant evaluation criterion for any policy. However the latter involves that an optimal climate policy target is determined in relation to well-being. In turn, efficient policy instruments are cost-effective, however not all cost-effective policy instruments are efficient. This is because the predetermined policy target may not be efficient (Tietenberg, 1996). To add complexities to the economic rationale, one has to bear in

mind that even if an instrument meets the efficiency criterion, very little—at best—can be said about the fairness of the distribution of costs and benefits. Thus, efficiency should not be a required or satisfactory condition in public policy choice (Panayotou 1998).

New promising emerging technologies must therefore be supported through various mechanisms. Sandén and Azar (2005) also claim that while higher carbon prices will create incentives for more innovation, using flexible mechanisms nevertheless tend to be cheaper than emerging technologies in most cases regardless of the carbon price. This, they claim, is an argument for pursuing technology specific policies rather than high carbon prices. A potential risk with a very high carbon price is that it may promote the wrong emerging technologies (and not those with long-term potential). They therefore propose additional investment in RD & D and policies that creates markets (these should be technology specific to avoid premature lock-in).

The provision of strong incentives for technology mandates, deployment and incentives in developing countries, coupled with mechanisms that would reduce free-riding and the risks of carbon leakage, could become very effective as means for furthering technology transfer, especially for certain types of technologies. Policies that would promote more stringent standards by using mechanisms of free trade (“race to the top”²⁰) using the mechanisms of free trade will work for some technologies in some jurisdictions, whereas other technologies, especially in the context of less industrialized economies, require more support.²¹

²⁰ The ‘California effect’, or ‘a race to the top’, means that countries tend to adopt stricter standards, while a ‘race to the bottom’ (also known as the ‘Delaware effect’) implies that countries opt for a reduced level of environmental and social protection in order to gain economic advantages (increased investments etc.). Several authors have discussed why there is often a race to the top, even though conventional wisdom may lead us to think that there would be a race to the bottom (Vogel, 1995; Princen 2004; Bernauer and Caduff 2004). A race to the top is however much more likely to occur in the case of product standards than other types of standards (Scharpf 1997; Dalhammar 2007a).

²¹

2.5.3 Technology agreements: connected to the post-Kyoto agreement, or separate?

The main arguments for establishing technology-specific agreement(s) under the Copenhagen agreement is that the Carbon Market can support technology policies and most notably that the establishment of additional funds for technology transfers under the UNFCCC can be a potential attraction for developing countries to initiate technology policies, and undertake mitigation actions. Technology transfer fits well into the development agenda. With the main focus of developing countries being on economic development, it may be crucial to add further “carrots” in order to increase the attractiveness of the climate regime. While climate change is often perceived as an environmental issue in industrialized economies, it is often perceived as a development issue in developing economies.

However there is a further complexity, which is relevant in the context of this study: How should we coordinate and harmonize the Carbon Market. With the KP into force, different GHG schemes and corresponding markets are taking off. Key questions to ask are: How compatible are these schemes, and how compatible will they be in the future? Do they deal with the same GHG? What kind of legal procedures do they apply in order to ensure environmental integrity? Do they apply the same timeframes? Do they address the same obligated parties and economic sectors? Do they all trade in Kyoto units (i.e. AAUs)? How different are measurement and verification procedures for the various technologies that are eligible to yield emission reductions? With these issues in mind, can the various carbon markets be harmonized? At the moment, we can witness a variety of several GHG related GHG certificates that are compatible in principle. However, one can observe key differences in terms of (i) price differentiation by certificate, (ii) project type, (iii) lifetime, and (iv) bankability.

Ueno holds (2006:8), “*Coupling technology cooperation with emissions trading creates an additional level of complexity, and the wisdom of combining the two can be disputed.*” There are two main issues here: 1) should technology oriented policies be pursued within the (post-)Kyoto framework?; 2) if the answer is yes, how do we manage the complexity of relating emissions and technology efforts? Institutional issues are of crucial importance here.

For developing countries CDM is so far the main mechanism for connecting technology related measures with market based instruments. The CDM is however criticized for its poor performance in furthering development

objectives in host countries, and additional measures would be attractive (see the discussion in chapter 3). Sectoral-CDM and NAMAs are options for furthering technology transfer within the climate regime. If Annex I countries are prepared to make detailed commitments on funds for technology transfer and capacity building, there is also a possibility that non-Annex I countries might be more willing to discuss binding GHG emission targets.

While there are hopes that CDM will be reformed in Copenhagen (vital issues include how to trigger more CDM projects in the poorest countries and the inclusion of CCS in CDM), the current negotiations have not progressed as expected in that regard.

Voluntary carbon markets obviously provide more flexibility, but have severe shortcomings. They could help to bring countries without Kyoto reduction obligations on board, but in order to ensure compliance peer review procedures must be combined with pressure. An interesting option concerns crediting voluntary agreements under the UNFCCC.²²

A potential way forward concerns having technology-oriented agreements where involved countries choose certain technologies to focus on which they consider most appropriate for them (cf. Caspary et al. 2007). This means that they choose a range of technological commitments. Ideally this structure would include binding emissions targets as well. However, if developing countries were to sign up for binding targets they would probably demand that 1) that all large-emitting industrialized countries set their own binding targets for emissions reductions and 2) commit to finance developing countries with large enough sums of money.

In order to increase diffusion of small-scale technologies, such as is the case in the building sector, policy options include need programmatic CDM, sector(al)-CDM, and some type of 'policy'-CDM (or alternatively, and more realistic as it currently stands, policy-related

²² However, in order for voluntary agreements to function, there needs to be criteria industrialised for deciding which agreements that would qualify (they should go beyond BAU, be transparent, etc.), and a monitoring mechanism. Such rules have been set in the context of the energy-using products (EuP) Directive (Dir. 2005/32/EC) in the EU, where industry voluntary commitments can act as substitutes for legally binding standards for product energy efficiency (Dalhammar 2007a).

NAMAs), to quickly advance technologies. Policy-CDM and sectoral-CDM approaches may aid in overcoming some of the problems and complexities associated with project-CDMs. Here we however run into a number of problematic issues (as is discussed in chapters 3-6). It is likely that technology diffusion should be pursued both inside and outside the scope of the post-Kyoto framework. As will be discussed in the coming chapters, some issues are probably better pursued outside of the climate regime; these may cover standardization of concepts (zero emission buildings, low carbon houses, etc.), a forum for exchange of best practices etc.

2.5.4 Development perspectives

For LDCs, the technology transfer taking place will always be suboptimal in relation to these countries' needs. Foray (2009) argues that for LDCs, it is relevant to initiate technology transfer projects which have few - or none - commercial benefits for technology-owning corporations in industrialized countries, i.e. the private gains are close to zero or even negative. He states (p. ix):

"...in the case of least industrialised countries (LDCs), the number, scale and domains of TT [technology transfer] cannot depend alone on general economic operations, such as foreign direct investment (FDI) or infrastructure construction; neither can they only take the form of market transactions (licences). In all these cases, the particular circumstances and conditions that prevail in LDCs imply a suboptimal level of TT in relation to these countries' needs.

There is therefore an obvious economic rationality for specific projects in which the TT is the primary product (an economic project in itself, not linked with another economic operation) but entails a low expected private profitability for the technology-owning firm. Such a prospect would involve acknowledging the existence of TT operations with far smaller commercial returns or no commercial return at all and finding operational mechanisms to incentivise these firms to sink costs in these operations. Such a strategy requires the provision of additional incentives from governments of industrialised countries."

But a main concern is how to engage technology-owners in such projects. In order to do so, governments must provide additional benefits for technology-owning firms to engage in

technology transfer activities, when the profits are low. However, it is still stressed that the locus of decision-making regarding areas of focus and learning should shift from foreign bodies to local authorities and agents (Ibid.).

Tomlinson et al. (2008) also stress the need to ensure that “orphaned” areas of research – where the market incentives are lacking, e.g. because the potential users can not pay market prices – should be covered by international action.

Foray (2009) argues that governments should assist only those projects that are 1) socially beneficial and 2) not very profitable. Further, he stresses the need to identify relevant partners, develop the right area of focus (most notably where there is an expressed local demand for a given technology), find the right organizational form, and look at the entrepreneurial dynamic. He further claims that public-private partnerships should be used to the extent possible because these can enhance effectiveness and efficiency of projects. She further stresses that technology transfer projects in LDCs should primarily be a response to a demand for technology stemming from local entrepreneurs.²³

What is needed in many developing countries and especially the LDCs, is more focus on small projects, where there is an expressed need for the technology among the (potential) users, and where local entrepreneurs play a key role. A main issue for climate policies in LDCs concerns whether it is beneficial to merge development and climate issues, e.g. by pursuing ODA projects that provides both development and reduced climate impacts. Obviously, climate change may in itself have impacts that hamper economic developments, so climate issues must be taken into account in development projects. Further, climate projects may provide developments through job creation, spreading of know-how and tacit knowledge, and so on. However, integrating climate concerns into development projects may not be so straightforward, and trade-offs must often be

made between climate change and different aspects of development (a well-known example from the area of bio energy production concerns food security, biodiversity and climate change) (Kok et al. 2008).

While some authors claim that there is a need to mainstream climate issues into poverty reduction efforts while providing additional funds for specific climate projects (Kok et al. 2008), a concern from developing countries is that ODA funds will be transferred from poverty eradication projects to climate projects, which may mean that less money goes to the poorest (Gupta 2007;2 009). There are also concerns that the mistakes made by aid agencies in the past will be repeated in climate-related aid projects. A relevant concern in the case of technology transfer is whether developing countries will get relevant technologies; the fear is that the transferred technology will in many cases be either outdated or poorly suited to local needs (ibid).

From a development perspective, it could be argued that many climate policies take a very narrow view on improvements, focusing on GHG reductions per invested dollar rather than development perspectives. The CDM - with its requirements on additionality - is the most blatant example of a mechanism where development objectives may become a hinder. There are indications that other mechanisms with a development perspective, such as the Community Development Carbon Fund (CDCF), will work better in LDCs, and that such approaches must be pursued in the future climate regime (Katima and Pritchard 2009).

²³ An additional implication is of course the low level of entrepreneurial activities in some LDCs, and another implication concerns how authorities may hinder entrepreneurial activities. As an example: in a seminar concerning small-scale solar PV projects in Africa held at the Joint Actions on Climate Change (JAOCC) (<http://www.jaooc.net>) conference in Aalborg in June 2009, several African participants pointed at the importance of *not* involving any authorities in the projects, as these often stifle entrepreneurial activities.

2.5.5 Intellectual property rights

The issue of patents and expensive licenses for technology deployment has often come up during climate negotiations. Several studies have indicated that IPR issues are not a main barrier for uptake of EST (Newell 2008), while other studies suggest that IPR issues may be a main impediment for technology transfer, especially to LDCs, and that the arguments that strong protection of patents are welfare-enhancing may well be exaggerated (see e.g. Friis Bach 2009; Tomlinson et al. 2008). Some authors state that the commonly-made claims that well-protected IPRs lead to more technology transfer to developing countries is supported by little evidence (Friis Bach 2009), while Brown et al. (2008) states that it is often impossible to “innovate around” patents due to lack of substitutes. Abbott (2009) however states that unlike in the pharmaceutical sector, where there are often no substitute for patented drugs, most approaches to solve problems in the renewable energy sector tends to be off-patent. Some studies however hint that unwillingness of patent holders to allow licenses (e.g. Tomlinson et al. 2008) and tariffs set for technology imports (Newell 2008) are more important hurdles than patents for effective technology transfer. A recent study by the World Bank found that varying tariff levels and non-tariff barriers are important hurdles for technology transfer to developing countries (World Bank 2008b). Some of tariffs concerns could be addressed in the current Green Goods negotiations, which aims to eliminate or lower the duties on environment-friendly goods.

There are several suggestions in the literature for measures to reduce the tensions and make patented technology more accessible to actors in developing countries (e.g. Newell 2008; Friis Bach 2009).

Friis Bach (2009) discusses some potential ways forward:

- Make better use of the flexibilities offered in the TRIPS Agreement and offer some guidance on to what extent EST can be part of such flexibilities. Several studies stress that a strong patent protection is problematic for LDCs and that there is a need to have separate rules for LDCs. Renegotiating the TRIPS Agreement is hardly a viable option, whereas providing the potential flexibilities to LDCs, and, in some cases,

other developing countries, should be possible;

- Provide exceptions to the TRIPS Agreement (or parts thereof) to LDCs;
- Develop new innovative IPR schemes for climate technologies and ensure easy access for developing countries;
- Develop a special IPR regime designed for public-private partnerships for the development of pro-poor climate technologies for mitigation and adaptation. As the licensing of some technologies for use in developing countries can hardly be a profitable affair for patent-holders, additional funds must be provided e.g. through CERs in CDM projects, or through ODA. Another potential way forwards is to involve TNCs in donor projects in LDCs (Friis Bach 2009).

Both Friis Bach (2009) and Abbott (2009) want a declaration on IPR and climate change, similar to the existing Doha Declaration on the TRIPS Agreement and Public Health. Such a declaration may be useful in the progression of international law as it may provide guidance on the balance of the rights of innovators and the public benefits from gaining access to new technologies.

In any case, the controversies surrounding IPR makes it a difficult topic to bring up in Copenhagen. Some ways for addressing IPR in the climate negotiations are outlined by Tomlinson et al. (2008) (see also next chapter), including the integration of IPR issues in a new treaty. While the TRIPS Agreement can hardly be renegotiated, the flexibilities offered in the agreement could be employed better, and governments could take measures to secure that actors in developing countries will gain better access to patented technologies, at reasonable costs (Friis Bach 2009; Tomlinson et al. 2008).

This study does not specifically deal with IPR and trade issues. However, these issues must be dealt with in the negotiations because they will strongly impact technology transfer.

3. MECHANISMS FOR TECHNOLOGY TRANSFER

This chapter briefly discusses the performance of existing mechanisms as vehicles to further technology development, deployment and transfer of technologies, and proposals for new mechanisms and strategies. First we look at existing TOAs in the sphere of technology cooperation and transfer. Then, the performance of project funding mechanisms (including the CDM and the GEF) are discussed.

This is followed by a review of proposals for actions to strengthen the technology component of the climate regime found in recent literature. The chapter ends with some concluding remarks.

3.1 Current mechanisms and funds

There is still limited analysis performed on the effectiveness of different financial channels as vehicles for technology transfer, although there are a growing number of studies. For instance, the need for better evaluation of ODA projects is something that is discussed in many countries at the moment.

Further, the criteria applied in evaluations of TOAs and technology oriented projects are not necessarily straightforward. For instance, de Coninck et al. (2008) have proposed some criteria for assessing the success of TOAs. These are:

- 1) *Environmental effectiveness*. This is obviously the most crucial criteria, and in the context of climate change effectiveness should usually be measured in reduced GHG emissions (or reduced GHG concentrations). However, the effectiveness of technology strategies may be hard to estimate, especially for long-term policies. Additional difficulties, such as estimations of rebound effects make this even more difficult;
- 2) *Technological effectiveness*. This is a measure of the specific contribution of a TOA in advancing science and technology. Different measures must be applied, depending on inter alia the maturity of the technology;
- 3) *Economic efficiency and cost-effectiveness*. Obviously, these are difficult to estimate in many cases, especially for long-term policies;

- 4) *Incentives for participation and compliance*. Obviously a key issue concerns the incentives provided for nations (and potentially, in some cases, regions, cities and corporations) to become part of an agreement;

- 5) *Administrative feasibility*. More generally, administrative feasibility relates to whether legal, institutional and practical means exist to implement a TOA in a cost-effective manner.

These criteria seems reasonable but absent from the list above are considerations relating to development, fairness, justice, ethics, and risks (in a wide sense). While these considerations are not necessarily crucial for the design and implementation of functioning technology agreements or single projects, they are crucial for the long term viability of technology agreements, and for the climate change efforts in general, and the furthering of such objectives are a necessity from a sustainable development perspective.

3.1.1 Experience with TOAs

There are few multilateral international environmental agreements that are considered very successful, and even fewer which have successful mechanisms for technology transfer in place. The Montreal Protocol is an obvious exception, and it has often been used as evidence that - given the right circumstances - grand-scale technology transfer is possible. The Montreal Protocol established an effective mechanism for new technology by combining legal commitments with access to funds for developing countries, in order to cover incremental costs. However, several authors have argued that the climate challenge is very different from the ozone challenge, and therefore the relative success of the ozone regime cannot easily be translated in the climate regime (e.g. de Coninck et al. 2008; Brunnee 2009); the sources of GHG emissions are more diverse than is the case with ODS and there is a lack of suitable alternative technologies available at reasonable costs. The required funds for climate mitigation and adaptation are of a much higher magnitude than the funds provided in the ozone regime. Further, the climate issue, which involves virtually all societal sectors in all countries, and numerous sources of pollution, is inevitably much harder to address than the ozone issue.

There are a number of international treaties, agreements, or coordination projects which deals with technologies. Ueno (2006) reviewed a

number of international technology cooperation projects (using a hierarchy developed by Putnam and Bayne (1987)) to evaluate the level of policy coordination:

1. Mutual enlightenment - sharing information on policy directions;
2. Mutual reinforcement - endorsing mutual policies to help each other combat domestic resistance;
3. Mutual adjustment - mitigating inconsistency among the policies of different countries;
4. Mutual concession - making a “package deal” that requires concessions by all participating countries to enhance collective welfare

Some findings were:

- ‘Concession’, the deepest level of cooperation, occurs only for cost sharing of large research, development, and demonstration (RD&D) projects and technology and performance standards.
- Most of technology cooperation occurs as “extension of national policies” without tough compromises among nations, such as legitimization (e.g. international endorsement) and non-binding coordination. Thus there a few significant cooperative arrangements.
- Nations are sometimes willing to take unilateral actions, for several reasons. For instance, the measures may be politically supported by domestic concerns such as energy security, job creation, and industrial promotion, even if they benefit other nations as well. Further, other nations willingly follow certain types of national policies, even without explicit policy coordination. As an example, catching-up states can deploy new technologies more easily because they can enjoy cost-reduction benefits brought about by the efforts of front-runner nations.

Thus, nations tend to cooperate at a deep level only to share the costs of large RD&D projects and to implement technology and performance standards.

In a similar - but expanded – review, de Coninck et al. (2008), reviewed 13 existing initiatives, classified into four categories (cf. table).

TABLE 3-1. TOAS RELATED TO CLIMATE CHANGE (SOURCE: DE CONINCK ET AL. 2008)

I. Knowledge sharing and coordination

1. Carbon Sequestration Leadership Forum (CSLF) and the International Partnership for the Hydrogen Economy (IPHE)
2. Methane to Markets Partnership
3. Task sharing in International Energy Agency Implementing Agreements (IEA-IA)
4. Asia Pacific Partnership on Clean Development and Climate (APP)
5. Energy Star bilateral agreements

II. RD&D

6. European Organization for Nuclear Research (CERN)
7. ITER fusion reactor
8. Cost sharing in International Energy Agency Implementing Agreements (IEA-IA)
9. The Solvent Refined Coal II Demonstration Project (SRC-II)

III. Technology transfer

10. Multilateral Fund under the Montreal Protocol
11. Global Environment Facility (GEF)

IV. Technology mandates and incentives

12. International Convention for the Prevention of Pollution from Ships (MARPOL)
 13. European Union Renewables Directive
-

It was concluded that whereas the cost-effectiveness of some initiatives (e.g. task-sharing and technology standardization within IEA-IA initiatives) is probably quite high, the effectiveness of different initiatives is often limited, or hard to quantify. Some recent initiatives, like the Asia Pacific Partnership on Clean Development and Climate (APP), were not considered to promote technological aims to any greater extent due to the limited funds and voluntary nature of cooperation, a view shared by other analysts (Lawrence 2008).²⁴ The

²⁴ Tamura and Ichibara (2006) notes a tendency that technology transfer projects, reported in order to demonstrate progress under Kyoto (submitted in accordance with Article 12 of the Convention and Article 3.2 of the Kyoto Protocol and related decisions), in many cases include

MARPOL and the EU renewables directive²⁵ were analyzed as examples of ‘technology mandates and incentives’ initiatives, which can be very effective under certain circumstances.

De Coninck et al. (2008) advocate the use of emission targets/emission prices combined with TOAs as the way forward, but caution that (p. 349):

“RD&D policy by itself is a poor substitute for mitigation incentives for reducing emissions, however, since it postpones the vast majority of the effort until after costs are brought down, requiring large R&D investments and forgoing many cost effective opportunities to reduce emissions”

Regarding the effectiveness (cutting GHG emissions) it is further concluded (p. 353):

“TOAs in the first three categories (knowledge sharing, RD&D, and technology transfer) are not likely to be effective on their own for achieving significant GHG reductions, and are better seen as complements, fulfilling the criteria for technological effectiveness where other environmental agreements may be insufficient. An exception may be technology transfer programs, if accompanied by significant financial resources. As emissions reduction is essential for climate-change mitigation, only TOAs of the fourth category - technology mandates, standards, or incentives - appear to have the potential to be effective in environmental terms as a substitute for emissions target-based agreements.”

3.1.2 Bilateral projects

Bilateral projects can be sponsored through various mechanisms, including various ODA channels, the GEF, the CDM and JI, the World Bank in cooperation with regional development banks (initiated in connection to the Bali Action Plan). Projects can also be funded jointly by these mechanisms (e.g. through combined GEF

only elements of “soft” technology transfer, i.e. information networks and capacity building.

²⁵ DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. The Directive sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport.

and ODA funds). There are a growing number of climate funds.²⁶

A study by Evander et al. (2004) examined 51 energy efficiency end-use projects and 110 renewable energy projects, which related to diffusion and development of new energy technologies in developing countries, carried out by international organizations under bilateral contracts. The study included projects financed by GEF, UNDP, UNEP, the Energy Sector Management Assistance Programme (ESMAP), Asia Alternative Energy Program (ASTAE), the Inter American Development Bank (IDB), the Asian Development Bank (ADB) and the USEPA. Some of the lessons learnt were:

- Projects should be based in the local context, which require knowledge about societal structure, local laws, local culture, and local actors.
- Careful selection of national participating organizations are crucial, and also the identification of project leaders with home organizations that can provide commitment, are affiliated with relevant institutions, and have relevant mandates and capabilities for program implementation and decision-making.
- The main foci should be not only on engineering work, but management and stakeholder participation is equally important aspects.
- Administrative standards and procedures of donor agencies should be adapted to the size of the project.
- Relevant agreements and pricing policies should be in place before projects are commenced, or market development can be impeded. For instance, price fluctuations on the world market may be a problem, requiring relevant measures.
- Coordination between different projects and programs could be improved.
- Phased implementation with pilot projects may allow for refined project design before scaling up.

²⁶ For more info about these funds see <http://www.climatefundsupdate.org/listing>. The GEF administers several financial mechanisms and funds.

- Market research can aid in identifying the most effective approaches; this is especially relevant for analyzing consumer preferences in market transformation programs.
- Market transformation projects should address both supply and demand side of the market.
- Matching the scope of activities with available funding.
- Voluntary agreements with industry and appliance labeling can be effective if designed properly.
- Project implementation should be done in a flexible way, and continuous evaluation can help respond to challenges and problems.
- Monitoring and evaluation mechanisms should be built into programs from the start.
- Projects should be sustained over a longer time period in order to make a real impact.

The CDM

Most CDM projects contain an element of technology transfer, and Seres (2007) claims that about half of CDM projects have brought in technologies that were not available in host countries before. This does however not mean that the CDM contributes to technology diffusion in developing countries in an efficient and effective manner, and the CDM has indeed been criticized for failing to deliver either development or sufficient technology transfer (Forsyth 2007; van der Gaast et al. 2009). We have also seen a high rejection of proposed CDM projects, due to overestimations of the carbon reduction potential.

Question marks have been raised about the governance structures, the rules regarding additionality, and the lack of transparency of contracts (Upston-Hooper 2009), which have a tendency to benefit the actors from developed countries (e.g. by specifying that the laws of the developed country shall be applied in legal disputes). Other questions concern the sustainable development benefits of projects, the tendency for large-scale projects, and the lack of projects involving the poorest countries, or the

poorest layers of the population; CDM projects seldom bring direct benefits to the poorest, which means that ODA funds should not be directed to CDM projects (Michaelowa and Michaelowa 2007). Transition countries like China, India, Mexico and Brazil have certain benefits – including infrastructure and financial systems – that make investments there more attractive than is the case in poorer economies. Further, non-Annex I countries often lack the institutional capacity to deal with CDM projects leading to uncertainty about the future situation affecting the willingness to invest (e.g. Mingyuan 2008; CCWG/ATF 2009).

China is very dominant as 60 % of CDM-generated CERs have originated in China. There are concerns that that developed countries are paying for Chinese projects that would have taken place without funding (Wara and Victor 2008; Reuters 2009b; Marr 2009; Danish 2009). EU finance ministers have stated that advanced developing countries should gradually move to sectoral mechanisms, while project-based CDMs should increasingly focus on LDCs and areas where other crediting mechanism are not suitable (Council of the European Union 2009).

Programmatic CDM may be well-suited to energy efficiency policies (Hinojosa et al. 2007), but should probably be supported by or linked to a technology framework to appropriately stimulate the market, and especially households and SMEs (Bazilian et al. 2008).

Whether the “CDM glass” is half full or half empty depends on the view taken. While most relevant literature tends to focus on improvements of the CDM, there is also literature which provides a more fundamental critique against the mechanism (Paulsson 2009). The CDM is however likely to remain a vital part of the climate regime, through perhaps in a revised form. New CDM approaches - possibly including sectoral CDM, reformed programmatic CDM, and policy-oriented CDM - are discussed in the current negotiations.

The GEF

The GEF was established in 1991. It performs a range of functions in connection to MEAs. GEF has invested almost 2 billion USD in climate change and generated co-financing of over 9 billion USD. Reviews of the GEF’s performance in the field of climate change are mixed (see e.g. GEF 2005a; GEF 2005b; Birner and Martinot 2005; Tamura and Ichibara 2006; Depledge 2008; Ballesteros et al. 2009; Wuppertal Institute 2009).

The climate change program has performed satisfactory according to GEF's own evaluations, although its role is small on a global scale. The administration however is considered complex and therefore quite costly for small projects. Depledge (2008) claims that the GEF has been an obstacle to the climate change negotiations as its lengthy procedures and alleged failure to follow COP guidance has created discontent among developing countries, and Ballesteros et al. (2009) raise similar concerns.

Birner and Martinot (2005) reviewed eight GEF projects related to market transformation for energy-efficient products in developing countries, and highlighted the need to target institutional and regulatory changes to support adoption of energy-efficient technologies, stressing instruments such as energy efficiency standards and labeling, and the creation of new independent institutions. While stressing that 'no single approach' guarantees success – as barriers, capabilities, and opportunities are unique for each market - they propose eight principles for designers of future projects (in the context of market transformation efforts):

- make sure to target both supply and demand sides of a market;
- take a holistic view of the market by carefully examining all stages of the supply and demand chain;
- leverage competitive market forces whenever possible;
- build flexibility into program design so that program activities can respond effectively and rapidly to changing market dynamics;
- carefully consider what vehicles for technical assistance and technical know-how transfer that will be workable;
- place emphasis on standards, labeling, and building codes;
- allocate a portion of the program's budget for activities that support replication and the dissemination of results; and
- begin monitoring and evaluation early to measure preprogram baselines.

3.2 Need for new TOAs – proposals found in literature

There are a vast number of proposals for technology-oriented measures in the literature, with differing perspectives, different focus, and varying levels of complexity and detail. Policy proposals and analyses for technology cooperation include Edmonds and Wise (1998), Benedick (2001), Schelling (2002), Barrett (2003), Justus and Philibert (2005), Victor (2004), Grubb (2005), and Ueno (2006). More recent studies include de Coninck et al. (2008), Newell (2008), Bazilian et al. (2008) and Tomlinson et al. (2008), and Wuppertal Institute (2009). Some proposals promote ways to reform the climate regime with respect to technologies, while other writings mainly deal with climate technologies or specific groups of climate technologies.

When going through the literature, it is evident that the suggestions for future technology cooperation depend very much on the background of the authors of the reports, as well as the assumptions made. For instance, some reports stress the vital role of technologies for achieving the 2 degree target, and the evident need for more international cooperation and a stronger focus on technologies within the UNFCCC framework. Others tend to base the assumptions and analysis in realpolitik and economic theory, assuming that states protect national interests, and put less faith in the potential to initiate more widespread technology cooperation at the international level. Further, some proposals are built on the assumption that states can abandon self-interest and move towards a global governance reform where the common good takes preference over more narrow national interests; other authors have less hope for such developments, instead arguing from a neorealist perspective.

Ueno (2006) summarizes some main proposals brought forward in earlier studies, see table. In this section we briefly summarize some of the proposals brought forward in recent studies.

TABLE 3-2: SUMMARY OF TECHNOLOGY COOPERATION PROPOSALS AND ANALYSES.
SOURCE: UENO (2006).

Citation	Proposals and Analyses	Reference Cases
Barrett (2003)	Based on a game-theoretic analysis of international environmental agreements, he proposes combining international R&D fund and technology standards.	CGIAR,* CERN, MARPOL, catalytic converters for automobiles
Benedick (2001)	He proposes portfolio of various cooperative actions from basic R&D to technology transfer through coordinated policy and measures among a limited number of countries.	Montreal Protocol
Justus and Philibert (2005)	Rather than making a specific proposal, they provide information and analysis on various cooperative actions and suggest combinations of carbon pricing and technology cooperation.	IEA, ITER,† CGIAR, clean coal technologies (including CSLF), Energy Star bilateral agreements, among others
Edmonds and Wise (1998)	They model mandatory installation of CCS‡ to new fossil-fuel power capacity and new synthetic fuels capacity as a “backstop” to failure of economically efficient approach.	No specific case mentioned
Victor (2004)	Rather than proposing a specific idea, he raises key issues associated with technology policy and cooperation and mentions the necessity for technology cooperation.	CERN, ITER, IEA
Schelling (2002)	Discussion centers on the nature of commitments and the inability of enforcement at an international level. Also emphasizes deep emissions cuts by innovative technologies in the long run and argues a financial mechanism for deploying low-carbonized technologies in developing countries is necessary.	Marshall Plan and NATO mentioned as precedents of “reciprocal scrutiny” as an alternative to an enforcement scheme
Grubb (2005)	Refers to innovation policy literature; mentions various options including Clean Energy R&D Fund, strategic deployment agreements, and technology transfer agreements. Emphasizes a combination of carbon pricing and technology cooperation.	No specific case mentioned

*CGIAR: Consultative Group on International Agricultural Research

†ITER: International Thermonuclear Experimental Reactor

‡CCS: carbon capture and storage

Among recent reports, many studies point out that the traditional focus of technology transfer policies has been too narrow, and that the main challenge is to help developing countries to build effective innovation systems (e.g. Bazilian et al. 2008; Tomlinson et al. 2008). Delivering technology to developing countries is ultimately a governance issue. The capacity of the workforce in a given country to absorb and apply new technology and know-how is considered a main barrier for a more rapid technology transfer to developing countries (World Bank 2008a). The potential to engage in technology transfer is strongly connected to factors like infrastructure, transparency, stability of government and the level of openness of the trade and investment regime (Hoekman et al. 2004). For many

developing countries there is a need to develop capacity to deal not only with technologies as such, but also – more generally - with increasingly complex product and process standards that are necessary to adhere to in order to get access to the international market (Messner 2003; Vorlet et al. 2002 UNCTAD 2006; Dalhammar and van Rossem 2009). Obviously, climate-friendly technologies should not be seen in isolation from other technologies.

While many studies point to the need to develop enabling environments and build effective innovation systems in developing countries, a fundamental issue concerns how LDCs with severe governance deficiencies and high levels of corruption can be effectively involved. For

instance, in many developing countries the government and authorities at different levels are often part of the problem, not part of the solution.²⁷ This suggests that capacity-building projects should in many cases target local entrepreneurs and local communities, and that funding should preferably be directed to these groups, with limited involvements of governments and authorities.

Bazilian et al. (2008) outlines the contours of a larger framework for human and institutional capacity building, suggesting the potential inclusion of several elements, e.g.:

- The establishment of an Institutional Capacity Building Program to assist mainstreaming climate change objectives within national policies;
- Technical assistance and support for transparent and inclusive integrated resource planning at the national and sub-national levels in an accountable manner;
- Support to strengthen regulatory agencies capacity for overseeing key sectors and industries, and for considering and implementing proactive measures that support the deployment of climate friendly technologies at the national and sub-national levels in ways that are fair and effective in order to meet local needs.
- Efforts to build the capacity of non-state independent actors, such as consumer organizations and independent research institutions, to monitor the design and implementation of policy and regulatory frameworks for key sectors to demand that climate change considerations are reflected in decisions consistent with local needs and priorities.

Tomlinson et al. (2008) has developed the perhaps most full-fledged proposal. They propose measures to increase the scale and pace

of international collaboration on low carbon innovation and the build-up of effective innovation systems - not just narrow technology transfer - in developing countries. It is claimed that traditional concepts of public technology transfer follow a too narrow approach with limited funding and capacity building support, while that private sector approaches center on balancing market access, providing limited licensing of technologies to local industries, including joint ventures. Thus, it is claimed that current approaches are unlikely to transform the way low carbon and climate resilient technologies are diffused to developing countries, especially countries without fast growing markets. It is stressed that actions both within the UNFCCC framework and outside it is required to ensure technology diversity and encouragement of innovative approaches at the regional and national level. A comprehensive set of policies are suggested, including new institutional structures within the UNFCCC (Cf. figure).

²⁷ For instance, at a workshop on PV technology in Africa at the Joint Actions on Climate Change Conference (<http://www.jaocc.net/>) in Aalborg, June 2009, several African speakers stressed the need to avoid involving authorities in projects in some African countries, as authorities often slowed down or stopped developments. They instead stressed that projects should involve local entrepreneurs, while contacts with authorities should be kept at a minimum level.

Figure ES1: Breakdown of proposed action within and outside of the UNFCCC

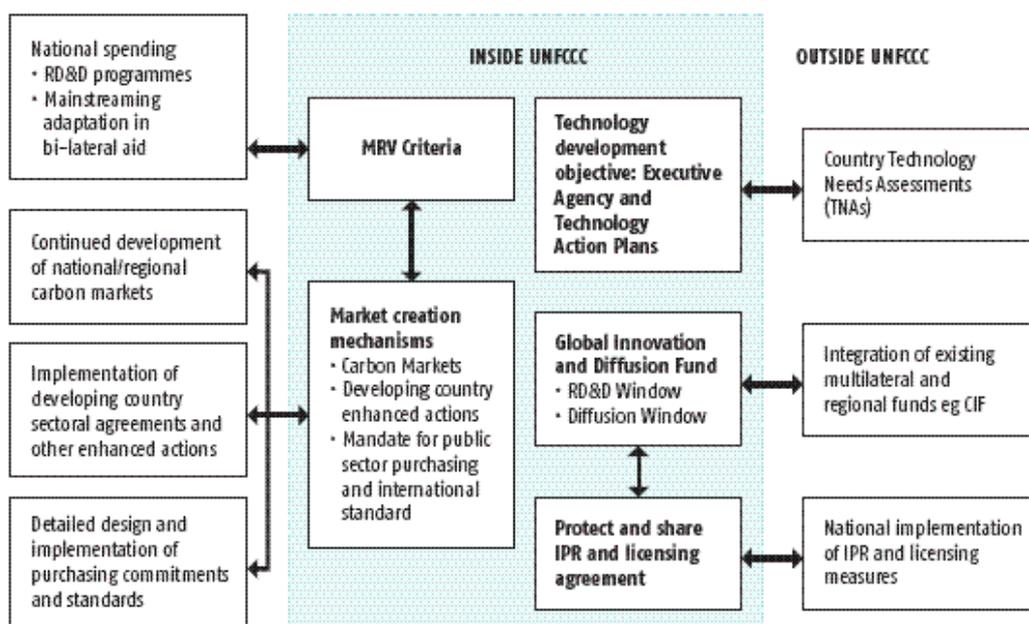


FIGURE 3-3. PROPOSED ACTION WITHIN AND OUTSIDE OF THE UNFCCC. SOURCE: TOMLINSON ET AL. (2008)

The specific proposals include (Tomlinson et al. 2008):

1. *Agreement to a Technology Development Objective*, which would establish a set of critical climate change technologies. The achievement of the technology development objective would be supported by a set of Technology Action Plans (TAPs) for each identified technology and a Technology Development Executive, who would monitor global efforts to deliver a portfolio of critical technologies - including public and private efforts - and propose complementary support and activity at the multilateral level needed to deliver agreed technology outcomes.

2. *The establishment of criteria for measurable, reportable, and verifiable (MRV) action*. These should set out the conditions under which national R&D and development spending by developed countries – including on sectoral agreements – would qualify as a contribution to their UNFCCC commitments on technology, financing and capacity building support. It is suggested that these conditions could contain the elements: additionality to existing ODA and RD&D spending; reciprocal knowledge sharing with other related R&D programs; demonstrable link to a developing country’s low carbon

development plan; required criteria for enhanced developing country access to new technology; increasing developing countries’ capacity to innovate and adapt; and climate proofing ODA.

3. *Market creation mechanisms*, which may include technology-led sectoral agreements for developing country enhanced actions; international standards agreements; and public sector purchasing commitments. The authors argue that these may be developed inside or outside the UNFCCC system, but that they must be guided by its principles and procedures if they are to count towards Parties’ commitments.

4. *A new multilateral Global Innovation and Diffusion Fund*: It is suggested the fund could integrate existing activity (e.g. the World Bank Climate Investment Funds) through two windows under the new Technology Development Executive (see above) described above:

a) *The Research, Development and Demonstration (RD&D) Window*, which would be responsible for the development of new technologies, and especially applied research and demonstration to push new technologies down the innovation

chain, and adapt them for use in developing countries and address orphan innovation areas (i.e. areas of high importance for developing countries where research will be suboptimal in relation to needs due to low expected market returns);

b) The Diffusion Window responsible for wide-scale uptake of new technologies including direct financing; patent buy-outs; and capacity building to ensure developing countries have the supporting systems necessary to use new technologies.

5. A 'Protect and Share' agreement for IPR and licensing, providing government-to-government commitments to 'protect and share' low carbon technologies and encourage joint-ventures and public-private partnerships. Financial support would be made available under the Fund (see point 4 above) to reinforce IPR protection measures in developing countries, consistent with their existing international commitments under WIPO and WTO. It is suggested that better IPR protection would be balanced by a Framework Agreement that would speed up sharing and licensing of low carbon technology to ensure speedy diffusion. A range of standardized agreements - covering five main areas - are proposed for this purpose:

a) Segmented/Parallel markets, to provide free licensing in certain developing country markets but also prevent re-importation to developed countries for a limited period of time;

b) Public sector buy-out, to guarantee a return to innovators and swift deployment of technology;

c) "Use it or lose it" agreements ('compulsory licensing'), which would allow countries to enforce compulsory licensing of technology if innovators withhold technology from the market;

d) Pay to license, which would provide direct subsidies or risk guarantees to increase licensing, and to ensure access when public funds are used to develop technology;

e) Global commons, to allow countries to provide open access to IPR where they have control of patents.

While the proposal outlined by Tomlinson et al. is perhaps the most full-fledged one, it may represent an 'ideal' to strive against rather than something that can be reached in the near future. Some elements in the proposal, for instance 'climate proofing' of ODA, and some elements related to IPR and licensing may prove controversial.

The Sao Paulo proposal (see Haites 2007) has proposals similar to the study by Tomlinson et al. Under the Sao Paulo proposal, a 2 % levy on international transfers of AAUs/ERUs/RMUs and other funding would be used to establish a Technology Funding Mechanism, governed by an Executive Board under the guidance of the COP/MOP. The main functions of the Mechanism would be to consider requests from Non-Annex I parties to fund their participation in international efforts to develop mitigation and adaptation technologies and enhance diffusion of relevant technologies, e.g. through buy-down. The mechanisms could also participate in such projects itself. This also means that the Mechanism may acquire intellectual property rights, and may provide guidance to the COP/MOP on how to best use these rights. The main function of the Mechanism would be to enhance the possibility of Non-Annex I countries to participate in existing mechanisms and efforts (e.g. the GEF and other climate funds, and various bilateral and multilateral cooperation measures) rather than to directly provide additional funds for technology transfer. A screening process would be used in order to ensure that the most useful projects, and most promising technologies, are supported.

Newell (2008) proposes a number of potential measures to enhance technology innovation and diffusion, including:

- Continue the trade negotiations on green goods, and make climate-friendly technologies a sub-package. An alternative is to make a trade pact for climate-related technologies, in the form of a plurilateral agreement;
- Harmonization of technical standards relevant for climate technologies should be pursued;
- Review and strengthen the guidelines for Export Credit Agencies to ensure

that investments are consistent with climate policy goals;

- An international agreement on R&D knowledge sharing, coordination and joint collaboration and funding;
- Stimulate domestic R&D through an international agreement, i.e. involving goal-setting interims of percentage of GDP;
- The use of innovation prizes as an engine to stimulate innovations relevant for developing countries.

Private-sector investments constitute 86 % of global investment and financial flows (UNFCCC 2007), and therefore Newell (2008) states that it is crucial to focus on private-sector investments in technology. Also in other proposals the role of the market is stressed (e.g. Haites 2007). However, several recent studies point to the important role of governments, as private sector investments may not bring about needed changes without governmental intervention that correct market failures. Some authors are also more fundamentally sceptical vis-à-vis the potential of the Carbon market to deliver necessary technologies, as discussed in chapter 2. Tomlinson et al. (2008) highlights the need for governments to ensure that R&D efforts are undertaken also in areas where private companies foresee few market opportunities, and the need for governments to step in when patent holders are not licensing important technologies. There is considerable disagreement regarding the importance of IPR issues (see chapter 2), but more agreement regarding the need to reduce tariffs on green goods (e.g. Newell 2008).

Ueno (2006) proposes three main strategies to enhance technology objectives: encouraging domestic policies and focusing on a handful of international actions; limiting interfaces between technology cooperation and emissions trading; and learning through bottom-up processes. He is skeptical towards too deep integration of emissions trading and technology cooperation, due to the complexities involved. However, in the case of integration of emissions trading and technology cooperation, he proposes that price-cap mechanisms and programmatic CDM may be useful in order to limit this complexity. De Coninck et al. (2008) also see carbon markets as the main drivers of technology innovation and diffusion, while TOAs – based on evidence of past experiences – are useful complements. They state (p. 354):

“The use of TOAs as an environmentally effective substitute for an emissions-based approach is limited to the category of standards, mandates, or substantial financial incentives. These would need to be applied on a sector-by-sector, if not technology-by-technology, basis, which can be limiting practically. This approach may make the most sense in certain specific settings: for highly trade sensitive sectors that make agreement upon targets and timetables difficult; for sectors not otherwise covered by emissions trading programs (e.g., possibly vehicles or endues energy demand, depending on domestic policies); for sectors that can benefit from international coordination (e.g., building codes, appliance standards, regulation of vessels for international transportation); and for situations where significant ancillary benefits are foreseen.”

Many regulations and other types of standard-setting, especially standards related to energy efficiency, tend to have very positive economic outcomes, not only from a socio-economic point of view but also for individual corporations and households (Dalhammar 2007a). Regulations may promote good investments that would otherwise not have taken place due to high transactions costs or other market failures. Several authors therefore promote a more widespread use of international standards. Examples of successful national and regional standards include the Top Runner Program in Japan and the EuP Directive in the EU.²⁸ While setting international standards would be a good way to move forward (e.g. Barrett 2003), in reality it is hard to reach consensus on standard-setting (Dalhammar and van Rossem 2009), and it is hard to evaluate how effective a regime based on “standards and mandates” will be, or the cost-effectiveness of such measures (de Coninck et al. 2008). In reality, it is easier to set standards domestically or within a small group of countries with similar interests. These standards are sometimes taken up by other countries for different reasons, and especially if the forces of economic globalization (trade objectives etc.) favours such developments.

²⁸ It should however be pointed out that both the Top Runner Program (see Tojo 2005) and the EuP Directive (see Dalhammar 2007a; van Rossem et al. 2009) has flaws, which hampers their potential to achieve energy savings. Apart from the flaws in the instruments themselves, another flaw concerns inadequate policy mixes.

Sectoral approaches

Whereas the UNFCCC and the Kyoto Protocol deal with wide economy-wide emissions of the major greenhouse gases, *sectoral approaches* with separate protocols for different sectors – e.g. forestry, land use, energy, transportation, aluminium, the cement industry – could be a complement. Sectoral approaches have gained considerable interest in the literature in recent years. While sectoral approaches are definitely a “second best option” from a theoretical perspective (Bodansky 2007), such approaches are often considered as more politically acceptable than more general approaches. It could help to broaden participation, simplify negotiations, allow countries to undertake targeted, staged efforts, and address some of the fears that more generic approaches will reduce the competitiveness of some industrial sectors (Bodansky 2007).

Multilateral sectoral agreements could come in many forms, including (Bodansky 2007):

- independent sector-specific agreements;
- an overall framework agreement on sectoral approaches, complemented by a number of sector-specific agreements;
- inclusion of sectoral approaches in a post-Kyoto framework;

Sectoral agreements could come in many forms (Center for Clean Air Policy 2008), and may be:

- Transnational, adopting similar standards or benchmarks for a global industry;
- Connected to the CDM, thereby broadening the project-focus of the current CDM to include the entire sector in a country (there has been proposals in literature to tie the CDM to sectoral approaches, e.g. Baron and Ellis (2006).);
- Make use of a sectoral bottom-up approach, where developing countries would adopt voluntary, no-lose GHG targets, based on country-specific CBAs or other methods of calculation.

Sectoral agreements could make use of the full spectra of mitigation commitments, including sectoral emission targets (absolute or indexed), the adoption of uniform or harmonized policies such as technology standards or taxes, and

cooperation on research and development (Bodansky 2007).

Sectoral approaches could include technology-oriented standards and measures. These include technology/specification standards which identify particular means of reducing emissions. Potential examples include sectoral agreements on transport which demands that a certain amount of new vehicles use low-GHG technology, sectoral agreements for the electricity sector which states that a certain percentage of energy must come from renewable sources, and/or that large coal-fired plants must make use of CCS technology (Bodansky 2007). Sectoral agreements could also encourage development and diffusion of new technologies, for instance by setting up structures for joint research or through resolving IPR issues (Ibid.). Sectoral approaches could also support capacity-building and technology diffusion in developing countries by providing financial means for such activities.

The main types of sectoral approaches currently discussed include (a) approaches linked to emissions trading, e.g. sectoral crediting and sectoral trading; (b) technology-based approaches centering on increasing dissemination of environmental technology in developing countries, and (c) policy-oriented sectoral approaches based on the priorities in host country's; where climate change is one part of an overall ambition towards sustainable development. A number of combinations of these three different types of sectoral approaches are possible and likely in a future agreement, including combining the policy-oriented or technology-oriented approach with the possibility of using credits (Naturvårdsverket 2009).

It appears likely that up-front financing for technology deployment and performance improvements will be a key element for a successful sectoral approach, especially for technologies with high capital costs and/or high operating costs (Center for Clean Air Policy 2008). A general problem for program-CDMs concerns methods for setting baselines for sectoral emissions, and monitor and report on the effects of sectoral measures (Schneider and Cames 2009; Naturvårdsverket 2009). Further, the boundaries between sectors are hard to draw in many cases. In any case, sectoral approaches may take several years to develop, due to the necessity to address capacity building needs in developing countries, including statistics and inventory systems, and the need to develop approaches for channeling capital from the

private sector via a sectoral approach (Naturvårdsverket 2009).

Sectoral agreements can be a useful tool for incorporating sectors that are not covered by other instruments. Tomlinson et al. (2008:71) mentions that zero carbon building standards for developing countries could be a very useful approach. Technology-focused sectoral agreements will probably meet less resistance than sectoral agreements that makes use of targets and benchmarks. Transnational sectoral agreements adopting similar standards or benchmarks for a global industry are probably impossible to implement due to resistance from developing countries (Center for Clean Air Policy 2008).

Funds for technology-oriented measures

Additional means for technology oriented measures in developing countries is a key prerequisite if a Post-Kyoto agreement is to be reached in Copenhagen, and several studies point to new institutions required in this respect. Depledge (2008) claims that the GEF has been an obstacle to the climate change negotiations, and states that the best way forward is probably to set up a new, dedicated fund for the financing of developing country mitigation efforts. She state that the costs would not be prohibitive and that theses would in any case be outweighed by the goodwill/trust created by such a measure. Depledge further states that the second best option is to set up a new board (Action Board or Copenhagen Board) similar to the Adaptation Board set up in Bali, where GEF would provide Secretariat services and the World Bank would serve as trustee. The Board would have a developing country majority and could devise and implement fast-track procedures to enable speedy allocation to developing countries, guided by the COP. Depledge holds that the Board could undertake reviews of support and actions.

In general, donor countries have often neglected the technology transfer issue, despite the fact that the issue has such a high profile for developing countries. While the Bali installed a 'strategic program' under GEF, a priority is to make sure that this program is well financed (Depledge 2008). Developing countries are however skeptical of the approach and calls for new innovative solutions, for instance a new multilateral fund to buy up and distribute rights to key climate-friendly technologies (Ibid.).

While the establishment of a new fund for technology transfer, with more substantial means

than provided by current mechanisms, and with stable sources of financing, would create much goodwill from developing countries. However, a G77 proposal for a new fund was rejected at COP13. Developed countries are not likely to agree on a new technology fund until some developing countries are willing to take on mitigation targets as this would undermine their bargaining position. Further, the issue regarding which countries that should benefit from such a fund must be resolved.²⁹ This can be difficult, not least as many US politicians are unwilling to provide money for Chinese projects.

However, whether such a fund is created, or whether additional means for technology oriented measures are distributed through other channels - such as regional development banks, the GEF, and a reformed CDM - a key question is whether developing countries have the capacity to absorb the investments and related shifts to low-carbon technologies, especially if this is to be effective within the time scale required by the IPPC scenarios (Lawrence 2008). It is also highly uncertain if carbon markets can provide incentives for developing countries to implement more ambitious climate policies. With sectoral mechanisms, developing countries will have to invest in improved systems for dealing with future projects, including MRVs, but sectoral CDMs will (probably) only deliver revenues ex-post (cf. Wuppertal Institute 2009). Further, the expected volatility of carbon markets provides little certainty as to the profitability of investments. It therefore appears as if funds must be distributed in advance to build-up capacity in developing countries, through NAMAs or policy-CDMs (see below), in order to build up effective systems for handling sectoral CDMs in developing countries.

Nationally Appropriate Mitigation Actions (NAMAs)

In a NAMA a country identifies a set of domestic policies and actions required to create a conducive environment for the use of low-carbon technologies. This then forms the basis for the identification of international support mechanisms that can enhance scale, scope, or

²⁹ Annex I of the UNFCCC includes poorer countries, while Annex II includes richer countries, and this creates a problem in the negotiations (Gupta 2007). In cases when the terminology developed/developing countries are used instead of Annex I vs. non-Annex I countries, this is also problematic as the status of some countries is strongly debated.

speed of the implementation of the actual NAMA. In order to facilitate the implementation and management of domestic and international components of a NAMA, the design should include the definition of suitable policy indicators. NAMAs may include:

- Domestic activities, including development of regulatory and institutional framework, and action to unlock energy efficiency potentials. This can build on long experiences with national policies in energy, transport, and other sectors – which have become well established and functioning
- International support for the specific sector (technology, training, support for incremental cost of new technologies)
- Support to facilitate transition from carbon intensive to low-carbon production, both for industry and employees. International support can balance some of the distributional implications and provide training and new job opportunities.

NAMAs could be of different types; most importantly a distinction is made between credit-generating NAMAs and non credit-generating NAMAs (Araya et al. 2009). The latter types of NAMAs can be unilateral (own commitments) or conditional (dependent upon support under relevant conditions under the UNFCCC) in nature. Thus, we can identify at least three types of NAMAs which can be relevant: 1) voluntary NAMAs which get international recognition; 2) “agreement based” NAMAs where developing countries agree to take measures and receive funds and/or technology from developed countries in exchange; 3) CDM-based NAMAs, where developing countries undertake CDM (or revised CDM) projects, and receive funds and/or technology from developed countries in exchange; developed countries receive carbon credits.

Some of the domestic actions set out in NAMAs will have strong international components, or require some international support to cover incremental costs for domestic actions. Staley and Freeman (2009) sees a strong role for NAMAs in order to deliver important functions. A strong framework for NAMAs can facilitate accelerated technology development and deployment and provide incentives for public spending on R & D and domestic policy frameworks. Stavins (2009) discusses the benefits of employing a “portfolio of domestic

commitments” where nations would agree to honor commitments to GHG reductions laid out in domestic laws and regulations, instead of a “targets and timetables” approach. NAMAs could provide an example of such commitments. Domestic commitments could be furthered also through international cooperation and projects.

NAMAs could also work very well in a technology setting, including Caspary et al.’s (2007) proposal regarding international agreements relating to “technology wedges”³⁰, where countries choose – based on their different circumstances – the most promising technologies for their context, and sign up for non-mandatory targets. There are a vast number of potential technologies, such as energy efficiency of buildings (targets could be expressed e.g. as reduced total amounts of GHG from buildings, or average GHG per square meter) and CCS (long-term targets could be e.g. avoided emissions due to CCS activities, or tones of captured GHG).

Araya et al. (2009) discuss the support required for NAMAs in Copenhagen. They stress the need to learn from mitigation efforts undertaken by leading developing countries. They stress that a priority must be to advance NAMAs with strong transformative potential; this implies that selection criteria for funding NAMAs should be designed carefully. They also stress that while the governance model underpinning NAMAs should be based on internationally agreed principles and mechanisms, it must allow for a high degree of decentralisation in order to fit regional needs and challenges. They also stress that capacity building support must be provided before 2012, and that there is a need for stable financing mechanisms for NAMAs. Other studies also stress the need to build capacity in LDCs in order for these countries to prepare LCDs and NAMAs (e.g. Wuppertal Institute 2009).

NAMAs could fulfil several important functions. Especially, the CDM can not be used to reward developing countries for policies (e.g. SD-PAMs), and therefore it has often been proposed that some kind of policy-CDM mechanism should be developed (Neuhoff et al. 2008). NAMAs also seem to fulfil a role requested in several studies that call for

³⁰ For a discussion on Stabilization wedges see Pacala and Socolow (2004).

Current positions by major players

Seligsohn et al. (2009) have analyzed the positions adopted by major countries in relation to technology issues in current climate negotiations, finding important areas of agreement among a number of the major parties (p.9):

- A forceful technology push through increased public spending for research and development (R&D), demonstration and deployment of technologies. There is broad agreement that these public funds should be used to leverage private capital, using venture capital-like approaches and public-private partnerships, among other tools.
- Increased strategic planning on technology under the UNFCCC, using tools such as Technology Needs Assessments (TNAs), action plans and convening stakeholders to inform decisions.
- Increased strategic cooperation, e.g. regional centers of technological excellence.
- Scaled up international joint R&D and demonstration projects.
- Enhanced enabling environments and capacity building for technology development and diffusion e.g. through policy dialogue, coordination and reform.
- Country driven formulation of technology needs and strategies that are then linked with developed country support.

3.3 Concluding remarks

Some overall conclusions are:

- Capacity-building, i.e. the creation of enabling environments is considered the most important element in creating a successful technology transfer framework. The question is however how this process can be speeded up.
- While CDM, GEF and other funding mechanisms can help funding important

“catalyst” projects, they cannot – in their current forms – deliver technology transfer at the pace required. Also, the capacity-building potential of CDM and GEF projects are probably quite limited. Further, CDM will mainly succeed in settings where CDM projects can leverage private sector funds, something that mainly happens in investment-friendly jurisdictions. There are several question marks concerning the potential for sectoral CDM, and many developing countries would be hesitant to invest in necessary capacity building to prepare for sectoral CDMs without receiving funds for this purpose. NAMAs could help solve some of these problems, and can also aid developing countries in implementing domestic carbon policies. However, criteria for NAMAs must ensure that funding goes to the most promising projects.

- As Depledge (2008) have argued, there is a need for moving from ad hoc funding approaches towards a more stable funding system. Ekman et al. states (2008:25) that: *“Developed countries should be required under the post-2012 agreement, to adopt legally binding annual funding commitments for both mitigation and adaptation measures in developing countries.”* The traditional approaches include assessed contributions and negotiation rounds, whereas new approaches may make use of the carbon market and other financial mechanisms in developed countries. One approach is to use the Montreal protocol as the model and make use of funding negotiation rounds every three years (Depledge 2008). There seems to be more and more consensus that the Carbon Market should be part of the funding solution, but additional funds are required. There could be extension of the adaptation levies currently applied on JI, CDM and emissions trading projects (Depledge 2008).

- While development assistance money should perhaps not be redirected to climate change measures, but kept separate, there is a need to make sure that development assistance do not contradict climate objectives, e.g. through funding carbon-intensive technologies (Depledge 2008; Newell 2008). While multilateral development banks and other relevant financial

institutions have started to address this issue, the process needs to be accelerated.

There is, among many actors, a fundamental scepticism towards the ability of UNFCCC and its related mechanisms to drive technology transfer (Tamura and Ichibara 2006). *The solutions must be both to reform the UNFCCC system, and add new components, but also to pursue technology objectives outside the UNFCCC framework.*

4. CARBON CAPTURE AND STORAGE: EXAMINING THE ROLE OF TOAS

This section provides a simple technical introduction to potential CCS process chains and presents examples of how technology-oriented treaties (or similar actions) relate to CCS. The discussion then examines how such actions may have potential to promote CCS technology transfer. The analysis uses existing frameworks for analysis of differing types of technology transfer action (so called ‘enabling frameworks’) to differentiate the typology of emerging actions in the field of CCS.

The majority of the technical information provided here has been drawn from the IPCC (2005) *Special Report on Carbon Dioxide Capture and Storage (SRCCS)*, the IPCC *Guidelines for National Greenhouse Gas Inventories: Chapter 5: Carbon Dioxide Transport, Injection and Geological Storage* (IPCC, 2006) and the recent IEA report: *Carbon Capture And Storage: Full-scale demonstration progress update* (OECD/IEA, 2009).

In the introductory chapter of this report, it was noted that the market penetration of already cost-effective technologies for reduction of climate gases is still prevented by a number of market imperfections – both in industrialized and developing countries. The content of this report that addresses energy efficiency measures is a marked case in point. CCS however, is a different case. As shall be outlined here, CCS is not yet ‘market mature’ or proven as cost-effective. It is however, seen as a critical component for efforts to meet climate goals. CCS thus falls in the category of technologies that require the building of effective frameworks for transfer and implementation. While it is not yet ready for large-scale use – even in industrialized countries – most mainstream analysts consider it vitally important that broad implementation is achieved in the near-term to medium-term.

This section has the following structure: first an overview of the CCS technology chain is provided and major target industries identified; second the general status and maturity of each major technology component or system is discussed. Implications of technology maturity are also examined briefly against the context of technology transfer to different regions, or major countries. Thirdly, a number of initiatives that in some way represent ‘treaties or agreements related to CCS technology transfer’ are documented as examples. These are classified within to a taxonomy for TOAs and then

compared against key components of ‘enabling frameworks’. This process is intended to highlight key phenomena (e.g. differences, similarities and/or synergies between various initiatives). Fourth, a number of important (pre)conditions for TOAs are identified and justified. Finally, areas where CCS-related TOAs may be pursued, or where new types of TOAs may be required are briefly discussed.

4.1 Simplistic overview of the CCS activity chain

Each of the technical components of the CCS activity chain represents an area where technology transfer of some kind will be required to some extent. It is likely however, that the modalities of technology transfer activities for individual components will be quite different. Similarly, it is likely that the recipients in need of technology transfer will have differing needs. This sub-section introduces components. Later sub-sections will introduce other parameters important to the definition of the types of technology transfer activities that may be required.

4.1.1 System components

In this discussion, CCS is portrayed as an activity chain or system consisting of five main sub-systems:³¹

1. **Capture and compression systems.** The systems boundary includes capture, compression and conditioning (if required) of CO₂ at a suitable generation source. This prepares the CO₂ for transport.
2. **Transport systems.** Pipelines and ships are the most likely means of large-scale CO₂ transport. The upstream systems boundary is the outlet of the compression/conditioning plant in the capture and compression system. The downstream system boundary is the downstream end of a transport pipeline, or a ship offloading facility. There might also be compressor stations located along the pipeline system. This system delivers CO₂ to the injection system.

³¹ This discussion includes monitoring systems and frameworks as a system component. Most other texts limit discussions of ‘components’ to the first four components listed above.

3. **Injection systems.** The injection system comprises surface facilities at the injection site such as storage facilities, distribution manifold(s) at end of transport pipeline(s), distribution pipelines to wells, additional compression facilities, measurement and control systems, wellhead(s) and the injection wells. The downstream system boundary is the geological storage reservoir. This system has delivered CO₂ into the geological storage.
4. **Storage systems.** Geological storage³² can take place in natural underground reservoirs such as oil and gas fields, coal seams and saline water-bearing formations. In essence, this method utilizes natural geological barriers to isolate the CO₂; just as natural geological barriers isolate natural gas and CO₂ that occur naturally in the deep subsurface. Geological CO₂ storage may take place either at sites where the sole purpose is CO₂ storage, or in tandem with enhanced oil recovery (EOR), enhanced gas recovery (EGR) or enhanced coalbed methane recovery operations (ECBM).
5. **Monitoring systems and frameworks.** The injection and storage processes require monitoring and verification. These processes mirror existing technologies for the monitoring of oil and gas fields and waste storage sites. Parameters (to be) addressed include injection rates and pressures, subsurface distributions of CO₂, the physical integrity of injection wells and local environmental impacts. The monitoring and verification regimes and risk-assessments for leakage; as well as legal frameworks and requirements for ongoing monitoring, and the transferability/preservation of institutional knowledge should be considered an important component of the CCS activity chain.

³² This discussion generally focuses upon this storage mode. Isolation of CO₂ from the atmosphere can (theoretically) be achieved in several ways. However, most discussions for short and medium term applications focus on geological storage.

4.1.2 Prime target application areas

Examples of large point sources of CO₂ where capture is deemed to be feasible or desirable include (IPCC, 2006):

- stationary combustion systems (mainly electric power and heat production plants);
- natural gas processing plants;
- hydrogen production plants;
- other industrial processes, with examples of foci processes being:
 - Cement manufacture,
 - Methanol manufacture,
 - Ammonia production,
 - Iron and steel manufacture
 - Pulp and paper plants.

CCS applied to Biomass combustion (e.g. in biomass fired combined heat and power plants) or to biomass conversion processes (e.g. ethanol production) are also of significant interest. In such cases, ‘negative emissions’ (i.e. net removal of CO₂ from the atmosphere) can be delivered from the capture and compression system if CO₂ generated from biomass is captured and sequestered. Sites that generate concentrated streams of CO₂ are primary targets for capture and storage due to their significantly lower costs.³³

³³ As a result of the stoichiometric balance of fossil fuel combustion with air, an overwhelming majority of large emission sources have CO₂ concentrations of less than 15%. However, a small portion of the fossil fuel-based industrial sources have CO₂ concentrations in excess of 95%. While these high concentration sources constitute less than 2% of the total (by number), they are potential candidates for the early implementation of CCS because of the significantly lower overall costs per tonne of carbon. In essence, only dehydration and compression are required at the capture stage. Indeed, the IPCC (2005) indicates that such high-purity sources – particularly those within 50 km of storage formations and with the potential to generate revenues (e.g. via the use of CO₂ for enhanced hydrocarbon production through ECBM or EOR) indicates that such sources could constitute as some 360 MtCO₂ per year. As such, they are pertinent to this discussion. Moreover, some biomass-based sources of CO₂ (e.g. bio-ethanol production) also generate high-concentration CO₂ sources.

4.2 Current Status of CCS

CCS is not a single technology or system. It has both a number of components and a significant number of potential system combinations. The current level of technology research, development, demonstration, or application – for each major system component – can affect differing aspects of technology transfer. Moreover, CCS is currently in the process of being developed and proven in (generally) industrialized countries. It is not yet ‘established on the market’ and thus all countries with CCS activities are building experience – there is no jurisdiction at the current time that is in a position to ‘transfer’ the technological system as a proven package.

Looking to the positive side of technological experience, many technological components of future CCS-systems are available and some have been in commercial application for many years. CO₂ capture technologies have long been applied to high-concentration CO₂ sources. CO₂ transport has been used safely for the past 30 years (e.g. in the US) to deliver CO₂ for enhanced oil recovery (EOR). Geological CO₂ storage has been operating for more than a decade at a growing number of sites worldwide and all available evidence shows that the CO₂ has performed as anticipated after injection.

However on the negative side, the overall lack of global experience of fully integrated systems, combined with an incomplete understanding of the costs of large scale CCS, still pose a major challenge. In addition, each site seen as a

prospective CO₂ repository has unique characteristics and more experience must be gained to improve predictions of CO₂ behaviour and to confirm the ‘suitability parameters’ of storage sites. This is particularly so for deep saline formations, which have the greatest global distribution and the most promise for long-term CO₂ storage potential. Moreover, thus far none of the existing large-scale projects involve the capture and storage of CO₂ from dilute sources such as coal-fired power plants or industrial plants in the cement, chemicals, metals, or pulp and paper sectors.

At the current time, there are four fully-integrated, commercial-scale CCS projects in operation, Weyburn-Midale, Sleipner, Snøhvit and In Salah. At Weyburn-Midale, compressed CO₂ is captured from a coal-based synfuels plant and piped to an oil field where it is injected for EOR. The latter three projects involve the extraction of natural gas with high CO₂ content. CO₂ must be reduced so that the gas meets market specifications. To achieve this, excess CO₂ is stripped, collected and stored in underground geological formations. In total, these plants store more than 5 million tonnes of CO₂ per year. While such initiatives are very expensive, Governments are beginning to address funding gaps and there has been a dramatic increase in government and industry demonstration activities in the past two years. Most of the major economies have announced ambitious plans (and associated funding) for large-scale CCS demonstration projects. A selection of these is provided in the text box below.

National plans or announcements for CCS

Australia: In April 2009, the Global CCS Institute (GCCSI) was launched to foster international collaboration, particularly around near-term, large-scale demonstration projects. Australia has also announced AUD 2 billion for large-scale domestic demonstration.

Brazil: Oil company Petrobras is investing in two to four large-scale demonstration projects as part of its sustainability and climate change plan.

Canada: Allocated CAD 3.5 billion for large-scale CCS project demonstration.

China: A consortium of companies has mobilised the GreenGen project with support and approval from the government. The total project budget (including power generation) is circa USD 1 billion.

European Union (EU): The financial stimulus package of 2008/9 includes EUR 1 billion for CCS demonstration and also set aside EUR 300 million of carbon trading allowance revenues for CCS funding.

France: Developing smaller-scale demonstration projects as part of the EUR 1 billion funding package for research and development.

Italy: Enel, the national electricity company, is developing one pilot plant.

Norway: (in addition to Sleipner and Snøhvit) is developing the Mongstad and Karstø projects.

South Africa: Scheduled to launch a CCS Centre in September 2009 and has the aim to have at least one full-scale project operational by 2020.

United Arab Emirates: Three large-scale CCS projects under development, building on the region's expertise in enhanced oil recovery.

United Kingdom: Progressing its CCS large-scale demonstration competition with one major project to be operational by 2014 and has announced proposals to establish a mechanism to support up to four large-scale CCS demonstrations and to require any new coal-fired power plant over 300MW capacity to demonstrate CCS on a proportion of its capacity. The UK government has received two bids in its 'competition' (E.ON and Scottish Power) and is now in the second stage of the selection process. The European Commission has provisionally approved EUR 180 million in funding to support the process.

United States: Announced USD 3.4 billion in new funding for CCS projects in May 2009.

4.2.1 Maturity of CCS technology components

Table 4-1 indicates the relative maturity of the major system components introduced in Section 4.1.1. As was indicated while the majority of system components are well advanced in their development, few have actually reached the status of 'market maturity'. Each grade of maturity for each system component implies differing needs or opportunities for technology transfer between differing parties.

For example, in the instance of technology transfer focusing on the external support of R&D efforts (e.g. for technologies in the research or demonstration phases) choices for technology transfer efforts may need to be made between resource allocation on *research and development*

or on *capacity promotion* policies.³⁴ Activities to promote transfer of mature market technologies on the other hand, may need to be more focused upon the facilitation of IP agreements or contractual arrangements between parties as the holders of intellectual property rights seek to protect their commercial interests and investments.

³⁴ One difference in such areas can be projects that focus upon *learning by research* (an example could be developing technologies in National laboratories) as opposed to *learning by doing* (an example could be participating in a pilot or demonstration activity run by another party).

TABLE 4-1 CURRENT MATURITY OF CCS SYSTEM COMPONENTS

CCS component	Technology	Research phase ^a	Demonstration phase ^b	Economically feasible under certain conditions ^c	Mature market ^d
Capture	Post combustion			X	
	Pre-combustion			X	
	Oxyfuel combustion		X		
	Industrial separation (natural gas processing, ammonia production, ..)				X
Transportation	Pipeline				X
	Shipping			X	
Geological Storage	Enhanced oil recovery				X ^e
	Gas or oil fields			X	
	Saline formations			X	
	Enhanced coal bed methane recovery (ECBM) ^f		X		
Monitoring and Verification ^g	Site selection & performance prediction			X	
	Injection and storage monitoring & verification			X	
Ocean storage	Direct injection (dissolution type)	X			
	Direct injection (lake type)	X			
Mineral carbonation	Natural silicate minerals	X			
	Waste materials		X		
Industrial CO ₂ uses					X

The X's indicate the highest level of maturity for each component. There are also less mature technologies for most components. After (IPCC, 2005, p21)

a Research phase means that the basic science is understood, but the technology is currently in the stage of conceptual design or testing at the laboratory or bench scale, and has not been demonstrated in a pilot plant.

b Demonstration phase means that the technology has been built and operated at the scale of a pilot plant, but further development is required before the technology is ready for the design and construction of a full-scale system.

c Economically feasible under specific conditions means that the technology is well understood and used in selected commercial applications, for instance if there is a favourable tax regime or a niche market, or processing on in the order of 0.1 MtCO₂ yr⁻¹, with few (less than 5) replications of the technology.

d Mature market means that the technology is now in operation with multiple replications of the technology worldwide.

e CO₂ injection for EOR is a mature market technology, but when used for CO₂ storage, it is only economically feasible under specific conditions.

f ECBM is the use of CO₂ to enhance the recovery of the methane present in unminable coal beds through the preferential adsorption of CO₂ on coal. Unminable coal beds are extremely unlikely to ever be mined.

g This parameter is discussed in most literature but is not addressed as a system component per se. The judgments of relative maturity have been made by the authors of this report as a broad assessment of the enfolding debate.

4.2.2 CCS technology components and potential implications for technology transfer initiatives

The current status of CCS technologies is also important when considering which form of technology transfer may be required for various system components. In recognition of this, Tables 4-2 and 4-3 on the following pages provide an overview of the current technological status of the key components within the CCS technology chain. They also include comments on potential implications for ‘diffusion and transfer’ of technology in terms of three key spheres: *hardware*, *software* and *orgware* suggested by the International Institute for Applied Systems Analysis (IIASA).³⁵ Application of these typologies supports discussion of technology issues (and thus also TOAs) by focusing attention upon particular aspects of the system that may need support. In this discussion these terms imply:

- ‘*hardware*’: manufactured objects (also referred to as ‘artifacts’);
- ‘*software*’: knowledge required to design, manufacture, and use technology hardware; and
- ‘*orgware*’: institutional settings and rules for the generation of technological knowledge and for the use of technologies.

In developing countries in particular, *orgware* is often experienced as a major challenge and technology related activities that build capacity in this area may need to be accorded significant attention (Outhred, 2008). Moreover, it is important to consider more than just the hardware required for CCS. Analysis must also take into account the systems in which they are embedded (e.g. for CCS, not just the capture, transfer and storage systems but also the markets and infrastructure that surround them).

For CCS, while the technological components are not entirely new or innovative (IPCC 2005), their application does require a complex and fundamental systemic change. This in turn will very likely require well developed policy frameworks and steering mechanisms. Moreover, even if there is a delay between application in industrialized countries and (presently) developing countries which could result in CCS NOT being widely applied in developing countries for two or more decades (IPCC 2005,

2006) – substantial changes to (power) plant design and build layout probably need to be achieved well within a decade in order to ensure ‘CCS ready’ generation infrastructure (IPCC 2006).

Further, it is reiterated that there are many areas and levels where technology transfer efforts may be applied. It is also important to recognize that the process of learning to understand, utilize and replicate technologies (and technology transfer activities) are mostly taking place in, between and among industrialized countries at the present time. While this can be seen as a pre-requisite for transfer towards less developed countries – this also alters the context of technology discussions as transfer towards developing and transition economy countries largely lies in the future.

Further, it is important to note that CCS often does not (generally will not) have a commercial benefit associated with its implementation. By this it is inferred that CCS is not expected to be profitable and thus have the potential to ‘self-fund’. As has been indicated earlier in this report, the marginal costs of CO₂ abatement are anticipated to be in the range of some USD 40 per tonne when the CCS systems are widely established. This in turn bears with it the likelihood that less developed countries will expect wealthier countries to contribute significantly to the costs associated with CCS implementation. More detail of the marginal costs of abatement for CCS in comparison to other actions is provided in IEA (2008) – *IEA Energy Technology Perspectives 2008*

³⁵ For further information visit <http://www.iiasa.ac.at/Research/TNT/WEB/Page10120/page10120.html>

TABLE 4-2 CURRENT MATURITY OF CCS SYSTEM COMPONENTS (CAPTURE & TRANSPORTATION).

CCS component	Technology	Current status of technological system	Potential implications for the diffusion and transfer of the CCS technology and considerations for technology oriented agreements.
Capture	Post combustion	Economically viable under some conditions	*Focus upon technology transfer processes between countries, including developed, developing and transition economies to promote market viability. Hardware is largely established in industrialized countries; software : knowledge required to design, manufacture, and use technology hardware exists to a significant extent in China but to a lesser extent in India and much lesser extent elsewhere. ' Orgware ': institutional settings and rules for the generation of technological knowledge and for the use of technologies appear to predominantly affect the economic viability of the process.
	Pre-combustion	Economically viable under some conditions	As above (*) with exceptions that: a) high ash coals such as those that dominant on the Indian sub-continent appear largely unsuitable for this technology, and b) the technology is widely used in hydrogen production and in petroleum refining operations – thus such capacities should exist in many developing countries that have refining capacity and can be built upon. (i.e. see industrial separation below.); c) pre-combustion technologies are symbiotic with IGCC technologies – this leads to both greater flexibility, but also greater capacity building requirements as IGCC is also yet to enter commercial application.
	Oxyfuel combustion	Demonstration phase	OFC will be suitable for retrofit to many existing generation units but is still in the demonstration form. Significant focus may be required on both building R&D and D capacity, as well as ensuring that demonstrations are performed in LDCs, so that when OFC enters the market there are skills in place (i.e. This implies the need for a focus on <i>hardware</i> and <i>software</i>)
	Industrial separation (e.g. natural gas processing, ammonia production, etc.)	Mature market	As an established technology, and one that is likely to exist in many LDCs (e.g. those with refining operations). Technology transfer efforts will presumably follow established trajectories for such plant.
Transportation	Pipeline	Mature market	Pipelines for transportation are standard 'on the market technologies'. While tech. transfer will be required, it appears that institutional frameworks for mobilizing the infrastructure installation and obtaining financing will constitute the major challenges (ie. <i>orgware</i> concerns for development of the systems). Safety and monitoring requirements will be similar to natural gas pipelines – however CO ₂ is less hazardous.
	Shipping	Economically viable under some conditions	It seems logical that the global shipping industry will mobilize to meet the demand for the required specialist tanker fleets. Opportunities for building industries in the production of such tanker fleets may be a desirable area for technology transfer. However, China is already a major maritime power and the world's third largest shipbuilder in terms of gross tonnage, surpassed only by Japan and South Korea. China may in fact emerge as a key technology provider in this area.

TABLE 4-3 CURRENT MATURITY OF CCS SYSTEM COMPONENTS (STORAGE OR APPLICATION).

CCS component	Technology	Current status of technological system	Implications for the diffusion and transfer of the CCS technology and considerations for technology oriented agreements.
Geological Storage	Enhanced oil recovery	Mature markets	As this technology is an established practice in the oil and gas sector, it appears logical that technology transfer to countries with oil and gas resources should occur within the industry and with lesser needs for support efforts from outside parties. Work to support the institutional frameworks surrounding the EOR/CCS nexus (e.g. storage safety and institutional longevity etc.) may be a focus area (ie. <i>orgware</i> support).
	Gas or oil fields	Economically viable under some conditions	*Indications are that this practice will rapidly become standard practice through the large scale demonstrations underway – and planned. Especially as EOR becomes more attractive with increased oil field depletion, and there is increased commercial benefit associated with EOR. Thus it appears that a technology transfer push at all levels <i>Hard/Soft/Orgware</i> will be required.
	Saline formations	Economically viable under some conditions	As above*.
	Enhanced coal bed methane recovery (ECBM) ^f	Demonstration phase	ECBM is put forward as a useful application for CCS but is still in the demonstration form. However, the volumes involved are likely to be marginal in comparison to other applications. Where ECBM is of interest, focus may be required on both building R&D and D capacity, as well as ensuring that demonstrations are also performed in LDCs, so that skills are in place when this application is valid in a specific geographical context (i.e. minor focus on <i>hardware</i> and <i>software</i>).
Monitoring & verification	Site selection & performance prediction	Demonstration phase	To a significant extent this will require straightforward application and transfer of existing established technologies – <i>hardware</i> and <i>software</i> .
	Injection and storage monitoring & verification	Demonstration phase	To a significant extent this will require straightforward application and transfer of existing established technologies – <i>hardware</i> and <i>software</i> . Storage safety verification (dependent upon institutional longevity etc.) may be a focus area (ie. <i>orgware</i> support).
Ocean storage	Direct injection (dissolution type)	Research phase	**Assumed not applicable at the current time for reasons of: scientific uncertainty <i>vis a vis</i> performance; long term viability, and ecological soundness
	Direct injection (lake type)	Research phase	As above **
Mineral carbonation	Natural silicate minerals	Research phase	***Assumed not applicable for reasons of cost.
	Waste materials	Demonstration phase	As above ***
Industrial CO ₂ uses		Mature market	To a significant extent this requires straightforward technical transfer of existing established technologies. However, volumes are likely to be several orders of magnitude smaller than those required for ‘CCS for climate’ storage sites and as such, this application appears to be of minor importance for this discussion. To a limited extent <i>Orgware</i> .

4.2.3 Financial crediting gap for CCS under carbon markets

A simple but illustrative financial analysis reveals that current carbon markets are inadequate to make CCS demonstration plants a financially attractive prospect. This analysis considers current and future cost estimates of CCS compared to actual and forecasted CO₂ prices from the EU Emissions Trading System

(EU-ETS). For a number of technical reasons however, this analysis should only be considered

indicative. All projects have differing morphologies, fuels, scales and specific CCS technologies – and there is a high level of uncertainty in the available cost data. Similarly, the forecasting of carbon prices is highly complex and outcomes are likely to have a high

degree of ambiguity due to a plethora of future policy and market uncertainties. As such, predicted allowance prices also need to be viewed with due caution.

Having stated these limitations, estimations for CCS abatement costs have been generated. These fall in the following ranges:

- currently – 100 to 70 Euro/ton CO₂;
- by 2015 – 90 to 60 Euro/ton CO₂ by 2015 (still early demonstration phase);
- by 2020 – 50 to 35 Euro/ton CO₂ by 2020 (early commercialisation phase);
- by 2030 – 45 to 30 Euro/ton CO₂ (mature commercialisation phase)

With the bulk of CCS project costs are heavily influenced by CO₂ capture as such (see Ecoal, 2005:8; IEA, 2008:270; McKinsey and Company, 2008:17).

Moving from costs to potential ‘revenues’, the European Union emission trading scheme is used as a basis for calculation. The EU is the only region in the world that has adopted a formal cap-and-trade scheme, the EU-ETS, that sets prices for CO₂ emissions. EU-ETS allowance prices – historic, actual and forecasted – are taken here as benchmarks for comparison with CCS costs. First, EU-ETS allowances prices reached an upper bound of nearly 30 Euro/ton CO₂ during the second quarter of 2008 and a lower bound of some 8 Euro/ton CO₂ approximately during the first quarter of 2009.³⁶ At the end of 2009, allowances were in the order of 15 Euro/ton CO₂ (PointCarbon, 2009).³⁷ Recently, Barclays Capital forecasted that EU-ETS allowances prices will be in the proximity of 11 Euro/ton CO₂ in 2010 (+/- 1 Euro/ton CO₂) (PointCarbon News, 2009) and in the latest World Energy Outlook (IEA, 2009c:68), the price of allowances under the EU-ETS is estimated to reach 28 Euro/ton CO₂ in 2020 and 36 Euro/ton CO₂ in 2030 – prices still confined to only the power and industry sectors under the scheme.³⁸

Taking into account the different cost ranges for CCS and projections for EU-ETS allowance prices reveals a financial carbon crediting gap for

CCS projects. Assuming business-as-usual policy and market conditions, the financial gap in the near term is in the range of some 40 to 70 Euro/ton CO₂. By 2020, one can observe that the gap still exists but is reduced to a range of 7 to 22 Euro/ton CO₂ by 2020. In 2030, the gap is further reduced to a range of -6 to 9 Euro/ton CO₂. With due caution, the analysis indicates that the costs of CCS might fall to within the range of EU-ETS allowance prices by 2030 at the earliest. In other words, the carbon price seems to be too low until this time to provide a clear incentive for the development of commercial CCS projects and to create market confidence to early movers in the European market. Once the costs of CCS are lowered, it appears feasible that carbon markets can support CCS as long as policy developments and internationally legally-binding commitments deliver ambitious emission reduction targets (e.g. in line with 450 ppm) that maintain high demand for carbon credits. In the meantime, additional and significant incentives to the carbon market price will be necessary to make CCS a financially viable option (WCI, 2008c). For instance, the EU has reserved 300 million allowances to fund 10-12 commercial CCS plants. Moreover, countries such as China, that have established a Clean Development Fund by taxing CDM revenues, could devote nationally available financial resources to support CCS technologies – eventually under a sectoral CDM crediting mechanism.³⁹

³⁶ The second phase of the EU-ETS runs from 2008-2012 to coincide with the first Kyoto Commitment period.

³⁷ Note that due to a number of political and design issues, the EU-ETS allowances reached a record low level of near zero Euro/ton CO₂ by the end of 2007 (Phase 1 -).

³⁸ 1 US dollar = 0.66 Euro at 17 November 2009.

³⁹ For details about potential options to finance CCS technologies see WCI (2008c).

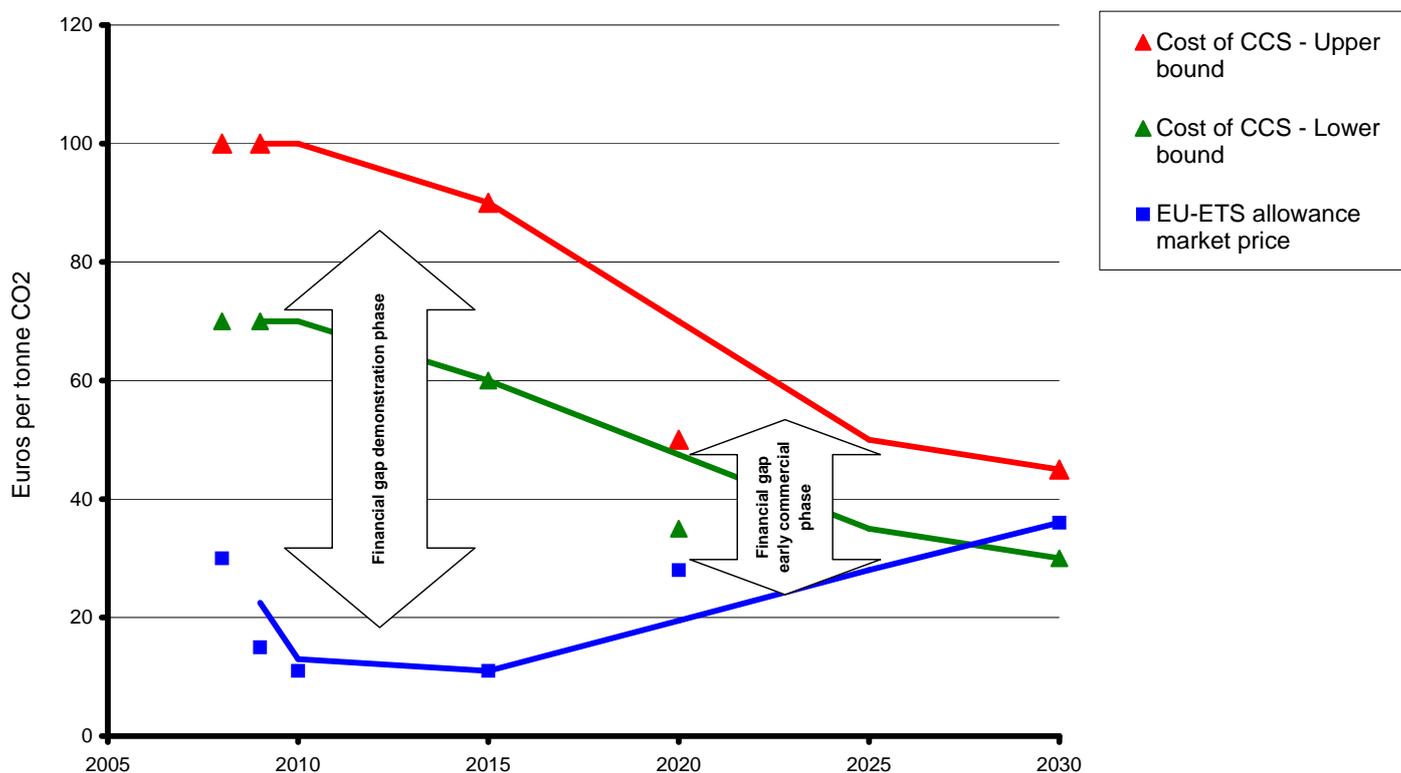


FIGURE 4.4. FINANCIAL CREDITING GAP FOR CCS PROJECTS IN CARBON MARKETS DURING DEMONSTRATION AND EARLY COMMERCIALISATION PHASES.

Note that average trend lines are also presented (in red for upper bound of CCS costs; in green for lower bound of CCS costs; in blue for EU-ETS allowance price) to better illustrate the estimated cost range for CCS and reveal the financial gap in relation to carbon market prices

4.3 Technology-oriented agreements for CCS and their characteristics

This section presents four general types of TOAs and a set of conditions held to be important to the achievement of an ‘environment’ conducive to technology transfer. As was discussed in the opening chapter of this report, an *enabling environment* approach was chosen to support the analysis of TOAs. Here, a point of departure is that advancement is required in five key areas to create conditions amenable for the uptake and deployment of CCS-related technologies. Significant weight is accorded to parameters such as human capacity and institutions as well as the policy, market and regulatory environments that they act within. Details of these areas and three additional categories considered important for CCS are provided in the next sub-section.

We expect that the achievement of technology transfer in general (and thus successful CCS transfer) is strongly connected to the build-up of *enabling environments* in developing countries and economies in transition (EITs). In recognition of the fact that CCS technologies are only just now emerging in industrialized countries, we also anticipate that the build-up of enabling environments must also take place in industrialized countries. This must occur to provide capacity for large-scale technology transfer elsewhere.

In the next section important characteristics of emerging CCS-related TOAs are presented. Then in Section 4.3.2, four different types of TOAs are outlined applying a typology proposed by De Coninck et al. (2008) and details of initiatives that we perceive as examples for each category are provided. However, this is neither a definitive typology nor an exhaustive listing of initiatives. As has been discussed earlier in this chapter the field is very dynamic and there is a rapidly

growing suite of projects and initiatives around the world and it is not feasible to address all here.

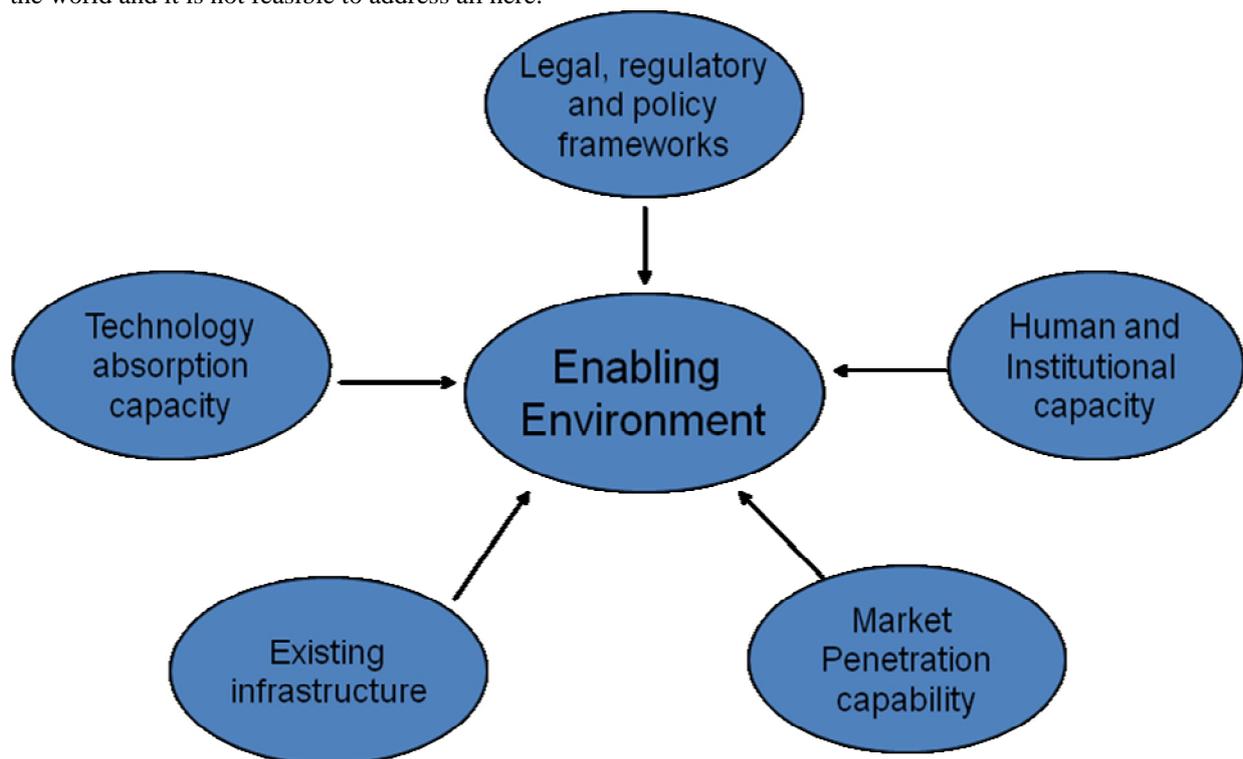


FIGURE 4-5. ENABLING ENVIRONMENTS SCHEMATIC, SOURCE: UNFCCC, 2003

Section 4.4 follows up from this introduction of initiatives with discussion and an ‘overview’ analysis of the examples. In particular, it seeks to highlight how they contribute to the building of the five key sub-components of *enabling environments*.

4.3.1 Important characteristics of emerging CCS TOAs

For any CCS related initiative, the manner in which it overlaps with, addresses, or facilitates the building of five ‘enabling’ parameters is important. These are:

- the existence of necessary infrastructure (in recognition of the near universal absence of integrated CCS infrastructure, the role of contributing to building, or advancing the status of such is considered here);
- technology absorption capacity in the receiving jurisdiction;
- legal, regulatory and policy frameworks;
- human and institutional capacity in the receiving jurisdiction;
- market penetration capability of the technology, or the system within which it is embedded.

Moreover, here it is considered that at least three additional parameters have significant potential to affect/impact processes of CCS-related technology transfer.

- In recognition of the multi-component and multi-agent nature of CCS – it being an integrated system with prominent legal/regulatory components rather than a ‘technology item’ – the *span of the technology transfer initiative* across the activity chain (including institutional components) is important.
- In recognition of the many levels of institutional influence or participation – from company level initiatives all the way up to inter-governmental fora – the *institutional level of action*, or the level that an initiative is ‘framed’ is relevant to analysis.
- Recognizing that diffusion and transfer of ‘technology’ takes place in at least three differing spheres (i.e. *hardware*, *software* and *orgware* as discussed in Section 4.2.2) – the *focus of the initiative* is a significant consideration.

4.3.2 Different types of TOAs

Considering these eight facets of technology transfer activity introduced above, the following pages present an overview analysis of some of the CCS initiatives underway around the globe. Most of this are in industrialized countries. The examples substantially represent each of the four main types of agreements suggested by De Coninck et al. (2008); namely:

- **knowledge sharing and coordination;** with activities or undertakings encompassing meeting, planning and information exchange, information about ‘best practice’, coordination and harmonization of research agendas and measurement standards;
- **research development and demonstration (RD & D) activities;** including jointly agreed RD & D activities and funding commitments, and agreements to expand or enhance domestic RD&D programs;
- **technology transfer;** including commitments for technology and project financing, and measures for the facilitation of licensing and patent protection;
- **technology deployment mandates, standards, and incentives;** including international agreements encouraging technology deployment through establishing deployment mandates for specific technologies (or groups of technologies), international technology performance standards, or technology deployment incentives.

Note that the initiatives selected here for analysis do not fall seamlessly into each category. Rather, each contains one or more ‘conceptual components’ of a given category. By extension, this indicates that some of the examples presented here are not ‘technically oriented agreements’ according to any strict definition. However, they are certainly ‘activities or initiatives related to CCS technology transfer where agreements are required between parties’.

4.3.2.1 Knowledge sharing and coordination

Knowledge sharing and coordination relevant to technology transfer can take place at several institutional levels, and can focus upon widely varying facets of the technology system. In general, this encompasses information-based activities. Thus key descriptive phrases include:

meeting, planning, information exchange, ‘best practice’ dissemination, research coordination and harmonization, measurement/monitoring standardisation and so forth. Three examples are presented here.

Intergovernmental (ministerial) level information-based activities

The **Carbon Sequestration Leadership Forum (CSLF)** [see <http://www.cslforum.org>] is a Ministerial-level and international climate change initiative focused on the development of improved cost-effective technologies across the entire CCS technology system. Membership is open to national governmental entities that are significant producers or users of fossil fuels and that have a commitment to invest resources in research, development and demonstration activities. As of the last quarter 2009, the CSLF is currently comprised of 24 members, including 23 countries and the European Commission. CSLF member countries represent approximately 60% of the world’s population.

The CSLF has been active within fora such as G-8 leader Summit(s), the U.S.-European Union Summit on Energy Security, Energy Efficiency, Renewables and Economic Development, discussions for the Mainz Declaration of Germany and the United States on Cleaner and More Efficient Energy, Development and Climate Change. The forum has also convened workshop series with the International Energy Agency (IEA) on the topic of near-term opportunities for carbon capture and storage (CCS).

The CSLF initiative establishes a broad outline for cooperation with the purpose of facilitating development of cost-effective techniques for capture and safe long-term storage of CO₂, while making these technologies available internationally. Its Charter indicates that work is to focus upon:

- identification of key obstacles to achieving improved technological capacity;
- identification of potential areas of multilateral collaboration on carbon separation, capture, transport and storage technologies;
- fostering collaborative research, development, and demonstration (RD&D) projects that reflect Members’ priorities;

- identification of potential issues relating to the treatment of intellectual property;
- establishment of guidelines for the collaborations and reporting of their results;
- regular assessment of the progress of collaborative R&D projects and provision of recommendations for the direction of such projects;
- establishment and regular assessment of an inventory of the potential areas of research need;
- organization of collaboration sectors of the international research community, including industry, academia, government and non-government organizations; and to constitute a complement to ongoing international cooperation in this area;
- development of strategies to address issues of public perception.

Regional (integrated demonstration) level information-based activities

The European Carbon Dioxide Capture and Storage (CCS) Network (CSLF)

[see <http://www.ccsnetwork.eu>]

The European Commission is sponsoring this first global network of demonstration projects. The goal is to create a prominent community of projects united towards the goal of commercially viable CCS by 2020.

The CCS Project Network is to facilitate knowledge sharing amongst the demonstration projects and work with public perceptions of CCS. The initiative aims to accelerate learning and assist CCS to safely fulfill its potential, both in the EU and in cooperation with global partners.

The Network initially and principally aims support the demonstration of CCS technologies in the EU. It was established with the purpose to enhance co-ordination between first-movers in the field of CCS and to enhance:

- exchange of information and experience, identification of best practices, optimal use of the best technologies available in Europe – primarily through knowledge-sharing;
- provision of a common EU identity to network members and a higher visibility for individual efforts;
- provision of detailed information and concrete results from the demonstration projects to help build public confidence about CCS;
- promotion of CCS, EU leadership and cooperation potential to third parties/countries.

Intergovernmental (technical system component) level information-based activities

The IEA GHG Networks involve a range of information and network activities.

[see <http://www.ieagreen.org.uk>
<http://www.co2captureandstorage.info/>]

The International Energy Agency (IEA) is an intergovernmental organization which acts as energy policy advisor to 28 member countries. The IEA mandate incorporates “Three E’s” of balanced energy policy making: energy security,

economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries. The IEA conducts a broad programme of energy research, data compilation, publications and public dissemination of the latest energy policy analysis and recommendations on good practices.

The IEA Greenhouse Gas R&D Programme (IEA GHG) is a collaboration aiming to:

- evaluate technologies for reducing emissions of greenhouse gases;
- disseminate the results of these studies;
- identify targets for research, development and demonstration and promote the appropriate work.

Within the IEA GHG is a series of activities focused on CCS. These seek to provide a central source of information on CO₂ Capture and Storage Research, Development and Demonstration (RD & D); promote awareness of the extent of RD & D now underway; and to facilitate co-operation between projects. As part of this, the IEA Greenhouse Gas R&D Programme maintains a website with a collection of resources related to the capture and storage of CO₂. Among other things, this contains:

- an interactive map of all known carbon capture and storage demonstration projects with pictorial and general information about the projects and includes web links;
- a Risk Scenarios Database that addresses aspects of risk assessment of CO₂ capture and storage and is to serve work on public perceptions;
- a Global CO₂ Emissions Database;
- a Best Practice Support database where examples of internationally accepted best practice for CO₂ capture and storage can be collected.

The IEA GHG also coordinates a number of technical Networks. These are of varying size and have varying degrees of development. CCS focused networks include:

- **International Network for CO₂ Capture** – a forum for actors involved in CO₂ capture test facilities;
- **Monitoring Network** – focused upon the dissemination of experiences from monitoring programmes;

- **Oxy-Fuel Combustion Network** – a forum for organisations with interest in the development of Oxy-Fuel Combustion Technology;
- **Risk Assessment Network** – aiming to provide clarity for what regulators are expecting and whether/how risk assessment can provide the answers they require;
- **Well Bore Integrity Network** – to disseminate current state of knowledge of well bore integrity and provide input to annual Risk Assessment Network Meetings;
- **Modelling Network** – a (proposed) network for modelling storage and risk factors;
- **High Temperature Solid Looping Cycles Network** – seeking to promote further development and scale-up of processes for CO₂ capture which involve solid looping cycles operating at elevated temperatures (a new method for capturing CO₂ during combustion).

4.3.2.2 RD & D activities

Input to the furthering of RD&D activities relevant to CCS can take several forms – indeed, the size and scope of CCS demands international collaboration. Consequently, key items required include jointly established RD & D activities between countries or jurisdictions – or between industry and government, significant funding commitments and cross-jurisdictional agreements to expand or enhance domestic RD&D programs. Brief outlines of three examples of initiatives that mirror these requirements follow.

Public-private sector partnership (technical system components)

The *European Test Centre Mongstad (TCM)* will conduct applied research to carbon dioxide capture technologies with the main focus being reduction of cost and risk.

In 2006, the Norwegian government and Statoil agreed on CCS initiatives at the Mongstad facility. This was part of the approval of a new 260 MWe and 350 MW_h combined power and heat plant. The first step is the realization of test facilities with the capacity to capture 100 000 tons of CO₂ annually. The second step of the agreement will be a full-scale carbon capture plant. The government has invited new companies to participate and in 2007 the Norwegian Ministry of Petroleum and Energy,

DONG Energy, Hydro, Shell, Statoil and Vattenfall entered into a co-operation agreement for TCM. The Norwegian state is represented by Gassnova SF, while Hydro's oil- and gas activities merged with Statoil to form StatoilHydro in October 2007.

TCM will include both amine- and carbonate (“chilled ammonia”) based technologies and will have access to flue gas sources with CO₂ content that covers the range from gas turbine- to coal fired steam boiler applications. The project will have a total annual CO₂ capacity of 100 000 tonnes per annum (tpa). The ambitions are to:

- develop technologies for CO₂ capture capable of wide national and international deployment;
- reduce cost and technical, environmental and financial risks related to large scale CO₂ capture;
- test, verify and demonstrate CO₂ capture technology owned and marketed by vendors;
- encourage the development of markets for such technologies.

[see

<http://www.statoil.com/en/TechnologyInnovation/NewEnergy/Co2Management/Pages/Mongstad.aspx>]

Public sector – intergovernmental organisation partnership (technical system components)

The *Weyburn Project* is a commercial project led by EnCana and the IEA. It captures CO₂ from coal gasification and utilises it for EOR. From 2000 to 2004, the Weyburn project was the site of a world-scale research initiative operated under the auspices of the IEA, which studies the sequestration of CO₂ in an oil reservoir. The study concluded that Weyburn is a suitable reservoir for long-term storage of CO₂. The second phase, expected to last until (at least) 2009, investigated how the technology can be expanded on a larger scale.

[See

<http://www.encana.com/operations/oil/weyburn/> and <http://www.ieagreen.org.uk/june78.htm#3>]

Public-private sector partnership (technical system components)

The **In Salah Gas project** being developed by In Salah Gas, a 50:50 joint venture between BP and state energy company Sonatrach, and came on stream in August 2004. Ultimately, In Salah Gas aims to supply 9 billion m³/y of gas to the southern European market.

A component of the project includes the facility to remove CO₂ from the produced gas, followed by large-scale re-injection into an underground formation. This activity has the aim to achieve industrial scale demonstration of CO₂ geological storage (Conventional Capture). The project has no commercial benefit and will store circa 1M metric tpa (17Mmt lifetime) at a cost of approximately \$6/tCO₂. The project shall also serve as a test-bed for CO₂ Monitoring Technologies.

[More info at http://www.co2captureandstorage.info/project_specific.php?project_id=71]

4.3.2.3 Technology transfer

Technology transfer activities are often presented as a sequence of events that shift technologies from a developed country into a developing country. ‘Standard’ sequences for a piece of technology may include (c.f. Ueno 2009):

- a) Production (of an established technology) → Export → Deployment/Diffusion (in a developing country);
- b) Commercialisation (of a technology) → technology licensing → Foreign Direct Investment or Joint Ventures → Imitation → Production → Deployment/Diffusion;
- c) R&D (to develop a technology) → technology licensing → Foreign Direct Investment or Joint Ventures → Imitation → Commercialisation → Production → Deployment/Diffusion.

Within such regimes, commitments for technology and project financing, and measures for the facilitation of licensing and patent protection are key components.

An immediate conceptual difficulty with CCS is that it is to be made up of an integrated suite of technologies. Moreover, as has been indicated throughout this discussion, institutional

components addressing the CCS chain will also be a crucial ‘system component’. As CCS is not ‘market mature’ – and does not have any commercial examples in operation, this report cannot address CCS system transfer. Rather, one example of an incipient technology transfer framework is noted here – there are two transfer projects within its remit.

Government-Government plus private sector partnership (technical system demonstration)

The **EU and China Partnership on Climate Change** represents an early example of international technology transfer. In 2005, the EU agreed to cooperate with China on a range of climate change issues, including CCS, in the context of the EU-China Climate Change Partnership. Included in the plan is the proposal to support a public-private partnership estimated at €300-550m to help build and run a coal plant fitted with CCS. This project is envisaged to serve as a ‘model’ for other technology cooperation projects between developed and developing nations. It is also an indication of acceptance that technology transfer is a key demand from developing countries in the international climate talks.

Two projects are underway: i) the co-operation action with CCS China-EU (<http://www.co2-coach.com/>) and ii) the UK-China near-zero emission coal (NZEC) project (<http://www.nzec.info/en/>).

[More information is available at: http://ec.europa.eu/unitedkingdom/press/press_releases/2009/pr0964_en.htm#_ftn2 and <http://ec.europa.eu/environment/climat/china.htm>]

4.3.2.4 Technology deployment mandates, standards, and incentives

The literature and current industrial experience (cf. IPCC, 2005) indicate that unless concerted efforts to mandate the application of CCS to limit CO₂ emissions – and to provide incentives for its application – are made, then there are only small, niche opportunities for CCS deployment. The costs involved are extremely large, and the potential contribution from CO₂ markets currently appears quite inadequate to cover the expected per-unit cost of the CCS process. There is thus a key role for items such as international agreements mandating application of CCS for specific sectors or operations; international technology performance standards (e.g.

maximum emissions/kWhr for electricity production, leakage standards for depositories, etc.), or CCS deployment incentives. While no mandates are found thus far, three incipient examples related to this category of TOA are noted here.

DIRECTIVE 2009/31/EC⁴⁰: geological storage of CO₂ establishes a legal framework for the environmentally safe geological storage of CO₂ to contribute to the fight against climate change. The Directive is intended to provide for environmentally-safe capture and geological storage of CO₂ in the EU. It is a part of a major legislative package. Issued in 2009, the Directive is a response to a call for standards from EU leaders at their Spring summit in 2007.

[Full doc at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF>⁴¹]

CCS under the CDM – CCS Proponents hold that the Kyoto Protocol's Clean Development Mechanism (CDM) provides a pathway that can support clean energy technology transfer to developing countries (WCI, 2008b). Under the CDM, industrialised countries may invest in emissions reduction projects in developing countries in order to generate emissions reductions credits that can be used to help achieve their Kyoto targets. The level of emissions reduced by the project must be additional to those that would have occurred without the investment from the developed country.

At present, CCS is not eligible for approval as a CDM activity because of a number of concerns that some Kyoto Parties have raised regarding the technology. However, CCS as already recognized as an important greenhouse gas mitigation technology, strong arguments exists that CCS should qualify for deployment as a CDM activity and many Parties to the Kyoto protocol have been supportive of the inclusion of CCS as a CDM activity. Proponents indicate that inclusion of CCS under the CDM would increase the potential to take advantage of the low cost CCS opportunities that may exist in developing

⁴⁰ DIRECTIVE 2009/31/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006

countries, which in turn will help to accelerate widespread global deployment. Several studies are available on this topic (cf. de Coninck, 2008; Philibert et al., 2007; Vormedal, 2008).

The Global Environmental Facility (GEF) and CCS. The GEF has expressed its view that transferring immature, low-GHG (e.g. CCS) technologies to developing countries is inappropriate because of the large extra costs and risks that would be imposed on the host countries' energy systems – it was not deemed relevant to the GEF strategy up to 2010. However, the Facility recognized that it needed to keep abreast of developments in such technologies. While the GEF supports work programs of mitigation projects, CCS is not currently eligible for GEF support. In the longer term, it is likely that the GEF will engage with CCS technology transfer. There are a number of ancillary activities that can be funded through the GEF. These include efforts to train personnel in technology issues, train installers, create technology transfer centres, develop courses and research initiatives, establish national and regional technology networks (Bazilian et al, 2008).

For details of the relationship between the GEF and CCS, [see: [http://www.gefweb.org/uploadedFiles/Document/s/Council_Documents_\(PDF_DOC\)/GEF_33/C.33%20Inf.14%20STAP_Carbon%20Capture.pdf](http://www.gefweb.org/uploadedFiles/Document/s/Council_Documents_(PDF_DOC)/GEF_33/C.33%20Inf.14%20STAP_Carbon%20Capture.pdf)]

Although not reviewed in this study, modelling work performed by Edmonds and Wise (1998) addressing a hypothetical CCS technology mandate for GHG mitigation scenario is also available.⁴²

4.4 Important precursors for CCS Technology Transfer

This discussion summarizes important precursors grouped under headings provided by each of the five key 'enabling' areas identified for transfer, uptake and deployment of CCS.

Note that this text seeks to portray how the examples of *technically oriented 'collective actions' or agreements* (of differing types) contribute to the building of the five key sub-components of 'enabling environments' addressed within the analysis. It also highlights where this study finds that the achievement of successful CCS implementation is clearly

⁴² For details see Edmonds and Wise (1998).

connected to the build-up of ‘enabling environments’ in all jurisdictions – i.e: in industrialized countries, developing countries and economies in transition (EITs).

An overview summary of the analysis is provided in tables 4-6, 4-7, 4-8 and 4-9, at the end of this section. The tables provide qualitative judgments of the degree to which each of the five functions of ‘enabling frameworks’ are addressed – or are relevant to the initiative.

4.4.1 Existing Infrastructure/Technology

Status

Full-scale deployment of CCS still requires significant effort in demonstration and the development of a suitable infrastructure. As there have been no deployments of integrated CCS to date, discussion of ‘existing infrastructure’ and ‘status of technology’ refers largely to the manner in which TOAs may contribute to advancement of:

- infrastructure used in **development and demonstration** that shall in turn contribute to fulfilment of expectations that CCS can become a mature technology for fossil-fuelled power plants by 2020 (IEA, 2008, p251);
- utilisation, advancement and/or modification of **existing** plant, facilities and technologies that are to serve as components of future integrated CCS systems.

When considering technology status, it is necessary to keep in mind that CCS is a multiple component system and that while a number of key components for the system are advanced – indeed as indicated in Table 4.2 and Table 4.3, some are market mature – the integrated systems are not mature anywhere. They still require demonstration. Moreover, the CCS systems envisaged for widespread transfer still have some components that are at research and development stages. The ongoing rapid expansion of power generation capacity in countries such as China, India and Brazil (both projected and expected) is also important – a massive suite of new generation infrastructure that can be built as ‘CCS ready’ is emerging. This implies that ensuring suitable layout or morphology of new power stations constitutes an important first component. If they are not constructed so that CCS can be readily retrofitted, then the costs of

eventual CCS implementation will be much higher.

Discussion of enabling environment parameters: The four points below present a cross-analysis drawn from each of the four typologies for *technically oriented ‘collective actions’ or ‘agreements’* – note that this discussion is focused on the influence/implications of the TOA activity category upon *Infrastructure status*.

Knowledge sharing and coordination

– A range of technical networks are forming and are actively promoted by influential and respected international (e.g. IEA), governmental (e.g. DG-TREN) and intergovernmental institutions (e.g. Carbon Sequestration Leadership Forum). While such initiatives are developmental they are addressing a broad range of areas ranging from the linking of technology providers together in focused networks, to the promotion of multilateral collaboration between nations. Networks also span from an infrastructure focus at a single technology level (e.g. post-combustion capture, oxyfuel combustion systems, etc.) to integrated CCS system level. There appears to be a high probability of the extension of such initiatives to less developed countries (LDCs) as the importance of CCS-uptake in LDCs is explicitly communicated in all fora assessed.

Research development and demonstration (RD & D) activities

– The number of test and demonstration centres (and projects) around the world is increasing rapidly. Indeed, recent acceleration in undertakings may even place such developments on (or near) the timelines projected as required to deliver CCS on the market by 2020. RD&D activities now exist that test both integrated CCS systems with a full range of components, as well as specific sub-components. Existing infrastructure is being utilized to demonstrate market viability, build capacity, prove the hardware at full scale, and to provide the empirical evidence of function required to formulate regulatory frameworks.

Technology transfer – In the absence of market mature systems, hardware

focused technology transfer is incipient and only relevant to demonstration activities such as the bilateral collaboration between the EU and China. That collaboration includes important elements of effective technology transfer such as financial support for the building of plant infrastructure, public-private partnerships and international governmental facilitation. It is anticipated that experience from this work shall serve as a model for future technology transfer activities. This analysis indicates that infrastructure related capacity that can underpin large-scale technology transfer is primarily being developed in the industrialized world and China at the current time.

Technology deployment mandates, standards, and incentives – Infrastructure-related mandates, standards and financial incentive systems are emerging but not established. Future ‘mandates’ (e.g. compulsory CCS ready status of new generating capacity) are under discussion but are not finalized. As such, pledges to establish technological infrastructure are being discussed – however, they are not cemented in legal requirements or firm undertakings.

4.4.2 Technology absorption capacity

Absorptive capacity is of primarily of interest in this discussion here at a National level.⁴³ While there are indeed private sector initiatives in industrialized countries (e.g. among large energy utilities) – technology transfer focus for this discussion is largely upon country-to-country efforts. Thus, technology absorption capacity is inferred to be a manner in which one can consider a country’s ability to value, assimilate, and apply new knowledge. Commonly accepted antecedents for this are prior-based knowledge (e.g. knowledge stocks for CCS technologies and knowledge flows) as well as communication. If

⁴³ The term absorptive capacity is used here following the form introduced by Cohen and Levinthal (1990) but considering its application at a national level. The theory involves organizational learning, industrial economics, the resource-based view of the firm and dynamic capabilities. It has undergone significant refinement, and now the absorptive capacity of a firm, organisation, or a jurisdiction (e.g. nation) is generally conceptualized as a *dynamic capability* (see Zahra and George 2002),.

seeking to evaluate such capacity, analysts would focus upon indicators such as innovation performance, aspiration level, and organizational learning.

Among other things, absorptive capacity is also said to be linked to a country’s:

- willingness to invest in R&D instead of simply buying the results such as patents (e.g. national R&D teams increase the absorptive capacity of a country);
- receptivity – or the overall ability to be aware of, identify and take effective advantage of technology.⁴⁴

Discussion of enabling environment parameters: The four points below present a cross-analysis drawn from each of the four typologies for *technically oriented ‘collective actions’ or ‘agreements’* – note that this discussion is focused on the influence/implications of the TOA activity category upon *technology absorption capacity*.

Knowledge sharing and coordination

– Most jurisdictions appear to have low absorption capacity at the current time. However, the examples of knowledge sharing and collaboration networks examined in this study are clearly contributing to the promotion of CCS and concomitant increases in CCS aspiration levels. As such, they also affect the value that nations attach to the system, and potentially the overall ability to be aware of, identify and take effective advantage of CCS. Examples of multinational collective actions (e.g. multilateral collaboration) appear to be contributing to both increased willingness and receptivity. The more members that such collectives attract also provide potential to reduce transaction costs, increase effectiveness, and reduce overall costs of implementation.

Research development and demonstration (RD & D) activities

– The process of establishing knowledge stocks for CCS technologies and a basis for knowledge flows is central to current demonstration activities for CCS.

⁴⁴ Consider also Seaton and Cordey-Hayes (1993).

While most RD&D activities are being conducted by industrialized nations, a deal of the knowledge stocks that they generate may contribute to national learning in many jurisdictions via dissemination activities and initiatives such as those mentioned in the previous category. A willingness to invest in R&D is seen in both the public and private sectors (e.g. large utilities and the coal sector) – such commitment also seems to be emerging in China.

Technology transfer – Indications are that technology transfer activities are incipient and the status and role of this category appears unclear at present.

Technology deployment mandates, standards, and incentives – There is little doubt that deployment mandates and incentive systems will affect the ability of different countries to value, assimilate, and apply new CCS knowledge in the future. However, until international climate-related frameworks are established that mandate application (e.g. place firm requirements for CCS on new generating capacity) or provide clear incentives (e.g. robust financial incentives that create ‘demand’ from developing countries), then the impact of such items appears largely theoretical. This stated, there does appear to be evidence of significant differences in ‘perceived CCS value’ between the important countries India and China. In India, activities have been limited to research projects and there is reportedly common skepticism; with CCS being regarded as inappropriate option for the country by many. China on the other hand, has been involved in a range of CCS projects with international partners and has already started construction of their own demonstration facilities. The country is reportedly considering more ambitious CCS projects (Christian Aid, 2009). Indeed a business intelligence online-newsletter (Young, 2009) reports that that some industry experts believe that Chinese companies may be more advanced in their development of carbon capture and storage (CCS) technology than those in the EU or US.

4.4.3 Legal, regulatory and policy frameworks

Development of *legal and regulatory frameworks* that provide viable, internationally robust and transparent guidelines for the transportation, injection and storage of CO₂ – and clearly delineate long-term liabilities – is vital to the establishment of widespread CCS systems. Moreover, risk management procedures that address operations, monitoring and remediation must be developed to ensure safe, secure CO₂ transport and storage. Such frameworks must function consistently both domestically and internationally if they are to support a global system of CO₂ transportation and storage.

Moving beyond CCS to underlying systems, there are also other areas where methods or knowledge in best-practice policy application is required to achieve market conditions conducive to CCS implementation. As an example, initiatives to improve efficiency or reduce environmental emissions of existing power generation facilities are often hampered by lack of capital, or a lack of cost-effectiveness (e.g. payback). Such difficulties may be contributed to by low margins (e.g. sale of electricity) or low fuel costs (e.g. subsidized fossil fuels) for incumbent (dirtier) systems that compete with cleaner technologies. A message to take from this with regards CCS is that cost competitiveness may be difficult when ‘traditional’ forms of production are allowed to pollute at low relative costs – even if drivers such as a vibrant market and strong carbon prices are achieved). Efforts to transfer good practice in policy/subsidy regimes are required, as are incentives systems based on the value of public goods generated. It remains desirable that work to achieve transfer of knowledge, capacity and experience in these areas is pursued.

Discussion of enabling environment parameters: The four points below present a cross-analysis drawn from each of the four typologies for *technically oriented ‘collective actions’ or ‘agreements’* – note that this discussion is focused on the influence/implications of the TOA activity category upon *Legal, regulatory and policy frameworks*.

Knowledge sharing and coordination

– The development of robust and transparent guidelines for the implementation of CCS and the management of long-term liability issues is a prime focus of the knowledge sharing and coordination networks examined in this analysis.

Research development and demonstration (RD & D) activities –

Demonstration activities all include aspects of performance monitoring and verification – however, it is clear that these are more strongly related to public perceptions of risk than to technical concerns regarding performance held by the scientific proponents of CCS.

Technology transfer – The strongest overlap of technology transfer to this category is encompassed by the institutional aspects required once the system enters the market. As the technologies are currently under demonstration, this remains a future task.

Technology deployment mandates, standards, and incentives –

This analysis identified a number of initiatives to establish frameworks that can form the legal, regulatory and institutional basis for CCS. The content of initiatives indicates that there is a growing mandate for existence of CCS systems, and substantial documentation addressing performance standards that they must meet. The recent EU directive on CCS provides an important example in this category. This provides a general framework (and firm requirement) for how member states should apply CCS throughout the EU. Other areas where there are expectations of progress are with the GEF – a pathway that can be used to provide a financing mechanism for LDCs etc. Important within this context is that the GEF can apply demanding performance standards. Related to this, the CDM will also provide a financing mechanism, encouragement of deployment in LDCs and a form of system subsidization. Transfer of standards or mandate frameworks to other countries can be expected as experience grows in the field.

4.4.4 Human and institutional capacity

The challenge of inadequate human capacity in developing countries is widely recognized as a barrier to technology transfer efforts. In the case of CCS, industrialized countries also lack capacity in many important areas – not least full-scale implementation of integrated CCS systems in the key target area of electricity generation. As such, when examining the context of CCS,

investment in capacity building is still to be achieved among first implementers in the industrialized countries. Subsequent technology transfer efforts are then required.

First implementers are presently undertaking the process of **learning to understand, utilize and replicate** technologies. The building of institutions and the generation of human capacity are key areas at the present time. Subsequent replication of such efforts in prime target zones such as Eastern Asia and the Indian sub-continent (IEA, 2008) will conceivably need to mirror these efforts, then move quickly to adapt them to local conditions. There is wide recognition of a need for the expansion of effective institutions and expertise, with additional research, development and training initiatives.⁴⁵ As CCS is to be an international system, and will be affected by international agreements and protocols, the evolution of robust international institutions to provide governance, guidance, and coordination – and to steer the development and diffusion of knowledge can be foreseen.

Discussion of enabling environment parameters:

The four points below present a cross-analysis drawn from each of the four typologies for *technically oriented 'collective actions' or 'agreements'* – note that this discussion is focused on the influence/implications of the TOA activity category upon *human and institutional capacity*.

Knowledge sharing and coordination

– Networks emerging to support CCS implementation directly address learning. However, they are currently focused upon building understanding of cost effective and legitimate application of the technological systems rather than the transfer to, or replication of them in other jurisdictions. All knowledge-sharing networks assessed in this study are in the process of building institutions and human capacity. Higher level collaboration efforts appear more focused upon building international legitimacy and establishing frameworks for CCS, while lower level networks address capacity building in areas such as the function of a technology sub-system.

⁴⁵ Cf. IEA (2009:7) http://www.iea.org/G8/docs/ccs_g8july09.pdf and de Connick et al. (2009)

Research development and demonstration (RD & D) activities – RD&D projects taking place around the world are clearly central to generation of knowledge regarding the development, utilization and replication of CCS systems however, these parameters do not appear ready for ‘transfer’. First mover countries are in the process of building their own pre-market infrastructure, human capacity, institutional frameworks and so forth.

Technology transfer – Transfer of ‘orgware’ activities (e.g. dissemination of experience related to, or techniques for the building of human or institutional capacity) are at an incipient stage. Activities that fall neatly within this category were not identified.

Technology deployment mandates, standards, and incentives – The future ‘rules’ for CCS are currently being defined and developed. While the final shape of CCS-related institutions, the incentive structures that they will provide, and the standards that they will contain is not clear, many of the sub-components are defined and under debate at a relatively mature level. While far from finalized, CDM related material for example, includes detail system descriptions, and methodological and accounting guidelines.

4.4.5 Market penetration capability of the technology system

A measure of the relative capability of CCS technology systems to penetrate markets may be the relative suitability or capability of CCS systems to mesh with the existing infrastructure. In this instance, a prime example is ‘the electricity generation market’ and thus the existing set of generation facilities. It is conceivable that there are important roles for TOAs in facilitating such penetration. As such, the higher the relative level of ‘fit’ with the existing systems and markets, and the more ‘stimulating factors’ there are – the deeper the potential for penetration (e.g. as a proportion of where CCS systems could theoretically be applied).

For this discussion, stimulating factors have been assumed to encompass phenomena such as: financial incentive mechanisms, significant intergovernmental facilitation, lobbying, public

facilitation and so forth. Several specific examples of areas where significant effort is required to strengthen *capability* appear in the CCS debate – these include:

- strong policy frameworks and international mechanisms that support the provision of sufficient and long-term *economic incentives* for CCS – among other things, this encompasses incentives via effective *integration of CCS into GHG* regulations and policies (IEA, 2009:7, de Connick et al. 2009) so as to achieve CO₂ reduction incentive pricing via a global market that sets a value for, and facilitates *effective trade in CO₂*;
- strong policy frameworks and international mechanisms that support the provision of infrastructure so that *technical efficiencies and economies of scale* can be achieved – including the the establishment of CO₂ transportation networks (IEA, 2009:7, de Connick et al. 2009);
- coherent and balanced communication strategies at local, national and international levels to address issues of public perception – the socio-political, and cognitive legitimacy concerns encompassed by the ‘public perception’ concerns are already a significant challenge in the first countries demonstrating integrated CCS systems;
- a stable policy environment that in turn provides long-term stability in markets and increases the availability of capital for technological investments.

Important to all the above points is that CCS investments are very large and very long term. Uncertainties in the economic systems discourage long-term investments, including those for more sustainable energy systems. Traditionally, multilateral and international lending institutions have been technologically risk averse. As a result, governments may be reluctant to invest in high-tech projects that entail high capital costs. As for high-efficiency or clean coal plants (an area where such challenges have already been experienced), CCS investments will be characterized by very large up-front investments – and availability of capital will likely constitute a bottleneck. International efforts – and TOAs that recognise and promote long-term stability appear relevant.

Discussion of enabling environment parameters: The four points below present a cross-analysis drawn from each of the four typologies for *technically oriented 'collective actions' or 'agreements'* – note that this discussion is focused on the influence/implications of the TOA activity category upon *Market penetration capability of the technology system*.

Knowledge sharing and coordination

– Building international mechanisms, particularly mechanisms that can provide a mandate for CCS that is sufficiently robust enough to provide stable markets and a broad socio-political legitimacy for the system is vital for the technology to penetrate markets. These networks are currently 'spreading the will to engage'. As such, they are both developing international collectives and seeking to develop and provide convincing communication strategies at local, national and international levels. A primary motivation for the latter is to address issues of public perception (including significant mistrust and doubt).

Research development and demonstration (RD & D) activities

– All RD&D activities examined are contributing to the building the foundation for "technical efficiencies and economies of scale" in eventual implementation.

Technology transfer – As CCS has not entered the market, and key *hardware, software* and *orgware* components to be transferred are still being defined, the role of technology transfer efforts for market penetration capability appears largely theoretical at this stage. One of the first areas for technology transfer however, will likely be the necessary design requirements of 'CCS ready' power plants. This is one aspect that cannot wait for CCS implementation to develop – as the 'fit' of CCS to new capacity built from this point in time onwards is vital for eventual market penetration.

Technology deployment mandates, standards, and incentives

– This analysis indicates that technology mandates and standards are under discussion and development. As indicated above, a prime area for mandating specific 'plant morphologies' will be for the design of new fossil-fuelled power generation capacity that is CCS ready. Examples of deployment mandates, standards or incentive structures appear to be rare at this stage – one example however is the announcement from the UK Government that is considering the establishment of requirements that any new coal-fired power plant over 300MW capacity must demonstrate CCS on a proportion of its capacity.

TABLE 4-6 EXAMPLES: TECHNICALLY ORIENTED ‘COLLECTIVE ACTIONS’, AGREEMENTS, ETC. ASSOCIATED WITH KNOWLEDGE SHARING & COORDINATION

Type of TOA: Knowledge sharing and coordination

(Including meeting, planning and information exchange, information about ‘best practice’, coordination and harmonization of research agendas and measurement standards)

NOTE: Focus on the contribution of **knowledge** to Enabling Framework parameters.

Carbon Sequestration Leadership Forum

IEA GHG Networks

European Carbon Dioxide Capture and Storage (CCS) Network

	(building) status of Infrastructure	Technology absorption capacity	Legal, reg., & policy frames	Capacity: Human & Institutional	Market penetration capability	Portion of activity chain addressed	Level of Action	Scope of tech. transfer activities
Carbon Sequestration Leadership Forum	(+)	(+)	(+++)	(+++)	(+)	All activities	Ministerial collaboration on 23	Hardware focused orgware
IEA GHG Networks	(+)	(++)	(+)	(++)	(+++)	Single chain activities –	IEA coordinated network	Hardware focused orgware
European Carbon Dioxide Capture and Storage (CCS) Network	(+++)	(++)	(+++)	(+++)	(+++)	All activities	Sponsored by EU Commission	Hardware and orgware

(+++) – Directly addresses this category	(+) – Partially addresses this category
(++) – Substantially addresses this category	(--) – Apparently not applicable
Note: For the purposes of this analysis, these evaluations are indicative only and are based upon material available at referenced web-sites. These are to serve as examples only.	

TABLE 4-7 EXAMPLES: TECHNICALLY ORIENTED ‘COLLECTIVE ACTIONS’, AGREEMENTS, ETC. ASSOCIATED WITH TECHNOLOGY TRANSFER

Type of TOA: Technology transfer

(Including activities related to technology transfer as such, commitments for technology and project financing, and measures for the facilitation of licensing and patent protection)

NOTE: Focus on the facilitation of **hardware** transfer and **financing** within Enabling Framework parameters.

EU and China Partnership on Climate Change:

(building) status of Infrastructure	Technology absorption capacity	Legal, reg., & policy frames	Capacity: Human & Institutional	Market penetration capability	Portion of activity chain addressed	Level of Action	Scope of tech. transfer activities
(+++)	(+)	(+)	(+)	(+)	All activities	Intergovernmental collaboration	East/ West exchange:

(+++) – Directly addresses this category	(+) – Partially addresses this category
(++) – Substantially addresses this category	(-) – Apparently not applicable
Note: For the purposes of this analysis, these evaluations are indicative only and are based upon material available at referenced web-sites. These are to serve as examples only.	

TABLE 4-8 EXAMPLES: TECHNICALLY ORIENTED ‘COLLECTIVE ACTIONS’, AGREEMENTS, ETC. ASSOCIATED WITH RESEARCH DEVELOPMENT AND DEMONSTRATION

Type of TOA: Research development and demonstration (RD & D)

(Including jointly agreed RD & D activities and funding commitments and agreements to expand or enhance domestic RD&D programs).

NOTE: Focus on RD&D activities, or joint RD&D activities that can expand or enhance domestic RD&D programmes.

Mongstad CHP - CCS

<http://www.statoil.com/en/TechnologyInnovation/NewEnergy/Co2Management/Pages/Mongstad.aspx>

Weyburn project See <http://www.encana.com/operations/oil/weyburn/> and <http://www.ieagreen.org.uk/june78.htm#3>

In Salah Gas project More info at

http://www.co2captureandstorage.info/project_specific.php?project_id=71

(building) status of Infrastructure	Technology absorption capacity	Legal, reg., & policy frames	Capacity: Human & Institutional	Market penetration capability	Portion of activity chain addressed	Level of Action	Scope of tech. transfer activities
(+++)	(+)	(+)	(+)	(+++)	All technical activities	Norwegian Gov. with consortium	Hardware and software
(+++)	(+)	(+)	(+)	(+++)	All technical activities	Intergovernmental/c ommercial	Hardware
(+++)	(++)	(+)	(++)	(+++)	All technical activities	Algerian State Energy	hardware

(+++) – Directly addresses this category	(+) – Partially addresses this category
(++) – Substantially addresses this category	(--) – Apparently not applicable
Note: For the purposes of this analysis, these evaluations are indicative only and are based upon material available at referenced web-sites. These are to serve as examples only.	

TABLE 4-9 EXAMPLES: TECHNICALLY ORIENTED ‘COLLECTIVE ACTIONS’, AGREEMENTS, ETC. ASSOCIATED WITH TECHNOLOGY DEPLOYMENT MANDATES, STANDARDS & INCENTIVES

Type of TOA: Technology deployment mandates, standards, and incentives Including international agreements encouraging technology deployment through establishing deployment mandates for specific technologies (or groups of technologies), international technology performance standards (e.g. concerning energy efficiency of appliances), or technology deployment incentives (e.g. subsidies for promising technologies or fuels). NOTE: Focus on international agreements with deployment mandates for technologies, international performance standards , or technology deployment incentives .	(building) status of Infrastructure	Technology absorption capacity	Legal, reg., & policy frames	Capacity: Human & Institutional	Market penetration capability	Portion of activity chain addressed	Level of Action	Scope of tech. transfer activities
EU Directive: geological storage of CO₂	(+)	(+)	(+++)	(+)	(++)	All activities	27 EU member states	Orgware
GEF and CCS.	(+)	(+)	(+++)	(+)	(++)	Potentially all activities	Intergover n-mental	Orgware
CCS under the CDM	(+)	(+)	(+++)	(+)	(++)	Potentially all activities	Intergover n-mental	Orgware

(+++) – Directly addresses this category	(+) – Partially addresses this category
(++) – Substantially addresses this category	(--) – Apparently not applicable
Note: For the purposes of this analysis, these evaluations are indicative only and are based upon material available at referenced web-sites. These are to serve as examples only.	

4.5 Advancing technically oriented technology agreements related to CCS

This chapter has established several important issues that are important when considering where to invest effort in technology transfer activities. The discussion should also support the position that there remain a number of issues associated with CCS that are still to be clarified. CCS technological systems are not yet ready for establishment in industrialized countries, let alone ready for full transfer to the developing world. Increasing amounts of R&D are now addressing such issues.

As the field of CCS is still developmental, this discussion seeks to remain general. There is no system ready for transfer. Until the evolution of CCS systems beyond specific applications (and into the main target sectors such as power generation, cement, iron/steel, pulp and paper, etc.) in industrialized countries is thoroughly demonstrated, and thus achieves a high probability of commercialisation, then technology transfer activities for a number of system components remain a hypothetical issue. Moreover, there is no integrated recipe for CCS technology transfer – nor does such appear likely to arise in the short term. Rather, this analysis indicates that agreements related to technology transfer probably need to be built piece by piece; concentrating on those technical or institutional items that are prerequisites for future action (e.g. CCS ready power plants and foundational regulatory and policy frameworks), or that contribute to future flexibility (e.g. increased human capacity).

This concluding discussion seeks to round off the content of the chapter in three areas. First a number of broad issues found relevant to the progress of CCS are reiterated. Each of these areas of work has implications for any work towards technology transfer as it has been defined in this discussion. Second, a brief discussion of (potential) future developments for CCS under the CDM is provided. Third, a small step beyond the scope of the paper is taken in order to introduce themes of ‘appropriateness’ and ‘relative priority’ regarding CCS application in developing countries. As public perceptions of CCS have been given a relatively high level of attention in this discussion, and emerging attitudinal differences between China and India have been alluded to, this potentially important public acceptance issue is also deemed worthy of mention. Lastly, some concluding remarks on the role of TOAs for supporting technology transfer are provided.

4.5.1 Broad issues relevant to CCS technology transfer

There are several areas where necessary technology transfer activities can be anticipated; several issues related to these are summarized here. This analysis indicates that these points should be considered as: a) areas where further development is required for CCS; and b) areas where transfer of learning – or the transfer of the results of such further development – will be required to achieve progress for CCS in the developing world.

- *Legal and regulatory issues*
 - Establishment of legal guidelines regarding the transportation, injection and monitoring of CO₂ remains a key issue. While many of the concerns to be addressed by guidelines may be related to ‘perceptions of risk’, the implications of public doubts about CCS can be considerable. Legal and regulatory frameworks are perceived as important for allaying stakeholder doubts. Resolution of such issues and avoidance of acceptance related barriers when seeking large-scale deployment will be important.
 - Delineation of regulatory frameworks, particularly for long-term liabilities must be achieved. Again, while some concerns may be ‘perception related’, robust liability frames that clearly address items such as permanence of storage, and risk management procedures that include monitoring and remediation, must be developed and established for all CCS implementation areas.
- *Commercial and financial issues*
 - CCS is expensive and consequently there is very significant interest in reducing

costs. This requires a combination of sound domestic market frameworks and well established infrastructure so that technical efficiencies and economies of scale accrue. Implementation of CCS also requires a global market that sets a value for, and facilitates effective trade in CO₂. Significant transfer of knowledge and technical systems will be required to achieve these items. Such transfer must take place amongst industrialized countries as well as between industrialized and developing countries.

- *International mechanisms*

- Indications are that technically related cost reductions and a global carbon market will not be enough to deliver CCS. As such, significant economic incentives for CCS need to be developed and agreed if CCS implementation is to become a reality. This in turn infers the need for significant financial incentives to the developing world as part of technology-oriented agreements enfolding CCS.

- *Technical issues*

- Almost all stages of CCS make use of existing technologies – some mature or almost-mature. Nevertheless, such technologies will be unfamiliar to scientists and engineers in other countries and there are very significant challenges remaining for technology transfer of even mature technologies at the scale required for broad implementation.

- There remains an absolute imperative to both improve reliability of systems and reduce costs – both of these rely to a significant extent upon continued improvement of existing technologies. Both also require the ongoing development and commercialization of new technologies that are still in the pilot or even R&D stages. Several decades of work to transfer both existing systems and emerging systems are projected even within the most optimistic scenarios.

- Formulation of procedures for dealing with potential leakage and ensuring longer-term isolation procedures remain important. Such procedures must be robust both through time and across national boundaries.

- *Public acceptance and understanding:*

- An apparently growing groundswell of support from the political sphere appears to indicate that political acceptance or legitimacy is relatively strong; political support is boosted by a very significant push from vested industrial interests. However, public support for CCS is certainly not established and public concerns can erode political commitment. Industrialized countries are in the process of learning how to deal with such issues at the current time – transfer of these experiences will be important for future roll-out of CCS to key developing countries.

- Legitimacy issues exemplified by ‘public awareness’ and ‘acceptance’ concerns are

strongly related to strong and trusted institutions. The establishment of robust and very long-term institutions in all jurisdictions engaging in CCS will be a key item for establishment of a 'social licence to operate'.

4.5.2 CCS under the CDM

Thus far, discussions regarding inclusion of CCS under the CDM within the context of the UNFCCC indicate that consideration of CCS under an international technology transfer climate policy regime is a concrete possibility. Even though there are numerous uncertainties, there are some options that can potentially unlock or overcome some of the challenges that CCS faces within the CDM. This discussion underlines the importance of developing robust institutional frameworks for assignment of CO₂ leakage liability if CCS is to fall under a CDM type arrangement.

Given a situation where CCS is broadly accepted as a suitable technological choice for non-Annex I parties under the CDM, options to overcome technical hurdles associated with related TOA (e.g. such as potential leakage) are emerging. Taking CO₂ leaks as an example; if repositories have been monitored during injection phase and then for a few decades after the end of the project operations without leakage; or if any occurring seepage has been properly addressed through remediation phase, then it is increasingly accepted that there is a very low probability that CO₂ will leak in the future (Philibert et al., 2007). Technically, this is related to processes where more and more CO₂ becomes permanently fixed by secondary storage mechanisms, the pressure diminishes and the possibility of unintended release of CO₂ decreases. However, institutional methods for dealing with such issues are also required. In this light, and as examples of how institutional development must proceed, several options have been suggested to address the possibility of leaks (Philibert et al., 2007).

- Discount any credits generated by CCS projects by a certain amount. This option has a point of departure that discounting should be applied when uncertainty about emissions reductions is very likely. Thus, discounting is suggested if a situation arose where leakage was almost certain. Nevertheless, one can argue that it is unlikely that a CCS project would be

qualified as CDM if (significant) leakage was expected to occur in the first place.

- Permit CDM projects to generate only 'temporary' CDM credits. Again, this option could be suitable if the risks of leaks were very likely, as in the case of CDM project-activities for land use, land use change and forestry (LULUCF) (cf. Bode and Jung, 2006). Both 'temporary credits' (tCERs) and 'long-term credits' (lCERs) expire at certain point in time whether the carbon remains stored or not. In the light of CCS however, one must consider that due to the likely lower market value of tCERs, the CDM would thus weaken, not strengthen, the incentives for long term monitoring and remediation.
- Allow CDM projects to issue 'permanent' CDM credits. This third option would aim to guarantee full 'fungibility' of the CERs in the international carbon market. It does require however that some countries do not limit eligibility in their domestic emissions trading schemes. This option would require appropriate accounting of any leaks. If leaks occur, this would require the assignment of liability *ex ante*. Liability arrangements would need to be framed in such way that they would encourage effective storage site remediation rather than simple replacement of allowances.

In terms of liability, three options are identified to move the CDM CCS case forward. A first possibility is to make CERs buyers (i.e. Annex B countries) fully liable for any long-run leaks. In this case, CERs from a CCS project must be replaced if leaks take place. A second option is that all project participants be made jointly liable after the crediting period and they should maintain effective monitoring – both during and after the crediting period – and ensure remediation via insurance mechanisms (Benson, 2006). Further, project participants should also reach an agreement with the host country for the very long term liability before a CCS CDM project-activity is proposed. A third liability option is that a host country is liable for potential leaks but that it can transfer such liability to project participants under certain conditions and time period (i.e. 'collateral liability').

Regardless of the crediting modalities, it is critical to determine up-front liability for any

leakage incident for the long term. Whereas it is suggested that during the crediting period liability should rest on project developers, project participants should be required to demonstrate that their liability is duly covered by an accredited insurance company (or similar) beyond the crediting period. This is assuming that the transfer of liability to the host country government is not possible to guarantee. For any event, the IEA/OECD report (Philibert et al., 2007) argues that in the long-term, liability would be best borne by the host country government.

Shifting to the issue of site eligibility, it is considered that the designated operational entity (DOE) would be in good position to undertake the evaluation of the suitability of the proposed CO₂ storage site and determine the level of associated risk (Philibert et al., 2007). Related to this option, detailed criteria for the assessment of the site characterization must be developed (cf. CDM EB, 2009). In order to guarantee long-term validity and transparency of site-specific storage information, a new international database management and/or archival institution may be required (Vajjhala et al. (2007).

There are also a number of policy developments that indicate that CCS could be addressed in more ‘sectoral terms’ under any post-Kyoto regime. This is pursuant to arguments that the CDM in its current form is in need of major reform (cf. Hepburn, 2009; Wara and Victor, 2008). One very likely modification calls for a CDM sectoral crediting mechanism, in particular the setting of voluntary ‘no-lose’ GHG emissions reduction targets.⁴⁶ The EU has already stated that it aims to gradually phase out the current CDM approach and replace it with a sectoral crediting mechanism. In addition, the UNFCCC has also stated in one of the latest draft negotiation (FCCC/AWGLCA/2009/8:23) that NAMAs may include sectoral approaches (e.g. sectoral targets, national sector-based mitigation actions and standards, and no-lose sectoral crediting baselines) for non-Annex I countries.⁴⁷ These policy developments infer that CCS-related TOAs in the context of the UNFCCC are likely to be discussed in the context of a sectoral CDM.⁴⁸ Thus, most of the technicalities

discussed previously are likely to be addressed in ‘sectoral terms’.

Within a ‘no-lose’ target sectoral crediting mechanism, developing countries would commit to achieve voluntary intensity emission reduction targets for certain sectors (e.g. cement, pulp and paper, transport). For the electricity sector, in which CCS would be a suitable option, an intensity target would be set in terms of CO₂/kWh. In this instance, the sectoral approach could take the form of a voluntary agreement and would scope down or confine technical and legal issues within the boundaries of the electricity sector – or even within the energy supply as a whole. As such, this sector could be taken as a point of departure to support CCS as an advanced set of technologies under a sectoral CDM. This stated, it remains unlikely that sectoral CDM will play a role in any baseline setting until the year 2020. Thus, there would be a need to evaluate whether CCS can contribute to achieve a voluntary intensity target and what kind policies should support it.

For developing countries under such arrangements, the potential exists for them to use a combination of policies and measures to overachieve the crediting baseline (e.g. emissions restrictions for coal-based power stations). In such a scenario, all emission reductions beyond the agreed sectoral baseline would be entitled to gain carbon credits – including those coming from CCS. Due to its voluntary character, no penalty applies in case eligible parties fail to meet the intensity target and actors committed to CCS could be clearly identified. However, if CCS is used as an eligible technology for gaining carbon credits, a protocol for long-term measurement and verification needs to be developed and implemented – this being a key requirement in any TOA-related activity. In any event, the baseline should include external support beyond the reference scenario (e.g. a coal plant fitted with CCS under the EU-China Climate Change Partnership).

Whereas the development of all these options may be plausible, they have to be further elaborated and evaluated to reduce technical and policy uncertainties under CCS TOA-related activities. Our discussion has attempted to identify critical conditions for TOA-related conditions and not to judge whether CCS is the ‘right technological choice’ for energy systems

⁴⁶ For further information about different sectoral approaches visit <http://www.sectoral.org>

⁴⁷ For further information see <http://unfccc.int/resource/docs/2009/awglca6/eng/08.pdf>

⁴⁸ In addition to a cap and trade scheme, the US Clean Energy and Security Act (Waxman-Markey) that the House of Representatives

passed in 2009 also foresees sectoral crediting mechanism. For further information see <http://www.govtrack.us/congress/bill.xpd?bill=h111-2454&tab=summary> .

and societies in the developing world. That question needs to be addressed within quite different studies and can only be touched upon here. Issues such as the sustainable development component and related performance of CCS CDM project-activities; the exact extent of required sound monitoring activities; increased transaction costs and impacts on carbon market prices; short and long-term cost-effectiveness of CCS in relation to current low-carbon technologies; liability of several entities with no responsibility on project management; determination of the right incentives for proper reservoirs remediation; accreditation and liability of insurance companies, among others, remain as open issues to be addressed.

4.5.3 Special considerations for developing countries

The discussion above touched upon the somewhat normative issue of the ‘right technological choice’ for the developing world. As was indicated, it is beyond the scope of this report to address such issues in any detail. However, when any technology related agreement that can act as a driver for CCS is under discussion, it is important that the topics of ‘appropriateness’ and ‘relative priority’ are both considered in a discussion of transferring

technologies such as CCS into developing countries.

Developmental Issues. A recent publication based on work by the Universities of Edinburgh and Surrey (Christian Aid, 2009) introduces a part of this discussion. Their discussion specifically addresses the role of CCS in India and contains a number of points that may be valid for many developing countries.

The report stresses for example that:

- plans to transfer technologies from rich to poor countries should consider how best to meet the needs of the (in that case India’s) energy poor – further they note that when a significant proportion of society has no access to electricity they will not benefit from CCS;
- a developing country should first work towards a renewable and sustainable energy future that will increase the access of the poor to power, improve energy security and decarbonise the economy;
- additional research is required to

China contra India – two very different developing country CCS contexts

There are very significant differences between India and China with respect to Climate Change responses. They will consequently take very different approaches to low carbon futures.

Poverty: India has a per capita income of circa USD 1000 against almost USD 3000 in China. Some 80% of Indians live on less than USD 2 per day - more than double the proportion found in China. Both countries have huge commitments to reduce absolute poverty but India’s challenge is much greater.

Carbon emissions: While both countries have rapidly growing carbon emissions, China has per capita emissions of some 4.23tpa compared to 1.07tpa in India. China is already the world’s largest emitter of CO₂.

CCS activities: In India, activities have been limited to research projects and there is considerable scepticism regarding CCS as an appropriate option for the country. China on the other hand, has been involved in a range of CCS projects with international partners and have already started construction of their own demonstration facilities. The country is reportedly considering more ambitious CCS projects (Christian Aid, 2009). Indeed a business intelligence online-newsletter (Young, 2009) reports that that some industry experts believe that Chinese companies are more advanced in their development of carbon capture and storage (CCS) technology than those in the EU or US. They report opinions from industry analysts that China may even be in a better position to export its technology in terms of the investment it has put into R&D and in terms of its supply chain.

examine the wider social and environmental impacts of CO₂ storage, particularly upon the poorest and most vulnerable;

- the cost is currently viewed as prohibitively high (for India), and that finance from outside is critical.

When developing technology related treaties, it is important that such moral and norms-based views are at least noted. When considering developmental issues, it is also important that environmental and distributive justice concerns are taken into account.

Having identified issues for a developing country such as India does not mean however that these issues are universal for all less developed countries. To the contrary, each country has its own special pattern of challenges or comparative

advantages, or both. The highlight box below indicates some fundamental differences between the two most important CO₂-emitting developing countries.

CCS penalty and developing world. CO₂ capture systems require significant amounts of energy for their operation. This reduces net plant efficiency and power plants require more fuel to generate each unit of electricity produced.

Analysts indicate that the increase in fuel consumption per kWh for plants capturing 90% CO₂ using best current technology ranges from 24–40% for new supercritical PC plants, 11–22% for NGCC plants, and 14–25% for coal-based IGCC systems when they are compared to similar plants without CCS.

TABLE 4-10 EXPECTED ENERGY PENALTIES WITH CO₂ CAPTURE (TURKENBURG 2008).

Power plant type	Expected CCS penalty today (extra fuel use/kWh produced)	Expected CCS penalty future (extra fuel use/kWh produced)
Conventional coal	24-40%	15-20%
Natural gas	11-24%	8-11%
Advanced coal	14-25%	9-12%

In addition, there is an increase in the consumption of chemicals such as ammonia and limestone used by pulverized coal plants for NO_x and SO_x removal – if and where it is in place. Such requirements have flow on implications when the challenges of electricity production in many developing countries are considered. Some of these include:

- the additional supply of fuel, and/or other materials required for clean operation to plants may represent a bottle-neck – logistics chains for the provision of fuel to power plants in some developing countries are already strained;
- increased fuel requirements result in an increase in most environmental emissions per kWh generated relative to new state-of-the-art plants without CO₂ capture, and in the case of coal, proportionally larger amounts of solid wastes (e.g. ash, post-scrubber residues etc);
- management of ash and other by-products of power production can also

pose logistical and environmental challenges;

- plant availabilities in developing countries are often low in comparison to best practice – this is often related to poor operating and maintenance practices, low human capacity and so forth – additional CCS plant/operational infrastructure places additional demands upon management;
- power distribution grids are poorly maintained, unstable, or both (e.g. there can be technology based failures, or frequency problems because the collective demand for electricity is higher than the available supply) – as such, efforts to pursue CCS have the potential to divert resources from core generation, operation and maintenance activities.

In the light of such issues, it could be that CCS applications in many developing countries (India is prime example in this case) might work counter to National efforts to achieve widespread electrification or reliable electricity supply, or both. This is a situation that can then negatively affect socio-economic development as clear links between modern energy service provision (e.g.

electrification) and development are universally recognized (cf. Deshmukh, 2009).

On the plus side within this discussion is that strategies to ensure electricity supply while avoiding a number of these challenges can be pursued. The planned coastal UMPPs for India to be fired by cleaner imported coal are one such example. If they are built as CCS ready plants and are later fitted with CCS, then they can be served by tankers for CO₂ shipping. Discussions of such strategies point towards potential supply of CO₂ to the Middle East where it can be used for EOR. Such strategies avoid terrestrial logistics challenges.

4.5.4 Concluding remarks

This chapter has presented an outline of the forms that ‘technically oriented agreements’ (TOAs) for the transfer of carbon capture and storage technologies may take. The discussion has presented an overview of different types of CCS-related TOA activities and has sought to delineate conditions that are important for the promotion or facilitation of CCS-related TOA activities. An inclusive approach was taken resulting in a broad definition of CCS-TAOs. In essence, all ‘collective actions’ or ‘coordinated activities’ undertaken by industry, governments or intergovernmental organizations have been considered within the scope of the discussion. While a number of norms-based developmental issues were briefly introduced for context, this analysis has largely avoided the issue of whether or not CCS is the ‘right’ technology choice for developing countries, rather it has concentrated on how might CCS technology transfer be facilitated.

The analysis of CCS-related TOAs suggests that there is no ‘magic TOA’ that can promote the transfer of technologies along the entire system chain. To the contrary, different TOAs are very likely to be needed to address different components of the system. Indeed, differing forms of agreement, coordination or collaboration may be required to address various aspects of the same components of a single technology (e.g. addressing hardware, software, or institutional aspects). The nature of each component largely frames the challenges that CCS-related TOAs face.

Due to the pre-commercialization phase of CCS technology systems, most TOA efforts are observed in the areas of: *knowledge sharing and co-ordination* and *RD&D activities*. Furthermore, ‘enabling environment’ parameters – a central item examined in this chapter – were found to be

extensively addressed by ongoing activities that can be placed within the sphere of TOA initiatives. However, the activities being addressed are largely ‘precursors to technology transfer’ rather than transfer of technologies *per se*. Moreover, such activities are largely conducted between industrialized countries at this point in time. While concerted technology transfer activities to developing countries are discussed in concrete terms, they generally lie in the future.

Shifting to the economic viability of CCS; TOAs that address CCS in the context of carbon markets offer (in theory) pathways to facilitate the development of CCS technologies. All discussions in this context focus on carbon markets as a foundation for economic viability at a future point in time when low-cost commercial application of CCS systems is achieved – a scenario that is projected for the medium-long term (e.g. circa two decades hence). However, given current policy and market conditions, carbon markets appear marginal or inadequate for CCS applications such as industrial-scale demonstration plants to be economically viable without (potentially significant) additional support. In turn, this could hamper or delay the commercialization of such systems – and thus exacerbate challenges in achieving scale economies for application.

The current climate of uncertainty surrounding climate policy (and thus carbon markets) poses a significant barrier to the establishment of market confidence for early movers in the European market. This also reinforces belief that incentives additional to the carbon market will be required if CCS is to become a financially viable option for the targeted industrial sectors. As such, a key question for actors involved in the formulation of agreements related to the promotion or transfer of CCS-related technologies is – How can they contribute to the mobilization of adequate financial resources?

In conclusion, this analysis does find that a number of CCS components are both sufficiently mature to be ‘transferred’ – and sufficiently ‘certain to be needed’. Thus, technology transfer is required and TOAs related to important CCS prerequisites should be pursued. A prime example given is ‘CCS-ready’ power stations. However, when the CCS technological system is viewed as a whole, it is not yet ready for establishment in industrialized countries, let alone ready for full transfer to the developing world. There remain numerous technical, financial, institutional, social and environmental issues to be addressed and overcome before key

stakeholders (e.g. industrialized country utilities) engage at large scale.

As such, CCS transfer to the developing world should be considered as a medium to long-term objective but preparations for specific precursors to such transfer should be made in the short-term.

5. ENERGY EFFICIENCY IN BUILDINGS

This chapter will first provide a brief introduction to the concepts of passive and low-energy houses. This is followed by a review of the main barriers for achieving improved energy efficiency in the building sector, and the various policy instruments applied in order to overcome the barriers. Then a review of international TOAs and related policies for energy efficiency in the building sector is performed, followed by an examination of EU mandatory policies. The chapter ends with a discussion on ways forward within/outside of the UNFCCC.

5.1 Background

5.1.1 Buildings and GHG emissions

For many years, energy efficiency has been advocated as a way to diminish environmental impacts, reduce GHG emissions, and create a more secure energy system (WEA, 2000; IPCC 2007). In recent years, energy efficiency in buildings has been given much attention as an important potential for reducing GHG emissions. In 2004, the total GHG emissions in Annex 1 countries was some 18 Gt CO₂ ekv, and the emissions from the building sector alone were 10.6 Gt CO₂ ekv (IPCC 2007). Moreover, the building sector accounts for almost 40 per cent of final energy use world-wide. Although the overall efficiency of energy utilization is increasing with time in many countries, the total energy use has been increasing. Indeed, within the IEA countries⁴⁹ the energy use in households increased by 19% from 1990 to 2005. At a buildings level, the continuation of overall consumption increases is driven by larger houses with fewer occupants per house and an increase in the use of different appliances in both residential and commercial buildings.

There are a large number of technical options for achieving increased energy efficiency in buildings available on the market today. Moreover, it has been demonstrated to be financially beneficial to invest in energy efficient technologies in buildings for many, if not most of these technical options. Indeed, the buildings sector probably has the highest (economic)

⁴⁹‘IEA countries’ refers to the 19 countries for which energy use statistics were available: Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, United States.

climate change mitigation potential (at least 30% greenhouse gas reduction) using technologies and practices already available on the market (IPCC 2007). The European Commission (2008) has stated that:

“The buildings sector – i.e. residential and commercial buildings - is the largest user of energy and CO₂ emitter in the EU and is responsible for about 40% of the EU's total final energy consumption and CO₂ emissions. The sector has significant untapped potential for cost effective energy savings which, if realized, would mean that in 2020 the EU will consume 11% less final energy. This in turn translates to a number of benefits, such as reduced energy needs, reduced import dependency and impact on climate, reduced energy bills, an increase in jobs and the encouragement of local development.”

There are a number of reasons why the climate change discourse should place strategic focus of the building sector; a number of these are listed below.

- New buildings will usually stand for a long period of time, often as long as 50-100 years. For developing countries where many new building projects take place, special attention should be given to energy efficiency. Justifiable investments can also include new technologies with sometimes higher investment costs, as future cost reductions of such technologies will rely on early investments and the investments in essential learning processes (e.g. learning-by-doing and learning-by-using).
- Energy efficiency in the building sector will rely on specific policy instruments. The building sector will most likely not be included in cap-and-trade schemes and probably not sectoral approaches either, and thus needs other mechanisms. In many developing countries, governments subsidize energy use in households and therefore pricing mechanisms such as taxes cannot be employed effectively to deal with energy efficiency.
- It is often claimed that improving the energy performance of buildings can contribute to a number of societal aims, such as reduced peak demand, improved energy security, and job creation.

5.1.2 Energy efficiency measures in buildings

The technologies and approaches for energy efficiency in buildings include a number of different solutions ranging from simple design changes to advanced technology solutions. Important measures applied all over the world include improved lighting and lighting design, insulation, improved windows, improved ventilation, heating and air conditioning systems, automated control systems, efficient appliances, on-site energy supply systems (solar, wind, gas fuel cells), metering and demand side measures (DSM) etc. Moreover, passive solar heating and cooling through the orientation of buildings and the use of shading are important measures for energy efficiency. The use of local materials and re-engineering to reduce the quantity of materials are also measures used to reduce construction resources and energy required.

However, the energy and GHG performance of buildings rely on more than the energy efficiency of the building. They are also strongly connected to the regional and local infrastructure. Factors such as features/performance of neighbouring buildings in a district, possibilities for connection to district heating (and district cooling) and possible fluctuations in energy and electricity supply (including peak performance etc.) are crucial when planning for low-carbon solutions.

In the following sub-sections, concepts for energy efficient houses are briefly presented. In addition to these, a number of concepts for sustainable buildings have been developed including criteria of indoor air quality, greater use of natural lighting, reduced and recycled water use, and energy and resource efficient construction methods and materials.

Low energy houses

The term “low energy house” usually refers to a house which requires less energy than required by houses built in accordance to the current building code standard.

According to an examination of the 30 European countries (the 27 EU members plus Croatia, Norway and Switzerland), seven countries had an official definition of low energy houses and seven countries have a planned official definition (Engelund Thomsen et al., 2008,). Due to large variations in intra-country climate, regionally relevant definitions are often required.

Several mandatory and voluntary classification schemes, or labelling schemes, have been introduced in order to set more exact standards

for energy efficiency. These include voluntary standards such as Minergie in Switzerland and the Passive house (Passivhaus) in Germany. The definitions applied in these standards often vary due to the climatic conditions of the country and established national calculation methodologies.

Passive houses

The heating demand of a passive house (Passivhaus) is maximum 15 kWh/m²/year and the total primary energy consumption is maximum 120 kWh/m²/year. To achieve these parameters in a cost effective manner a number of measures can be employed including significant insulation, orientation of the building, shading in the summer, energy efficient windows and glazing, airtight building envelopes, passive pre-heated air exchange and renewable energy sources which supply hot water (ICE et al., 2007).

The passive house concept and standard was formally established in Germany 1996, and later spread to other jurisdictions, requiring adjustments to the standard. Thus, summer cooling instead of winter heating is the primary demand for energy in hot climates. In colder climates the heating energy demand is much higher than is the case in Germany, requiring other standards. For instance, in Finland the energy demand limit is between 20 and 30 kWh/m²/year depending on the region (Elswijk and Kaan 2008).

According to Hermelink (2009), which conducted a theoretical environmental lifecycle analysis of a passive house and low-energy house for a period of 80 years, the passive house is favourable from both environmental and economic (cost effective) perspectives.

Net-zero energy and plus-energy houses

‘Zero’ is the point when a building moves from a resource consumer to a resource producer. This can take place through a combination of reduced resource demands, plus supply of the required resources through renewable technologies. There have been strong calls for net zero buildings (WBCSD 2009; IEA 2008), but there is no consistent definition or understanding of “zero” or “net zero” buildings (Torcellini et al., 2006). In North America energy is used as the measurement unit, but in the United Kingdom the resource is carbon (Zavody, 2007). Torcellini et al. (2006) claim that the difference in measurement unit and the interpretation of what ‘zero’ entails have a large influence on the energy efficiency solutions, energy supply strategies, energy sources purchased, real-time

pricing structures, renewable energy solutions and fuel-switching and conversion options.

TABLE 5-1. U.S. DEFINITIONS OF NET ZERO ENERGY. SOURCE: TORCELLINI ET AL., 2006

<p>U.S. Definitions of Net Zero Energy</p> <ul style="list-style-type: none"> • Net Zero Site Energy: A site zero energy building produces at least as much energy as it uses in a year, when accounted for at the building site. • Net Zero Source Energy: A source zero energy building produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. • Net Zero Energy Costs: In a cost zero energy building, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year. • Net Zero Energy Emissions: A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. Carbon, nitrogen oxides and sulphur oxides are common emissions that are offset.
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According to Torcellini et al. (2006) several issues are important as they may cause confusion:

- Where the energy is measured (site or source) is important (the quantity of energy produced at source is not the same as the energy delivered to the site; there is actually a large difference);
- Including energy cost in the calculation of net zero allow for factoring different fuel types, but energy costs can vary based on time-of-day and bulk purchase rates, and therefore this method may be ineffective;
- The “net zero energy emissions” definition allows only energy produced from non-renewable sources to be considered in the net-zero calculation. Thus a house built in an area primarily generating electricity with renewable resources (e.g. large scale hydro) would not be required to offset any of electricity use; houses in this area would immediately be deemed near net zero without any energy efficiency measures if their space and water heating was provided with electric energy (this may be the case in e.g. some Canadian provinces, cf. Finney 2009).

“Zero net energy” is a situation where “buildings as a whole (but not every individual building) would generate as much energy as they use over

the course of a year” (WBSCD 2007; 2009). This means that efforts will focus on energy efficiency and reducing energy consumption in the home and in the manufacturing of building materials and construction.

The UK Department for Communities and Local Government defines “zero carbon homes” as homes that “over a year, the net carbon emissions from energy use in the home would be zero” (United Kingdom Department for Communities and Local Government, 2006).

The US Department of Energy does not use one definition but allows the building design team to use one of five definitions of net-zero building: net-zero site energy, net-zero source energy, net-zero energy costs, net-zero energy emissions, and near zero energy (75% of energy is provided from on-site renewables, or off-grid buildings that use non-renewables as backup).

The International Energy Agency has identified the lack of a consistent definition as a problem and formed a joint task force (Solar Heating and Cooling Programme and the Energy Conservation in Buildings and Community Systems Programme) to examine the concept of net zero energy solar buildings. One of their main tasks is to create “a clear definition and agreement on the measures of building performance that could inform “zero energy” building policies, programs and industry building practices and design tools, case studies and

demonstrations that would support industry adoption” (IEA SHC & IEA ECBCS 2009).

5.2 Barriers for improved energy efficiency in buildings

Despite the great interest for energy efficiency worldwide, only a fraction of energy efficiency gains estimated to be both feasible and economically viable have been achieved. The reasons why investments in energy efficiency are not made, even though they are cost-effective, are explained by a number of barriers. We can conclude that the primary barrier for energy efficiency has not been the lack of technology, but a poorly functioning market where energy savings are not accurately valued. Some very important hurdles identified in literature studies include (e.g. Koeppl and Ürge-Vorstaz 2007; Finney 2009):

- High initial costs for energy efficient and renewable energy equipment. This means that payback periods are long (up to 30 years) for many investments;
- A fragmented and complex construction process, with an inherent “split incentives” dilemma: Building markets prefer low initial costs, and get no benefits from life cycle energy savings, whereas users may be willing to pay a high upfront cost if significant economic benefits are possible during the use phase. Thus, building professionals choose critical energy use features, but it is the owner or tenant that reaps the costs or benefits of those decisions;
- A lack of awareness and information of the opportunities, technologies and low cost of installing energy saving features;
- Uncertain energy savings from equipment due to the influence of users’ behaviour;
- The limited importance of energy expenditures as compared other household improvement or financial concerns;⁵⁰

⁵⁰ This mainly applies in the developed world. However, in some developing countries, not least in some African countries, a large part of household income is spent on energy.

- The lack of government interest in energy efficiency and renewable energy, and insufficient enforcement of existing policies also present barriers to energy saving in the building sector.⁵¹
- Poor enforcement of building codes and other mandatory standards, even among front-runner countries.

Another barrier to energy efficiency measures is the aesthetics of the buildings. Buildings are a vital part of cultural expression, and low energy buildings must therefore adapt to regional tastes in order to gain acceptance. Today, it is possible to build low energy buildings in all kinds of designs. However, as there are often doubts among local populations as to whether low energy buildings can work in a regional context there is often a need for demonstration projects in order to convince stakeholders.

Further, the “conservativeness” of the building sector itself inhibits innovations. Some special characteristics of the building sector which may inhibit invention and especially diffusion of new technologies and new knowledge include (see e.g. WBCSD 2007; Emtairah et al. forthcoming):

- the project-based (instead of process-based) orientation, where actors cooperate in coalitions in specific projects, before dissolving again; learning (which is often tacit in nature) can be difficult to capture and transfer, and actors initiating new practices must constantly renegotiate practice in new constellations;
- the fragmentation of actors’ networks in the building supply chain with material suppliers not involved in the building process, and little interaction with the design phase means that lessons learned in one stage of the chain may not be passed on to another;
- the end-product building is expensive and visible, and around for a long time – as such reputations are at risk through involvement in riskier projects – this leads to a preference for tried-and-tested solutions.

⁵¹ A general barrier is that energy efficiency policies, while being the most cost-efficient, are not considered as interesting as policies promoting newer technologies.

Barriers in developing countries

Some barriers of special relevance for developing countries include (Koeppel and Ürge-Vorstaz 2007):

- lack of awareness of the potential and importance of energy efficiency measures, lack of financing, and lack of qualified personnel;
 - poor market surveillance and/or certification measures mean that low-quality products can enter the market and destroy consumer confidence in the technology;
 - building codes tend to be less effective, due to insufficient implementation and enforcement, and corruption – for instance, in China the compliance rate is much higher in large cities than in rural areas; moreover a widespread challenge is that donor agencies support the implementation of codes, but do not provide necessary means for capacity-building and enforcement;
 - mandatory energy audits and similar tools require training of auditors, however, there is often a lack of monitoring of quality of audits;
 - lack of evaluation and follow-up is a major concern;
 - adaption to the local situation is crucial, not least for utility demand-side management (DSM) programs, and projects should be designed to fit the local situation; however, institutional settings are crucial determinants for market success in developing countries⁵² however, this is a requirement that is often neglected;
- some instruments such as tax exemptions, may not work well in developing countries where consumers lack financing options, and therefore subsidies may be required – further, price elasticity for energy is quite low also in developing countries;
 - labelling can work in developing countries, if labels are constantly updated – moreover, they are dependent upon capacity-building and confidence among authorities, industries, sales-persons, and consumers;
 - voluntary agreements may not work as well in developing countries as in developed countries since there are fewer supporting policies and frameworks for such agreements;
 - there is often a need for planning and zoning in order to further potential for energy efficiency of buildings; simple issues such as the way street orientations and plot orientations are drawn on the maps can be very influential;
 - a lack of formal training and capacity building among construction workers makes it difficult to introduce new techniques and innovation in construction work (e.g. avoidance of thermal bridges); there is very little knowledge of passive design techniques among architects, consultants and engineers do not know how to work with u-values, providers of materials have little or no knowledge or the thermal performance of materials, and so forth.

⁵² For example, Kovic (2009), looking at solar PV projects in Africa, states that the success of a project in a developing country tends to lie in the project's conformity with the institutional system in that state; legal and economic institutions, values and attitudes, and cultural beliefs are factors that all play a part. Some factors, including the potential for consumers to obtain small-scale loans, and the potential to enforce contracts swiftly and justly, may greatly vary between neighbouring developing countries, and therefore differing business models have been promoted even for neighbouring countries where

– at first glance – the local conditions appear to be similar in nature.

5.3 Policy instruments for sustainable buildings

Many countries are currently taking measures to overcome the various barriers to energy efficiency in buildings and to create market demand for energy-efficient buildings. This commonly involves the creation of new policy

instruments and various support mechanisms. However, many developing countries in regions such as Africa and Latin America have no policies for improved energy efficiency in the building sector, or have just recently started to adopt such policies. Koepfel and Ürge-Vorstaz (2007) looked into policies employed in 52 countries; the 20 most frequent policies found in their research are listed in Table 5.2.

TABLE 5-2 POLICY INSTRUMENTS FOR ENERGY EFFICIENCY. SOURCE: KOEPPEL ÜRGE-VORSTAZ (2007) POLICY INSTRUMENT

Appliance standards	Define a minimum energy efficiency level for a particular product class such as refrigerators – to be fulfilled by the producer.
Building codes	Address the energy use of entire buildings or building systems such as heating or air conditioning.
Procurement regulations	Provisions for energy efficiency in the public procurement process
Energy efficiency obligations and quotas	Requirement for utilities to promote energy efficiency: e.g. for electricity and gas suppliers to achieve targets for the promotion of improvements in energy efficiency in households.
Mandatory labelling program	Mandatory provision of information to end users about the energy consumption performance of products such as electrical appliances and equipment, and even buildings
Utility demand-side management (DSM)	Planning, implementing and monitoring activities of energy efficiency programs among/by utilities.
Energy performance contracting	A contractor, typically an Energy Service company (ESCO), guarantees certain energy savings for a location over a specific period, then implements the appropriate energy efficiency improvements, and is paid from the actual energy cost reductions achieved through the energy savings.
Cooperative procurement	Private sector buyers who procure large quantities of energy-using appliances and equipment work together to define their requirements, invite proposals from manufacturers and suppliers, evaluate the results, and then purchase products, all in order to achieve a certain efficiency improvement.
Energy efficiency certificate schemes	Tradable certificates for energy savings (often referred to as “white certificates”).
Kyoto flexible mechanisms	Joint Implementation (JI) and Clean Development Mechanism (CDM).
Taxation (on CO ₂ or household fuel)	Imposed by government at some point in the energy supply chain. The effect is to increase the final price that end-users pay for each unit of energy purchased from their energy supplier, although the tax may be levied at any point in the supply chain.
Tax exemptions/reductions	Used to provide signals promoting investment in energy efficiency to end use customers.
Public benefit charges	Raising funds from the operation of the electricity or energy market, which can then be directed into DSM/energy efficiency activities.
Capital subsidies, grants, subsidized loans	Financial support for the purchase of energy efficient appliances or buildings.
Voluntary certification and labelling	Provision of information to end user about the energy using performance of products such as electrical appliances and equipment, and even buildings – voluntary for producers.
Voluntary and negotiated agreements	Involving formal quantified agreements between a responsible government body and a business or organization which states that the business or organization will carry out specified actions to improve the efficiency of its energy use.
Public leadership programs	Energy efficiency programs in public administrations, demonstration projects to show private sector which savings and technologies are possible, etc.
Awareness raising, education, information campaigns	Policy instruments (promoting outreach campaigns) designed by government agencies with the intention to change individual behaviour, attitudes, values, or knowledge.
Detailed billing and disclosure programs	Display detailed consumption information to the user either on bill and/or directly via an appliance or meter.

It is important to point out that no country, even among the front-runners has been very effective in transforming the housing market. Thus, efforts towards policy learning and the transfer of energy efficient technologies remain crucial to improve energy efficiency worldwide.

According to Koeppel and Ürge-Vorstaz (2007) some of the most important lessons from existing policies include that:

- regulatory and control instruments (e.g. building codes, appliance standards, mandatory labelling and certification, mandatory auditing and energy efficiency obligations) are the most cost effective and effective category of instruments, *if* enforcement is in place;
- public procurement can have a high impact due to the large influencing power of public sector actors such as a contractors, financiers, and purchasers;
- energy performance contracts and white certificates have displayed varying results, but the potential is deemed to be very high for such instruments.

A number of studies hold that a comprehensive policy package of coordinated policies are required to address the numerous barriers to energy efficiency and renewable energy in the residential sector (WBSCD 2009; Geller et al. 2006; Koeppel and Ürge-Vorstaz 2007; Finney 2009). Studies of the most successful countries show that synergistic multi-policy packages are required rather than single policies. Some successful features of policy packages have however been noted (e.g. Koeppel and Ürge-Vorstaz 2007; Finney 2009).

- Packages combining regulations, financial incentives and measures to attract attention (e.g. information campaigns or public leadership programs) have the highest potential to reduce GHG emissions.
- Policy packages must address the specific interests of various actors (including energy companies, building owners, users, planners, retailers, manufacturers, builders, and energy service companies).

- Packages of instruments should be designed to take advantage of the synergies between the instruments and be implemented in a prescribed sequence so as to build upon earlier policies.

Such policy packages provide the “backbone” of successful programs in front-runner countries, and have been complemented with additional components in order to overcome various barriers and market imperfections, and prepare for market transformations. Some of these components include (Finney 2009):

- demonstration projects;
- voluntary standards;
- technology R&D;
- early consultations with the building industry regarding regulation changes;
- awareness campaigns;
- preparatory education and training for those supporting and working in the building sector;
- support policies that reduce risks and provide market stability and predictability; these include clear long-term targets and national plans, periodic progressive updates of all policies and programs, and long-term financing measures (such as feed-in tariffs or loans).

Further, in Austria and Germany, support from intermediary organizations⁵³ was found to be fundamentally important, as they have helped to develop/coordinate the systems needed to support the rapidly growing markets for low energy and passive houses (Finney 2009). Finney also found that policies addressing building systems rather than individual components achieved the largest energy reductions. He stresses the importance of:

- solutions geared to whole buildings rather than individual components;

⁵³ An intermediary organization is an independent energy saving agency that can 1) support both consumers and building professionals, 2) monitor and publish progress results, and 3) assist in the market transformation (Finney 2009).

- consideration of the whole building lifecycle rather than individual phases or participants;
- deployment of solutions optimal for whole communities rather than individual buildings.

However, while inspiration can be drawn from successful countries, local factors such as existing building codes, consumer knowledge, and the availability of technologies strongly influence the cost efficiency and effectiveness of the policies. Therefore no generic policy package can be put forward as “the” solution for all settings.

The well-known “conservatism” of the building sector, and the special characteristics of the building sector and its final products, which often inhibit innovations (discussed in the section on barriers) remains however, a problem that may have to be overcome partly by the industry itself. Emtairah et al. (2009) provides examples of how Nordic companies, which have introduced new building technologies have had to develop innovative strategies to overcome these barriers and convince resistant actors about the virtues of the new solutions. Some of the measures that they have undertaken include:

- development of strategies to communicate benefits to different target groups, based on the respective priorities of these groups – within these, it has been found that different virtues of the technologies should be stressed, depending on the actor addressed (⁵⁴);
- provision of relevant information through credible channels;
- building strategic alliances with different actors to promote new technologies;
- development of business models that reduce the perceived risks for other actors, such as financial guarantees if the promised energy performance is not achieved.

⁵⁴ For example, the energy performance may not be the main sales argument, but rather factors such as the potential for time-saving due to quick installation times compared to previous technologies may be of prime importance.

The special characteristics of the building sector mean that government support – for example, financial support for promising technologies, support for pilot projects, technology procurement, and other types of support for the creation of niche markets – is considered promising for the building sector.

Policies in developing countries

Some policies have worked relatively well in a developing country context when enforced and monitored adequately. These include appliance standards, building codes, public procurement programs, mandatory certification and labelling schemes (most address appliances, but there are also schemes for buildings), mandatory audits for public and commercial buildings, and energy performance contracting. Public leadership programs dealing with energy efficiency in public buildings (e.g. through retrofitting) have also proven effective, and these programs can both reduce costs and demonstrate that new technologies work in a local setting and thus provide inspiration for the private sector. It is observed that mandatory programs seem to work better than voluntary ones (Koeppel and Ürgen-Vorstaz 2007).

5.4 International TOAs and policies that promote energy efficiency in buildings

There are relatively few international agreements or even substantive cooperation efforts addressing energy efficiency in buildings. However, there are a number of interesting, voluntary international efforts, often supported by governments at different levels, addressing cities and infrastructure (e.g. Covenant of Mayors, Sustainable Cities).⁵⁵ There are also a number of voluntary building rating systems, developed nationally but with international certification systems, especially for public buildings. These include:

⁵⁵ These include, to mention only a few, Covenant of Mayors (http://www.eumayors.eu/about_the_covenant/index_en.htm) Sustainable Cities (<http://sustainablecities.net/>), The Sustainable Cities and Towns Campaign (<http://www.sustainable-cities.eu/>), One Planet Living (<http://www.bioregional.com/what-we-do/our-services/one-planet-initiative/>), and ICLEI’s Sustainable Cities initiative (<http://www.iclei.org/index.php?id=801>). These initiatives receive varying degrees of support from governments and the EU.

- the Leadership in Energy and Environmental Design (LEED) rating system, developed by the United States Green Building Council (USGBC) in the late 1990s and formally launched in 2000;
- UK Building Research Establishment's Environmental Assessment Method (BREEAM) launched in 1990 for the UK market and later spread to a number of other countries;⁵⁶
- the Australian Green Star rating system, developed by the Green Building Council of Australia (GBCA) based on other rating systems in the international markets;
- Estimada: a sustainability program aiming to support sustainable urban and community development in the Middle Eastern context – it is currently being developed as a publicly-led initiative in Abu Dhabi, and the vision is that it will be used in whole Arab region.⁵⁷

agreements), Table 5-3 outlines some current initiatives.

There are also a number of relevant developments in standardization organizations, such as ISO.⁵⁸

There are however few government-supported technology oriented agreements (TOAs) promoting sustainable buildings. Using a rather “inclusive” definition of TOAs (including cooperative efforts rather than formal

⁵⁶ The system has been updated a number of times due to changes in building codes, the latest version being released in 2008. Globally, there are over 110,000 buildings certified and another half a million registered as pursuing BREEAM certification.

⁵⁷ As part of the Estimada program, a new buildings rating system, the Pearls Design and Rating System, is currently under development for sustainable buildings. Among the organisations acknowledged in the development process are UK Building Research Establishment (BRE), USGBC and GBCA.

⁵⁸ For instance, ISO has developed relevant standards, including ISO 13790 (for calculations on energy performance of buildings). The Sustainable Building Technology Committee (SBTC) is working with the development of the First Draft of the International Green Construction Code (IGCC) (<http://www.iccsafe.org/cs/IGCC/Pages/default.aspx>). The First Draft is scheduled for completion and posting for comments by March 15, 2010. The latest interim version of the draft is available for download (at http://www.iccsafe.org/cs/SBTC/Documents/IgCC_First_draft-v3.doc).

TABLE 5-3 TOA-LIKE INITIATIVES PROMOTING SUSTAINABLE BUILDINGS

Type of TOA	Identified initiatives
<p>Knowledge sharing and coordination: including meeting, planning and information exchange, information about ‘best practice’, coordination and harmonization of research agendas and measurement standards</p>	<ul style="list-style-type: none"> • UNEP SBCCI - Sustainable Building & Construction Initiative. The initiative has four main objectives: 1. To provide a common platform for all building and construction stakeholders to collectively address sustainability issues of global significance; 2. To establish globally acknowledged baselines for sustainable buildings based on the life cycle approach; 3. To develop tools and strategies for adoption of sustainable building practices throughout the world; 4. To promote adoption of the above tools and strategies. Activities include the development of tools and capacity-building and demonstration projects. • IEA- Energy technology agreements. For more than 30 years the IEA Energy technology agreements (Implementing agreements) have supported collaboration and knowledge sharing to facilitate progress of new energy technologies. To encourage collaboration, the IEA creates a legal contract – implementing agreement –that allows member and non-member countries to pool resources for joint research, development and deployment projects within specific technology focus areas. These focus areas include, for example, demand-side management, district heating and cooling, heat pumping technologies, photovoltaic power systems and solar heating and cooling. For more information see: http://www.iea.org/techno/index.asp. * Few evaluations on performance and deepness of IEA initiatives and cooperation are available
<p>Research development and demonstration (RD & D) activities: including jointly agreed RD & D activities and funding commitments and agreements to expand or enhance domestic RD&D programs.</p>	<ul style="list-style-type: none"> • EU RD&D projects on buildings • IEA initiatives • MED-ENEC
<p>Technology transfer: including activities related to technology transfer as such and also commitments for technology and project financing, and measures for the facilitation of licensing and patent protection</p>	<ul style="list-style-type: none"> • CDM and Programmatic CDM • MED-ENEC project –funded by the EU, is probably the most comprehensive effort made to transfer knowledge for energy efficiency in buildings in the Mediterranean countries. A second phase addressing urban scale interventions is approved. Website: http://www.med-enec.com/en/studies.aspx • ODA-financed projects including projects by various donor agencies; for examples of projects funded by the Swedish International Development Cooperation Agency (SIDA), see http://www.cecdesign.se/research.php • JI • GEF projects • Green Goods negotiations: aiming to reduce/eliminate tariffs for green goods; could have implications for several building technologies
<p>Technology deployment mandates, standards, and incentives: including international agreements encouraging technology deployment through establishing deployment mandates for specific technologies (or groups of technologies), international technology performance standards, or technology deployment incentives (e.g. subsidies).</p>	<ul style="list-style-type: none"> • EU Directives: There are a number of EU Directives addressing energy issues in the buildings context, for example, Energy Performance of Buildings Directive (2002/91/EC); Eco-design of Energy-using Products Directive (2005/32/EC), Directive on the Promotion of Cogeneration (2004/8/EC), Energy End-use Efficiency and Energy Services Directive (2006/32/EC), and the proposed Directive on the Promotion of the Use of Energy from Renewable Sources. Provisions on buildings can also be found in the Construction Products Directive (89/106/EEC); and in the Sustainable Production and Consumption and Sustainable Industrial Policy Action Plan (COM(2008) 780 final, 2008).
<p>Potential TOA, not yet defined but explicitly suggested or addressed in various policy forums</p>	<ul style="list-style-type: none"> • Policy-CDM or NAMAs (these two instruments could fulfil similar functions; with the emergence of NAMAs, policy-CDM is probably not very relevant) • Sectoral CDM solutions for the buildings sector • Reform of programmatic CDM • Reform of CDM and especially ‘additionality’ requirements

With the exception of EU Directives there are no identified TOAs for technology deployment mandates, standards, and incentives. This, to some extent, reflects the national character of the building sector.

In the next section, discussion is provided that addresses the performance of 1) mechanisms for technology transfer, focusing on the CDM, and 2) EU efforts to promote energy-efficient buildings through mandatory standard-setting. These topics are held to be central in the context of this report, as technology transfer and technology mandates have the highest potential for delivering energy-efficient houses (cf. for example de Coninck et al. 2007).

5.5 Performance of mechanisms for technology transfer

Most technology transfer projects aimed at developing countries, i.e., GEF/CDM/ODA projects have addressed energy efficient lighting, and appliances. The performance of such GEF/CDM/ODA projects has been relatively widely reported (cf. e.g. Evander et al. 2004; Birner and Martinot 2005) and is discussed elsewhere in the report, as is the guidance of proper design of projects for successful outcomes. While the potential and experience of other energy efficiency projects including energy efficient building concepts (e.g. passive houses), building envelope related technologies (walls, insulation windows etc), heating and cooling systems and shading technologies has appears to have been given less attention. A number of studies do relate experiences with building materials and insulation, compact building design, passive solar power, and renovation of multifamily buildings (cf. UNECE 2009; Visser 2009). These projects indicate that building projects can save large amounts of energy at low costs, and also deliver other sustainability functions.

To improve the experience in technology transfer CDM was developed. Initially, there were high expectations that CDM would help the development of building projects in developing countries, but neither the JI nor CDM have been very successful in this respect. In fact, only a few building projects have been initiated under each instrument.⁵⁹ Thus, estimation was that in April 2009, 14 out of 4500 CDM projects targeted energy reductions from buildings (UNEP SBCI

2009). The reasons are well-known (cf. UNEP SBCI 2008):

- emission reductions in buildings can in most cases be achieved mainly through a combination of technological modifications of the building and changes in user behaviour, however measures addressing these issues may be difficult to capture as CDM eligible activity;
- existing CDM methodologies are not suitable for building projects, and the demands for verification and monitoring are unsuitable for many users as administrative costs are too high;
- a lack of established methods to develop baselines and standards makes it difficult to calculate GHG savings;
- a large share of new construction in developing countries aims to provide adequate housing to disadvantaged groups; as these groups often suffer from energy poverty, it is difficult for housing projects to both meet the needs of the users and the emission reduction criteria of CDM;
- there is a lack of financial tools and risk strategies for energy efficiency investments and high transaction costs for individual building projects;
- dispersed end-use and numerous but individually small mitigation opportunities – the large mitigation potential is spread over millions of individual buildings, requiring multiple and very diverse types of interventions – as such, opportunities are hard to capture as ownership, design, location etc. are dispersed;
- there is a lack of information and awareness of impact of energy efficiency in buildings among professionals, investors and end-users;
- developing countries typically have poor energy management skills and supporting tools, such as energy efficiency standards for buildings.

As such, the CDM does not provide sufficient incentives for such projects, and cannot overcome the barriers existing in the sector discussed previously in this chapter. The

⁵⁹ For the latest data see e.g. <http://cdmpipeline.org>.

economic benefits from CDM projects cannot justify the transaction costs associated with project management, dealing with CDM methodologies, and monitoring programs. Programmatic CDM has not been the boost hoped for, and the ultimate conclusion is that the CDM in its current form simply does not encourage projects for improved building energy efficiency.

5.6 Mandatory regulations: efforts in the European Union

The EU has implemented a large number of directives which address energy in buildings, directly or indirectly. These include: the Energy Performance of Buildings Directive (2002/91/EC); Eco-design of Energy-using Products Directive (2005/32/EC); Directive on the Promotion of Cogeneration (2004/8/EC); Energy End-use Efficiency and Energy Services Directive (2006/32/EC) and the proposed Directive on the Promotion of the Use of Energy from Renewable Sources. Provisions addressing buildings can also be found in the Construction Products Directive (89/106/EEC); and in the Sustainable Production and Consumption and Sustainable Industrial Policy Action Plan (COM (2008) 780 final, 2008). These developments are supported by strategic programs such as the Lead Market Initiative, which supports EU capacity-building in the construction sector through standardisation, procurement and educational activities.

The Directives, supporting policies, and the EU-ETS, provide a comprehensive policy package for supporting energy-efficient infrastructure, energy-efficient appliances, and more energy efficient buildings. However, there are often complaints that the policies are not properly coordinated and sometimes even contradictory. There are plans to implement further rules – one option currently discussed is white certificate schemes in the EU member states. There is potential however, that this will complicate the situation even further; this will be discussed later in this chapter.

The EU rules for energy efficiency in buildings provide an interesting case, and a more thorough account for some of the developments is provided here in recognition of that.

In 2002, the EU adopted the Energy Performance of Buildings Directive (2002/91/EC) (EPBD), to improve the energy performance of buildings within the EU through cost effective measures, and to promote the convergence of building

standards towards those of Member States which already have ambitious levels. Measures in the EU Directive include: a methodology for calculating the energy performance of buildings; application of performance standards on new and existing buildings; declaration (or certification) schemes for all buildings; and regular inspection and assessment of boilers, and heating and cooling installations. Member states were obliged to implement the provisions of the Directive in 2006, but most states decided to delay transposition until January 2009 due to a lack of qualified independent experts. This has resulted in so-called infringement procedures against several countries.

The Directive provides a common methodology for calculating energy performance of buildings and obliges member states to draw up minimum standards. These should be applied to all new buildings and to existing buildings with a usable floor area above 1000m² when they undergo a major renovation. However, the legislation stopped short of imposing EU-wide minimum efficiency standards, instead opting for a flexible approach that required member states to lay down concrete requirements while accounting for local climate conditions and building traditions. The EU took an integrated approach to calculating efficiency standards that extends beyond insulation to aspects such as heating and cooling, and heat recovery and lighting installations. Inspections of boilers and central air-conditioning systems and assessments of heating installations that include boilers more than 15 years old were made mandatory. Further, alternative systems like decentralized energy from renewables, combined heat and power generation, district heating and heat pumps must be considered in new buildings with a usable floor area of more than 1000m².

To promote greater public awareness the Directive also introduced energy declarations (certificates). The certificate will help buyers or tenants in their efforts to compare the building's energy performance against established standards and benchmarks, and consider cost-effective improvements. The public sector was expected to take the lead through displaying energy certificates in "prominent" places in public buildings. A major problem is that expected energy savings due to the directive have been delayed due to insufficient workforces and lack of ambition. The lack of qualified experts to issue declarations and carry out inspections has been a key problem, delaying the entry into force of the Directive. Also, the 1000m² threshold means that over 70 % of the building stock does not fall within the scope of the Directive.

In order to address the obvious problems, the Commission proposed major changes to the Directive in November 2008, including:

- an extension of the scope of the directive by eliminating the current 1000m² thresholds. Thus, all existing buildings undergoing major renovations would have to meet minimum efficiency levels;
- alternative energy systems would have to be considered for all new buildings;
- The development of a methodology to calculate the “cost-optimal level of standards – member states would have to compare their actual requirements against these standards;⁶⁰
- improve the user-friendliness of energy declarations;
- the public sector must implement the legislative demands earlier – the requirement to display the energy performance certificate would be extended to all public buildings larger than 250m²;
- alternative energy systems would have to be considered for all new buildings.

Most importantly, the Commission wished to promote the uptake of very energy-efficient buildings and therefore introduced the idea of very low or zero-energy buildings. The recast Directive would therefore require member states to draw up targets for increasing the share of such buildings. As there is no universal definition of very low energy buildings, the Commission wishes to define common principles according to which member states would come up with their own definitions.

⁶⁰ The flexibility provided in the original directive had led to very different levels of ambition in the minimum requirements laid down by member states. The draft directive therefore develops a methodology to calculate the “cost-optimal level of standards; member states would have to compare their actual requirements against these standards, and after a certain period EU states would no longer be allowed to provide incentives for the construction of buildings that fail to achieve the cost-optimal level. Eventually, the cost-optimal level would form the basis of a country's minimum standards.

The European Parliament amended the proposal by adding a condition that new buildings constructed as of 2019 would have to be zero-energy. All new buildings would consequently have to produce their own energy using renewable energies like solar panels, and minimize energy losses with better insulation, double-glazing and so on.

Regarding existing buildings, the Parliament urged member states to set percentages for a minimum share of existing buildings to become energy-neutral in 2015 and 2020.

The Parliament also wanted smart meters installed by default in all new buildings.

EU member states however considered the Parliament's proposals to be ambitious and unrealistic, and several states wanted to weaken the demands or at least be provided more time for implementing such rules. Administrative burdens due to inspections and hiring of experts to issue certificates were also highlighted as concerns by some member states. The Commission has however held that investments and administrative costs are low compared to the benefits of the proposed rules. The Commission's calculations suggest that that abolishment of the 1000m² threshold for buildings undergoing renovation would trigger an annual €25 billion return on additional yearly investments of €8 billion by 2020, mainly via savings in energy bills.

In accordance with a recent agreement between the Parliament and the Council of Ministers, new buildings in the EU must be zero-energy from 2020.

As such, it can be seen that the EU has started to enact a more comprehensive policy package to kick-start the market for energy efficient buildings. The fact that mandatory standards will probably be set for new and existing buildings is considered to be a good way to provide for consistency and innovation in the construction and building industries. Existing and planned rules will aid in market creation through the setting of long-term, realistic goals, provide a better harmonization of national standards, create a (more) level playing field, and hopefully promote trade objectives. Currently there is limited transfer of building technology within Europe.

Recent developments will further support energy efficiency in buildings; through an agreement between the European Parliament and the Council of Ministers, the Ecodesign Directive will be expanded to include not only energy-using products, but also energy-relevant products.

Therefore we can expect future energy efficiency standards for building materials such as insulation and windows.⁶¹

5.7 Ways forward

Domestic policies, in both developed and developing countries are the key drivers for improved energy efficiency in buildings and there is clearly room for improvement in this area. From the material examined in this study, it is concluded that all countries should move towards mandatory building codes that are adapted to local climate conditions – and that these should be developed and tightened over time. Standards for energy measurements and labelling are also crucial, as is an effective system for monitoring and enforcement. Institutionalization of energy efficiency through the creation of measures such as policy frameworks, relevant agencies, the integration of energy efficiency in other functions (such as health and safety inspections in commercial and public buildings), and through university curricula, are also vital. Several studies stress the need to pursue demonstration and pilot projects, and to disseminate results. Here, it is not only a matter of spreading best practices to professionals, but also more generally to raise awareness among people about the importance of energy efficiency and availability of options, through both mandatory (e.g. mandatory labelling of buildings, building materials, and appliances) and voluntary instruments.

Capacity-building is required in all countries, but especially in developing countries. Developing countries start at different levels. They need policies, and monitoring and enforcement mechanisms, but also activities that support learning. Demonstration projects will be critical to show that new solutions exist in the local context, and that they save money. For many countries, promoting energy efficient technologies and building techniques in public and commercial buildings will create new knowledge, which can later be transformed to new private building projects, and eventually in renovation projects when supported by the right policy frameworks. For developing countries “local design, outside advice” is probably a good rule in many cases, as knowledge on sustainable approaches can be imported and then adapted to local circumstances.

International cooperation on standards, financial mechanisms for technology transfer and supporting policies can support domestic policies, and even act as catalysts for change. However, these cannot be expected to replace national efforts. The question is how such positive developments can best be supported.

In the following sub-sections a discussion of some critical preconditions, i.e. factors required for successful technology transfer and enabling of new energy efficient technologies if provided. This is followed by presentation of a number of options that can be pursued both within and outside of the UNFCCC framework.

5.7.1 Critical (pre)conditions identified

In this sub-section preconditions for developed countries and developing countries are presented and issues that can significantly benefit from increased international cooperation are highlighted.

Developed countries

There is a large need for capacity-building in developed countries – this is required to deliver the promise of the policies and support measures outlined in previous sections. Apart from a credible policy packages with both supply and demand side measures, sufficient enforcement mechanisms, relevant training and education programs, building standards and supporting tools, additional tools for promoting new or improved technologies – such as technology procurement, and subsidies for promising but yet not commercial technologies – need to be considered. Experiences with national and EU policies have shown that there is a significant lack of capacity, with a shortage of trained people already contributing to poor implementation or delays.

Developing countries

In developing countries and EITs, energy efficiency should best be considered as a part of a broader social policy agenda, and not merely as a technocratic project (UNECE 2009). This may be part of the reason for the CDM failing to deliver as a promoter of energy efficiency in buildings, and why ‘additionality’ requirements may not be suitable for such projects (indeed rebound effects may indeed be positive in the sense that they reflect higher standards of living). In several cases successful instruments in developing country contexts have been initiated in response to urgent needs for measures; for

⁶¹ EU agrees extension of product eco-design law. ENDS Europe Friday 27 March 2009.

example as a result of high energy prices or energy shortages, or both. Therefore, high energy prices and energy shortages are seen as strong enabling factors in developing countries, as such factors tend to mean energy issues are ranked high on the political agenda (Koeppel and Ürge-Vorstaz 2007). Special needs for developing countries identified in literature are listed below (cf. Koeppel and Ürge-Vorstaz 2007; Energy Efficient Buildings Forum 2007; UNECE 2009).

- **Capacity-building** (i.e. technical assistance and training) Construction know-how for architects and designers is crucial in the developing world where the construction rate is high and markets often very dynamic; international consultants and organizations may have to play a role while national capacities are developed (Koeppel and Ürge-Vorstaz 2007).
- **Demonstration projects and information** – human barriers such as lack of trust in new solutions must be overcome through information and training projects. While regional cooperation and exchange of best practices are useful tools, demonstration projects are especially important in countries where people are illiterate or where the communication channels are few.
- **Financial assistance and funding mechanisms** – high initial costs are a huge barrier for new technologies such as solar PV, especially in LDCs, and therefore investment support or affordable loans are required. ; These can come from domestic governments, donor agencies, and energy service companies (Deringer et al. 2004). While some developing countries can raise money through taxes and charges, it may well be required that such funds be managed by independent agencies or institutions in order to avoid political influence (Koeppel and Ürge-Vorstaz 2007). Lack of access to loans to invest in energy efficient technology is a major barrier not only for developing countries but very often for EITs, even when projects have short payback periods. For instance, the economic recession has meant that many eastern European EU members have problems obtaining EU funding for relevant energy efficient projects due to the low level of risk-taking among financial institutions.

Some projects were not allowed loans even when the state guaranteed up to 80 % of the total funds (CEE/FoE 2009);

- **Different regulatory measures** – including mandatory building codes and mandatory labelling schemes are crucial components of an effective mix of policies. As enforcement is often weak, both capacity-building (e.g. training of inspectors), and ‘carrots’ (e.g. bonuses for authorities with energy-efficient buildings) can increase compliance rates.
- **Implementation of monitoring and evaluation programs** – has been shown to be a crucial factor in order to establish baselines, and evaluate progress.
- **Institutionalization strategies** – successful developing countries tend to start with adoption of energy efficiency laws or strategies, and set up specific departments, energy agencies and/or other functions in order to institutionalize the efforts. Energy agencies that have an independent role, in some cases financed wholly or partially through external funds, often play an important role. Implementing energy-related courses in universities also builds both knowledge and capacity. Institutionalization establishes energy efficiency as a prioritized policy area and provides continuity for governments and private investors.
- **Regional and local adaptation of policies** – is perceived as crucial as legal, political, economical and social-cultural contexts differ throughout countries and regions. In the case of building, building codes must be adapted to account for climatic differences. Not only single policy instruments, but preferably policy packages, should be adapted.

Some studies stress that the policy packages must be comprehensive and include a number of different, complementary measures, and be cross-sectoral in nature, in order to create a snowball effect. Targeted efforts relying on a few policy instruments are considered likely to achieve little (UNECE 2009). Often successful policies need a supportive legal framework, and tend to be dependent on the existence of other instruments (e.g. effective procurement

interventions may require existing labelling schemes).

International cooperation needs

There are several issues that would greatly benefit from increased international cooperation efforts. Needs for work in such areas are briefly listed below.

- Better coordination of concepts, standards and terminologies is considered likely to help reduce confusion, and aid technology transfer.
- It is considered that experiences on best practices in sustainable building design, and successful transfer of relevant technologies must be shared. Most national policies are poorly evaluated, and evaluations are often written in the domestic language. Better evaluations, available in more languages, are desirable. There is a need to deepen cooperation and spreading of best practices.
- International, structured, well-funded and formal mechanisms for knowledge and technology transfer are required.
- The sharing of experiences on best practices in education and communication are considered vital for capacity building efforts.
- Cooperation on several issues that are relevant to trade and technology transfer, most notably tariffs, non-tariff barriers like certification schemes, and IPR and licensing issues is necessary.

5.7.2 Ways forward within the UNFCCC framework

UNEP-SBCI has stressed that energy efficiency in buildings must be prioritized within climate negotiations. The discussion below provides discussion of a number of options that this analysis finds promising, and which could promote energy efficiency in buildings within the UNFCCC.

CDM

There were initially high hopes that the CDM would deliver projects dealing with building energy efficiency. When it became obvious that

CDM could not, those hopes shifted focus to the programmatic CDM. Again they did not materialize, largely as programmatic CDM could not overcome some of the main barriers within the CDM framework. While programmatic CDMs were supposed to lead to more small-scale projects (e.g. by bundling together a large number of household-level applications), few such projects have been initiated. While several obstacles have been experienced; a main barrier experienced is that DOEs (Designated Operational Entities) are not prepared to provide independent validation of such projects, as there is potential that they become liable for items over which they have no control (due to the limited possibility to do on-site audits) (Hild 2009).

UNEP-SBCI (2008) has suggested a number of pathways to overcome the barriers posed by the current CDM framework. Suggestions include changes in indicators, validation, and the setting of baselines, in order to reduce transaction costs, and a prime focus on sustainability instead of additionality. They even suggest opening up for the possibility to issue CERs for “avoided emissions”, e.g. when new houses are built with energy efficiency features and will require less energy than “traditional” houses. It is further proposed that CERs can be generated in projects that meet legal building standards rather than set higher standards than required by laws in order to encourage building projects in countries where legal enforcement is poor – although this is problematic from an additionality perspective (cf. UNPP-SBCI 2008 for more details). The final proposition also makes sense because there have been concerns that some developing countries may be hesitant to implement mandatory energy efficiency standards for buildings as these could be barrier for the potential to have CDM projects in the future (cf. the discussion on additionality and baselines in section 1.1) . In such cases, CDM and other mechanisms can in fact constitute barriers for improvements in building standards.

While this analysis indicates that the propositions from UNEP-SBCI have merit, a number of problems are foreseen in getting them accepted – mainly related to practical and methodological issues. Further, there is general consensus in literature that domestic policies are the key drivers for energy efficiency in buildings. Therefore CDM (including programmatic CDM) cannot be expected to be the main driver for building energy efficiency. This stated, there may still be a role for CDM to play if the mechanism is reformulated. It is feasible that CDM projects could act as “catalysts” in some cases, and in particular may be suitable for countries where

government capacity is very low but where commercial actors – with support from ODAs and other sources of funding – have the capacity to implement sustainable housing projects.

In general however, this analysis indicates that the CDM will never be a suitable instrument for addressing the building sector; the transaction costs for dealing with calculations, methodologies, monitoring and validation etc. in 10 000 households, where no proper baseline or benchmarks are available, must be compared to projects that target one or two large production plants, where benchmarks and methodologies exist. When viewed in this light, CDM and building efficiency projects appear largely incompatible.

Policy-CDM

The complexities involved in applying CDM to certain types of projects have led a number of analysts to suggest that policy-CDMs, with simplified calculating methods, could be a manner in which to use the CDM in cases where conventional CDM approaches will not work (Neuhoff et al. 2008). If such approaches were applied, then credits could be rewarded for credible policies, or even other types of capacity-building. This does require however, that the requirements for ‘additionality’ be renegotiated. With the emergence of NAMAs however, the need for policy-CDMs has likely diminished.

Sectoral CDM

A second option is to consider sectoral CDM approaches for the building sector in developing countries. While sectoral CER-generating approaches constitute an interesting option for the buildings industry, application of building sector CDM is also problematic.

- Firstly, sectoral CDM is considered likely to work best for easily defined production sectors such as cement and steel. The building sector is problematic as GHG emissions from buildings can be and are influenced by changes in both the construction sectors (e.g. materials applied) and the energy sector. This is also related to a general problem for program-CDMs concerns – that of methods for setting baselines for sectoral emissions, and monitor and report on the effects of sectoral measures (Schneider and Cames 2009; Naturvårdsverket 2009).

- A second major issue concerns criteria for going beyond business-as-usual/additionality. It is anticipated that some kind of additionality requirements – or at least “avoided emissions” requirements – will need to be applied in CER-generating mechanisms. A first challenge within this is related to determination of the sector that should be credited for improvements if measures are taken on both the supply and demand side. Another issue concerns establishment of whether a project goes beyond business-as-usual if several policies are addressing the same issue. It is expected that this challenge will become very real in Europe in the coming decades because of the high number of energy efficiency instruments applied. Simply put, as soon as one policy instrument affects – or can be expected to affect –energy efficiency performance, the outcome of this instrument must affect the “business-as-usual” scenario.

In addition to the issues raised above, sectoral CDM requires more government involvement than traditional CDM. In some countries the involvement of government agencies and other authorities is not perceived as viable way forward as a result of inadequate governance structures.

The factors above, in combination with all the other uncertainties connected to sectoral CDM which must be solved (cf. e.g. Schneider and Cames 2009; Naturvårdsverket 2009; Aasrud et al. 2009) indicate that sectoral mechanisms, and especially sectoral CDM, cannot be the main road forward for the building and construction sector. Moreover, there is an urgent need to address the building sector now, and it will take years before sectoral approaches are ready to commence.

Despite the considerable limitations listed, some analysts still indicate that sectoral approaches in the building sector could deliver results if applied in larger developing countries that have well-developed governance structures – and if a number of the important hurdles listed in this discussion are addressed. However, this analysis indicated that it is likely that the challenges are too large to overcome.

NAMAs

UNEP-SBCI has promoted a targeted energy efficient approach under NAMAs, claiming that such an approach would benefit both climate objectives and sustainability objectives including job creation, upgrade of workforce skills, and energy security. This analysis also concurs that NAMAs offer the most workable approach for addressing energy efficiency of buildings within the UNFCCC framework.

Regarding the three main types of NAMAs (unilateral commitments; NAMAs supported and funded by developed countries, and; mitigation actions eligible for carbon credits), pathways can be seen for all three where it is possible to relate them to building polices. As such, developing countries could undertake unilateral, no-lose commitments as part of their mitigation efforts, but should not expect funding for such commitments. For the reasons presented in the preceding sections, the third type of NAMA - credit-generating – can be difficult to use for addressing energy efficiency in buildings. A major concern that affects NAMAs in this context is the additionality issue. It is not likely, and for development issues not necessarily desirable, that energy efficiency measures will lead to reduction in total energy demand. Due to this, credit-generating NAMAs for the building sector are very likely problematic, but not impossible if the hurdles addressed carefully.

The most viable option appears to be NAMAs where developing countries commit to undertake certain actions that can be expected to lead to energy efficiency improvements, and are provided financing – but no credits – from developed countries. The extent to which projects promoting energy efficiency in buildings should be a separate category of NAMAs must still be discussed. The funding of building-related NAMAs would need to be in accordance with the general structure for funding of NAMAs, but it is recommended that significant amounts are set aside for building projects, due to the potential for GHG emissions and the other sustainability benefits associated with energy efficiency in buildings.

This analysis finds that a special financial arrangement for building-related projects would be desirable, even though it may not be likely in the near future. One conceivable “promising” way forward for NAMAs in the building sector is to be very “direct”, using an approach built on both incentives and coercive measures. A number of the potential elements are included below.

- Non-Annex I countries that sign up to implement credible “policy packages”, should receive *significant* funds to implement the packages. These funds would need to cover both added investment costs and capacity-building efforts.
- Countries with well-designed NAMAs, and a good past track record of policy implementation and capacity-building, should be rewarded by better access to funds. This may lead to tensions in some cases, but is considered a sound manner in which to maintain trust and integrity in the system. In order to avoid a majority of funds being allocated to advanced developing countries, funds should be assigned to certain categories of countries, and some mechanism for regional coverage should be developed. Countries should be compared with countries with similar circumstances.
- While the demands for criteria for validation of projects may be challenging, this analysis indicates that they should be based on both qualitative and quantitative parameters. Most importantly, it seems reasonable to demand that NAMAs in the building sector bring about energy efficiency, and energy savings, based on an agreed upon baseline, and that they fulfil certain sustainability parameters.
- Funding should be phased and funds for the next phase should only be provided when progress goals are met.
- Policies can be adapted to fit local circumstances; an important facet is that policies are credible, i.e. likely to be implemented and likely to achieve GHG reductions. However, all NAMAs should have credible monitoring and enforcement programs, and built-in mechanisms for evaluation.

In consideration of the above, it is likely that the setting of criteria for awarding funds for NAMAs will be a controversial issue. Some problems could be avoided if developed countries could decide themselves what countries and NAMAs to support, but if funds are pooled and then distributed, the issue will become more problematic.

5.7.3 Ways forwards outside the UNFCCC framework

There is a range of support activities that are probably best pursued outside the UNFCCC framework. Not least as its mechanisms are often accused of being slow and bureaucratic. As such, standard-setting, pilot projects, and knowledge sharing may best be promoted in other settings. Even if outside the UNFCCC process, they can still support UNFCCC mechanisms.

Currently, there are number of international initiatives addressing sustainable buildings, however there is an obvious need to coordinate, and in some cases harmonize different efforts. Some kind of platform for the promotion of energy efficient buildings, which could help grounding current efforts, would be highly desirable. In the ideal case, such a platform could be established through an international agreement, receive significant funds, and deliver a number of functions, including:

- knowledge-sharing, through regular meetings and development of evaluations and information material in several languages;
- deliver pilot projects of high significance;
- perform state-of-the-art training and education, and related materials.

Some activities that could be worthy of pursuit under such a platform are:

- establishment and communication of national estimates for energy use in the housing sector (heating, cooling, ventilation, machinery, pumps, fans etc.) with the purpose to increase awareness of energy needs for heating and electricity, and of regional variations in such;
- performance of structured evaluations and communications on state-of-the-art projects both placing the projects in context, and highlighting the differences from “traditional” regional building techniques;
- initiation of international projects for testing and evaluation of ex ante and ex post energy modelling and life cycle costing (LCC) with the purpose of developing reliable and user-friendly models for locally adapted energy efficiency design;

- testing and adaptation of “designer tools” such as BREEM; LEED etc., with dual purposes of knowledge dissemination and regional tool adaptation.

Considering the importance of buildings not only as energy users but as providers of basic human needs, and as a part of the cultural landscape, a platform could fulfil several purposes. If such a platform were indeed created, it should contain the institutional set-up, and the resources, to participate in relevant initiatives to promote sustainable buildings and related technologies. A number of these are described below.

- The Green Goods negotiations. This process that was initiated with the aim to eliminate tariffs for environment-friendly goods has recently accelerated. It is now considered that an agreement (outside, but not in contradiction of WTO-administered agreements) is may eventuate in the near future. It now has the support of large importers/exporters such as China, EU and US. The negotiations should be intensified, and the implications for the building sector should be reviewed.
- ODA funds devoted to infrastructure and buildings should preferably incorporate best practices for sustainable buildings and especially climate-friendly building techniques. Calculations on investments should be based on life cycle costing techniques, and the development of local capacity should be put to the fore in such projects. Nations should agree on guidelines for ODA financing of public buildings, and publicly run buildings projects.
- Efforts to strengthen ongoing projects to integrate courses on sustainable design for relevant educations, such as architects, designers, and engineers. Many universities have implemented such an approach, and there is increasing cooperation between universities for this purpose, but in many regions such courses do not yet take place. Through various support and cooperation mechanisms these efforts can be strengthened.

To complement technology and infrastructure related issues a policy focused platform could be developed to support policy learning, experiences sharing for best practices and coordination of

different policy instruments. It should explore opportunities for working with a variety of different actors. The business sector does a lot of work in the area of green building and energy efficiency (such as voluntary standards which has become drivers of regulatory developments in e.g. the US and the UK). Collaboration with NGOs has been a key success factor and commended as ‘visionary’ by the project evaluators. The above-mentioned international platform could benefit from the representation of such actors.

To share experience of different policy instruments such as building codes, loans, procurement processes could improve policy interventions in developed as well as developing countries. Some projects that appear promising for progress are listed in the following points.

- International reviews of policies to establish the tools that are actually used, and how they are applied and followed-up. The purpose would be to get a better picture as to what tools that exist and where there are gaps;
- Develop international graduate level programs for energy efficient buildings for architects, designers, and building engineers. The purpose is to increase the knowledge and create international networks of professionals;
- Conduct policy reviews, with special focus on policy instruments with high potential to initiate change. Public procurement in particular is an interesting area. Best practices among public clients in designing procurement tools and knowledge management, for public contracts, should be reviewed, and how requirements in tenders are evaluated and enforced during the building process;
- Review best practices for communicating the benefits of low energy buildings and related technologies; and review what drivers that appeal to actors in different settings.

6. ENERGY EFFICIENCY AND APPLIANCES

In this chapter, cases of energy efficiency improvement measures for appliances, including lighting sources, in the household sector are examined. As discussed below, electricity consumption by the appliances is currently growing very fast worldwide, and this trend is expected to accelerate in the coming decades. Meanwhile, it is one of the areas where large potential for improvement exist.

After briefly introducing the current status and future projection of the energy/electricity use and energy efficiency improvement of the sector, selected policy measures to address energy efficiency for appliances are examined. Subsequently, activities and international agreements related to energy efficiency for appliances as well as experiences of market transformation cases in developing countries are reviewed. Based on the first three sections, critical conditions for successful transfer of technology are discussed. The chapter concludes in an exploration of ways forward.

6.1 Background: why energy efficiency in appliances?

This section presents a concise introduction of the current trend of energy/electricity end-use by electrical and electronic appliances, and the rationales for addressing energy efficiency in appliances.

6.1.1 Energy/electricity consumption in the household sector is growing

Despite various efforts, the use of *energy* has been increasing: the overall final energy use increased by 14% between 1990 and 2004 in a suite of 14 IEA countries.⁶² During the same period, the CO₂ emissions also increased by 14% (OECD/IEA 2007).

When examining the breakdown of the energy consumption by sector, as of 2004, the *household sector* constituted 22% of the total final energy consumption in the 14 IEA countries. Between 1990 and 2004, the increase of energy

consumption in the sector is 14 % in the 15 IEA countries,⁶³ and that of CO₂ emissions is 15%. In light of the increase of population in these countries by 10% during this period, per capita energy use in households grew by 4% (OECD/IEA 2007).

Among various sources of energy used in households, it is *electricity* consumption that experienced the largest increase. The increase of electricity use between 1990 and 2004 in a set of 15 IEA countries was 35%, and the share of electricity within various energy sources rose from 29% to 34% (OECD/IEA 2007).

The increase in the residential electricity consumption has been experienced both in the OECD and non-OECD countries, with the annual per capita growth rate of 2.0% on the average between 1995-2005. While the growth rate is twice as high in non-OECD countries, OECD countries still consume 65% of total global electricity used in the household sector (OECD/IEA, 2009a).

6.1.2 Appliances are the largest contributor to the increase of residential electricity consumption

Studies of end-use within households indicate that appliances are the major contributor to the increase of energy/electricity use. Among five categories of end-use – space heating, appliances, water heating, lighting and cooking – appliances experienced the most rapid increase: 50% in terms of energy between 1990 and 2004 in the 15 IEA countries, 48% in terms of electricity and in terms of CO₂ emissions, 44%. In 2004, the use of electricity by appliances constitutes 57% of the total electricity used in household sector (OECD/IEA 2007).

A closer look at the trend of specific types of appliances indicates that electricity consumption of some of the large home appliances, such as refrigerators, freezers and washing machines, in OECD countries is decreasing. This is despite the increase of per capita ownership and size. The improvement of energy efficiency of individual equipment driven mainly by government policies contribute to this achievement (OECD/IEA 2003; OECD/IEA 2007).

A rapid increase in the use of a variety of small appliances – namely Information and

⁶² These 14 IEA countries include Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Sweden, the United Kingdom and the United States.

⁶³ The 15 IEA countries are the 14 IEA countries mentioned in Footnote 62 plus Spain.

Communication Technology (ICT) equipment and Consumer Electronics (CE) – and in some countries, of air conditioners, is deemed to be the main reasons for the overall increase of electricity consumption by appliances. In the IEA countries, the share of electricity used by the small appliances increased by 10% between 1990 and 2004. Globally, the use of electricity for ICT and CE equipment has been growing more than 7% annually since 1990, constituting close to 15% of the total household electricity consumption. Even taking into account the foreseen energy efficiency measures, electricity consumption by the appliances is projected to increase by 250% by 2030 (OECD/IEA 2009a; OECD/IEA 2007).

6.1.3 Potential for energy efficiency in appliances in mitigating climate change

Observing the energy use in the IEA 17 countries⁶⁴ between 1990 and 2006, it is said that the final energy use in 2006 would have been 17% higher without various economy-wide energy efficiency measures taken during this period. Meanwhile, the average annual efficiency improvement of 1.5% over this period is lower than that achieved during the period between 1973 and 1990 following the oil shocks in which the average annual efficiency improvement was 2%. The rate of efficiency improvement in the household sector is even lower: 0.7% between 1990 and 2004 among the 15 IEA countries (OECD/IEA 2009b; OECD/IEA 2007).

Meanwhile, according to the IEA's Energy Technology Perspectives 2006, as much as 45% of the reduction of global CO₂ emission is to be achieved through the improvement of end-use efficiency (OECD/IEA 2006). It is estimated that that uptake of the best available technologies in the ICT and CE equipment sector would help reduce the end-use electricity consumption and CO₂ emission by the sector by more than a half by 2030, compared to business as usual scenario (OECD/IEA 2009a).

6.2 Government intervention for energy efficiency

An important driver for the aforementioned energy efficiency improvement in appliances,

⁶⁴ The 17 IEA countries included in the analysis are Australia, Austria, Canada, Denmark, Finland, France, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States.

albeit one that remains insufficient to fully address the increasing energy use from appliances, is policy measures introduced by a number of governments worldwide. Government interventions can be introduced with varying level of coerciveness (mandatory to voluntary). They can be categorized into administrative, economic and informative instruments.

The following subsections provide a review of a number of policy instruments that have been widely used to improve energy efficiency of appliances.

6.2.1 Energy efficiency standards

Energy efficiency standards set the level of energy efficiency performance that needs to be met if one is to decrease the use of energy arising from the use phase of “energy intensive” products. According to the Collaborative Labeling and Appliance Standards Program, as of September 2004, as many as 47 types of appliances in total of 70 countries have either mandatory or voluntary energy efficiency standards (CLASP, 2009b). The stringency of energy efficiency standards depends on factors such as: the level of the standards, the manner in which the standards is considered fulfilled, and the time frame given to the addressees to meet the standards (Tojo and Lindhqvist 2009).

Regarding the level of standards, the most prevailing approach is *minimum energy performance standards (MEPS)*. When a product does not meet the MEPS, it cannot be put on the market. The approach cuts laggards from the market (OECD/IEA 2009a). The ecodesign of energy-using products directive (Dir. 2005/32/EC) was adopted by the EU in 2005,⁶⁵ now replaced by Dir. 2009/125/EC, which has a wider scope as it relates to “energy-relevant” products. Binding standards for different product groups are set under the directive through so-called Implementing Measures. To date, 9 implementing measures, setting mandatory energy efficiency standards for 9 product groups have been implemented. The expected savings from these measures are outlined in the table.

⁶⁵ An earlier problem has been the slow update of standards by the European Commission. Thus, energy efficiency standards enacted before Dir. 2005/32/EC, set forth in Directives for selected products – e.g. water boilers (92/42/EEC), refrigerators and freezers (96/57/EC) and ballasts for fluorescent lighting (2000/55/EC) – were not updated though this has been motivated from both environmental and environmental reasons (Boardman 2005).

TABLE 6-1. EXPECTED SAVINGS FROM IMPLEMENTING MEASURES UNDER THE FIRST 9 IMPLEMENTING MEASURES ADOPTED UNDER DIRECTIVE 2005/32/EC. SOURCE: EUROPEAN COMMISSION.

Adopted implementing measures	Estimated savings (yearly by 2020)
Standby and off mode losses of electrical and electronic equipment (household and office)	35 TWh
Simple set top boxes	6 TWh
Domestic lighting	37 TWh
Tertiary sector lighting (office and street)	38 TWh
External power supplies	9 TWh
Televisions	43 TWh
Electric motors	140 TWh
Circulators	27 TWh
Domestic refrigeration	6 TWh
	= 341 TWh = 12% of the electricity consumption of the EU in 2007

The numbers show the significant potential to cut GHG emissions through the setting of mandatory energy efficiency standards for appliances. However, the stringency of the standards has also been cast into doubt, and a key concern is whether standards will constitute a genuine challenge for manufacturers and deviate from BAU scenarios (e.g. Dalhammar 2007a; van Rossem et al. 2009). The working plan 2009-2011 establishes a list of 10 priority product groups for the period 2009-2011:

- Air-conditioning and ventilation systems
- Electric and fossil-fuelled heating equipment
- Food-preparing equipment
- Industrial and laboratory furnaces and ovens
- Machine tools
- Network, data processing and data storing equipment
- Refrigerating and freezing equipment
- Sound and imaging equipment
- Transformers
- Water-using equipment

An alternative approach to this has been taken in a so-called *Top Runner* Program in Japan. Introduced in 1999 as a part of revised Law concerning the Rational Use of Energy, the Program has gradually expanded its scope and as of 2009 covered 21 product groups. As indicated by the name, among the targeted products available in the market the year before the standard is discussed, the use-phase energy efficiency of the product that achieves the highest energy performance (top runner) becomes the basis of the standards. The approach in principle moved away from the prevailing minimum standards that typically only cut the laggards – a group that constitutes only a small

part of product groups.⁶⁶ Unlike the MEPS, the standards are to be met by manufacturers on a so-called fleet average/weighted average basis (Tojo 2005). A differentiated time of 5-13 years was given for manufacturers to meet the standard in the case of Top Runner Program. While the compliance with the standards on individual product basis (not fleet average basis) was achieved only at the deadline year for some product groups such as refrigerators and air conditioners, other products such as computers met the standards some years earlier. In these cases, new standards were discussed and determined even before the first deadline came.

⁶⁶ Meanwhile, the standards should also take into account the potential for technological innovation and diffusions. This in practice means that the “top runner” product may not become a standard setter when, for instance, the achievement of the same efficiency would require the application of a unique technology used in the product. In addition, standards are often differentiated within the product group depending on various parameters such as the size (e.g. refrigerators, TV screens), the weight (e.g. cars), the functions (e.g. inclusion of video tape recorders in TVs) and the like. This on one hand helps secure the availability of a variety of products (e.g. refrigerators in different sizes, air conditioners tailored for rooms of different sizes, TVs with screen of different size and shape, private cars in different size and weight). On the other hand, the necessity of having some of these products (e.g. wide-screen TV, large and heavy vehicles) can be questioned in light of the pressing need of taking actions for energy efficiency. An analysis of the manner of concrete implementation of the Top Runner Program can be found at, for instance, Tojo, 2005.

Upgrading of the remainder of the products take place as the deadline comes. The results of improvement ranged from 25.7 % in the case of TV sets with CRT between 1997 and 2003, 55.2% for refrigerators between 1997 and 2004, and 99.1% for computers between 1997 and 2005 (ECCJ 2008).

Energy efficiency standards have been used as a criterion for various other instruments such as green public procurement, the so-called Type I eco-labels that address various environmental impacts from life cycle perspective⁶⁷ and tax reduction schemes. Moreover, the standards often come in hand with energy efficiency labels. In addition to the government, distributors, by utilizing their own purchasing power, can also set their own standards. They can demand that producers meet certain energy efficiency criteria for their products to be put on the shelf.

6.2.2 Energy efficiency labels

First introduced in Canada in 1978 (OECD/IEA 2000), energy efficiency labels have been widely used in many countries. As of September 2004, 75 countries have introduced them for over 60 types of home appliances (CLASP 2009b). The idea of the energy efficiency label is to inform consumers of energy-using products of the level of energy efficiency of products during the use phase of products' life, thereby helping them make an informed choice (informative instrument). Meanwhile it aims to provide manufacturers with incentives to develop products that are more energy efficient.

The labels can be categorized into *endorsement* labels and *comparison* labels (OECD/IEA 2009a). An example of the former is the Energy Star Program developed in the US, which indicate that the product with the label conforms to the standard set by the labelling scheme. Participation in this type of labeling scheme is voluntary. The examples for the latter – comparison labels – include, among others, the EU energy labelling scheme for selected home appliances and the Top Runner Program in Japan. In the EU, selected home appliances must bear

⁶⁷ According to the International Standardised Organisation (ISO), Type I eco-label is defined as “a voluntary, multiple-criteria based, third party program that awards a license that authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations”. As of 2007, the Global Ecolabelling Network included 26 members from 24 nations and regions (GEN 2008).

the labels that indicate the efficiency level of the appliances ranked from A to G (in the case of refrigerator, A+ and A++ have been added). Selected appliances covered under the Top Runner Program in Japan indicates the efficiency level in comparison to the Top Runner standards by percentage, as well as by colour of the label (green suggests compliance while orange suggests non compliance). The comparison labels can be mandatory or voluntary, and are often accompanied by information such as average energy consumption, life time, annual energy consumption and the like.

The average energy saving of using Energy Star awarded products compared to standard products is reported to range from 5-10% (e.g. boilers, air conditioners, printers) to 70-90% (e.g. lighting equipment, TVs/DVDs/VCRs) (USEPA 2008). The label schemes under the Top Runner Program in Japan as well as the one in the EU based on the Directive 92/75/EEC are relative: it indicates the level compared to the standard/energy efficiency index.

Similar to the energy label standards, it is important to periodically update the standards upon which the labels are based in order to continue to provide incentives to the producers to supply more energy efficient products. The level of the standards under the Energy Star and the Top Runner Program has been increased based on the improvement of energy efficiency of the overall product group. In the EU, the revision of the labels for refrigerators and freezers with the intention to reflect the energy efficiency improvement over the years has also been under discussion (ENDS 2009, February 16).

Periodic market surveillance and verification of information could help enhance the awareness and credibility to the said energy efficiency of the products.

In cases where energy efficiency standards exist, energy efficiency labels have been used as a complementary tool to inform consumers. Moreover, the standards set in energy label programs have been used as a criterion for so-called Type I eco-labels as well as green public procurement.

6.2.3 Green public procurement

Green public procurement means that public authorities –national, regional and local – take environmental issues into account when obtaining goods or services with tax payers' money. The sheer magnitude of purchasing power that the public bodies have – in Europe 16% of the GDP – enables them to send a strong

signal to the producers concerning their design strategies.

Green public procurement has been strongly promoted as an important economic instrument to enhance the demand on greener products. In Europe, it is an integral part of the Integrated Product Policy (IPP) (COM (2003) 302 final) and Environmental Technology Action Plan (ETAP) (COM (2004) 38 final), among others. A study conducted in 2005-6 suggests that 7 countries (Austria, Denmark, Finland, Germany, Netherlands, Sweden and UK) are among the leading countries in Europe (Bouwer et al. 2006). In Japan, a law from 2001 obliges public authorities to integrate environmental consideration when purchasing goods and services.⁶⁸ Under the legislation, the criteria for products and services commonly purchased by public authorities have been developed.

Standards available from various instruments – including those from energy efficiency standards and labels – can be incorporated as criteria for green public procurement.

The study of the Top Runner Program indicates that the inclusion of the Top Runner standard in the green public procurement criteria accelerate compliance, as the timing to meet the green public procurement criteria comes sooner than that for the Top Runner standard. Moreover, as green public procurement concerns individual products instead of brands (i.e. not fleet average of the products put on the market by one brand), it urges them to meet the standards on the individual product basis (Tojo, 2005).

6.2.4 Fiscal measures

Different types of fiscal measures can be introduced by the government to provide incentives to various actors in the supply chain. For consumers, discounts, subsidies and tax reduction are among the measures that can be effective in inducing their purchase of more energy efficiency products that have an initial price of which is higher than less energy efficient alternatives. Provision of financial support for initial investment in the production process, such as low interest loan or grant, could help manufacturers of equipment to develop more energy efficient products (Birner and Martinot 2005; Tojo 2005; OECD/IEA 2009).

6.2.5 Information and awareness activities

In addition to the labelling programs discussed in Section 0, information and awareness raising activities are essential complementary measures for various other instruments mentioned above. For consumers, awareness of the general importance of energy saving as well as meaning of labels can be facilitated via mass media campaigns and information provision in public places including schools. Furthermore, distributors can play an important role by highlighting energy efficient products in the shelf. Moreover, training and seminars can be helpful in updating knowledge and competencies of actors such as retailers, manufacturers and government officials.

⁶⁸ Kunitou ni yoru Kankyoubuppintou no Choutatsu no Suishintou ni kansuru Houritsu. 2001[Law on the promotion of the purchasing of environmental products by nation and the like.]

6.3 Current agreements and activities related to technology transfer of energy efficiency in appliances

Article 4 of the UNFCCC sets a general obligation to the signatories to transfer environmentally sound technologies to other parties, and in particular to developing countries. Mechanisms to operationalize this general obligation have been gradually developed, with landmarks including the Kyoto Protocol (1997), Marrakesh Accord (2001) and Bali Action Plan (2007) (Seres 2007; UNFCCC 2009). Another mechanism available under the UNFCCC to transfer the technology from developed to developing countries is the Clean Development Mechanism (CDM) established via Kyoto Protocol to the UNFCCC in 1997. In addition, there are a few agreements between nations regarding the development and management of energy efficiency labelling, standards and technologies for appliances.

Various types of activities related to technology transfer of energy efficiency in appliances have emerged. For instance, the Global Environmental Facility (GEF), which operates the financial mechanisms of various global environmental treaties including UNFCCC, has financed a total of 131 projects related to energy efficiency since 1991 (GEF 2009). The funding given to the energy-efficiency related projects have grown with time, has and have amounted to 6734.5 million USD over the 18 years (of which 848.9 million is provided by GEF, the remainder supplemented by co-financers) (GEF 2009). A review of 51 energy efficiency projects financed by various international, regional and national institutions identified 25 projects related to appliances and lightings (Evander et al. 2004).⁶⁹

Although the CDM does not have explicit mandate to carry out technology transfer, it may facilitate such activities via the financing of activities in host developing countries that relate to emission reduction. Analysis of 2293 project design documents categorized registered and proposed as CDM in 2007 indicates that approximately 39% of the projects claim to involve technology transfer. However, projects related to energy efficiency in households are limited to 5, of which 3 involve technology transfer. The follow up analysis from 2008

⁶⁹ Some of the 25 projects concern application of energy efficient lighting and appliances in the commercial and industry sectors, thus not limited to residential sectors.

suggests that 9 out of 3296 projects reviewed relate to energy efficiency in households, of which 5 involves technology transfer (Seres 2007; 2008).

Addressing another facet of this topic, the following sub-sections briefly review activities related to technology transfer in the area of energy efficiency in appliances, inside and outside of the UNFCCC framework, as well as international agreements related to energy efficiency for appliances. Following the taxonomy developed by de Coninck et al. (2008), the activities are categorized into a) knowledge sharing and coordination, b) research development and demonstration, c) technology transfer and d) technology deployment mandates, standards, incentives.

6.3.1 Knowledge sharing and coordination

The International Energy Agency (IEA) provides a database for energy efficiency policies and measures taken in the IEA member countries plus Brazil, China, the European Union, India, Mexico, Russia and South Africa. The IEA also provides various news items related to energy efficiency and climate change and archives them in chronological order.

Under the IEA umbrella, the Implementing Agreement for a Co-operative Programme on Efficient Electrical End-use Equipment (4E) was agreed with a view to promote wider use of more energy efficient electrical equipment. Current signatories include Australia, Austria, Canada, Denmark, France, Korea, the Netherlands, South Africa, Switzerland and the UK. They work on four main areas: 1) *mapping and benchmarking* of energy performance of products in the market, product performance standards and policy instruments; 2) share information on successful approaches to reduce *standby power*; 3) harmonization of standards and promotion of high-efficiency *electric motors* in appliances; and 4) development of a common testing procedure and harmonized approach for energy efficient *set top boxes*⁷⁰ (IEA 2009; IEA-4E 2009).

The Collaborative Labeling and Appliance Standards Program (CLASP) provides among other things a web-based database for energy efficiency labelling programs and standards found in different countries.

⁷⁰ A set-top box is a television device that converts received signals to viewable images (IEA/OECD 2009).

6.3.2 Research development and demonstration (RD & D) activities

The activities of the Agreement on 4E mentioned above include various RD&D activities, especially in the area of set-top box. Examples of such activities include development of a test procedure for energy performance of set-top boxes, demonstration of new and energy-saving technologies and establishment of technical specification (IEA-4E 2009).

Development of a common energy performance testing methodology is also found in the area of external power supplies, the devices that supply power for other appliances such as mobile phone. A notable collaboration in this case is made among the US, Europe, China and Australia. Initiating their collaboration in 2003, they also started to coordinate the performance standards, as discussed further in Section 0 0 (Zhou 2008; OECD/IEA 2009a).

6.3.3 Technology transfer

Existing cases of technology transfer related to energy efficiency appliances from developed countries to developing countries identified in the literature (Martinot and Borg 1998; Evander et al. 2004; Birner and Martinot 2005; Van Buskirk et al. 2007; Zhou 2008) have the following characteristics:

- They are based on projects funded and supported by international, regional or bilateral funding agencies, as well as national government bodies;
- They concern mature products, such as refrigerators, lighting sources and air conditioners.

Many of the identified cases concern the introduction of standards, labelling schemes and incentive measures. These are discussed in Section 0, while focus is given to measures directly related to technology transfer *per se* in this section.

Examples of activities related to technology transfer found in identified case studies include (Evander et al. 2004; Birner and Martinot 2005):

- training of local manufacturers, specialists and technicians involved in different stages of refrigerator manufacturing regarding design and manufacturing methods (Cuba, Tunisia, China);
- training and capacity building of local agents regarding testing and

certification procedures (lighting in Vietnam and China, air conditioners in Vietnam,; refrigerators in Tunisia);

- international and domestic study tours (lighting in China, refrigerators in Cuba and China);
- seminars and workshops with international and national experts (lighting in Vietnam and China, air conditioners in Vietnam, refrigerators in China);
- financial support for upgrade of manufacturing facilities (refrigerator in China); and
- international technology exchange meeting(s) (lighting in China).

Unlike buildings for which domestic manufacturing industries exist in virtually all the countries in the world, manufacturing of appliances does not take place in all countries in the world. The relevance and the capacity building potential of technology transfer is, at least in the short term, generally higher in cases where a domestic manufacturing industry exists in the country. In this regard, it is not so surprising that the cases of technology transfer is somewhat limited compared to the cases focusing more broadly on market transformation via standards, labelling schemes and incentive measures (discussed below).

One of the challenges identified in the implementation of technology transfer is the unwillingness of foreign manufacturers to provide access to their technology. A perceived reason concerns international competition. The studies (e.g. Evander et al. 2004, Birner and Martinot 2005) report that the foreign manufacturers contacted refused to accept study visits and to visit the country for training. As an alternative, experts from universities and research centres were visited during the study tours, and retirees and academics were invited for training. Nonetheless this has made it difficult for the manufacturers to receive hands-on knowledge.

6.3.4 Technology deployment mandates, standards, and incentives

The dominant activities related to technology transfer in the area of energy efficiency for appliances to date involve technology deployment mandates, standards and provision on incentives. The vast majority of activities

discussed under the previous three subsections have something to do with diffusion of energy efficient products in the market through various means and are often combined with the introduction/implementation of energy efficiency standards and labels. Policy measures mentioned under Section 6.2 have been employed in different manners. In the area of appliances, activities covered under this section are often referred to as *market transformation*.

Similarly to technology transfer, products found under *market transformation projects* are mature equipment, such as refrigerators, air conditioners and lighting. Birner et al. (2005) stress the importance of involving both the supply side and the demand side of the market when deciding upon which interventions that should be included in the projects. In addition to technology transfer discussed previously examples of *supply-side measures* found in the cases of market transformation in developing countries include (Evander et al. 2004; Birner et al. 2005; Van Buskirk et al. 2007; Zhou 2008):

- introduction of standards and/or labelling schemes (e.g. refrigerators in Thailand and China, lighting in Thailand, China, Poland and Mexico, air conditioners in Vietnam and Ghana);
- design competitions (e.g. refrigerators in China, lighting in Poland);
- Negotiated agreements between producers and governments (e.g. lighting in Poland and Thailand, refrigerators in Thailand);
- improvement of product testing (e.g. lighting in Thailand and China, refrigerators in China); and
- cultivation of new distribution channels (lighting in Thailand and Mexico).

Regarding the labels and standards for energy efficiency of appliances, the Collaborative Labeling and Appliance Standards Program (CLASP) offers technical assistance and provides support in the national implementation of standards and labels. The activities were initiated by Lawrence Berkeley National Laboratory in the US in 1996, which led to the launch of the program in 1999 and are currently funded by 15 national and international organizations (CLASP 2009a).

According to the database maintained by CLASP (2009a), in addition to the three appliances often

targeted in the market transformation projects (refrigerators, air conditioners and lighting), an increasing number of developing countries have started to set standards and/or labeling schemes for products such as washing machines and TV sets.

Examples of measures that enhance *demand* of energy efficient appliances include (Martinot et al. 1998; Evander et al. 2004; Birner et al. 2005; Van Buskirk et al. 2007, Zhou 2008):

- free distribution of/provision of discount/subsidies for energy efficient products during the pilot phase (found mostly in the case of light sources, e.g. Jamaica, Brazil, Egypt, Palestine, Vietnam);
- leasing agreements and spread payment together with the electricity bill (mostly in the case of light sources, e.g. Mexico);
- bulk purchases by public agencies thus reducing the retail price (especially in the case of lighting sources, e.g. Jamaica, Mexico, Poland, China); and
- various educational and information campaigns for consumers via mass media and at public places, seminars and trainings for manufacturers, retailers and public authorities.

Some of the measures addressing supply side (e.g. improvement of product testing and cultivation of new distribution channels) also contribute to the enhancement of uptake on the demand side. Product testing is considered especially important in addressing consumer distrust towards the quality of energy efficient equipment. Availability of competing products with lower quality/energy efficiency sold at lower prices pose obstacles to the diffusion of products with better energy efficiency. This is a problem not only in developing countries but also in developed countries. In addition to informative instruments and educational campaigns, financial incentives such as subsidies and discounts could help remedy the problem, especially in cases where initial high cost pose difficulties for low-income consumers.

In relation to the purchasing power of consumers, a case study in Ghana highlights challenges in the application of energy efficiency standards and labelling schemes as a way to transform market. This is most notably due to a large number of second-hand products in the market handled/repared and rehabilitated in the informal

market. Indeed, more than half of the refrigerators sold in Ghana are second-hand. This, together with weak enforcement, makes it difficult to set up a meaningful standard for the market. The energy efficiency of a large number of second hand products that come across national borders is also challenging (Van Buskirk et al. 2007).

Cumbersome and inflexible requirements from international funding agencies are found to reduce adaptation of the project to changing dynamics of the local condition (Birner et al. 2005).

In addition to market transformation projects targeting developing countries, there are a modest number of *international agreements* on energy efficiency standards for appliances. One such example is the US Energy Star Program. Initiated by the US Environmental Protection Agency (EPA) in 1992 – the Program has been implemented for selected appliances in Australia, Canada, the EU, Iceland, Japan, Liechtenstein, Norway, Switzerland, New Zealand and Taiwan (USEPA, n.d).

In the European Union earlier Directives setting up the energy efficiency standards for selected products have now been integrated in the Ecodesign Directive 2009/125/EC (previously Dir. 2005/32/EC), discussed previously in this chapter. The scope of their Directive will however be widened to include ‘energy-relevant’ products (which may include windows, insulation, and so on) in addition to energy consuming products. This will create a more integrated tool to deal with all energy-relevant products.

As discussed previously in this chapter, in the EU selected home appliances must bear the labels that indicate the efficiency level of the appliances ranked from A to G (in the case of refrigerator, A+ and A++ have been added) (the system is currently under revision).

The harmonisation of the energy performance standards for external power supplies have been attempted among the US, Europe, China and Australia. Although the participating countries realized at an early stage of their collaboration that it would be difficult to agree on one standard due to differences in their approaches (e.g. endorsement label vs. comparison label), they set up a common system that informs professionals of the level of efficiency (OECD/IEA 2009a).

In addition, the so-called Type I labelling schemes have been striving to develop

mechanisms for mutual recognition between different national labelling schemes. There are two types of mutual recognition: 1) on the whole or part of the *criteria document* per se, and 2) on the certification *process*. Although the development of mutual recognition has been slow, due in part to the differences of significant environmental impacts in the respective nations, there are examples. For the former, the eco-labelling schemes in the Nordic countries, Japan and Germany currently agree on the mutual recognition of parts of the criteria for copying machines (JEA 2005). Among various environmental criteria, the mutual recognition for energy efficiency criterion has been agreed upon between the eco-labelling schemes in Japan and Nordic countries (JEA 2005). For the latter, the eco-labelling scheme in Japan also made agreements with their counterparts in Korea, Thailand, Taiwan and New Zealand (Fine co. Ltd. 2007). Conclusion of the latter means that producers who would wish to apply for eco-labels in Japan could ask certifying body of any of these four countries to conduct the certification. In addition, the Global Ecolabelling Network currently seeks to develop a set of common core criteria for personal computers (GEN 2008b). The Type I eco-labels are different from energy efficiency labels in that the former take life cycle approach and the environmental aspects covered in the criteria document are not limited to energy efficiency. Nevertheless, the efforts of harmonization in the eco-labels will most likely have positive implications for the harmonization of standards behind energy efficiency labels.

6.4 Critical issues identified

By observing the trend of energy use and efficiency related to appliances, existing policy instruments addressing energy efficiency of appliances and technology transfer activities in the area, the following issues can be highlighted for consideration. First, the varying characteristics of appliances need to be recognized. Second, tailor-made solutions are needed to respond to the social, economic, market and political characteristics of developing countries in question.

6.4.1 Differences between different types of appliances

As discussed previously in this chapter there are distinctive differences in the market development of mature products (e.g. refrigerators, air conditioners, washing machines) and ICT and CE equipment in developed countries. While the number of the former sold in the developed countries market have more or less stabilized, the market is still growing for the latter and so is the individual ownership of the latter. Meanwhile, markets for both types of products will almost certainly continue to expand in developing countries.

The vast majority of developed countries have now introduced energy efficiency standards and/or mandatory labelling scheme for the mature products. Meanwhile, except for the stand-by energy consumption, only a limited number of countries address the energy efficiency of the normal usage of ICT and CE equipment – with the exception of TVs (OECD/IEA 2009a).

Appliances in general have similarities in that they are composed of various components. Meanwhile, while the functions of the mature products will most likely stay as they have been, the functions of ICT and CE equipment have been changing, and new products are developed to combine the functions that are previously found in several separate pieces of equipment.

Most of the appliances are durable, and repair/exchange of malfunctioning components can often extend their life: thus second hand markets tend to exist. A marked exception in this regard is lighting.

6.4.2 Characteristics of different developing countries

Situations specific to a country in/to which activities to enhance energy efficiency of appliances take place should be carefully considered before such activities are planned and implemented. A number of issues to be considered in this regard exist.

- **Existence of manufacturers** (components or final products): this would determine, for instance, if transfer of technology *per se* is appropriate, or other market transformation measures should be undertaken.
- **Available technologies and capacities in the country**: when energy efficiency technologies already exist in the country there is high potential to utilise domestic expertise, as much as international expertise. In some cases (e.g. lighting in Thailand and Poland, see previous sections), the manufacturers may possess the technologies yet they feel uncertain about the reaction of the market. In these cases, information-oriented interventions towards consumers and retailers can be useful. When the technologies in question do not exist in the country (e.g. the case of refrigerators in China discussed previously), use of international expertise becomes more necessary at least for a quick transition.
- **Capacity for testing and verification**: literature points to the necessity of gaining confidence among consumers towards the quality of energy efficient products. The same experience was found in developed countries at the earlier stage of introducing energy efficient lighting (Martinot et al., 1998). Development of sufficient capacity for testing and verification is a prerequisite for making standards and labelling scheme credible.
- **Perception on the trustworthy actors**: in relation to the former point, testing and verification should be carried out by actors whom the citizens consider reliable. These actors may vary from country to country: often independence from industry is considered important to gain credibility.

- **Perception on various types of policy instruments:** perceptions of policy instruments can be different from country to country. For instance, rebate and subsidies are well accepted in some countries (e.g. Mexico, Poland), but not in others (e.g. Thailand). Careful consideration is needed to examine the social acceptability of different policy instruments.
- **Negotiated agreements and the market structure:** in some cases (e.g. refrigerators and lighting in Thailand), development of new technologies, standards and/or labelling schemes work very well through negotiated agreements between the manufacturers and the government. In others (e.g. the case of air conditioners in Thailand), it has not worked very well. Negotiated agreements tend to work better when there are only a limited number of manufacturers in the country, and that they have good relation with the producers. The experiences in developed countries indicate additional conditions: the willingness of manufacturers to cooperate, and continuous existence of the threat of legislation (Menanteau, 2003).
- **The size and structure of the second hand market:** In many developing countries, the relatively high price of new products coupled with limited funds for initial investments, mean that consumers with lower income tend to purchase second hand products. The size and structure of second hand market have important implications for the effectiveness and implementation of prevailing policy instruments such as standards and labelling.

In addition, the existing cases highlight the importance of measures on the demand side. A crucial component, though often complementary to other policy measures, is education and awareness-raising activities directed to various actors in the society, such as consumers, retailers and government officials in charge of implementing the energy efficiency programs. Another important measure is to reduce the initial purchase price which could be introduced at various stages of the product value chain. For instance, it could take the form of agreements between manufacturers and the government, bulky purchasing by public agencies (between

manufacturers and consumers), or direct subsidies or rebate at the point of sales.

All in all, the overall capacity building of various actors involved in the promotion of energy efficiency for appliances, and in the development of sustainable institutional structures for the continuation of activities, are prerequisites for successful market transformation (Birner and Martinot 2005).

6.5 Potential options to advance TOAs for appliances

Review of market transformation activities in developing countries in the area of energy efficiency for appliances reveals that there is much potential to expand these activities via replication and adaptation. Meanwhile, the on-going increase of energy use both in developed and developing countries require urgent actions to improve energy efficiency of various types of appliances.

In this last section, policy measures considered to enhance the actions, including TOAs inside and outside of UNFCCC framework, are explored.

6.5.1 Continuous upgrade of standards in developed countries

As discussed in previous sections, different trends can be observed between the so-called mature products and ICT and CE products. For both types of products, it is of utmost importance that *developed countries* continue to strive for the improvement of energy efficiency. Even when the market for mature products is saturated and energy use from these products have more or less stabilized in developed countries, the sheer number of users of these products continue to increase around the globe. The standards need to be continuously improved to capture the best available technology, so that the decrease of energy use from the developed countries could at least partially cancel the increase in developing countries. Some of these energy efficient products could also be sold immediately in some developing countries.

The standards upgraded in developed countries can be useful for developing countries as well. A study of the Top Runner Program in Japan (Tojo 2005) indicated that the comparison of standards for energy efficiency between different countries pose challenges. The differences in climate (e.g. humidity, temperature, etc.), housing situation and pattern of usage are among the reasons for

which testing methods of energy efficiency for some products (e.g. refrigerators, air conditioners) vary among the countries. This indicates challenges in the simple transfer of efficiency standards from one country to another, at least for some types of products whose energy efficiency may be affected by surrounding circumstances. Thus, despite the common need of periodic upgrade of standards, the concrete standards themselves may need to take different shapes.

Moreover, as the case from Ghana illustrated, durable mature appliances that end their first life in developed countries or in their domestic market, are often used as second-hand products by lower income consumers. Considering the high initial cost of purchasing new equipment and the basic function these mature appliance (e.g. refrigerators) provide to enhance quality of life, it would not be appropriate to prohibit the sales and use of second-hand mature appliances because of low energy efficiency requirement. An improved situation would be to upgrade the energy efficiency of products when they re-enter the market. In this regard, as suggested by Van Buskirk et al. (2007), raising awareness of the dealers in second hand market – repairers, reconditioners, refurbishers and the like – and providing them with tools and means for energy efficiency upgrade, seem to be very effective in improving the situation.

In this regard, a consideration could be made to address components in mature products that are essential for energy efficiency improvement, such as compressors in the refrigerators. An idea could be to build local capacities to improve the efficiency of the components, to incorporate new components with better efficiency, or to establish manufacturing plants for components. Similar to some car components (Tojo, 2004), certification schemes for the second hand components could also be considered. Meanwhile, the less organized structure of second hand markets as well as the involvement of larger number of informal market actors pose challenges to organize such schemes.

This approach – the modular upgradability – is also very much needed for ICT equipment, and in fact is happening in both developed and developing countries. It can be considered in parallel with one of the core policy suggestions by the OECD/IEA (2009a) to improve energy efficiency for ICT and CE equipment: development of standards based on function, instead of products. In light of continuing development and dynamics in the combination of a variety of functions (e.g. use of screen both for

TV and computers, mobile phones with the function of computers, mobile phones with cameras and audio devices), it may not be feasible to develop product-specific efficiency standards. Instead, it would be more useful to set standards for respective functions a product serves. This so-called horizontal approach is reflected in the on-going work on the energy efficiency improvement of, for instance, TVs (e.g. stand by modes and external power supplies). Another measure suggested is the better use of power management in various devices: it is argued that the default setting for power management should be most energy efficient, and consumers, unless they want to, should not have to set it themselves (OECD/IEA 2009a).

In all cases, the compliance to the standards, as well as elimination of products and components that do not meet the standards from the market, is crucial. In this regard, the weaknesses of monitoring and enforcement capacities could be complemented by the surveillance by manufacturers. It is in their interest to make sure that their competitors are also fulfilling the standards.

6.5.2 Coordination with other environmental policies should be enhanced

Among the literature reviewed on energy efficiency measures, very few, if any, discuss issues other than energy efficiency (with the exception of some cases concerning ozone depleting substances in refrigerators). For instance, the importation of second-hand electronics has been highlighted under the context of Basel Convention that deals with the transboundary movement of hazardous waste. In light of existing transboundary movement of second-hand electronics highlighted in the recycling and product policy arena, it was surprising that none of the case studies in the developing economies in Asia discussed the issues of second hand products. It would be useful to consider potential synergies for the two issues in the area of, for instance, the capacity building of the custom authorities. Meanwhile, it would be also important to consider the coherence with other policies, such as bridging the digital divide – an argument used to enhance exportation of second-hand electronics to developing countries.

The question can be also raised whether the replacement of less energy efficient products to more efficient ones is always preferable from the life cycle perspective. Essentially the same problem is found in the implementation of EU's Ecodesign Directive (2009/125/EC) where –

despite its mentioning of life cycling thinking as a starting point – a strong and narrow focus on the issue of use-phase energy efficiency as well as dismissal of the material and energy use from the production process have been pointed out (van Rossem et al., 2009).

Consideration to these aspects, to name but a few, is needed in order to avoid the introduction of incoherent – or in the worse case contradictory – policies.

6.5.3 Promotion of energy efficiency measures within the UNFCCC framework

The report on technology transfer within CDM from 2007, when comparing the content of CDM and the technology needs assessment submitted by the signatories, indicates that more needs are identified for energy efficiency in households (Seres 2007). It also highlights the wishes of some countries that more technology transfer in the area of energy efficiency in households should fall under the CDM (Seres 2007). The difficulties of proving additionality and the delay of the establishment of methodologies have prevented the wider inclusion of energy efficiency measures in the framework of CDM.

Perhaps it is more realistic and administratively less cumbersome to take the NAMAs path. For instance, in cases where an Annex I country provides funding to the undertaking of measures in non-Annex I country, a retroactive credit could be given, when the actual reduction is proven.

As such, it can be conceived that NAMAs for supporting appliance-related measures in non-Annex I countries could be used, in a manner similar to those discussed in chapter 5 for buildings. However, for NAMAs relating to appliances, it is crucial that funds are devoted to market surveillance – which is key in this area⁷¹ - and different capacity-building schemes that relate to capacity for monitoring and measurement, participation in international efforts for standard-setting etc. Such efforts should be coordinated with other measures that aid developing countries in the process of dealing with product standards in order to gain access to global markets (cf. Dalhammar and van Rossem forthcoming 2009).

⁷¹ Poor market surveillance is a problem also in the EU context, as business associations have in some cases decided not to make voluntary commitments on reducing energy efficiency in their appliances, due to free-riders (Dalhammar 2007a).

While some studies promote the view that some standards could be developed under the framework of UNFCCC (cf. e.g. Tomlinson et al. 2008), it is difficult to see how this could be done in an acceptable way, especially given the needs to adapt standards to climatic conditions and other circumstances, and the fact that EU and other jurisdictions are in the process of setting - and updating - several standards for appliances.

6.5.4 Another TOA outside of the UNFCCC framework?

An alternative approach is to establish technology oriented agreements to promote energy efficiency for appliances outside the framework of UNFCCC. An approach parallel to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer could be considered. Namely, instead of ozone depleting substances, objects would be energy efficiency standards set for specific products/components/functions, and the standards could be upgraded/revised/added based on the technological development. Based on common but differentiated responsibility, depending on the feasibility, differentiated time lines can be set for developing countries to comply with the standards. Developing countries, when becoming a member, become eligible to receive assistance in obtaining technological know-how to achieve the efficient solution from developed countries.

Given the relatively successful cases, but also recognising the tendency of international agreements to create various administrative burdens, it is difficult to say whether it is useful to develop such an alternative agreement at this moment. It may be more meaningful to allocate the resources that might be used for establishing and running such a treaty, to the financing of smaller scale projects that facilitate the reduction of overall environmental impacts from the products on the ground.

7. CONCLUDING REMARKS

7.1 The need for technology approaches in climate governance

A key concern is whether carbon markets and the applied instruments, such as current and proposed cap-and-trade schemes, will lead to innovation and diffusion of technologies at national, regional and international levels. An increasing number of actors call for technology-specific approaches in order to complement economic instruments, or even replace them. While much of the discussion on the use of markets vs. technology-specific policies is theoretical, and not always supported by empirical studies, one thing is clear: there is a danger in putting too much faith in market mechanisms. There appears to be a broad foundation for consensus in the area “we must also pursue technology-specific policies”.

However, little progress has been made regarding technology issues within the climate regime, and this is especially relevant in the case of technology transfer to developing countries. Current negotiations are flavoured by mistrust and self-interest, and involve a high number of countries with differing levels of economic development and varying systems of governance. Current instruments, such as the CDM, fit the needs of many developing countries poorly where the main focus should be on capacity-building efforts.

The chances for a successful climate regime have never been very high. If no satisfactory, effective agreement can be reached in Copenhagen or in the near future, a scenario that looks increasingly likely, we may see the rise of a new agenda for climate change mitigation, possible using other strategies and relying more on sticks than carrots. One conceivable pathway for instance, is the implementation of border tax adjustments (BTAs). Thus, trade mechanisms can be used as an engine to promote the climate agenda. This would however require tools to deal with climate-trade relationships. A new agenda will also increase the risks of fragmentation of international climate efforts. The inherent conflict between that which one may label ‘idealistic’ and ‘realistic’ approaches will, most likely, become increasingly apparent if the global community is serious about achieving the two degree target.

7.2 Pursuing technology needs inside or outside of the UNFCCC

Many analysts state that in the ideal case robust mechanisms can be pursued within the UNFCCC, under a (post-)Copenhagen deal (see e.g. Tomlinson et al. 2008; Depledge 2008). A number of actors also pursue such an agenda within the current negotiations. However, it is broadly recognised that some issues will probably be too contentious to deal with in the climate negotiations, and therefore must be dealt with in other settings. There is also a fundamental scepticism among many actors towards the ability of UNFCCC and its related mechanisms to drive technology transfer (cf. e.g. Tamura and Ichibara 2006). The solutions must be both to reform the UNFCCC system, and add new components, but also to pursue technology objectives outside the UNFCCC framework.

A major benefit of keeping technology agreements separate from the UNFCCC is that there is a perceived need for more flexibility in the current system. This stated, coordinating technology agreements with UNFCCC mechanisms would in any case be necessary, and there is potential to explore the use of relevant linkages between the UNFCCC and technology oriented agreements in order to provide incentives for increased technology transfer activities. For instance, the possibility for awarding CERs for a wider range of technology transfer projects also outside the UNFCCC framework should be considered in the future. This would however increase the complexity of the system as that would require rules regarding what projects that would be eligible for CERs, the assignment of credits⁷², a monitoring system, and a governing body. The system must also be transparent. Experiences with the CDM are not encouraging, and there is a need to create a more flexible and transparent system than the CDM. There is also a need to create a system that suits small projects.

⁷² We could imagine a situation where credits would be distributed to several actors, e.g. municipalities, corporations, aid organizations, either through rules or through contractual agreements. Such approaches could provide more incentives for GHG reduction projects, but would of course need proper governance structures. The criteria applied for evaluations must be different from those used in CDM.

7.3 Carbon capture and storage

The analysis of existing CCS-related TOAs suggests that there is no ‘magic TOA’ that can or will promote the transfer of technologies along the entire system chain. Different TOAs are very likely to be needed to address different components of the system. Differing forms of agreement, coordination or collaboration may even be required to address various aspects of the same components of a single technology (e.g. addressing hardware, software, or institutional aspects). The nature of each component largely frames the challenges that CCS-related TOAs face.

Due to the pre-commercialization phase of CCS technology systems, most TOA efforts are observed in the areas of: *knowledge sharing and co-ordination* and *RD&D activities*. Furthermore, ‘enabling environment’ parameters – a central item examined – were found to be extensively addressed by ongoing activities that can be placed within the sphere of TOA initiatives. However, the activities being addressed are largely ‘precursors to technology transfer’ rather than transfer of technologies *per se*. Moreover, such activities are largely conducted between industrialized countries at this point in time.

Given current policy and market conditions, carbon markets appear marginal or inadequate for CCS applications to be economically viable without (potentially significant) additional support. This is especially so for industrial-scale demonstration plants that must emerge in the near future. This could hamper or delay the commercialisation of such systems – and thus exacerbate challenges in achieving scale economies for application. The current climate of uncertainty surrounding climate policy (and thus carbon markets) poses a significant barrier to the establishment of market confidence for early movers in the European market. This also reinforces belief that incentives additional to the carbon market will be required if CCS is to become a financially viable option for the targeted industrial sectors.

This analysis does find that a number of CCS components are both sufficiently mature to be ‘transferred’ – and sufficiently ‘certain to be needed’ that transfer initiatives must take place. However, when the CCS technological system is viewed as a whole, it is not yet ready for establishment in industrialized countries, let alone ready for full transfer to the developing world. There remain numerous technical, financial, institutional, social and environmental issues to be addressed and overcome before key

stakeholders (e.g. industrialized country utilities) engage at large scale.

7.4 Energy efficiency in buildings

Regarding energy efficiency in buildings, the preferred way forward within the UNFCCC framework is probably through nationally appropriate mitigation actions (NAMAs). This report has proposed a relatively straightforward approach, where non-annex I countries may receive funding if presenting credible packages of policy instruments, supportive actions, and evaluation and enforcement mechanisms. Funding should not be given for just “additional costs”; an effective scheme also requires funding for capacity-building efforts. Evaluation of such packages must make use of both qualitative and quantitative approaches. Funds should be provided in phases, and reward high-performing actors. This analysis has found that such a system the only reasonable way to go forward, though controversies will no doubt arise. The NAMAs approach requires an intelligent design to find a balance between effectiveness and “fairness” considerations.

This study also concludes that a platform for sustainable buildings initiatives should be formed that can act as a coordination body for different national and regional initiatives, fund strategically important pilot projects, and deliver key functions related to dissemination of best practices and set-up of networks and educational activities. With the proper institutional set-up, such a platform can also lobby for its policies in relevant settings, such as the Green Goods negotiations, standardization processes, and policies and guidelines for official development assistance (ODA) projects.

7.5 Energy efficiency of appliances

Concerning appliances, specific international agreements will be very difficult to negotiate and implement, for several reasons, but due to the transferability of standards, it is important that developed countries continue to set stricter standards. The recent trend to focus more on functions provided than product groups *per se* should be supported, as this approach will be very important in the future.

The main potential role that this analysis has found for policies within the UNFCCC framework is the potential applications of NAMAs, taking into account the special needs required. Funds should be provided to develop capacity for monitoring and measurement,

market surveillance, participation in international for standard-setting etc. Such efforts should be coordinated with other ongoing, initiatives that aid developing countries to deal with product standards in order to gain access to global markets.

Finally, it should be noted that the authors of this report have doubts that the CDM (or programmatic CDM), except possibly in a much revised form, can be a suitable instrument to deal with energy efficiency in buildings and appliances. It is also very doubtful if sectoral approaches are a feasible or desirable way to proceed in these areas.

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Advancing technology transfer for climate change mitigation

Considerations for technology orientated agreements promoting energy efficiency and carbon capture and storage (CCS)

IIIEE Report 2009:3

Technology and technology transfer have emerged as key issues in recent climate change negotiations. This study examines a number of critical (pre)conditions for technology oriented treaties that can effectively promote technology transfer – both within or outside the UNFCCC framework.

This study addresses two technology spheres.

1. Carbon capture and storage (CCS) technologies, with a focus upon technology status implications, technology availability, and the significance of capacity-related issues for large scale implementation.
2. Technical applications for energy efficiency within the building sector, including:
 - i) building envelopes, materials, mechanical services, and lighting systems; and
 - ii) domestic appliances.

The study discusses potential pathways for promotion of these technology systems.