Environ Dev Sustain (2010) 12:89–102
DOI 10.1007/s10668-008-9182-z

The clean development mechanism—catalyst for wide spread deployment of renewable energy technologies? or misnomer?

Alexandros Flamos

Received: 18 July 2008 / Accepted: 10 December 2008 / Published online: 8 January 2009

Abstract The (usually not professed) truth is that we are not destroying the planet due to lack of technology, but due to lack of application of technology. Indeed, opportunities exist for renewable energy technologies' diffusion under the new climate change regime as they contribute to global sustainability through GHG mitigation and, they conform to national priorities by leading to the enhancement of local economic activity, capacities and infrastructure. The clean development mechanism (CDM), although is considered one of the global policy tools to contribute to sustainable development and technology transfer, has recently been criticised for its unequal distribution of projects across countries and for insufficiently being embedded in developing countries' national energy context. In the above framework, this article presents the ENTTRANS approach, five indicative renewable energy technologies, and insights about a more effective application of CDM, which may be part of the international process striving towards sustainable development.

Keywords Renewable energy · Sustainable development · Technology transfer · Clean development mechanism

Abbreviations

CERs	Certified emission reductions
CDM	Clean development mechanism
CO2	Carbon dioxide
EC	European commission
EU	European union
GHG	Green house gas
HFCs	Hydroflurocarbons

Readers should send their comments on this paper to: BhaskarNath@aol.com within 3 months of publication of this issue.

A. Flamos (✉)
Management & Decision Support Systems Lab (EPU-NTUA), School of Electrical and Computer Engineering, National Technical University of Athens, 9, Iroon Polytechniou str., 15780 Athens, Greece
e-mail: aflamos@epu.ntua.gr

IEA	International energy agency
IFIs	International Financing Institutions
IPCC	Intergovernmental Panel on Climate Change
NGOs	Non Governmental Organisations
N_2O	Nitrous oxide
PFCs	Perfluorocarbons
PV	Photovoltaic
R&D	Research & development
RES	Renewable energy sources
RETs	Renewable energy technologies
SD	Sustainable development
UNFCCC	United Nations Framework Convention on Climate Change
WEC	World Energy Council

1 Introduction

As globally greenhouse gas (GHG) emissions are already higher than the worst-case emissions scenario envisaged by the Intergovernmental Panel on Climate Change (IPCC), it is imperative that industrialised nations act immediately to make large cuts in emissions and in parallel developing countries are assisted in striving towards more sustainable energy paths. It is clear that GHG emissions in developing countries will overtake those of industrialised countries within the next few years. Without a change in direction there is a serious risk that the objective set out in the EU's post-2012 climate change strategy to limit the average global temperature increase to 2°C will not be met.

Moreover, it has been increasingly acknowledged at international discussions and negotiations that the issue of climate change cannot be seen in isolation of such issues as poverty alleviation and energy security of supply. For instance, poverty in developing countries could be alleviated by offering to rural communities reliable, affordable and sustainable (with a view to local aspects) energy technologies (e.g. decentralised systems such as mini-hydro or solar energy), which would be in line with the Millennium Development Goals. As these technologies often also reduce or avoid GHG emissions, such projects would also address the climate change issue.

The clean development mechanism (CDM), is a mechanism for project-based emissions trading that enables project co-operation between industrialised and developing countries (UNFCCC 1998). The GHG emission reductions resulting from CDM projects can be sold as credits to an industrialised country. In addition to the GHG emission reduction objective, CDM projects, according to the definition of the mechanism in the Kyoto protocol (UNFCCC 1998; Article 12.1), must also support the sustainable development of the host countries. The CDM has officially been operational since 2000. However, it remains to be seen how important the mechanism has been in terms of stimulating the technology transfer of GHG technologies to developing countries (Van der Gaast et al. 2008).

An overview of the distribution of CDM projects per category (as per August 2008) is shown in Fig. 1.

Renewable energy projects are most popular with a combined share in the project pipeline of 62%. An overview of the expected emission reductions of GHGs (i.e. expected certified emission reductions (CERs) for use during the first commitment period of the Kyoto Protocol, up to the year 2012) is shown in Fig. 2.

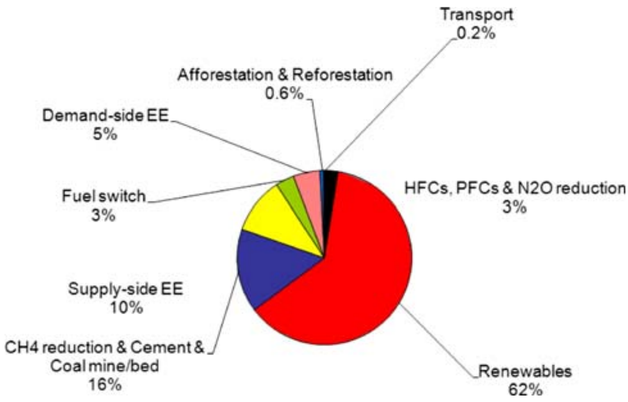

Fig. 1 Number (%) of CDM projects in each category (*Source*: UNEP RISOE 2008)

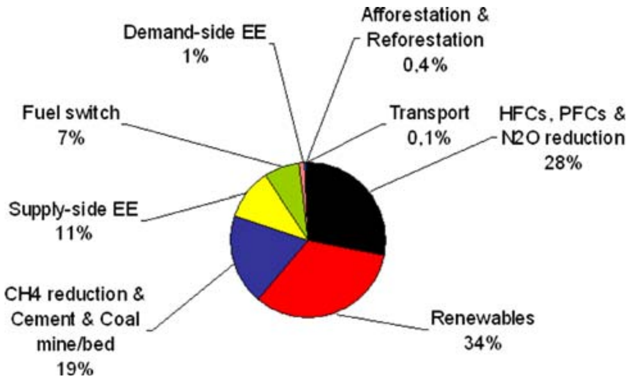

Fig. 2 Expected CERs (%) until 2012 in each category (*Source*: UNEP RISOE 2008)

A first aspect that attracts attention is that the distribution of expected CERs from the present CDM project pipeline is different from the distribution of projects across categories. For instance, Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Nitrous oxide (N_2O) emission reduction CDM projects, although representing only the 3% of the total number of CDM projects are expected to be credited the 28% of the expected CERs until 2012. HFCs have a purely anthropogenic origin and their global warming potential is 11.700 times as large as that of CO2. However, HFC abatement projects do not contribute significantly towards the achievement of Sustainable Development (SD) goals in the host countries (Schneider 2007; Olsen 2007; Pearson 2007; Schwank 2004). Indeed, the CDM could better facilitate the adoption of SD practices through the adoption and wide spread implementation of Renewable Energy Technologies (RETs). RETs meet the two basic conditions to be eligible for implementation under the CDM: they contribute to global sustainability through GHG mitigation and, they conform to national priorities by leading to the enhancement of local economic activity, capacities and infrastructure (EC Joule Thermie 1997). The problem that RET's knowledge is not easily fed into the countries' decision making process is evident, especially when there are attempts to set-up a series of ad hoc projects for the purpose of greenhouse gas emission reduction, rather than serving the overall policy objectives of the host countries.

In this regard, the European commission (EC) FP6 project with title "The potential of transferring and implementing sustainable energy technologies through the clean development mechanism of the Kyoto protocol (acronym: ENTTRANS)" (Foundation Joint Implementation Network 2008a) has applied a participatory approach for the acquisition of country specific information about the energy needs and requirements for an effective application of CDM under a new climate regime, which is characterised by the carbon constraints but also the raising green economy opportunities. One of the project outcomes was an analytical technology description document for sixteen technologies concerning electricity production, five technology options for heat production/consumption, two combined heat and power production technologies, nine technology alternatives covering cooling, lighting, and cooking needs, four technology alternatives regarding energy conservation in industry, three technologies for municipal solid waste management and one for carbon capture and storage (Foundation Joint Implementation Network 2008b).

This article presents insights that have been provided by the ENTTRANS project. Apart from the introduction, it is structured along four sections. Some methodological notes regarding the approach adopted for the elicitation of information are presented in the second section. In the next section, based on the presented structure, a brief review analysis is provided, concerning five particular CDM energy technologies: Hydro, Wind, Solar, Geothermal and Ocean energy, in terms of their perspectives for deployment and status in the developed world and their potential in the developing world. Section four is discussing the main points that could be drawn up for the presented technologies and the application of the CDM. Finally, the last section is the conclusions, which summarises the main points that have arisen in this article.

2 Approach

The ENTTRANS project has followed a three stage methodological approach in order to acquire the required data and to develop concise technology descriptions that report the current renewable energy technologies status, expected potential and benefits for developed & developing countries. The proposed methodological approach is structured along three steps as presented graphically in Fig. 3.

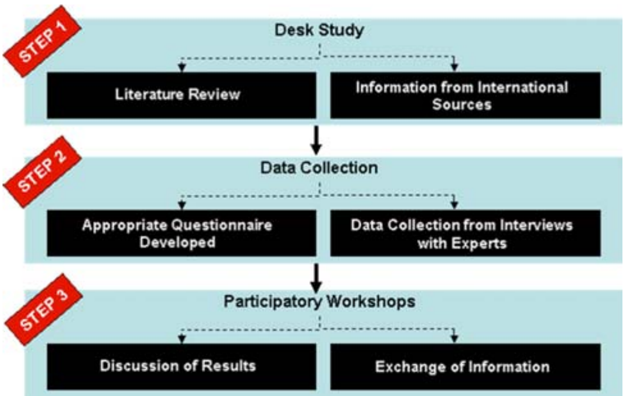

Fig. 3 Methodological approach

2.1 Stage 1. Desk study

The 1st stage involved a desk study for the examined renewable energy sources (RES) technologies providing an overview of the current status of these technologies in developing countries. In particular, the study included a literature review of the RES technology options for CDM projects development and analytical information collection from international sources and publications. The current penetration of the examined technologies in energy systems in various regions and an estimation of growing potential of the technologies with a view to research and development (R&D), availability of space and resources, social acceptability, etc. set the framework of this study.

2.2 Stage 2. Data collection

An appropriate questionnaire was developed for the examination of the technologies that would be appropriate with a view to the sustainable development benefits that could be delivered based on the stakeholders specific view (stakeholders have been asked to rank technologies according to economic, environmental and social benefits). Each question could be answered by assigning values from 1 (low priority, suitability) to 5 (very high priority, suitability). The stakeholders provided appropriate data, information and useful feedback to the interviewers. The stakeholders have been selected from government departments responsible for energy, environment and development, local governments, representative national and international companies or bodies in GHG intensive sectors (e.g. energy intensive industry), companies, industry and financial institutions involved in the manufacture, import and sale of environmentally sound technologies, international organizations and donors, local organizations, small businesses and other end-users of the technologies and practices in question, as well as Non Governmental Organisations (NGOs) involved in the promotion of environmental and social objectives.

2.3 Stage 3. Participatory workshops

Organisation of participatory regional workshops in Chile, China, Israel, Kenya and Thailand with the participation of key energy market players in order to collect appropriately structured information. Data gaps were filled and information crossover has taken place at country workshops. Moreover, the workshops atmosphere was appropriate for commenting, interpreting the proposed structure of the review, discussing the primary outputs and the main points that emerged so far. The study, therefore, ensured that the elaborated structure review of RES technologies is explicit, brief and targeted. The workshops enabled the active participation of all the key actors that have been involved in Stage 2.

This approach resulted in a set of brief RES technology descriptions with a view to the new climate change regime and particularly the umbrella of CDM, which would deliver an overview to decision makers. The structured review of these CDM technologies contains three main parts, as illustrated in the Fig. 4:

In particular, the structured review contains:

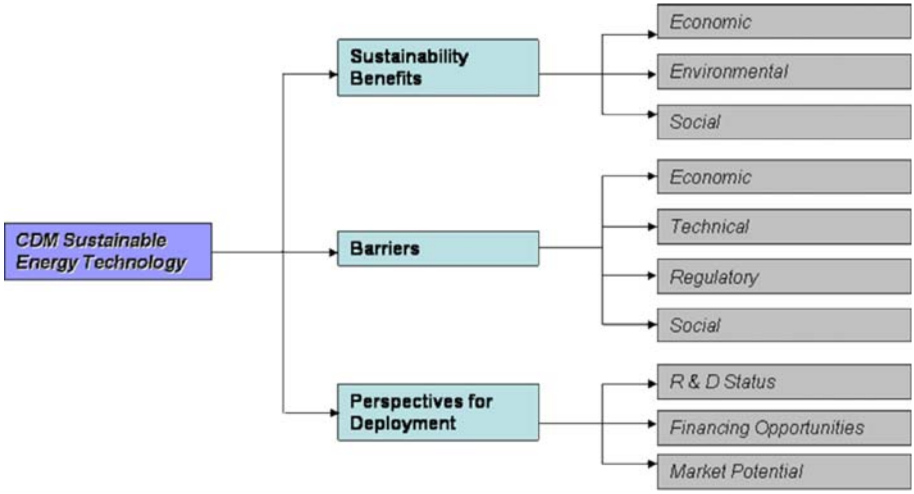

Fig. 4 The adopted structure

2.4 Sustainability benefits

Technologies' specific sustainability benefits are assessed in terms of:

- *Economic benefits:* Energy supply diversification, replicability potential in the host country, lower dependency on imported fuels, greater transmission reliability and grid stability, energy price stability, contribution to the country's overall economic development and employment, etc.
- *Environmental benefits:* Improvement of local air quality, GHG emission reduction, land protection, improved water management, solid waste management, ecological conservation, etc.
- *Social benefits:* Increased socio-economic welfare, poverty alleviation, health improvement, better education, empowerment through training, etc.

2.5 Barriers

The identified RES technologies are also examined in terms of the extent to which their implementation is presently hampered by a number of economic, technical, regulatory and social barriers. Examples of such barriers could be:

- Limited affordability of the technology due to relatively high implementation costs, energy costs and limited availability of local and regional financial resources;
- The existing domestic legal/institutional framework, especially with a view to existing energy subsidy policies, bureaucracy (e.g., in favour of conventional energy sources), non-transparent decision-making procedures, large-scale state-ownership of enterprises, availability of cheaper but less sustainable alternative technologies;
- Non-transparent investment climate, lack of investment protection, lack of knowledge of technology operation and management as well as limited availability of spare parts and maintenance expertise;
- Negative impact on community social structures, etc.

2.6 Perspectives for deployment

The study focuses on providing an overall picture of the RES technologies R&D status, financing opportunities and market potential in developing countries as well as in the rest of the world. The main topic areas that the current R&D activities focus on—the future trends in the R&D field, the existing financial opportunities for the examined technologies in terms of financial incentives, grants, which also influence the implementation of a CDM project as well as the market potential for each technology, the allocation of potential for power generation and targets around the world—are identified and presented.

3 Technologies review

The full technologies structured review analysis is available as a deliverable of the EC-FP6 "ENTTRANS" (Foundation Joint Implementation, 2008b). The aim of this section is to present the status of an indicative set of selected RETs in the developed and developing world.

3.1 Hydro energy

3.1.1 Developed world

This technology has been in use in Europe for hundreds of years. More than 80% of European Union's (EU) hydraulic capacity is installed in Italy, France, Spain, Germany and Sweden. Current average annual growth rate (2% for the 25 member EU) will bring the EU's installed capacity of small hydro up to approximately 13,000 MW in 2010 (Renewable Energy World 2006). Italy and France with more than 2,000 MW are the two countries best equipped with hydraulic installations (Lins and Laguna 2002). An improvement to the economic situation of producers, in parallel with a decrease in environmental constraints, is expected to increase the total contribution of small hydropower in the EU 15 member countries to a level that could reach 60 TWh at the decade 2020–2030.

3.1.2 Developing world

Asia, especially China (IC-SHP 2004), tends to become a leader in hydro-electric generation (Paish 2002). Markets such as South America (Taylor and Upadhyay 2005) and Africa also possess great, unexploited potential (Bartle 2002). Great potential also exists in several countries in the world, offering opportunities for a mature European industry to compete in an expanding market (Taylor and Upadhyay 2005). Under current policies, installed capacity of small hydro will increase to 55 GW by 2010 with the largest increase coming from China (World Energy Council 2001). In developing countries, hydropower development depends mainly on the economic growth and the increase in energy demand. Asia, especially China (IC-SHP 2004) and India (Iniyan and Sumathy 2003), is affirming itself as the leading continent for hydropower, with 83,000 MW scheduled to be installed (Renewable Energy World 2006). By contrast, Africa has only 2,000 MW of new installations planned. The economically viable world hydro potential is around 7,000 TWh per year, 32% of which have already been exploited with 5% devoted to small-scale installations (Bartle 2002).

3.2 Wind energy

3.2.1 Developed world

All the major wind energy manufacturers have established local manufacturing abroad at various levels or are considering such expansion in emerging markets in South America and Asia (IEA 2007). The most successful wind energy markets in recent years have been in Europe, particularly Denmark, Germany and Spain (Herbert et al. 2007). The fast development of wind power capacity in countries such as Germany and Denmark (Baroudi et al. 2007) implies that most of the wind sites with significant potential have already been exploited. Therefore, any new onshore (or land-based) wind turbine capacity has to be developed at sites with a marginally lower average wind speed. In the UK, wind energy is the fastest growing energy sector (Baroudi et al. 2007).

3.2.2 Developing world

The total available wind resource in the world today that is technically recoverable is 53,000 TWh per year (Joberta et al. 2007). The global wind energy market is expanding rapidly, creating opportunities for employment as well as upgrading the living standards and the quality of services provided, mainly in remote and isolated areas. A new impulse has also been provided to the use of the technology in many developing countries, including India, China and South America (Martinot 2003). Within the next decade, the Philippines hope to become the leading wind power producer in Southeast Asia. The country's goal is to double its renewable energy capacity by 2013 (Martinot 2003).

3.3 Solar energy

3.3.1 Developed world

Today, Europe is a net importer of photovoltaic (PV) cells, whilst PV production is growing faster in Japan. The European industry is well positioned to assume a world leadership role in the expansion of this technology. Realising this objective requires a co-ordinated strategy incorporating both technology suppliers and users. The statistics show that whilst in 1994 only 20% of new capacity was grid-connected, this had grown to over 80% by 2005. The market forecast demand scenarios of analysts assume that worldwide industry revenues will reach approximately 14–17 billion € with annual PV installations between 3.2 and 3.9 GW in 2010 (World Bank 2006). Southern European countries will increase their market share dramatically as a result of their current policy.

3.3.2 Developing world

During the recent decade, more developing regions and countries mainly in North Africa, South East Asia and South America, are taking the challenge of PV solar energy usage in remote and isolated areas such as India, Kenya, Morocco and China. Their main incentive is their desire to supply electricity for the household's basic needs, which was still lacking even at the beginning of the 21st century. In Kenya, nearly 20,000 rural households use PV solar electricity. Kenya and India remain the main notable markets, where PV sales have emerged spontaneously without governmental or other subsidies (IEA 2007).

3.4 Geothermal energy

3.4.1 Developed world

The technologies needed for geothermal power and heat production have been proven and are used by around 60 countries in the world. The potential of geothermal power generation in industrialised countries is limited to those countries that are located in volcanic areas. Within the EU, Italy has the potential to generate geothermal electricity at significant levels followed by Austria, Portugal, Iceland and France. Since 2000, geothermal generation has tripled in France and Russia (Michaelowa and Jotzo 2005). Austria and Germany have been added to the list of those producing geothermal power. Assuming that the worldwide direct use growth of 50% during 1995–2000 will continue, the direct energy use production may be about 100 TWh in 2010 and 200 TWh in 2020 (Lund et al. 2005).

3.4.2 Developing world

The potential for power production through geothermal energy is mainly located in the ‘ring of fire’ around the Pacific Ocean and the rift valley in Eastern Africa (REN21 2006). Most of geothermal energy is produced in Asia when both geothermal heat and power production are taken into account. Geothermal power production has also been successfully developed in the Philippines, Mexico, Indonesia, Kenya and El Salvador (World Bank 2006), whilst Papua New Guinea has just entered the field. Countries as diverse as the Philippines, Iceland and El Salvador generate an average of 25% of their electricity from geothermal sources and geothermal serves 30% of Tibet’s energy needs (Renewable Energy Policy Network for the 21st Century (REN21) 2006). Indonesia, Philippines and Mexico aim at an additional 2,000 MWe before 2010 (Bertani 2005). In the direct use sector, China has the most ambitious target: substitution of 13 million tons of polluting coal by geothermal energy. Recently, in El Salvador a CDM project has been set up to generate electricity from geothermal energy (La Geo project) (Abraham 2006).

3.5 Ocean energy

3.5.1 Developed world

Wave energy is a niche market, with potential for increased exploitation in the future. The wave energy potential in the EU has been estimated conservatively as 120–190 TWh per year (offshore) and 34–46 TWh per year (nearshore) (IEA 2007). The main countries involved in the development of wave power are Denmark, Ireland, Japan, Norway, Portugal and the UK (Henfridsson et al. 2007). A conservative estimate indicates a future wave energy market (in 2010) of approximately 5.5 TWh per year. The largest tidal facility, the La Rance station in France, has a total capacity of 240 MW. The exploitable tidal energy potential in Europe is approximately 100 TWh per year from tidal barrages (mostly in France and the UK) and around 50 TWh per year from tidal stream turbines (mostly around UK shores) (Bernhoff et al. 2006). Scotland is committed to cover 18% of its power needs from green sources by 2010, including 10% from a tidal generator, which is expected to replace one huge fossil fuelled power station (Agamloh et al. 2008).

3.5.2 Developing world

Wave power could in the long term make an important contribution to the world's energy demand, on condition that it is developed up to the level where it is technically and economically feasible. A potential 2,000 TWh per year, or 10% of global electricity consumption (World Energy Council 2001), has been estimated, with predicted electricity costs of €0.08/kWh (Agamloh et al. 2008). India has successfully been involved in producing wave energy (Henfridsson et al. 2007). Three Asian countries have built (or are about to build) demonstration wave energy machines: China, India and Indonesia (Johnstone et al. 2006). The energy potential of tidal basins in the developing world is large. The extraction of energy from tides is considered to be a very promising and feasible solution in Korea, China, Mexico, Chile, on the Patagonian coast of Argentina and Western India (Agamloh). The Executive Board of the CDM has now registered the first tidal CDM project (the Sihwa Tidal Power Plant, South Korea).

4 Discussion

Although, it is widely understood that science and technology alone could not deliver global sustainable development (Nath 2003; Nath and Kazashka-Hristozova 2005), CDM has widely been acknowledged as a mechanism to assist emerging and developing countries in achieving a sustainable development path, with enhanced energy security of supply and lower greenhouse gas emissions (Flamos et al. 2008). On the other side, in its present form is insufficiently suited to help developing countries streamline the implementation chains for low-carbon technologies (Foundation Joint Implementation 2008a). Also, the CDM has proven that it mainly suits large-scale projects as small-scale GHG emission reduction projects have difficulties in covering the CDM transaction costs. In this framework and taking into account the recent criticism of CDM projects across countries and for insufficiently being embedded in developing countries' national energy strategies, through the ENTTRANS methodology we have tried to identify potential ways for improving the current situation. The implementation of sustainable energy technologies in the framework of CDM has to overcome many constraints. Based on the results of the review analysis, in general it can be noted that the market conditions in the developing world hampers, in many cases, the widespread deployment of RES technologies, due to a number of non technical barriers (regulatory, social, market, etc.). As an example, the current single buyer form and the power tariff structure, which is characterised by heavy cross subsidies of most electricity markets in the developing world, is mentioned, as one of the main reasons reducing the financial attractiveness of RES. Regarding each technology examined, the following points can be drawn up:

- *Hydro energy:* Large hydroelectric plants face limited difficulties in competing in the energy market with conventional generation, whereas small hydro, especially the very small and the low head plants, can normally only compete in isolated areas or in case of beneficial financing (e.g. soft loans, short pay back periods). Even if small hydro is a proven technology, obtaining financing is often difficult due to the unforeseeable production in the short term and the small scale of projects that could not attract financing with good terms from international financing institutions (IFIs). Carbon financing could act as an additional incentive for further technology deployment.

However, only the bundling of activities under big scale programmatic CDM could definitely act as a catalyst for the widespread implementation of this technology.

- *Wind energy:* Wind power is the most advanced and commercially available among renewable energy technologies and is amongst the cheapest and most competitive compared to the new installations of fossil fuel and nuclear generation for particular sites (especially for islands and isolated areas). Direct support for investment has been used to facilitate the wind market development in several European countries and the relative manufacturing industry. The CDM has acted as additional incentive for the implementation of large scale wind projects in the developing world and more than 100 wind projects have already been registered by the CDM executive board, of which more than 60 are large scale projects. Under the CDM umbrella the wind project proposers can easier access International Donors and Funds in order to achieve better than average commercial financing terms. A few social acceptability barriers are expected to be overcome with the required awareness campaigns. Programmatic CDM could be proved useful for bundling small wind exploitation applications.
- *Solar energy:* the investment attractiveness of solar applications vary significantly from one place to another, due to the differences in the relative availability of solar radiation, and the terms of financing for the procurement of equipment. Several EU countries are using fixed feed in tariffs for PV generation in order to facilitate the wide technological deployment of PV that is expected to strive towards lowering the prices of PV installations. Solar energy technologies have a significant potential particularly appropriate for developing countries and mainly in rural, remote and isolated areas. Currently, solar electricity generation is economically competitive only where grid connection or fuel transport is difficult, costly or impossible. Examples include satellites, island communities, remote locations and ocean vessels. PV installations in buildings (e.g. roofs) for electricity generation are an environmental friendly option for decentralised electricity generation in both developed and developing countries. However, the non existence of the required regulatory framework in most of the developing countries and the very high capital costs usually strangles the interest for this type of projects in developing countries. Programmatic CDM could play a pivotal role for the implementation of large scale interconnected solar power exploitation installations.
- *Geothermal energy:* The technologies needed for geothermal power and heat production have been proven and are used by many countries in the world and meets the electricity needs of some million people worldwide. However, in terms of exploration, confirmation, well drilling and field management, the technology is rather costly. Under the emerging electricity markets development, geothermal technologies and its supporting industries will face significant economic difficulties unless such installations are supported with beneficial taxation and other economic benefits. Programmatic CDM is expected to face difficulty in the application of commonly accepted methodologies for baseline calculation.
- *Ocean energy:* Uncertainties about the cost and technical performance of wave energy schemes, especially offshore ones, must be overcome before large-scale commercial investment can be attracted. Tidal barrages and tidal stream turbines are commercially unattractive at present and no further deployment is anticipated before 2010. Ocean energy technologies supply power continuously, rather than intermittently like solar and wind generation. On the political and public levels, the profile of wave power appears to be relatively low, with significant differences across Europe. Significant capital expenditure will be required at the outset of wave energy projects; hence fixed

feed in tariffs and a secure market for electricity sales is the key to gaining the confidence of investors.

The participatory approach of ENTTRANS provided the insight that the discussion about RETs should not always be "what the north should be transferring to the south". It is considered of crucial importance to identify the barriers hampering the wide spread implementation of readily available RETs that are not effectively deployed. The ENTTRANS adds to regular technology needs assessment approaches the insight that the choice of low-carbon energy technologies is preferably derived from countries' energy service needs information and demonstration of practicality in country context. Also under the CDM, technologies are often selected because they generate CERs, and only in a few countries CDM technologies are selected because they meet systematically and clearly defined domestic energy service needs. The issue of familiarity of stakeholders with low-carbon energy technologies should also be highlighted and not underestimated. The CDM in its present form could easily lead to lock-in effects into existing and known technologies so that the mechanism presently can only limitedly contribute to low-carbon energy technology transfer to developing countries. Therefore, should the full technology transfer potential of the CDM be used, the familiarity of energy and environment policy and decision-makers in developing countries with new technologies must be increased. Obviously, the next step is to look at technology implementation chains in the CDM host countries. This conclusion is much broader than regular CDM barrier assessments focusing on capacity, transaction costs and CDM credit prices. The comparative presentation of Renewable Energy Technologies status in developing and developed world would also like to show that high opportunities exist in developing world for the adoption of SD practices towards their economic development. The last century industrialisation process has adopted unsustainable strategies that are important to be considered as a case to be avoided by the current developing countries.

5 Conclusion

The article provides an overview of five indicative RES technology alternatives and their perspectives for deployment in developing world. The attractiveness of the presented RES technologies as regards their potential for implementation as integrated activities of programmatic CDM, is also briefly discussed. It should be mentioned that in the framework of the ENTTRANS project this structured review of RES technology alternatives proved to be useful to decision makers and energy experts and facilitated the participatory workshops organised in each case study country (China, Thailand, Chile, Kenya, Israel); for the assessment of their sustainable energy needs and priorities, and technologies suitable to fulfil these. One important aspect that has been addressed by the ENTTRANS is the lack of familiarity with new technologies. ENTTRANS has shown for five potential CDM host countries that lack of familiarity with new low-carbon energy technologies among energy and environmental stakeholders could easily result in a focus, when elaborating on a sustainable energy strategy, on technologies that already exist in a country and/or that stakeholders are familiar with. The CDM could play a role in this respect by enabling demonstration projects, which involve technologies that follow from clearly assessed energy service needs in the host countries. In addition, through a programmatic CDM project people could become familiar with the technology which could then create knock-on effects to the rest of the economy. By doing so, CDM projects would become an integral part of national energy strategies instead of ad hoc projects to satisfy industrialised countries demand for CERs. Therefore, should the full technology transfer (both north–south and south–south) potential of the CDM be used, the familiarity of energy and environment policy and decision-makers in developing countries with new technologies must be increased. The choice of which technologies to be transferred to and implemented in a country must begin with an assessment (with stakeholders) of the country's energy service needs and priorities (e.g. modern energy for rural communities, cooling technologies etc.). Then the low carbon and energy efficiency energy technologies most suitable to fulfil these needs should be identified together with the stakeholders. Subsequently, how such technologies can be implemented in the countries, what benefits they can deliver, and where the technology transfer system can be facilitated have to be explored. Finally, the analysis should lead to an assessment of how CDM can best support the technology transfer process.

In any case, it has to be clarified that CDM is not considered a panacea for the achievement of sustainability, but as a "tool" that may facilitate the adoption of more sustainable paths of development than those adopted by the developed countries during the previous century large scale industrialization. A significant perspective for further research in this area is to elaborate on technology implementation chains and to explore how ad hoc CDM project implementation will be bundled in programmatic CDM activities and how these activities will be incorporated into an integrated sustainable energy strategy for the developing countries, serving the threefold energy policy objective of security of supply, environmental protection and competitiveness.

Acknowledgements This article was based on research conducted within the "ENTTRANS: The potential of transferring and implementing sustainable energy technologies through the Clean Development Mechanism of the Kyoto Protocol" FP6 project, funded by the EC (EC-DG Research FP6). The author would like to acknowledge the support from the EC. Furthermore, the author wishes to thank the valuable suggestions and comments made by Mr. Wyzte van der Gaast (senior researcher of the Foundation Joint Implementation Network, JIN) and his colleagues at the National technical University of Athens, Prof. J. Psarras, Dr. H. Doukas and Mrs. Chara Karakosta. The content of the article is the sole responsibility of its author and does not necessary reflect the views of the EC.

References

Abraham, J. (2006). Investment prospects for geothermal power in El Salvador's electricity market. *Energy Policy, 34*, 3877–3886. doi:10.1016/j.enpol.2005.09.009.

Agamloh, E. B., Wallace, A. K., & Jouanne, A. (2008). Application of fluid–structure interaction simulation of an ocean wave energy extraction device. *Renewable Energy, 33*(4), 748–757.

Baroudi, J. A., Dinavahi, V., & Knight, A. M. (2007). A review of power converter topologies for wind generators. *Renewable Energy, 32*(14), 2369–2385. doi:10.1016/j.renene.2006.12.002.

Bartle, A. (2002). Hydropower potential and development activities. *Energy Policy, 30*, 1231–1239. doi: 10.1016/S0301-4215(02)00084-8.

Bernhoff, H., Sjostedt, E., & Leijon, M. (2006). Technical note: Wave energy resources in sheltered sea areas—A case study of the Baltic Sea. *Renewable Energy, 31*, 2164–2170. doi:10.1016/j.renene.2005.10.016.

Bertani, R. (2005). World geothermal power generation in the period 2001–2005. *Geothermics, 34*, 651–690. doi:10.1016/j.geothermics.2005.09.005.

European Commission (EC). (December 1997). The demonstration component of the Joule-Thermie Programme, Energy Technologies, ETSU.

Flamos, A., Gaast, W., Doukas, H., & Deng, G. (2008). EU and Asian Countries Policies & Programmes for the Diffusion of Sustainable Energy Technologies, Asia Europe Journal, International Co-operation on Environmental Issues: Asian and European Perspectives, Springer, ISSN: 1610–2932.

Foundation Joint Implementation Network (JIN) (2008a). Final report, ENTTRANS: The potential of transferring and implementing sustainable energy technologies through the clean development

mechanism of the Kyoto protocol FP6 project, funded by the European Commission (EC-DG Research FP6).
Foundation Joint Implementation Network (JIN) (2008b). Synthesis report D5&D6, transferring sustainable energy technologies through the clean development mechanism—Technology descriptions.
Henfridsson, U., Neimane, V., Strand, K., Kapper, R., Bernhoff, H., Danielsson, O., et al. (2007). Wave energy potential in the Baltic Sea and the Danish part of the North Sea, with reflections on the Skagerrak. *Renewable Energy, 32*(12), 2069–2084. doi:10.1016/j.renene.2006.10.006.
Herbert, J., Iniyan, S., Sreevalsan, E., & Rajapandian, S. (2007). A review of wind energy technologies. *Renewable and Sustainable Energy Reviews, 11*, 1117–1145. doi:10.1016/j.rser.2005.08.004.
Iniyan, S., & Sumathy, K. (2003). The application of a Delphi technique in the linear programming optimization of future renewable energy options for India. *Biomass and Bioenergy, 24*(l), 39–50. doi:10.1016/S0961-9534(02)00089-2.
International Center on Small Hydropower (IC-SHP) (2004). Small hydropower in China: Policy and market overview.
International Energy Agency. (January 2007). Renewables in Global Energy Supply, An IEA Fact Sheet, OECD/IEA.
Joberta, A., Laborgne, P., & Mimler, S. (2007). Local acceptance of wind energy: Factors of success identified in French and German case studies. *Energy Policy, 35*(5), 2751–2760.
Johnstone, C. M., Nielsen, K., Lewis, T., Sarmento, A., & Lemonis, G. (2006). EC FPVI co-ordinated action on ocean energy: A European platform for sharing technical information and research outcomes in wave and tidal energy systems. *Renewable Energy, 31*(2), 191–196.
Lins, C., & Laguna, M. (2002).Development of Small Hydro Power, Examining the potential of small hydropower plants, Water Power, European Small Hydropower Association (ESHA).
Lund, J. W., Freeston, D. H., & Boyd, T. L. (2005). Direct application of geothermal energy: 2005 Worldwide review. *Geothermics, 34*, 691–727. doi:10.1016/j.geothermics.2005.09.003.
Martinot E. (July–Aug 2003). Renewable energy in developing countries—Lessons for the market, Renewable Energy World.
Michaelowa, A., & Jotzo, F. (2005). Transaction costs, institutional rigidities and the size of the clean development mechanism. *Energy Policy, 33*, 511–523. doi:10.1016/j.enpol.2003.08.016.
Nath, B. (2003). Education for sustainable development: The Johannesburg summit and beyond. In L. Hens & B. Nath (Eds.), *The world summit on sustainable development: The Johannesburg conference* (pp 275–298). The Netherlands: Springer, ISBN 1-4020-3652-3.
Nath, B., & Kazashka-Hristozova, K. T. (2005). Quo vadis global environmental sustainability? A proposal for the environmental education of engineering students. *International Journal of Environment and Pollution*, *23(1)*, 1–15, ISSN o957-4352.
Olsen, K. H. (2007). The clean development mechanism's contribution to sustainable development: A review of the literature. *Climatic Change, 84*, 59–73. doi:10.1007/s10584-007-9267-y.
Paish, O. (2002). Small hydro power: Technology and current status. *Renewable and Sustainable Energy Reviews, 6*(6), 537–556. doi:10.1016/S1364-0321(02)00006-0.
Pearson, B. (2007). Market failure: Why the clean development mechanism won't promote clean development. *Journal of Cleaner Production, 15*, 247–252. doi:10.1016/j.jclepro.2005.08.018.
Renewable Energy Policy Network for the 21st Century (REN21). (2006). Renewables, global status report 2006 update, REN21.
Renewable Energy World. (Jan–Feb 2006). Flowing to the East, small hydro in developing countries.
Schneider, L. (2007). Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement, Report prepared for WWF.
Schwank, O. (2004). Concerns about CDM projects based on decomposition of HFC-23 emissions from 22 HCFC production sites.
Taylor, S. D. B., & Upadhyay, D. (2005). Sustainable markets for small hydro in developing countries, Hydropower & Dams Issue Three.
UNFCCC. (1998). The Kyoto protocol to the United Nations framework convention on climate change, http://unfccc.int/resource/docs/convkp/kpeng.pdf.
Van der Gaast, W., Begg, K., & Flamos, A. (2008). Promoting sustainable energy technology transfers to developing countries through the CDM, *Applied Energy International Journal*, Elsevier, ISSN: 0306–2619.
World Energy Council. (October 2001). Survey of energy resources, London.
World Bank Independent Evaluation Group (IEG). (2006). *New renewable energy, A review of the world bank's assistance*. Washington, DC: The World Bank.