Fostering low carbon growth initiatives in Thailand

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Foreword

This document is based on the study "Fostering low-carbon growth initiatives in Thailand" sponsored by Agence Française de Développement. It is designed as a background and discussion document, reviewing selected information available, and synthesizing various contributions from administration, specialists and academics in Thailand.

The study was organized with three main objectives:

(i) Review of background information and relevant international scientific literature to build a framework of climate policy instruments;

(ii) Analysis and exploitation of existing scientific contributions in Thailand, and particularly presentations at the seminar hosted by Chula Global Network in 2009;

(iii) Exploration of relevant issues for future climate mitigation policies and further research to contribute to policy instruments.

The present document was prepared by the LEPII team of the EDDEN Research Unit (CNRS, University of Grenoble: Prof. Patrick Criqui - CNRS, Scientific Director, Dr. Pierre-Olivier Peytral - EDDEN Lab, Economist, and Dr. Jean-Christophe Simon - IRD, Senior Economist), in collaboration with Chula Global Network (CGN, Chulalongkorn University), presided by Prof. Suthiphand Chirathiwat (coordination of the seminar by Prof. Charit Tingsabadh).

The study was supervised in Thailand by a Scientific Committee, chaired by the Office of the Secretary General, NESDB of Thailand, in coordination with Chula Global Network at Chulalongkorn University and Agence Française de Développement.

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Summary

The current debate on climate strategy and low-carbon economy has increased in complexity: negotiations on the international scene are lacking clear prospects (the forthcoming UNFCC preparation of the Durban 2011 meeting is indeed a challenge, following disappointment over past conference outcomes), while the world economic context, international governance and growth prospects remain highly uncertain. In spite of these difficulties, contributors to the study "Fostering low-carbon growth initiatives in Thailand" consider that there is a major opportunity for Thailand to address climate change mitigation as part of its overall development strategy, within the 11th NESDP (2012-2016).

We strongly believe that Thailand could maximize the benefits of proactive strategies to address climate change adaptation and mitigation by strengthening and expanding already substantial efforts and existing policies (see cases in Part 4). It is also considered that climate policy can be seen as a relevant component of both sustainable development strategy and promotion of national competitiveness.

Several key points can be stressed here regarding climate change mitigation strategies and policies in Thailand:

- A set of existing policies has already been implemented, mostly focused on the energy sector.

- Substantial experience of government departments and agencies has built up over the past two decades in identifying options, coordinating exchanges of views and implementing targeted policies.

- A national scientific potential is already established, with a diversity of expertise and a capacity for nationwide field work. Coordinated initiatives of the private sector have been diverse and substantial in major sectors of activity.

- Growing awareness in civil society, which is nevertheless combined with entrenched attitudes, resistance to change in everyday life, as in most other countries, whether developed or developing.

Recent policy debate, backed by a strong corpus of scientific analysis, considers that a national strategy for Green Economy, or Low-Carbon Economy, should comprise both cross-sector policies and targeted sector-oriented policies.

A preliminary analysis of the existing policy mix in Thailand shows several areas where policies are currently not fully developed and require further efforts and coordination (*e.g.* transport sector, provincial urban areas, low density residential, forestry and land conservation). Revision or upgrading of some existing policies should also be considered (such as the renewable energy programme and CDM projects).

In addition, the expansion of low-carbon initiatives increases opportunities for the promotion of innovations to strengthen the framework of a Green Economy in Thailand, provided sufficient efforts are made to facilitate acquisition, local generation and technology appropriation. The decision to initiate a preliminary carbon-pricing system through a tax and/or an emission quota system for some sectors is both highly sensitive in political terms and topical as a way to raise public awareness.

Current economic analysis considers that the expected benefits of low-carbon strategy must be considered not only in quantitative terms (overall growth, job creation, foreign exchange gain), but also in qualitative terms, in terms of vulnerability and risk reduction, competitiveness re-building, social benefits and health improvement.

Besides the implementation of economic instruments for the environment, there should also exist a regulatory framework based on a system of norms and technical standards in order to favour environmentally friendly and Green economic activities and technologies. This system should aim at enhancing the level of performance in terms of energy efficiency and emission reduction, with adequate review of the level of severity and associated costs.

Therefore, this report advocates for a national strategy of Thailand that will face the ambitious goal of reconciling sustainable economic and social development with climate strategy. In that respect, government and public administrations should be proactive, promoting actions benefiting low-carbon activities in various economic sectors and contributing to awareness and behavioural changes in civil society.

The report presents a summary of some analytical elements from the first background paper and subsequent documents (February and June 2010). The framework for promoting Green Growth, its political challenge and current debate in Asia is reviewed, and then an initiative for Low-Carbon Economy in Thailand is considered (Part 1). A quantitative decomposition analysis for Thailand shows that there is significant room for action to strengthen low-carbon policy initiatives (Part 2). A review of several low-carbon scenarios contributes to the identification of relevant issues and policies for various sectors in the domestic context (Part 3). In order to understand policies promoting a low-carbon economy, the paper reviews a range of past and present measures and policy options through a policy Matrix approach. The report presents prospects and suggestions for low-carbon policy options and recommendations for further relevant investigations (Part 4).

1. The dual challenge of climate change and development

Since 1988, when the United Nations initiated the Intergovernmental Panel on Climate Change (IPCC), global warming has been increasingly perceived as a major challenge facing mankind. This has resulted in an internationally negotiated framework first implemented in the Rio Conference (1992), then developed through the series of Conferences of the Parties (COP), and particularly the milestones in Kyoto (1997), which promoted the flexibility mechanism, giving opportunity to developing economies to contribute to climate mitigation strategy, and more recently Bali (2007, COP-13), which promoted mitigation actions for developing countries.

There is now an almost general consensus in the scientific community on the fact that our societies and their technical and economic foundations have to experience an unprecedented transformation in order to reconcile economic growth and the need to curb carbon emissions. Climate change has indeed become a paramount element both for debate in civil society and an inspiration for fresh scientific investigations in all major scientific areas. In addition, mitigation and adaptation strategies to face the challenge of climate change are now a key component of overall development strategies, providing ample justification for strengthening exchanges of views between scientists and all bodies and public institutions concerned with economic and social development.

The above-mentioned issues show special relevance in the developing or emerging world where the past decades have shown clear evidence of the increasing opportunities and constraints related to rapid industrialization in a globalized economy. This is particularly true of the Asia and Pacific region, which has been the fastest growing region in the world for several decades (Stiglitz and Yusuf, 2001). Rapid growth, based on export-oriented industrialization and tremendous diversification of production and activities, has lifted millions of people out of poverty. It has been made possible though dynamic changes with new socio-technical systems shaping production, communication and consumption (Rock and Angel, 2005). But up to now these systems have been heavily technology and energy intensive.

Thus, rapid industrialization in emerging Asian economies has also boosted demand for energy and raw materials, contributing to price increases in world markets (although prices are currently falling, most analysts expect them to move upwards again when the global economy recovers). At the same time, stronger demand has led to natural resource depletion as well as environmental degradation and increasing carbon-dioxide emissions over the past decades.

Consequently, there is a dual rationale for a transition to Low-Carbon Economy: it is expected to increase flexibility and security of supply through better management of energy requirements and sources (thereby improving economic performance and international competitiveness), and it also addresses the climate and environmental challenges thanks to cleaner production, transport systems and improved energy and natural resource management[1].

[1] For further development see Asian Development Bank (2009) and OECD/IEA (2009).

Thailand is a telling case on these aspects – it has been one of the brightest Newly Industrialized Economies[2] over the past decades, experiencing remarkable diversification and international opening of its economy, whilst it has also suffered from severe environmental degradation. At the same time, it has initiated an active national debate on these issues and promoted thinking in international arenas such as the ASEAN. The Thai government has also designed and implemented a range of policy measures ranging from environmental protection to energy conservation and diversification, which opts for the so-called Green Growth approach presented below. In addition, the context of the financial crisis and the related fiscal stimulus initiative offer additional opportunities for well targeted publicly sponsored measures that strengthen the adaptation of Thailand's economy and prepare orientations for the next National Plan.

1.1 The relevance of the "Green Growth" agenda

We begin here by considering the Green Growth approach, in which low-carbon initiatives can be embedded in the longer run. This section offers an overview of the Green Growth approach. It briefly summarizes the origins of the concept of Green Growth, and illustrates some recent developments (1.1.1). It also analyses the relevance of Green Growth in the context of Asia, as seen by international institutions and some selected countries (1.1.2).

1.1.1 Green Growth: an area for political debate and a new scientific agenda

Over the past decade, the thinking on reconciling overall economic growth and environmentally friendly policies has led to coining the notion of Green Growth. It has enjoyed increased popularity over the past two years, due *(i)* to increasing flows of data and scientific analyses on global climate change impacts, and *(ii)* to the expansion of debates on environmental damages and climate change challenges. Should Green Growth be seen as a promising research area, or rather as a controversial issue for debate?

The idea of Green Growth has benefited from various prestigious contributors and promoters such as J.G. Speth, former Head of the United Nations Development Programme (presently at Yale University), United Nations Secretary General Ban Ki Moon (coining the Green New Deal) and former United States Vice President Al Gore. Further, international institutions, such as various agencies of the UN system, or more recently the European Union, have also increasingly referred to Green Industries and Green jobs as components of new foundations for growth. Therefore, Green Growth is probably a major opportunity to foster a full renewal in economic activities and technological packages in order to give an impetus to a more sustainable development pattern, both in developing and in already mature industrialized countries.

The OECD also endorsed the concept in its June 2009 ministerial meeting, issuing a "declaration on Green growth" that emphasizes:

(i) The need to jointly address the challenges associated with the current economic crisis issues with the targets of sustainability strategies through "Green Investment" and policies;

(ii) The crucial role of international cooperation in promoting low-carbon economies, through the development of adequate technologies and an institutional framework;

(iii) The strategic orientation for OECD member countries to encourage Green Investment, related knowledge and training capacities, and to engage in relevant policy reforms;

(iv) The willingness to share information, to initiate projects as well as to strengthen international cooperation with non-OECD member countries.

[2] Muscat (1995).

This OECD declaration suggests that Green Growth is a package-oriented approach to be considered in a global context: it is evidently associated with long-term climate change mitigation measures, with consideration for crucial international relations and interactions, but also emphasizes short-term policy and orientations for various sectors and activities of national economies.

The 2009 UNCTAD report also emphasized the need to promote national strategies and international negotiation/cooperation to reconcile growth, economic opening and climate mitigation. Thus, the idea of Green Growth can be connected to a larger set of scientific developments, ranging from industrial ecology to the "industrial transformation" approach that support holistic thinking to reconsider current development patterns and feed new ideas into strategies, beyond a simplistic consideration of environmental protection and incremental technological progress. Recent debate has flourished in the academic world illustrating the thought-provoking character of "Green Growth" – this being particularly true among economists[3].

1.1.2 Scope for the Green Growth concept in Asia

Green Growth is already high on the agenda in Asia, as seen through several major international debates over the past years. In 2009 in Manila, the International Conference on Green Industry in Asia (UNIDO, Manila declaration 10 September[4]) gathered senior officials from 22 Asian countries, who unanimously adopted the Manila Declaration on Green Industry in Asia and Framework of Action, which is the outcome document of the International Conference on Green Industry in Asia. This document affirms "[the necessity to investigate] *how industries in the region[5] can effectively manage the transition to resource efficient and low-carbon industry, and in the process sustain rapid economic growth and trade competitiveness. The Conference will discuss: (i) the policies and strategies that would enable countries in the region to successfully manage this transition; (ii) the regulatory and institutional framework as well as the support services that would be required by industry to shift to more sustainable patterns of production; and (iii) the new business opportunities that the shift to a resource-efficient and low-carbon economy would create and how countries in the region could benefit from such opportunities"*.

Throughout East Asia, and notably in Tokyo and Beijing, many meetings have already promoted scientific exchanges, debates and training on the transition to a low-carbon economy, green growth challenges and related issues and policies. A major area of debate on Green Growth in Asia has been initiated by UN-ESCAP. Its Green Growth approach acknowledges the need to reconsider sustainability issues and shift from previous economic and development models to New Green Growth patterns. UN-ESCAP proposes a five-track approach, adopted by the 5th Ministerial Conference on Environment and Development (MCED) held in Seoul in March 2005:

(i) Green Tax and Budget Reform
(ii) Development of Sustainable Infrastructure
(iii) Promotion of Sustainable Consumption and Production
(iv) Greening the Market and Green Business (measures envisaged range from green procurement policies to regulations for greening the supply chain or incentives and support for green innovation, green products and services)
(v) Eco-efficiency Indicators.

Recent experiences in Asia show some determination to tackle the double challenge of "a green stimulus package"in the current economic context and exploring Green Growth strategies. Major emerging Asian economies have also played a decisive part in negotiations while actively contributing to the international debate on climate change mitigation.

[3] See Aghion *et al.* (2009).
[4] http://www.iisd.ca/download/pdf/sd/ymbvol166num3e.pdf
[5] 10 September 2009 – Senior officials from 22 Asian countries adopted unanimously the Manila Declaration on Green Industry in Asia and Framework of Action, which is the outcome document of the International Conference on Green Industry in Asia - the Manila Declaration and Framework of Action is a non-binding document.

Several examples can be mentioned at this stage:

China. A Green Growth policy orientation would combine a resource-saving society and a new industrial path. China has selected and targeted policies to slow carbon emissions, and develop resource-saving and pollution control options. A wide range of measures is being implemented. It is declared that this approach should alleviate environmental damage, reduce costs affecting activities and human life (*e.g.* the cost of pollution amounting to 3% of GDP in 2004). Recently, China implemented a fiscal stimulus with a "Green Growth" component: a two-year stimulus package of USD 585 billion (Yuan 4 trillion) was introduced in late 2008 to cushion the domestic economy against impacts of the global financial crisis. In this package, a significant amount of capital is dedicated to projects related to environmental protection.

Korea. The Republic of South Korea has been an early and proactive supporter of the Green Growth concept in Asia. The Green Growth strategy in the "Korean way" was announced in 2008 and is entitled "sustainable development in a low-carbon society". A national Green Growth commission was appointed in early 2009, chaired jointly by the President Lee Myung Bak and a senior academic, Professor Kim. A Green Growth planning office was also created to assist the commission. The current energy strategy has a 2030 horizon. Other components to be tackled in Green Growth include water and waste management. The President of the Republic of South Korea has pledged his support for Low-Carbon Green Growth as the core of the Republic's new vision. As addressed on the 60th anniversary of the founding of the Republic, the president believes that Green Growth will enable Korea to take a lead towards a low-carbon society[6]. As evidence of the regional scope of this emerging debate, the 3rd Policy Consultation Forum of the Seoul Initiative Network on Green Growth was held in parallel with the 8th "Asia Pacific Roundtable on Sustainable Consumption and Production", 18-20 September 2008, Cebu, Philippines. Korea has also been recently identified as the country with by far the highest green component in its 2008-2009 stimulus package.

Put simply, the Green Growth Approach provides a convenient framework for Climate Change policies, as it offers different levels of thinking and action:

(i) A common perspective for new ideas and strategies against global warming to be shared among Asian countries;

(ii) A flexible agenda for policy measures in various sectors, with a low-carbon Economy prospect;

(iii) Areas for fostering overall growth with job creation, innovation and creation of new activities;

(iv) A preliminary conceptual framework for negotiation and cooperation in climate mitigation actions, relevant for both developed and emerging/developing nations.

1.1.3 The quest for a low-carbon economy

The debate on the low-carbon economy is spreading throughout Asia – from advanced industrial economies, such as Japan, to emerging or even developing countries. Recent studies for China[7] show that the more economically advanced provinces in this country are also the least carbon intensive, while those with lower income and human development indicators tend to have higher carbon emissions patterns. The report makes explicit that human development does not necessarily need to generate greenhouse gas (GHG) emissions. As suggested in the following paragraphs, low-carbon scenarios may help to outline and envision a low-carbon society (LCS).

Japan is one of the leading countries promoting low-carbon scenarios and founded the LCS R–net[8]. The National Institute for Environmental Studies (NIES), together with other institutes, has developed visions for a low-carbon

[6] see http://english.president.go.kr/pre_activity/speeches/speeches_view.php?uno=270

[7] The preliminary findings of the 2009/2010 China Human Development Report for China, entitled "Towards a low-carbon Economy and Sustainable Society," were presented during a side event hosted by the UN Development Programme (UNDP) during the UN Copenhagen Climate Change Conference. See the main findings of the report on http://www.undp.org.cn/downloads/copenhagen/key_findings.pdf

[8] Low-Carbon Societies in developing countries was one of the topics that prompted intensive discussion at the LCS-RNet Inaugural meeting. See the first newsletter on http://lcs-rnet.org/pdf/Newsletter_Vol1.pdf

society and roadmaps for several cities in Asia. Modelling research on LCS in Japan suggests that a 70% to 80% reduction in GHG emissions could be achieved by 2050. This research helped to reduce public scepticism over Japan's ability to achieve a steep reduction in GHGs required for an LCS. Dr. Mikiko Kainuma (National Institute for Environmental Studies, Japan)[9] also pointed out that while innovative technology is important to realizing an LCS, policy support for technology dissemination is critical.

Therefore, achieving LCS is a major challenge, but there would be potential for multiple benefits such as energy security, air pollution reduction, green jobs and sustainable lifestyles. All these co-benefits would make the challenge much more manageable. In the Part 3 of this report, we will present the methodologies and tools available to build LCS, including details on the different issues at stake and the LCS study for Thailand (Shresta *et al.*, 2009[10]).

In spite of the mixed results of the negotiation at COP-15 in Copenhagen, a new impetus was given in Cancun to foster low-carbon activities and climate-mitigation policies. The debate on LCS continues to grow in importance as seen through several international symposiums and scientific conferences organized in Asia over the past years[11]. For all developing countries, the basic needs of the population must be met and economic growth must be pursued in order to ensure a better quality of life. To achieve this, developing countries must also seek to avoid the negative impacts - *e.g.* local air or water pollution - associated with growth in the conventional patterns and technologies. "Leap-frogging" strategies are required that skip or at least shorten the material and energy-intensive industrial stage experienced in the past by industrialized countries.

1.1.4 LCS and models of human development: the need to identify local initiatives and evaluate their contribution, cost and benefits

In that perspective, the sixth report from the Working Group on Climate Change and Development[12], launched before COP-15, argued that the chances of controlling climate change will rise dramatically if people recognize that there is not one but many models of human development. The report describes how the costs and benefits of global economic growth have been very unfairly distributed, with the lowest-income populations getting the fewest benefits and paying the highest costs. A wide range of examples of more positive approaches is derived from the extensive and practical experience of partners in the coalition. It presents a picture with more qualitative development, which should not be dependent on further global over-consumption by the already rich, considering false hopes that bits of poverty alleviation could benefit those at the bottom of the income ladder.

"Other Worlds are Possible" notes that differences between success and failure in the international climate negotiations will depend on whether governments and financial institutions continue to support outdated and failed economic approaches, with their policy frameworks, or whether they will move to encourage and replicate new approaches that take account of the deeply transformed economic and environmental circumstances. This timely report makes the case in compelling terms that there is not one model of economic development, but many to be tailored to local conditions.

Therefore, the aim of this document is not to deal with a generally defined economic development model, but rather to evaluate the economics of low-carbon strategies that may contribute to a transition to a new growth pattern, in a manner appropriate for Thailand. This takes into account the fact that the country has already experienced thought-provoking debate in that respect, most notably with explorations on qualitative development and sufficiency economy in previous National Economic and Social Development Plans.

[9] See report on the side event in COP15 at http://www.iges.or.jp/en/news/cop15/pdf/LCS-Rnet_summary.pdf

[10] For a quick overview of the key issues as well as session summaries of the Bologna inaugural meeting, one can refer to the synthesis report available through LCS-RNet Secretariat (http://lcs-rnet.org): "Achieving a low-carbon Society - Synthesis Report: Inaugural Meeting of the LCS-RNet [International Research Network for low-carbon Societies]."

[11] For example, The APN and the Hyogo Prefectural Government International Symposium "Challenge 25 Beyond Borders? Promoting a low-carbon Society" 23 January 2010 at the Hyogo Prefectural Museum of Art in Kobe, Japan. http://www.apn-gcr.org/en/indexe.html.

[12] New Economics foundation, 2009, featuring contributions from Dr Rajendra Pachauri, Prof. Herman Daly , Prof. Wangari Maathai, Prof. Manfred Max-Neef, Prof. Jayati Ghosh and David Woodward. See http://www.neweconomics.org/publications/other-worlds-are-possible

1.2 Fostering low-carbon initiatives and the transition to a new growth pattern for Thailand

1.2.1 Thailand's development: issues, ambitions and visions

Thailand presents a showcase Southeast Asian emerging economy. It has experienced six vibrant development decades, faced economic opening and globalization, and achieved tremendous modernization of infrastructures such as a diversification of production systems in major sectors. The current level of satisfaction with basic needs and human development is also remarkable. These economic and social achievements were actively sought by the Thai government in a constant effort to elaborate public policies within the framework of the National Economic and Social Development Plan, which has acquired an increasingly qualitative focus since its 8th edition.

The rapid economic development process, however, has not operated without costs. Alongside notable economic successes, the environment has indeed suffered significant degradations. Three major degradations or massive environmental externalities are noteworthy: *(i)* deforestation and land degradation, *(ii)* water resources and pollution, and *(iii)* air pollution (Kaosa-ard, 1993). While these developments induced severe environmental damage, the sustained growth and transformation of the country have undoubtedly contributed to the increase in energy consumption and hence to higher emissions of GHG, particularly CO_2 emissions (Sungsuwan-Patanavanich, 1991). Taken together, these factors are today putting at risk both economic growth and social welfare achievements experienced by the country over the past decades.

Growing energy needs have indeed directly reflected the sustained growth and transformation of the country, as in fact Thailand has taken a high-carbon-economy course over the past decades. This has also generated the constraints of dependence on energy imports, a burden on external accounts as well as on household expenses, and has required consistent policy initiatives to reduce vulnerability. While some actions were taken before, energy and environmental issues have penetrated deeper into the political agenda with the sixth plan, covering the 1987-1991 period[13]. Since then, these issues remain as key elements of public policy, with significant recent evolutions.

A major stone was laid with the Enhancement and Conservation of Environmental Quality Act, ratified in 1992. As described by the Thai authorities, this Act remains "*a key factor for promoting natural resources conservation and environmental protection in Thailand.* (…) *To further promote sustainable development, the Act also requires preparation of long-term environmental policies and medium-term action plans*"[14]. This mandate is set to promote energy conservation and energy efficiency in industry, construction and commerce. At the same time, an important focus has been placed on reforestation. Efforts have also been made to find solutions to the serious problem of imported energy dependency and increasing energy security. Finally, and not unrelated, political actions have been taken to develop new and renewable energy, particularly at the turn of the 2000s.

These past political actions and the underlying political concerns have been well crystallized in the energy policy and energy strategy formulated in 2009 by the Thai government. Indeed, the energy policy and strategy are organized along five main axes: *(i)* energy security, *(ii)* alternative energy, *(iii)* supervision of energy prices and safety, *(iv)* energy conservation and efficiency, and *(v)* environmental protection[15]. The degradation of the environment is exacting a heavy toll on human health and straining the country's health care systems. It is also straining the absorption limits of the ecosystems. In turn, these factors are jeopardizing the rapid economic growth that the country has experienced in the recent past. Tellingly, though, the Tenth Economic and Social

13 Ministry of Science, Technology and Environment (2000).

14 Ministry of Science, Technology and Environment (2000).

15 Abhisit Vejjajiva (Prime Minister) and Wannarat Channkul (Minister of Energy), 2009, "Thailand's Energy Policy and Energy Strategy", Paper delivered to the National Assembly, 30 December and 12 January.

Development Plan calls for an adaptation of the development pathway, which should take into account both major trends and increasing constraints in the contemporary situation. Prominent among these issues are national energy use and the preservation of the environment and natural resources.

Consequently, the 10th Plan advocates the vision of "… *Green and Happiness Society… in which people have integrity and knowledge of world standard, economy is efficient and stable, and equitable, environment is of high quality and natural resources are sustainable … and the country is a respected member of the world community*".

1.2.2 Low-carbon initiatives: initiating the transition towards a new growth pattern

Is there a favourable context for a new growth pattern in Thailand? The economy is currently facing a potential transition from rapid industrialization based on the diversification of manufacturing, experienced over a span of more than four decades, to a higher technology- and knowledge-content production system. On the one hand, the conditions of international and regional competition are changing, probably calling for new forms of negotiations and regulations. On the other hand, Green Growth orientations could establish a nexus between the consideration of qualitative improvement of economic and social welfare, adopted under the 10th National Plan, and current concerns for additional stimulus for the economy, following the recent financial crisis. In this context, initiatives to better control carbon-emission growth and promote development of low-carbon options in various domains could trigger a transition towards a more sustainable development pattern.

Although the Thai government ratified the United Nations Framework Convention on Climate Change at Rio in 1992, it has not been associated up to now with international commitments to reduce GHG. Thailand belongs to the list of the Non-Annex 1 of the UNFCCC. Also, while the measures taken since the early 1990s have potentially influenced CO_2 emissions and at least motivated a general concern toward sustainability, the political willingness or public policy commitment were not, properly speaking, oriented toward the reduction of carbon dioxide emissions. Indeed, it is only very recently that the political will to reduce CO_2 emissions has been affirmed. During the first half of 2008, the Thai government announced targets for reducing CO_2 emissions by 15 to 20 percent[16], compared to a reference projection, or no-policy case. This commitment was reaffirmed at the Copenhagen Conference of Parties (COP-17), the Thai government announcing a target of GHG emissions reduction in the energy sector by up to 30% by 2020[17]. However, this was not translated into a written letter of intent after the conference.

This political statement, clearly oriented toward the control and the reduction of CO_2 emissions, is certainly welcome. Indeed, estimates by the World Resource Institute indicate that Thailand's contribution to World CO_2 emissions is non negligible. In 2006, its emissions represented 0.83% of World total, ranking 25th among 140 countries (developed and developing). From the point of view of their dynamics, CO_2 emissions also increased very rapidly as estimated by the World Bank's Environment Department: between 1994 and 2004, when emissions increased by 72%, Thailand was ranked sixth in a group of 70 countries (developed and developing) in terms of CO_2 emissions growth rate (World Bank, 2007).

Thailand has thus placed itself on a carbon-intensive trajectory over recent decades, and a high one by international comparison. In this context, initiatives to better control carbon-emission growth, promote the development of low-carbon options in various domains of life and the socio-economic system could trigger the transition toward a low-carbon society, while taking the path of sustained green growth. A better understanding of the causes of past intensification in CO_2 emissions, of their potential evolution in the future and of the economic benefits and costs of more climate-friendly policies may inform political decision-making with the aim of creating a new growth pattern. However, the promises of a new impetus have to be

[16] UNEP (2008), "The Environment in the News", 31 March, http://www.unep.org/cpi/briefs/2008March31.doc#IRINThailand

[17] Bangkok Post, 15/12/2009, http://www.bangkokpost.com/business/economics/29289/goal-set-to-cut-energy-emissions-30

balanced against the obvious difficulties and challenges that will certainly be experienced throughout the process, as follows:

(i) Price increases, induced by policy measures such as a carbon tax or quotas, would certainly negatively impact production and make it more difficult for industries in the region to compete in world markets;

(ii) However, there is a growing consensus that the coming decades will witness increased pressures on countries in the region to shift to more resource-efficient and low-carbon production patterns as part of global efforts to slow the pace of climate change and other environmental degradation. It is thus argued that countries and regions that successfully manage this transition will be better placed to take advantage of the opportunities created by the shift towards a low-carbon world economy (UNIDO, 2009[18]);

(iii) This will imply changes at micro- and macro-economic level and require new policy tools to be analysed and managed, as well as new regulatory institutions;

(iv) This will also impose major changes of behaviours and lifestyles of the citizens, which will in turn imply considerations of fairness and solidarity.

18 Refer to http://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Events/2009/Green_Industry_Conference/concep.pdf

2 A retrospective analysis of CO_2-emission profiles in Thailand (1990-2008)

The purpose of this section is to analytically clarify the determinants of CO_2 emissions during the period 1990-2008. To this end, we use the structural emission/energy decomposition method, as popularized in the so-called "Kaya equation". The usefulness of this method is that the results obtained allow to identify the main determinants, among those pre-identified, underlying the dynamics in CO_2 emissions and thus provide guidelines for further policy action. This can be very useful for a country like Thailand, which in the future, according to the Bali Action Plan and the conclusions of the Copenhagen conference, will have to define Nationally Appropriate Mitigation Actions (NAMAs) at a macro and/or sectoral level.

In a first stage, the methodology of the approach of structural decomposition is exposed. In a second stage, the data set and the sources are specified. In the third and final stage, we proceed to estimate the structural effects for the economy as a whole and, separately, for the seven sectors included (agriculture, mining, construction, manufacturing, transport, electricity, residential and services). Results are then presented and commented[19].

2.1 Methodology of structural decomposition analysis

This stage exposes the approach of structural decomposition in three steps. A short review of the literature is then performed, while focusing on existing empirical studies for Thailand. The strengths and weaknesses of different existing approaches are put into perspective in order to choose the most suitable model for providing a complete and adequate decomposition (LMD method).

2.1.1 A short review of the literature

At the heart of the problem of CO_2 emissions decomposition lies the Kaya identity, named after its creator, Japanese professor Yoichi Kaya. As is well known, this identity captures the underlying factors that contribute to changes in aggregate CO_2 emissions. In the literary form used by Kaya and Yokobori: "*Environmental problems are caused by intensifying use of natural resources, in particular fossil fuels (the major form of energy used and produced), which in turn results from growing human economic activities. At the same time, economic development can also promote the development and use of environmental protection technologies. Further, economic development, energy use and production, and environmental degradation are taking place on a global scale.*" (Kaya and Yokobori, 1993).

With some knowledge in the field of applied energy economics, these few words can be put in order and reinterpreted as an equation. This will be rendered intelligible in the following sections. In return, this equation can then be used to estimate the differential impacts of a given number of distinct factors on CO_2 emissions, as implied in the previous statement of Kaya and Yokobori.

[19] Full decomposition analysis available in background paper, 2010, and on Lepii website (cf. Criqui *et al.*, 2010).

This is precisely the object of decomposition analysis: *"Decomposition analysis is a methodology used to decompose an energy aggregate or an energy-related environmental aggregate whereby the effects associated with several meaningful factors can be quantified*" (Sun and Ang, 2000).

Decomposition techniques are widely used and continuously developed. On the one hand, the extent of decomposition analysis has been greatly expanded to include the study of the consumption of energy, energy intensity, the elasticity of energy to GDP, material flows and dematerialization and energy-related gas emissions. These studies are then conducted at the macroeconomic level, by economic sector and/or by energy types. On the other hand, a growing number of publications relating to specific countries or cross-country/region have been registered. For instance, while Ang referenced 51 contributions in 1995, he noted just a decade later that some 200 publications had been reported on this subject (Ang, 1995, 2004; Zhang and Ang, 2001). Undoubtedly, qualitative improvement and quantitative expansion of scientific research in this area is related to growing political concerns about global warming.

By focusing on countries (or regions) covered by existing empirical analysis, it is clear that interest has initially focused on already industrialized countries like the U.S., the U.K., Japan, Italy, and other OECD countries. More recently, attention has also been paid to newly industrialized countries like Taiwan, Singapore or South Korea. In contrast, less marked interest was given to emerging economies (see Ang and Zhang, 2000). This discrimination in the interest expressed towards different countries can be seen as logical: industrialized countries belong to Annex I and are thus subject to emission constraints in the Kyoto Protocol. As a result, there is a more urgent need for this group of countries to elucidate the factors underlying the dynamics of their energy or emissions aggregate. Ultimately, this can help them to better define their policy actions. However, this kind of study will be more and more useful for emerging countries that express a political will to reduce their CO_2 emissions, or that have even already developed national policy actions or NAMAs directed towards this purpose[20].

Considering the emerging Thai economy in particular, only three studies to our knowledge have been dedicated to the structural decomposition of environmental impacts. Shresta and Timilsina (1998) in particular decompose NO_x-emission intensities from three determinants: technology-mix, fuel-mix and fuel-intensity. The sector analysed is the power sector in Thailand and Korea during the 1985-1995 period (time-series). The method used is an arithmetic mean with Divisia index. The following results are obtained:

- Each factor has contributed positively to the reduction of NO_x-emission intensities, fuel intensity being the main one, thanks to efficiency improvements in technology production.

- For fuel-mix and technology-mix, their positive contribution is attributable, respectively, to the substitution of gas for heavy fuel and to a change in technology production.

Punyong, Taweekun and Prasertsan explored energy efficiency in Thai industry from 1987 to 2002 (Punyong *et al.*, 2008). They have modified their 2-D, or two factor model, previously developed (2004), by adding the effects of the industrial economic structure (*i.e.*, specific Value Added in each economic sector), in addition to energy intensity and GDP. The result is a three-dimensional complete decomposition model that they use with complete time-series. They then apply this model to Thai industry, which is broken down into three main components: Mining, Construction and Manufacturing (the Rest of Industry). Finally, they proceed to a sensitivity analysis of energy savings. Three findings are obtained:

(i) The Thai industry as a whole had an increase in energy consumption of 1401.95 thousand [metric] tons oil equivalent (ktoe) in the 1987-2002 period.

[20] For references focusing on GHG emissions, see Ang and Pandiyan (1997) for China, Korea and Taiwan, Ang *et al.* (1998) for China, Korea and Singapore, Chung (1998) for China, Japan and Korea, Han and Chatterjee (1997) for nine developing countries, and Shrestha and Timilsina (1996, 1997) for twelve Asian countries.

(ii) While mining and construction have saved energy (25.84 and 145.84 ktoe, respectively), manufacturing has failed, and its increase in consumption is estimated at up to 1573.62 ktoe.

(iii) In terms of trends, energy saving in industry is a decreasing function of energy consumption and an increasing function of GDP, the first factor overwhelming the second.

As a result, they conclude that "*although having the Energy Conservation Promotion Act and Energy Conservation Fund as the tools, the success of energy saving in Thai industry has not yet been achieved. (…) Emphasis should be placed on [manufacturing] sector*" (*Ibidem*).

The Thai economy has also been integrated by Lee and Oh (2006) into an analysis focusing on CO_2 emissions in 15 out of 21 APEC countries between 1980 and 1992. However, their analysis, based on a complete decomposition method and period-wise analysis, proceeds by a grouping of countries in terms of income level so that Thai-specific results are not separately identified. However, these aggregated results may be useful to compare Thailand with some member countries of APEC.

Considering the limited range of studies concerning Thailand, the analysis below proposes to add an analytical element to the understanding of Thailand's emissions dynamics by providing a decomposition analysis. We first describe the approach and decomposition methodology that has been chosen for this purpose.

2.1.2 Approaches and decomposition methodologies

Different approaches and decomposition methodologies have been analysed and critiqued (Ang, 1995; Ang and Zhang, 2000; Sun and Ang, 2000; Zhang and Ang, 2001). The purpose was of course to scientifically establish the pre-eminence of one among them. This task can be considered as successfully completed by Zhang and by Ang (Ang and Zhang, 2000; Ang, 2004). The methods of decomposition that are the most intensively used remain those related to the Laspeyres and Divisia indexes. The Laspeyres index measures the impact of a factor by changing its value, while keeping constant other factors at their respective levels for the base year. The Divisia index is a weighted sum of growth rates, where relative shares of components in total value are the weights, expressed in the form of a line integral. Both indexes have been modified from their original form to refine the estimation method associated with them.

In its conventional (read original) use, the mathematical expression of the Laspeyres index gives rise to a residual factor (Ang, 1995; Ang and Zhang, 2000). This residue is not without posing a problem, while we seek to specifically identify the causal factors of an observed phenomenon. The higher the residual value is, the more difficult it is to interpret the results, if not impossible. The residual equally appears in the Divisia index, where the index takes the form of an arithmetic mean. Thus, these two indexes expressed in their conventional forms do not satisfy the factor-reversal test (Ang, 2004). The Laspeyres index, like the Divisia index, was refined with the specific aim of removing the residue. In compliance with the terminology used by Zhang and Ang (2001), a refined Laspeyres method has been developed by Sun (1998). The removal of the residue is performed by assigning the residual term to each effect taken into account. This is done using the "*jointly created and equally distributed*" principle. The Divisia index has equally been modified to suppress the residue, but using a logarithmic mean (Ang, Zhang and Choi, 1998).

Since each modified index allows removing the residue, it remains to be determined which of them should be used to make the CO_2 decomposition analysis. Decomposition can use the multiplicative or the additive technique. The multiplicative technique proceeds by calculating estimated impacts of a factor x from the ratio of its value of the target year T to that of the initial year 0 (*i.e.*, $X = x_T/x_0$). Conversely, the additive technique estimates the differential change of a factor x between the year T and the year 0 (*i.e.*, $\Delta x = x_T - x_0$). However, while both techniques are related under the Divisia index, these linkages cannot be established as clearly under the Laspeyres index. Finally, Ang added that the logarithmic mean Divisia index method should also be preferred because of its theoretical foundation, and its ease of use and interpretation of results (Ang, 2004).

Finally, it should be noted that the decomposition can proceed either through a time-series analysis or a period-wise analysis. The choice between the two remains conditioned by the availability of statistics, also considering that the first method is data consuming. However, the problem of the second is that taking the figures of the two years that define the period, it can hardly claim to account for a trend, being especially sensitive to the effects of random events occurring during the years selected (*e.g.*, rising energy prices). This being considered, we chose for our analysis the logarithmic mean Divisia index used in time-series analysis. This model is presented in the following sub-section.

2.1.3 Model specification: LMD method

We decompose the CO_2 emissions using a governing function that integrates four commonly used independent variables in line with the previous works of Kaya and Yokobori, such as:

$$CO_2\ emissions = \sum_{i=1}^{n} \underbrace{\frac{E_{it}}{EC_{it}}}_{pollution\ coefficient\ effect} \cdot \underbrace{\frac{EC_{it}}{VA_{it}}}_{energy\ intensity\ effect} \cdot \underbrace{\frac{VA_{it}}{G_t}}_{structural\ effect} \cdot \underbrace{G_t}_{activity\ effect} \qquad (1)$$

where n is the number of sectors in the economy; E_{it} the CO_2 emissions of the ith sector at time t; EC_{it} the energy consumption of the ith sector at time t; VA_{it} the value added of the ith sector at time t; G_t the GDP at time t.

Each of the four independent variables listed in equation (1) refers to a determinant effect in terms of CO_2 emissions:

(i) *Carbon intensity effect* ($E_{it}/EC_{it} = C_{effect}$). It reflects the carbon content of energy used by an economy. It measures changes in the energy mix, including fuel-switching and quality of fuel used, and applications of abatement technology;

(ii) *Energy intensity effect* ($EC_{it}/VA_{it} = I_{effect}$). It captures the ability of an economy to efficiently use the energy resources it consumes. Improved efficiency may come from policies implemented, technological changes and socio-economic behaviours;

(iii) *Structural effect* ($VA_{it}/G_t = S_{effect}$). It reflects the changes in the structure of production that take place during the development process, and thus the shift to more or less polluting industries;

(iv) *Activity effect* ($G_t = A_{effect}$). It is the theoretical CO_2 emissions caused by economic activities and the main determinant of emissions (Sun, 1999).

The change in CO_2 emissions between a base year 0 and a target year T is the sum of the carbon-intensity effect, energy-intensity effect, structural effect and, ultimately, activity effect, such as in an additive form:

$$\Delta E = E_T - E_0 \\ = \Delta C_{effect} + \Delta I_{effect} + \Delta S_{effect} + \Delta A_{effect} \qquad (2)$$

where E is the total CO_2 emissions. When subscript i is added to each effect, this effect is then estimated for the ith sector. For instance, E_i denotes CO_2 emissions for the ith sector.

In compliance with the foregoing, the decomposition proceeds by using the LMD method. With this method, and following Zhang and Ang (1999), each effect in the right hand side of Eq. (2) is given by:

$$C_{effect} = \sum_{i=1}^{n} \left[L(E_{iT}, E_{i0}) \ln(C_{iT} / C_{i0}) \right],$$

$$I_{effect} = \sum_{i=1}^{n} \left[L(E_{iT}, E_{i0}) \ln(I_{iT} / I_{i0}) \right],$$

$$S_{effect} = \sum_{i=1}^{n} \left[L(E_{iT}, E_{i0}) \ln(S_{iT} / S_{i0}) \right],$$

$$A_{effect} = \sum_{i=1}^{n} \left[L(E_{iT}, E_{i0}) \ln(A_{iT} / A_{i0}) \right],$$

where is $L(E_{iT}, E_{i0}) = (E_{iT} - E_{i0}) / \ln(E_{iT} / E_{i0})$ a log mean of CO_2 emissions in year 0 and year T.

This set of equations is applied for each sector taken into account. When assessment of empirical results proceeds for the economy as a whole, all these equations are conserved (subscript i disappears), except the S_{effect}, which is equal to one. Also, CO_2 emissions from the economy as a whole can be written as:

$$CO_2\ emissions = \sum_{i=1}^{n} \underbrace{\frac{E_t}{EC_t}}_{pollution\ coefficient\ effect} \cdot \underbrace{\frac{EC_t}{GDP_t}}_{energy\ intensity\ effect} \cdot \underbrace{\frac{GDP_t}{POP_t}}_{activity\ effect} \cdot \underbrace{POP_t}_{population\ effect}$$

As proposed first by Sun (1999), the preceding equations can be used to assess "theoretical" and "real" CO_2 emissions by sector and for the overall economy. CO_2 emission increases are due to effects, which can be depicted as "inevitable" because imputable to economic activity and/or demography. Taking into account the effects already identified, the A_{effect}, the S_{effect} and the POP_{effect} can be considered as "inevitable". In aggregate, we thus obtain "theoretical" CO_2 emissions. "Real" CO_2 emissions are logically induced by all the pre-identified effects of CO_2 emissions (*i.e.*, A_{effect}, S_{effect}, POP_{effect}, C_{effect}, I_{effect}).

Equations for "theoretical" (T_i^t) and "Real" (R_i^t) CO_2 emissions by the ith sector then can be written as:

$$T_i^t = E_i^0 + A_i^t + S_i^t \geq \mathrm{B}$$

$$R_i^t = E_i^0 + A_i^t + S_i^t + C_i^t + I_i^t$$

and for the whole economy:

$$T^t = E^0 + A^t + POP^t$$

$$R^t = E^0 + A^t + POP^t + C^t + I^t$$

The difference between (R) and (T) then represents an increase ($R>T$) or a decrease ($R<T$) of CO_2 emissions in a sector or in the overall economy. This differential in CO_2 emissions is thus attributable to the C_{effect} and the I_{effect}. Also, for convenience, we named this difference the "CO_2 emissions differential".

2.2 Data description: 1990-2008

This part focuses on the data set and their sources. The trends in energy aggregates or energy-related environmental aggregates chosen are then analysed over the 1990-2008 period (CO_2 emissions at aggregate and sectoral levels, Energy Consumption by sector, Value added by sector, GDP)

2.2.1 Data used

We use the Enerdata database (website) for energy use and CO_2 emissions. This database provides homogenized statistical time-series, year by year from 1990 to 2008. CO_2 emissions and sector-wise energy consumption are measured in thousands of tons, respectively of CO_2 and of oil equivalent (ktco$_2$ and ktoe). Seven sectors are identified: agriculture, mining, construction, manufacturing, transport, electricity, residential and service. Five types of energy are used: oil, natural gas, coal and lignite, biomass and electricity.

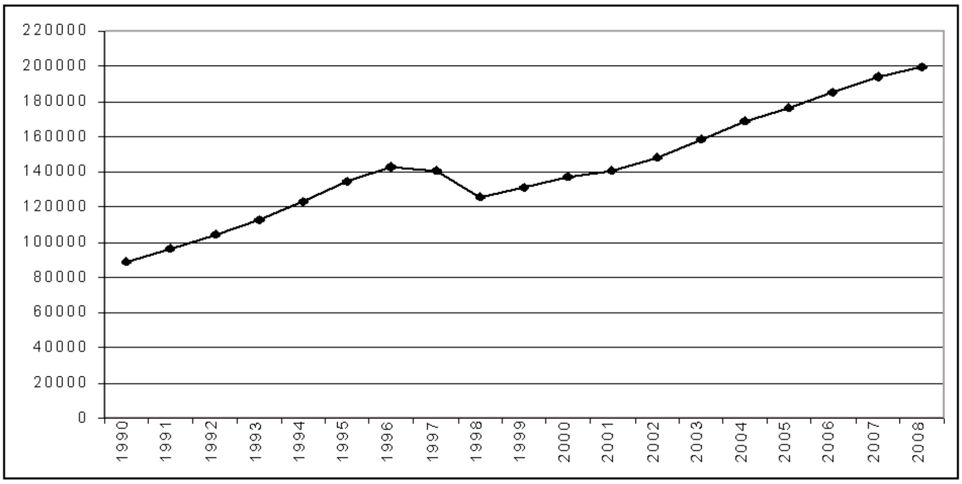
The GDP is equally collected from Enerdata and is expressed in USD in constant price and 2005 exchange rate. However, the distribution of the GDP by sector (in percent) is obtained from two other, complementary sources. The Energy Policy and Planning Office of Thailand website provides data for the period 1993-2008. The National Economic and Social Development Board (2003) gives data for the 1990-1991 period. In both cases, GDP (in millions of Baht at constant 1988 prices) is considered as the sum of the relative contributions of each of the seven sectors listed above. Because data on energy and CO_2 emissions for agriculture exclude forestry, we subtract the fraction of GDP of forestry in agriculture.

2.2.2 The dynamics of GDP: a disrupted process of rapid growth

From 1990 to 2008, Thailand's GDP has multiplied by 2.2, increasing from USD 89 billion (at constant 2005 price and exchange rate) in 1990 to USD 199 billion in 2008. Its growth thus proceeded at an average annual rate of 4.3% over the same period. However, as shown in Figure 1, this strong growth process was repeatedly disrupted. During the first half of the 1990s, the economy was in a dynamic growth process that began in the late 1980s, after a period of structural adjustments. From 1990 to 1996, the economy grew on average at a rate of 8.2%. However, the eruption of the Asian financial crisis in July of 1997 stopped this impulse. Economic activities then underwent a drastic slowdown: in 1998, all economic sectors showed negative growth rates, sometimes after several years of double-digit growth, depending on the sector considered. As a result, the economy as a whole recorded negative growth rates of -1.4% in 1997 and -10.5% in 1998.

The crisis was short-lived and GDP growth started to accelerate beginning in 1999 (4.4% yearly average growth rate). But the economy slowed in 2001, primarily as a result of the impact of the global slowdown on the industrial sector and on exports, coupled with sluggish domestic demand (ADB, 2001, 2002). The growth rate thus decreased from 4.8% *per annum* (p.a.) in 2000 to 2% p.a. in 2001. Growth bounced back in 2002 (5.3% p.a.) and 2003 (7.1% p.a.). A further slowdown began in 2004 (6.3% p.a.), more marked in 2005 (4.6% p.a.). This sluggish state of the economy can be attributed to a succession of unexpected events: tsunami, drought, avian flu, sporadic political unrest in the southern provinces and, not least, rising oil prices (ADB, 2005, 2006). The next period, 2005-2007, was a time of relatively stable growth, but the rate was substantially slower than in the early 1990s, *i.e.*, 4.9% .a. on average. Finally, growth fell to 2.6% p.a. in 2008. This is due to domestic political turbulence, which aggravated the economic impact of the global recession (ADB, 2009).

Figure 1 - Thailand's GDP, 1990-2008



Note: GDP USD at constant price and exchange rate 2005.
Sources: Enerdata - Global Energy & CO_2 Data (2009).

2.2.3 Value-added by sector: large structural changes

During this past growth process, the economy underwent major structural changes (see Fig. 2). The most notable one is that manufacturing took precedence over the agriculture and service sectors in the conduct of economic growth by the turn of the 2000s. This reflects the economic transformation with rapid industrialization in Thailand. The contribution of manufacturing increased almost continuously during the period considered, except in 1998, at an average annual rate of 6.1% from 1990 to 2008. Its share in total GDP thus trebled, increasing from 29.2% in 1990 to 40.1% in 2008. Its growth was most dynamic until 1997 (on average, 7.8% *per annum*). However, the rate was halved during the remaining period (4.1% p.a. in 1997-2008). The growth of manufacturing occurred primarily at the expense of the residential and service sectors[21]. While this latter sector was the principal contributor to GDP in 1990, its share declined from 41.1% to 33.3%, because of low average annual growth, 3.2% (lower than the average GDP).

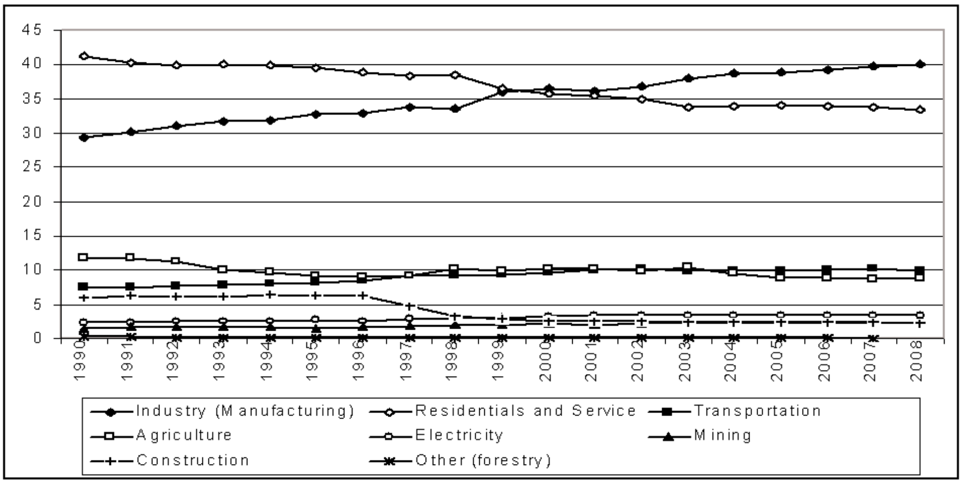
[21] In reference to EPPO classification, "Residential" includes "Private Households with Employed Persons".

The position of agriculture (excluding forestry) also suffered from manufacturing industry growth. Its share dropped from 11.8% in 1990 to 8.9% in 2008. In fact, the share of agriculture decreased during the first half of 1990, after which it remained relatively stable and grew at a positive but low average annual growth rate (2.7% p.a.).

The electricity sector has contributed little to GDP throughout the period considered, although its share has increased slightly from 2.4% in 1990 to 3.4% in 2008. Because of its low level in 1990, this sector grew at an average annual rate of 6.2%, *i.e.*, slightly higher than manufacturing industry. The mining sector is subject to the same observation. Its share increased slightly from a low of 1.6% to only 2.2%, respectively, but at an annual average growth rate of 6.2% p.a. In time, transportation contributed a slightly increasing share of GDP, from 7.5% in 1990 to 9.8% in 2008, a relatively high average annual growth rate of 5.8% p.a.

Finally, construction was the only sector for which the average annual growth rate was negative over the period, *i.e.*, -1.1% in 1990-2008. As a result, its share of GDP was divided by 2.7, decreasing from 6% in 1990 to 2.2% in 2008. In fact, the construction sector benefited from the real estate and construction boom induced by the high economic growth of the early 1990s. But it was then undermined by the bursting of the speculative financial bubble in 1997-1998, its share falling from 6.3% in 1996 to 2.5% in 2000. Subsequently, its contribution remained relatively stable, at around 2.4% on average from 2001 to 2008. Thus, construction never managed to regain its previous momentum.

Figure 2 - Value added by sector, 1990-2008



Note: Sectoral share in percentage of GDP.

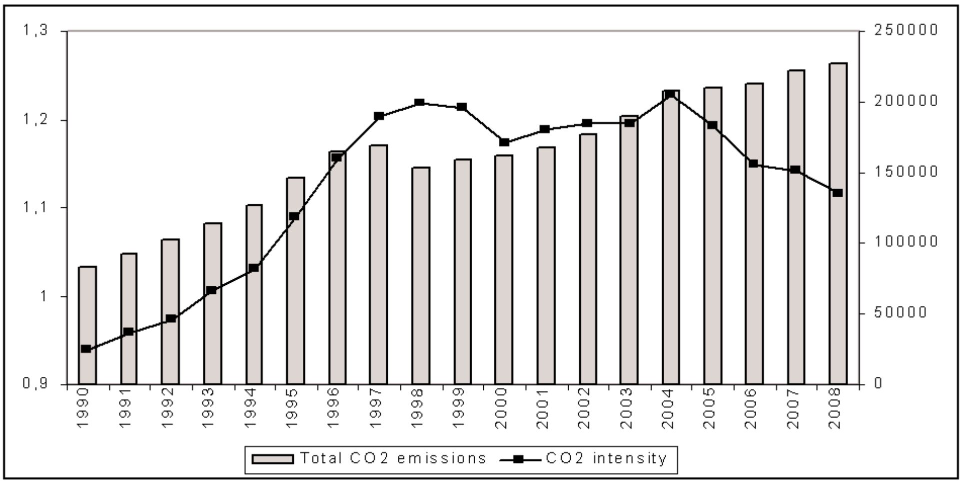
Sources: 1990-1991, NESDB (2003); 1993-2008, EPPO web site.

2.2.4 CO_2 emissions and CO_2 intensity at the aggregate level

During the 1990-2008 period, CO_2 emissions increased by 2.7, rising from 83,674 ktco$_2$ to 226,672 ktco$_2$ respectively (see Fig 3). This increase occurred at an average annual growth rate of 5.4%. In the same time, CO_2 intensity increased from a low of 0.94 ktco$_2$ /MUSD(constant price and exchange rate 2005) in 1990 to 1.12 ktco$_2$ /MUSD in 2008).

CO_2 emissions increased most significantly and most rapidly until 1997, increasing at an average growth rate of 9.2% in the period 1990-1997. Following the Asian crisis and the sharp slowdown in economic activity, CO_2 emissions declined significantly in 1998 (-9.3%). The emissions then increased again until 2004, but at a much slower pace than before, by an average annual rate of 2.6%, due to the slow recovery until 2002. After 2004 and the economic slowdown, CO_2 emissions increased moderately until new rises in 2007 (4.2%) and to a lesser extent in 2008 (2.3%).

Figure 3 - CO_2 emissions and CO_2 intensity, 1990-2008



Notes: left axis: CO_2 intensity defined as CO_2 emissions (in ktco$_2$) divided by GDP (at USD constant price and exchange rate 2005); right axis: CO_2 emissions expressed in ktco$_2$.

Source: See Figure 1.

Regarding CO_2 emissions, growth was more intensive in CO_2 until the Asian Financial crisis, increasing from 0.94 ktco$_2$/MUSD (constant price 2005) in 1990 to 1.22 ktco$_2$/MUSD (constant price 2005) in 1998. Also, one point of growth has produced on average 1.6 percentage points of CO_2 emissions during this period (see Table 1). During and following the Asian financial crisis (1997-1999), CO_2 intensity remained quite stable, but dropped significantly in 2000 to 1.17 ktco$_2$/MUSD, against 1.21 ktco$_2$/MUSD in 1999. Like CO_2 emissions, CO_2 intensity grew gradually until 2003. Because of a higher increase in CO_2 emissions than of GDP, CO_2 intensity reached a peak of 1.23 in 2004. From that moment, CO_2 intensity began a gradual but significant decline, reaching 1.11 in 2008. This is due to a reduction in the growth rate of emissions being greater than that of GDP.

In spite of growing CO_2 emissions, CO_2 intensity was quite different at the end of the period: economic growth became less and less emissions-intensive as of 2004.

2.2.5 CO_2 emissions at sector level

Each of the seven sectors identified, contributed positively to the growth of total CO_2 emissions during 1990-2008 (see Fig 4). The electricity sector was the biggest polluter, followed by transport and then manufacturing. But manufacturing remained the most dynamic.

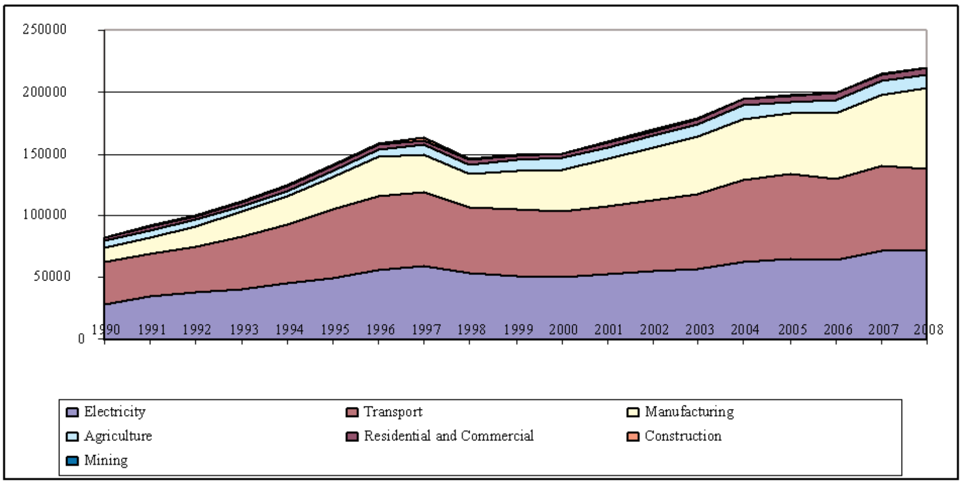
Electricity was the main emitter in 2008 (31.7%), while it was the second in 1990 (34.2%), taking precedence over transport. Its CO_2 emissions increased at an average annual growth rate of 5% in the period 1990-2008. While their growth was striking in 1990-1997 (on average, 9.6% *per annum*), the growth rate of CO_2 emissions dropped significantly in 1997-2004 (0.7%). Although the growth rate remained lower than that in 1990-1997, it still increased slightly in 2004-2008 (*i.e.*, 2.8%).

Transport was the main transmitter in 1990, its CO_2 emissions representing 40% of total CO_2 emissions. After a moderate increase over 1990-2008, increasing at an average annual growth rate of 3.7%, transport became the second-largest polluter in 2008 (29.3%) closely followed by manufacturing. However, the growth of its emissions was more marked in 1990-1997 (on average, 7.6% *per annum*) than later, increasing only by 1.2% on average and by year in 1997-2004. CO_2 emissions remained stable in 2004-2008.

CO_2 emissions from manufacturing grew most rapidly from 1990 to 2008, at an average annual growth rate of 9.3%. As a result, their contribution to total CO_2 emissions doubled, increasing from 14.2% in 1990 to 28.6% in 2008. Like the two previous sectors, the increase in CO_2 emissions was faster in 1990-1997 (on average, 12.1% *per annum*) than during the following period up to 2008. However, the growth rate of emissions after the Asian financial crisis remained higher, *i.e.*, 6.5% in 1997-2004 and 5.6% in 2004-2008.

Although CO_2 emissions from agriculture increased at an average annual growth rate of 3.6% in 1990-2008, their contribution to total CO_2 emissions decreased slightly from 6.8% in 1990 to 4.9% in 2008. The pace of emissions growth was stronger in 1990-1997 (on average, 4.9% *per annum*), and then slowed in 1997-2004 (3.7%) and in 2004-2008 (0.2%).

Figure 4 - CO_2 emissions by sectors, 1990-2008



Notes: CO_2 emissions expressed in $ktco_2$. The total in this figure is not strictly comparable to those of Figure 4 because exclusion of some parts of the energy sector (for instance, equivalent to 979 $ktco_2$ in 1990 and 14,785 $ktco_2$ in 2008). Electricity corresponds to public electricity and heat production. Manufacturing includes self-producers and, in 2007-2008, mining.

Source: See Figure 1.

Residential and commercial CO_2 emissions grew on average by 4.5% per year in 1990-2008. However, their contribution to total CO_2 emissions decreased slightly from 2.8% in 1990 to 2.4% in 2008. Their growth was most dynamic in 1990-1997 (on average, 6.3% *per annum*) and then slowed in 1997-2004. As with electricity, CO_2 emissions increased again in 2004-2008, although remaining below the level prevailing in 1990-1997 (4.1%)[22].

Finally, construction and mining are the only sectors where CO_2 emissions declined, at an average annual rate of -1.5% 1990-2008 and -3.8% in 1990-2006 respectively. As a result, their contributions to total CO_2 emissions decreased from 0.6% and 0.2% in 1990 to 0.2% in 2008 and 0.04% in 2006 respectively.

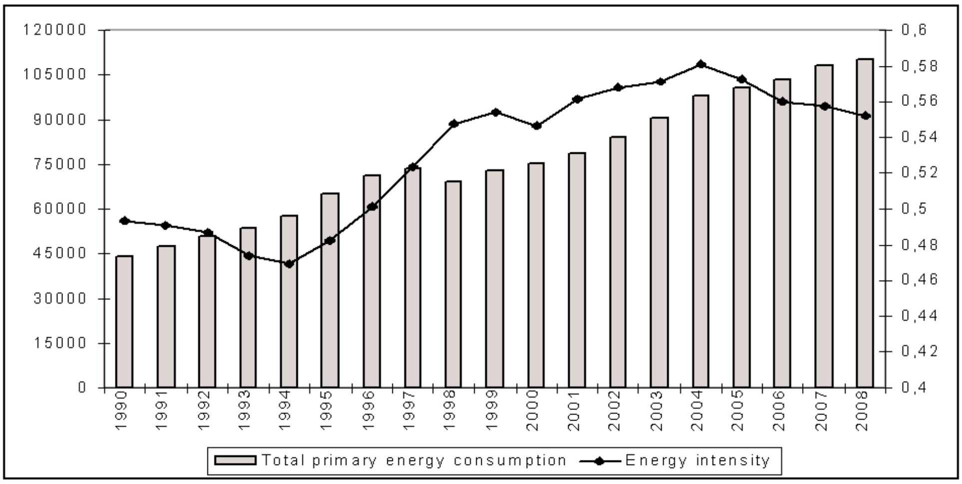
2.2.6 Total primary energy consumption and energy intensity at the aggregate level

Since 1990, total primary energy consumption (TPEC) increased significantly (see Fig. 5). The final level of consumption in 2008 accounted for 2.5 times that of 1990 (from 43,899 ktoe in 1990 to 110,021 ktoe in 2008). At the same time, energy intensity rose from 0.49 ktoe/MUSD in 1990 to 0.55 ktoe/MUSD in 2008. TPEC increased at an average annual growth rate of 5% over 1990-2008. However, its growth fell considerably after the Asian financial crisis. While TPEC grew on average by 6.7% per year in 1990-1997, the average annual growth rate fell to 3.6% in 1997-2004 and further to 2.3% in 2004-2008.

Contrary to the TPEC, energy intensity decreased during the first half of 1990, going from 0.49 ktoe/MUSD in 1990 to 0.47 ktoe/MUSD in 1994. During this period, GDP increased faster than energy consumption. However, from 1994, energy intensity increased until 2004 to reach a peak of 0.58 ktoe/MUSD. Energy intensity thus began a gradual decline thanks to the faster growth of GDP compared toTPEC. In 2008, energy intensity reached 0.55 ktoe/MUSD. However, this level is higher than that which prevailed throughout the 1990s.

Thus, in spite of growing TPEC, the end of the period showed a changing trend in terms of energy intensity: economic growth became less energy intensive beginning in 2004.

Figure 5 - Total primary energy consumption and energy intensity, 1990-2008



Notes: left axis: total primary energy consumption expressed in ktoe; right axis: energy intensity defined as total primary energy consumption per dollar of GDP (at USD constant price and exchange rate 2005).

Source: See Figure 1.

22 Note that the data of Enerdata do not take into account the CO_2 emissions from commercial and residential alone. DEDE provides aggregated data for these two sectors over the period 2000-2007 (DEDE, 2004, 2008). Comparing these data with those of Enerdata, an average difference (and constant) of only 6% is observable during this period. This slight difference could not therefore bias the results so as to radically change the results obtained from decomposition analysis.

2.2.7 Energy consumption by sector

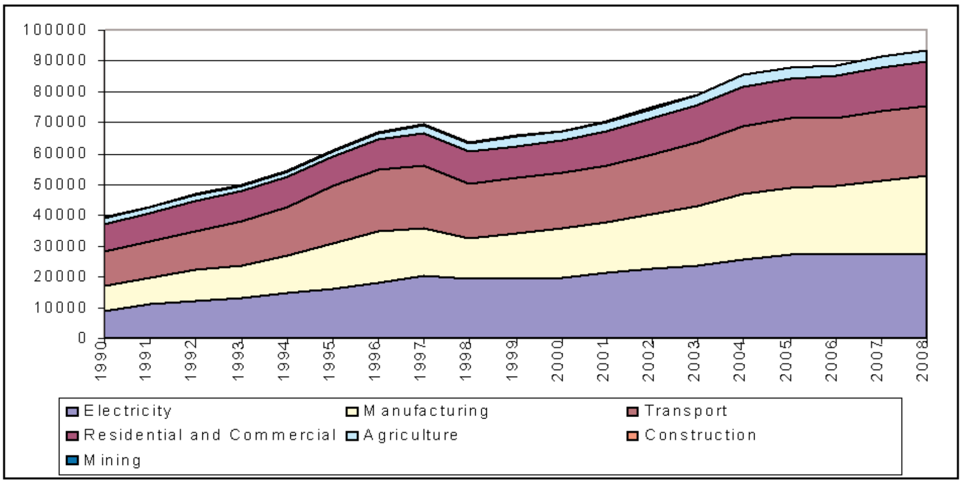
Energy consumption has been dominated by three sectors: electricity, manufacturing and transport (see Fig. 6). From 1990 to 2008, major changes occurred in the structure of consumption between the sectors shown on Figure 6.

While residential and commercial was the principal energy consumer in 1990, representing 25.5% of TPEC, its share fell to 20.2% in 2008. This decline is attributable to increased consumption by the electricity and manufacturing sectors. Indeed, their shares in TPEC rose from 20.8% and 18.1% in 1990 to 24.8% and 23.6% in 2008, respectively. As a result, the electricity and manufacturing sectors were the first and second-largest consumers of energy in 2008. The share of energy consumption of residential and commercial also declined, but more significantly, from 20.3% in 1990 to 13.1% in 2008. The same evolution is observable for agriculture (from 4.2% to 3.3%), construction (from 0.3% to 0.1%) and for mining (from 0.1% to 0.02%).

Consumption by manufacturing was the most dynamic, increasing at an average annual growth rate of 6.4% in 1990-2008. Electricity, too, increased its consumption rapidly, on average 5.9% per year in the same period. The growth of consumption in other sectors was lower than that of TPEC: transport (3.7%), agriculture (3.6%), residential and commercial (2.6%). Construction and mining are the only sectors for which consumption growth has been negative: -1.5% and -4.6% in 1990-2008, respectively.

In this long-term trend, it is apparent that energy consumption for each sector was most rapid between 1990 and 1997, while a significant slowdown is observed for the post-Asian financial crisis period. For instance, the growth rate of energy consumption for the building sector fell on average from 12.1% per year in 1990-1997 to -9.2% in 1997-2004 and to -8.4% in 2004-2008. For electricity, the rate fell from 10.5% to 3% and 1.1%, respectively; for transport from 7.6% to 1.2% and 0.1%. The growth of consumption by manufacturing also underwent an impressive fall, from 8.9% in 1990-1997 to 3.6% in 1997-2004. However, the growth of consumption accelerated again in 2004-2008, reaching an average annual growth rate of 4.3%.

Figure 6 - Energy consumption by sector, 1990-2008



Notes: Energy consumption expressed in ktoe. Electricity corresponds to public electricity and heat production. Manufacturing includes self-producers and, in 2007-2008, mining.

Source: See Figure 1.

Aggregate analysis

The empirical results of decomposing CO_2 emissions for the overall economy over the period 1990-2008 are presented in Figure 21 as before.

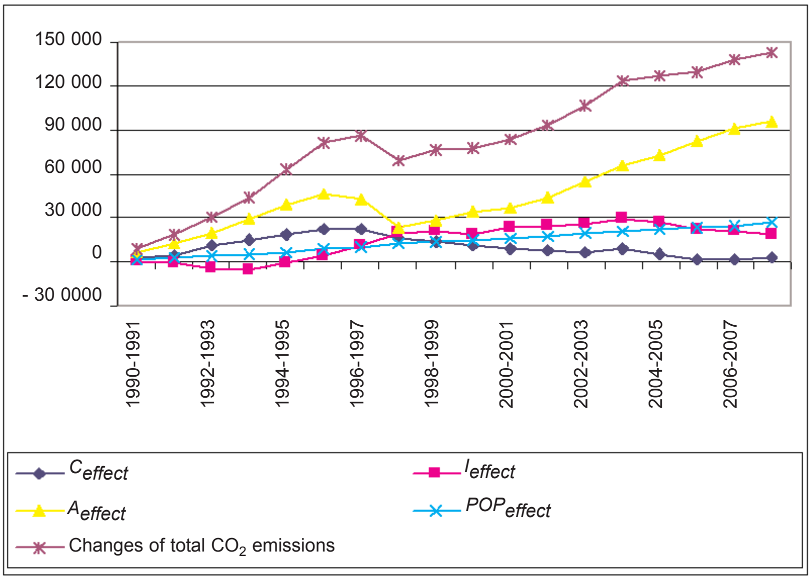
The A_{effect} is the main contributor to the increase in total CO_2 emissions. In aggregate, this effect induced a progressive increase by 95,145 $ktco_2$ of CO_2 emissions over the period considered (except around the Asian financial crisis); 66.5% of total emission increase is thus due to this effect.

The Population effect (POP_{effect}) is the second major contributor to CO_2 emissions. It explains 18.4% of the increase of total CO_2 emissions over the period, *i.e.*, 26,370 $ktco_2$. Because of a constant increase in population, its contribution has progressively increased along the period observed.

The I_{effect} is the third contributor. It caused an increase of 18,644 $ktco_2$ of CO_2 emissions, *i.e.*, 13% of total CO_2 emissions over 1990-2008. While I_{effect} contributed negatively to CO_2 emissions before 1994 (*i.e.*, CO_2 saving), its contribution became positive and growing until 2004. However, I_{effect} decreased thereafter.

Finally, the C_{effect} also increased CO_2 emissions by 2,839 $ktco_2$ (*i.e.*, 2%) during the period considered. However, this positive contribution took place at the beginning of the period, since from 1997 it became negative (except in 2004 and 2008).

Figure 7 - Empirical results of decomposition of CO_2 emissions for the overall economy, 1990-2008

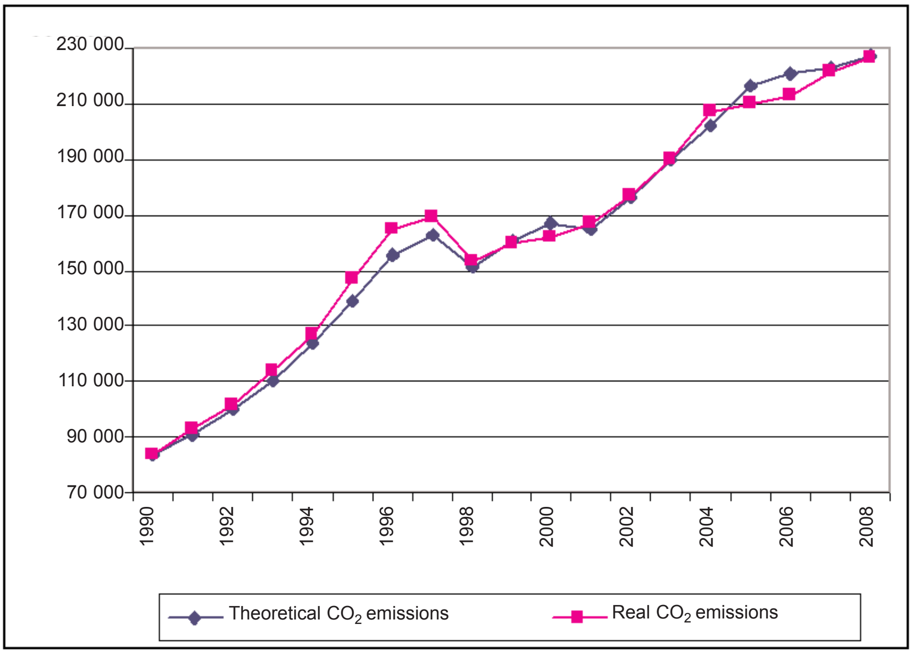


Notes: Expressed in $ktco_2$. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: See Figure 1.

As shown in Figure 8, the CO_2 emissions differential increased by 21,484 ktco2 from 1990 to 2008. However, a comparison of changes in effective emissions and theoretical ones indicates that reductions in CO_2 emissions differential occurred mostly in the 2000s.

Figure 8 - Theoretical and real CO_2 emissions for the overall economy, 1990-2008



Notes: Expressed in ktco2. Theoretical and real CO2 are calculated as described in section 2.1.3.
Source: See Figure 1.

2.3 Conclusion and discussion

We showed that all sectors, except mining and construction, and also the overall economy, experienced increases in total CO_2 emissions for the period 1990-2008. The impact and the magnitude of each effect are specific to each sector considered (see Table 1 below). The Activity effect appears as the main determinant of total CO_2-emission increases in all sectors, and thus for the overall economy. In a sense, this is bad news, since this effect is not expected to decrease, given that prospects for growth are envisaged to be upward (as will be presented in Part 3). Also, emissions attributable to this effect will certainly continue to increase. It must also be noted that the Structural effect and the Population effect for the overall economy, which have contributed to increasing total CO_2 emissions (except for a few sectors considering the S_{effect}), are those showing the most stability – thus difficult to alter – as they require radical and deep changes, which can come only in the long run.

The Carbon intensity effect and the Energy intensity effect are now considered. For the overall economy, both these effects increased total CO_2 emissions. However, C_{effect} allowed for CO_2 emissions savings from the second part of 1990s and from 2004 for the I_{effect}. But these decreases were not sufficient to compensate the CO_2-emission increases in the earlier period. That is why the CO_2-emission differential increased.

From the point of view of sectors, C_{effect} and I_{effect} contributed either to CO_2 increases or to CO_2 savings. However, it is noteworthy that these effects generated CO_2 savings, but not in a significant and/or long-lasting way, except for the I_{effect} in the mining, transport and electricity sectors. These three sectors also benefited from CO_2 savings coming from the C_{effect} – leading to a decrease in their CO_2 emissions differential. However, it should be recalled that the transport and electricity sectors remain the principal polluting sectors. For industry, it is the only sector where C_{effect} and I_{effect} (and the other effects) contributed to increased CO_2 emissions, without the initiation of a downward trend for one or another of these effects. The CO_2 emissions differential thus increased, industry being an important polluter whose emissions are growing most rapidly. Finally, the CO_2 emissions differential in agriculture, construction, and residential and service increased, in spite of reductions generated by C_{effect}, I_{effect}, or both.

Consequently, opportunities exist for political action. And given that the impact of the C_{effect} and I_{effect} show significant variation between sectors, some additional selective actions seem to be more relevant than generic ones. This does not disqualify generic-oriented policies: for instance, the Enhancement and Conservation of Environmental Quality Act ratified in 1992 has been a first step, but its effectiveness is debated – see the earlier cited analysis by Punyong, Taweekun and Prasertsan, who concluded that this Act, when applied to the industry sector, has not been efficient so far. There is scope for both additional impetus for implementing existing policies and more debate on priorities for additional measures.

Table 1: CO_2 emissions profiles resumed by sector and for the overall economy for the whole period

	Main contributors to		Changes of total CO_2 emissions	CO_2 emissions differential
	CO_2 increases	CO_2 saving		
Agriculture	A, I, C	S	+	+
Mining	A, S	I, C	-	-
Construction	A, I	S, C (neutral)	-	+
Industry	A, C, S, I		+	+
Transport	A, S	I, C	+	-
Electricity	A, S	C, I	+	-
Residential and Service	A, C	S, I	+	+
Overall economy	A, POP, I, C		+	+

Notes: abbreviations correspond to the different effects already used. Effects are ranked in decreasing order (e.g., in agriculture sector, A_{effect} increased CO_2 emissions more than I_{effect} which increased CO_2 emissions more than C_{effect}). In the last two columns, +/- signs indicate increases/decreases of total CO_2 emissions or CO_2 emissions differential (i.e., the difference between real (R) and theoretical (T) emissions; cf. section 2.1.3) over 1990-2008.

3. Low-carbon scenarios

3.1 Scenarios as tools to explore low-carbon futures

Recent years have seen a proliferation in the use of scenario methods to examine low-carbon futures. Low-carbon scenarios aim at exploring the prospects for decarbonization within a certain sector, a national economy, multi-nationally, or in some cases globally. The time frame of low-carbon scenarios is long – they tend to extend over at least 20 years, though a 50-year time horizon is also common. The scope of low-carbon scenarios is potentially huge, and could encompass not just energy but various land-use activities, as well as other physical or natural processes. By their very nature, low-carbon scenarios also explore radically different energy futures and have to consider issues of major technological and behavioural change.

3.1.1 Current research on LCS scenarios

A major agenda for research is focusing on energy demand modelling in developing and emerging economies. Bhattacharyya and Govinda (2009) provide an extended review of energy-demand models highlighting the methodological diversities and developments over the past four decades. They also investigate whether the existing energy-demand models are appropriate for capturing the specific features of developing countries. According to Urban *et al.* (2009), many models are biased towards industrialized countries, neglecting major characteristics of developing countries, *e.g.* the role of the informal economy, supply shortages, the poor performance of the power sector, structural economic change, electrification, traditional bio-fuels, the urban–rural divide and explain how and why they should be adjusted to take into account characteristics of developing countries.

Fundamental institutional, individual and social changes are needed to accompany economic and technological change, as energy is embedded into overall development patterns. Indeed, following Shukla in NIES (2007), Low-Carbon Societies can be seen as a "Development Pathway" with dual goals. National socio-economic objectives and targets can be tackled, while addressing global objectives for the stabilization of GHG concentrations in the atmosphere.

Foresight studies and methodologies for scenario analysis have already been applied by a variety of organizations seeking to speculate on the direction that the future might take and to motivate political action. Among the most famous are the SRES scenario published by IPCC authors, the UN Millennium Ecosystem Assessment (MEA) and the International Energy Agency (IEA) scenario exercises (known as WEO, or World Energy Outlook). Looking at radically different futures or low-carbon scenarios is relatively new. The use of the Low-Carbon Societies concept significantly improved policy discussion in European countries[23]. In the Asia Pacific region, NIES (2007) encouraged research on low-carbon scenarios.

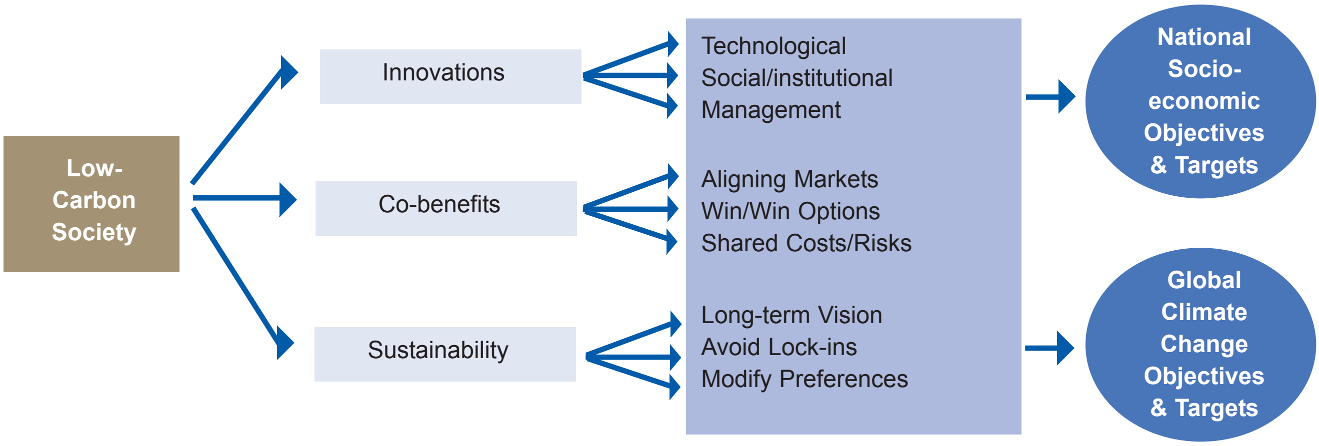
[23] In a review conducted of selected recent UK-focused and international low-carbon energy scenarios (Hughes *et al.*, 2009), it was found that low-carbon scenarios have played an important role in both imagining the possibilities, and demonstrating the technical feasibility, of low-carbon energy systems in the future.

3.1.2 Sustainable low-carbon societies

The concept of Sustainable Low-Carbon Societies involves developing the mutual efficiency of social/economic indicators and climate quality. This interaction could be developed through: innovations (technology), institutions, international and regional cooperation; targeted technology and investment flows; aligning stakeholder interests; focusing on inputs (and not only outputs) and long-term perspective to avoid lock-ins. A roadmap for a Low-Carbon Society can be drawn with the intention of delivering a new global efficiency frontier, balancing cost-effectiveness, equity and sustainability goals (UNFCCC, 1992). The specifics of the roadmap would differ across countries.

The following definition was proposed by the Steering Committee of the Japan–UK Low-Carbon Society project. It was not intended as a scientific statement, but rather as a flexible framework that would allow fruitful discussions, leading to practical actions.

Diagram 1 - Roadmap for a Low-Carbon Society



Source: NIES 2007.

Box 1: Definition of Low-Carbon Societies (NIES, 2006):

A Low-Carbon Society should:

- take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met;
- make an equitable contribution towards the global effort to stabilize the atmospheric concentration of CO_2 and other GHG at a level that will avoid dangerous climate change, through deep cuts in global emissions;
- demonstrate a high level of energy efficiency and use low-carbon energy sources and production technologies;
- adopt patterns of consumption and behaviour that are consistent with low levels of GHG emissions.

Although the definition is intended to cover all national circumstances, the implications are different for countries at different stages of development. Scenarios are used to define the different variables such as GDP or energy demand.

3.1.3 Visions for low-carbon societies

The methodology of building LCS takes roots in academic and policy-oriented exercises on energy-prospective and foresight sciences. It requires strong inter- and multi-disciplinary competences. This emerging research field is exemplified by network-based programmes such as LCS-RNet[24], the International Research Network for low-carbon Societies. Recognizing the need to promote research in this area and exchange the information to help more countries develop their own roadmaps towards LCS, participants at the G8 Environmental Ministers Meeting (EMM) held in Kobe in May 2008 supported the idea of creating an international network of research institutions.

LCS-RNet recognizes that there are various definitions of LCS and it is not a purpose of LCS-RNet to define LCS with a single common context. Each country and society has its own vision of the future society that achieves low-carbon emissions with sustainable development. Different energy and climate scenarios are defined with contrasted paradigms and visions. Indeed the promotion of a low-carbon society requires to develop visions that will be credible and attractive to civil society or the general public[25].

In the Japan low-carbon Society project, one path of social development is consistent with the outcome. Two contrasting visions of a Japanese low-carbon society are detailed: Vision A (Doraemon) is technology-driven, with citizens placing great emphasis on comfort and convenience. They live urban lifestyles with centralized production systems and GDP per capita growing at about 2% *per annum*. Vision B (Satsuki and Mei) is of a slower-paced, nature-oriented society. People tend to live in decentralized communities that are self-sufficient: both production and consumption are locally based. This society emphasizes social and cultural values rather than individual ambition. In both cases, a 70% reduction in CO_2 emissions is achieved by 2050. However, the mix of technologies employed is different (Table 2). In both cases, energy efficiency improves considerably – both in industry and in the home.

Low-carbon societies may have more balanced patterns of demand for inputs if the use of materials is not greater than is strictly needed to achieve quality of life with an adequate level of consumption of goods and services. Research on new indicators is needed to support the transition to LCS. These indicators should cover the following: material use efficiency, perceptions of the quality of life, and the achievement of innovation targets. Such new indicators may underpin the setting of country- and region-specific targets for low-carbon societies while better reflecting local conditions.

An international modelling comparison has also been undertaken by nine national teams, with a strong developing-country focus (Strachan *et al.*, 2008). The comparison emphasis was to focus on individual model strengths (notably technological change, international emissions trading, non-price (sustainable development) mechanisms and behavioural change) rather than a common integrated assumption set. A complex picture of long-term LCS scenarios comes from the range of model types and geographical scale (global *vs.* national); however, common themes for policymakers do emerge.

A core finding is that LCS scenarios are technologically feasible. However, preferred pathways require clear and early target setting and incorporation of emissions targets across all economic activities. For targets such as a 50% global CO_2 emission reduction, most models in this LCS project comparison showed an associated GDP loss in the range of 0.35–1.35% annually by 2050, though one model showed an increase in GDP due to the stimulus provided by higher levels of investment in low-carbon technologies. However, the required carbon price signal or marginal cost of abatement was found to be in the range of USD100–330/tCO_2[26].

[24] The network's first meeting was held in October 2009. See http://lcs-rnet.org. LCS-Rnet is an international network integrating research and knowledge from ten of the largest research institutes on climate change in six countries. The international network is an open group willing to grow and integrate those who show skills and commitment to sharing the same multidisciplinary goals, combining scientific research knowledge and political, economic, social and environmental systems.

[25] For example, The Japan low-carbon Society project envisages a world in which global temperature rise is held below 2°C, global CO_2 emissions are cut by 50% by 2050, and Japanese emissions are cut by 70%. The results are presented in Matsuoka (2007; NIES, 2007).

[26] This greatly exceeds the current price of carbon in the EU Emissions Trading Scheme. However, it is of the same order of magnitude as other impacts of climate change (Stern, 2006).

Table 2: Comparison of CO_2 emission reduction drivers

	Vision A (Doraemon)	Vision B (Stasuki and Mei)
Society	High economic growth Decrease in population and number of households	Reduction of final demand by material saturation Reduction in raw material production Decrease in population and number of households
Industrial	Energy-efficient improvement of furnaces and motors etc. Fuel-switching from coal/oil to natural gas	Energy-efficient improvement of furnaces and motors etc. Increase in fuel-switching from coal and oil to natural gas and biomass
Residential and commercial	High-insulation dwellings and buildings Home/building energy management systems Efficient air-conditioners Efficient water heaters Efficient lighting systems Fuel-cell systems Photovoltaics on the roof	High-insulation dwellings and buildings Eco-life navigation systems Efficient air-conditioners Efficient water heaters Efficient lighting systems Photovoltaics on the roof Expanding biomass energy use in home Diffusion of solar water heating
Transportation	Intensive land use Concentrated urban functions Public transportation systems Electric battery vehicles Fuel-cell battery vehicles	Shortening trip distances for commuting through intensive land use Infrastructure for pedestrians and bicycle riders (sidewalk, bikeway, cycle parking) Biomass-hybrid engine vehicles
Energy transformation	Nuclear energy Effective use of electricity in night time with storage Hydrogen supply with low-carbon energy sources Advanced fossil-fuelled plants + carbon capture and storage Hydrogen supply using fossil fuel + carbon capture and storage	Expanding share of both advanced gas combined cycle and biomass generation

Source: Matsuoka (2007).

In the run-up to Copenhagen, several reports were issued looking at alternative trajectories of development for selected developing countries. The report from the Working Group Climate and Development Network[27] describes how the costs and benefits of global economic growth have been very unfairly distributed, with those on lowest incomes receiving the fewest benefits and paying the highest costs. A wide range of examples of more positive approaches are given from the wide, practical experience of the agencies in this coalition. Altogether they paint a picture of more qualitative development that is not dependent on further global over-consumption by the already-rich, in the hope that crumbs of poverty alleviation are perhaps passed to those at the bottom of the income pile. In another radical but very welcome essay, Prof. Jackson's book (2009) consistently emphasizes that a twofold change is needed to tackle global change challenges in a finite world: in addition to these economic changes, he calls for social and values changes, especially in developed countries and among elites. The book summarizes an essay by economist Amartya Sen that calls for a shift from an economy aiming at opulence or utility to an economy aiming at human flourishing.

27 Pachauri *et al.* (2009).

3.2 Review of the different LCS scenarios for Thailand

In this section, we focus on different studies that deal with Thailand's case and consider their parameters. A number of studies focused on the interrelationship between energy use and the environment in Thailand. Various aspects of these studies include sector-specific energy planning and its impact on global and local air pollutants (see *e.g.*, Dang *et al.*, 1994; Shrestha *et al.*, 1998; NEPO, 1999; Tanatvanit *et al.*, 2003, 2004; Bhattacharyya and Ussanarassamee, 2004; Malla and Shrestha 2005; Limmeechokchai and Suksuntornsiri, 2007a, b). Different models were used such as Leap[28], AIM from AIT, or Markal.

3.2.1 Overview of major studies

Most studies deal with energy futures, the evolution of the power sector and not specifically low-carbon development. However, those scenarios propose assumptions on the main drivers, such as population, GDP, evolution of the economic structure, etc.

IEA (2009) develops a baseline scenario along with the so-called 450 ppm scenario. The latter sets out a timetable of actions needed to limit the long-term concentration of GHG in the atmosphere to 450 parts per million of carbon-dioxide equivalent and keep the global temperature rise to around 2°C above pre-industrial levels (compared to 6°C in the Reference Scenario)[29]. As qualified by Executive Director, Nobuo Tanaka, "*the IEA 450 scenario is the energy pathway to Green Growth*"[30]. To carry out the assessment, assumptions are made about population, growth, macroeconomic trends, energy prices, technological development and government policies. Energy-related environmental aggregates are then the primary energy mix (demand and production), trade and GHG emissions (CO_2, NO_x, PM2.5, SO_2). Assessments proceed for the world, by region, by country (selected, including Thailand), and at the macro- and sectoral- levels.

Shresta *et al.* (2007) use the bottom-up modelling framework based on a minimum-cost linear programming approach. Four scenarios are specified. The global market integration scenario (TA1) in which the Thai economy is more integrated into the global economy and, consequently, has more access to foreign technology and benefits from external forces to modernize its economic sector. The dual track scenario (TA2) considers that international specialization follows comparative advantage and the national development plans and policies. The sufficiency economy scenario (TB1) is one in which activities that promote sustainable development are supported. Finally, the local stewardship scenario (TB2) postulates an unbalanced global economy characterized by strong economic turmoil in different regions; strong local communities are needed. Under these four scenarios, they then simulate changes in the primary energy supply mix, sector-wise (agriculture, commercial, industry, residential, transport) final energy demand, energy import dependency and CO_2, SO_2 and NO_x emissions over 2000-2050.

Tanatvanit *et al.* (2003) forecast growth in energy demand and corresponding emissions until the year 2020 for three sectors, namely, residential, industrial and transport, by using a model based on the end-use approach. The energy savings from energy conservation strategies such as energy efficiency improvement and energy demand management are assessed, and the implications on electricity generation expansion planning are also examined. The integrated resource planning (IRP) model is used to find the least-cost electricity generation expansion plans.

[28] LEAP has been developed by the Stockholm Environment Institute-Boston. The LEAP tool includes a Technology and Environment Database that provides descriptions, technical characteristics, costs, and emissions of a wide range of energy technologies. It is not a general equilibrium model. See www.seib.org

[29] OECD/IEA (2009)

[30] IEA, "From Financial Crisis to 450 ppm: The IEA Maps Out the Energy Sector Transformation and Its Financial Consequences Under A Global Climate Agreement," http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=290.

Mulugetta *et al.* (2007) focus on the power sector, and scenarios represent the range of opportunities and constraints associated with a diverging set of technical and policy options. They include Business-As-Usual (BAU), No-New-Coal (NNC), and Green Futures (GF) scenarios over a 20-year period (2002–2022).

Chaivongvilan & Sharma (2009) investigate the long-term (energy) impacts of alternative energy policies (with specific emphases on renewable and nuclear energy policies), using a scenario-based method. The three scenarios developed in their paper encompass different story lines for major energy parameters, energy technologies, as well as energy efficiency and environmental policies and plans. The impacts are assessed in terms of changes in the primary energy-supply mix, energy-import dependency, and fuel shares in the power sector. The study employs a dynamic linear programming model, namely, MESSAGE (Model for Energy Supply System Alternatives and their General Environmental Impacts)[31]. The model determines the feasible least-cost solution of energy supply/energy technology for satisfying future energy demands corresponding to each scenario (IAEA 2007). The required database for MESSAGE includes details of energy types, energy technologies, and energy-related parameters (*e.g.*, prices, availability, bounds on activity, etc.). The database was established from a variety of sources including DEDE (2005), EGAT (2008), Thasnes (2007) and Shrestha *et al.* (2007). In addition, Tiyapun (2008) was used as the basis for the data on energy demand forecasts and other exogenous variables. The future energy impacts are estimated for three long-term alternative energy-policy scenarios, namely, Business-As-Usual (BAU), Nuclear Power (NP) and Renewable Energy (RE).

3.2.2 Hypotheses and scenarios

We synthesize below the different hypotheses of scenarios in terms of GDP rates, appliance ownership and use of road transport (personal vehicle or public transport). For hypotheses on technology costs, the reader should refer to the annex of the published papers.

Table 3: Hypothesis for the LCS in Thailand by Shresta, Malla and Liyanage (2007)

	GDP	
a.a.g.r.*	2000-2020	2021-2050
TA_1	7,5	5,5
TA_2	6,0	5,0
TB_1	6,5	5,5
TB_2	4,0	3,5

	Population	
a.a.g.r.*	2000-2020	2021-2050
TA_1	0,02	0,02
TA_2	0,74	0,74
TB_1	0,02	0,02
TB_2	0,39	0,39

	TPED		
(Mtoe)	2010	2030	2050
TA_1	82	197	450
TA_2	75	173	337
TB_1	77	165	326
TB_2	69	114	201

	$C0_2$	
(Mt)	2010	2050
TA_1	158	1 312
TA_2		1 172
TB_1		1 035
TB_2		647

*Note: *a.a.g.r., average annual growth rate.*

[31] Originally developed by the International Institute for Applied System Analysis (IIASA), MESSAGE has been used extensively in the past three decades in global, regional, national and sectoral settings for analysing a variety of energy issues. In this model, the objective function emphasizes the minimization of total energy system cost, subject to a set of pre-specified constraints.

Shresta & Pradhan (2009) recently published the results of their modelling exercises in the framework of the work of NIES on LCS for 2050. Hypothesis and results for the scenario in Shresta & Pradhan (2009) are detailed in the following table.

Table 4: Hypothesis for the LCS in Thailand by Shresta & Pradhan (2009)

Base Case Scenario (Business As Usual)	Moderate CO_2 Reduction Scenario (LCS20)	Accelerated CO_2 Reduction Scenario (LCS50)
	Hypothesis	
Growth (CAGR): GDP (5.6%), population (0.4%) during 2000-2050 Conventional scenario No CO_2 Reduction policy	Cost effective CO_2 reduction in the base case Least-cost measures targeting cumulative CO_2 reduction of 20% during 2000-2050 The target corresponding to cumulative CO_2 reduction to be achieved by gradually increasing carbon tax from USD10/tCO_2 in 2015 to USD100/tCO_2 in 2050 in Thailand.	Cumulative CO_2 reduction 50% from the base case emissions during 2005-2050 Comprehensive technological measures High cost
	Results for the increase in CO_2 emission in 2050 compared to year 2005 CO_2 emission	
Base case: 8 times.	LCS20: 5 times, *i.e.* over 30% CO_2 reduction compared to year 2050 base case emissions	LCS50: 2 times. *i.e.* about 60% CO_2 reduction compared to year 2050 base case emissions

The following table synthesizes the hypothesis used by Chaivongvilan & Sharma (2009), while ongoing work by Chaivongvilan & Sharma aims at providing valuable inputs for the estimation of economy-wide impacts of alternative energy environmental settings.

Table 5: Hypothesis for the energy scenarios in Chaivongvilan & Sharma (2009)

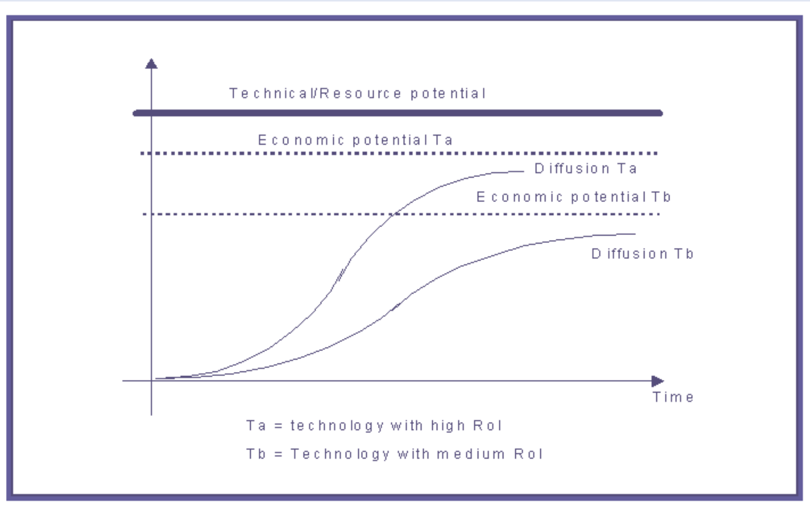
Main features in energy scenarios	Descriptions
Economy	GDP growth rate (annual) – 4.5% per year for 2005-10 – 5% per year for 2010-15 – 5.8% per year for 2015-20 – 5.5% per year for 2020-2050
Energy	GDP of energy growth rate (annual) – 9% per year for 2005-2010 – 5% per year for 2010-15 – 7% per year for 2015-20 – 6% per year for 2020-25 – 5,5% per year for 2025-50
Demography	Population growth rate at an average 0.6% per year

In terms of results, the different scenarios enable looking at the evolution of energy consumption by sector, and at shifts in infrastructure and technologies. It is however, difficult to assess the technical or economic feasibility and even acceptability of such scenarios, especially in the light of competing agendas and the evolution of the global and national economic and political context: financial crisis, limited financial resources for social protection, improving wages and working conditions, etc.

Decomposition analysis techniques, following Agnolucci *et al.* (2009) and as presented above in section 2, may be used to assess the feasibility of LCS and the realism of the results. Indeed, the realism may be assessed by comparing past rates of economic growth and diffusion of particular technologies. In the scenario presented, the rates of diffusion of different technologies, in particular in the energy sector or road transportation, their economic and political rationales are not always (and cannot be) fully detailed. For example, Shresta *et al.* (2007) estimate that the share of hybrid and fuel cell vehicle stocks together in total vehicles would reach 81% in 2050. In the different scenario, industry still remains a major energy consumer. Therefore, there is a strong interest in the potential diffusion of energy-efficient as well as radical innovations in the manufacturing sector, such as cement, steel, papermaking, etc.

Box 2: Technology diffusion in the POLES model

Many studies on international energy perspectives either disregard new and renewable energy technologies as offering insufficient economic potential for development in the medium term or, conversely, try to assess their potential with a purely technical approach in order to identify their overall potential contribution to world energy supply. The approach adopted in the New and Renewable Energy module of the POLES model tries to supersede these limits while recognizing the difference between technical and economic potentials as well as the time constants that characterize the diffusion process. Elements such as learning curves and "niche-markets" have been introduced, which allow for a truly dynamic approach to the development and diffusion of these technologies.



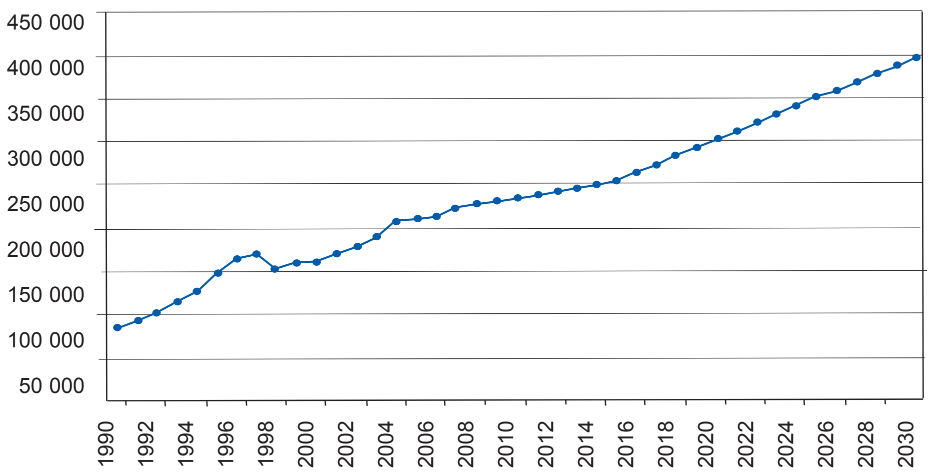
The module that is dedicated to the simulation of new and renewable technologies identifies the generic technologies that are representative of the solutions to be implemented in different types of countries and might have a significant quantitative contribution to the long-term development of energy systems. The time horizon of the model (2050) in fact allows considering that, given the development time constants, the technologies that might have a significant role in this horizon should today be at least identified and have passed the first stages of development. Twelve technologies have been selected in the current version of the model.

3.2.3 Exploration of alternative LCS scenario results

From the previous review of LCS, it is possible to explore the alternative trajectories that could be taken by the Thai economy in the future. This exploration can proceed in two ways. The first is simply to graph the expected evolution of energy-related aggregates in the long term, specifically CO_2 emissions and total primary energy supply or demand. The second is to assess which effects would be the main determinants of expected CO_2 emissions in the period 2007-2030 compared to the period 1990-2007 (and sub-periods) through the decomposition analysis already used (LMD method; cf. 2.1.3 and 2.3.8).

By focusing first on CO_2 emissions, Figure 9 reproduces the emissions estimated by the IEA (2009) in its Baseline Scenario over the period 2007-2030 plus those for the earlier period 1990-2007 (base year 2007). Figure 10 reproduces in the same way estimations by Shresta *et al.* (2007), but for a longer period, *i.e.* until 2050 (base year 2000). Comparing these figures, it is apparent that earlier estimations for 2030 by Shresta *et al.* are higher than that of IEA. Indeed, CO_2-emission estimates by IEA correspond only to, but are slightly lower than, the "most optimistic" scenario of Shresta *et al.* (*i.e.*, TB2). In fact, "real" Thai CO_2 emissions correspond closely to those projected from this TB_2 scenario. For instance, "real" CO_2 emissions were equal to 225,709 $ktco_2$ in 2008 comparing to 241,494 $ktco_2$ projected through the TB_2 Scenario. Also, since 2000 the Thai economy appears to have followed the better alternative trajectory as estimated by Shresta *et al.* If this continues, CO_2 emissions would be 397,993 $ktco_2$ (Scenario 450) or 461,143 $ktco_2$ in 2030 (TB_2 scenario) and 661,396 $ktco_2$ in 2050. CO_2 emissions should thus increase by almost 300% by 2050 compared to 2008. The other trajectories (*i.e.*, other scenarios by Shresta *et al.*) give rise to significantly higher increases in emissions.

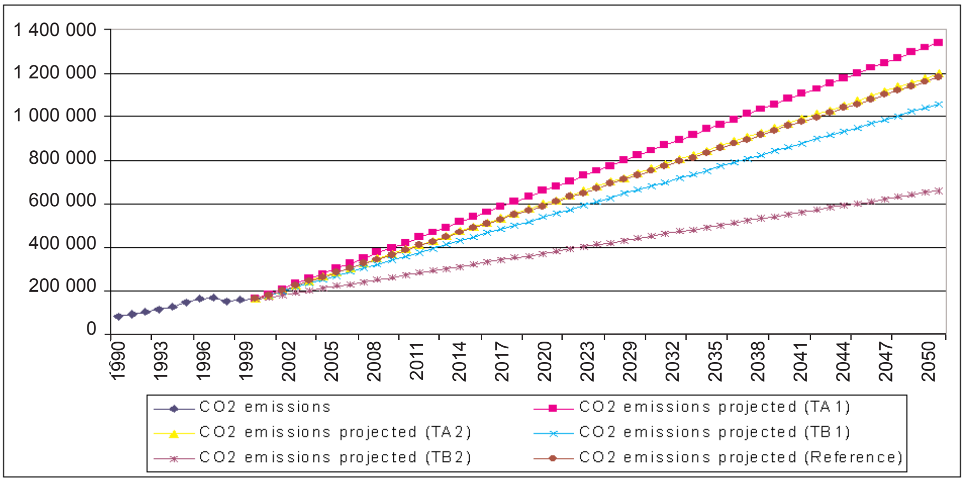
Figure 9 - CO_2 emissions in respect of Baseline Scenario by IEA, 1990-2030



Notes: Expressed in $ktco_2$.

Sources: 1990-2007, data from Enerdata (2009); 2015 and 2030, estimated from data projected by IEA (2009).

Figure 10 - CO_2 emissions in respect of Scenarios by Shresta, Malla and Liyanage, 1990-2050



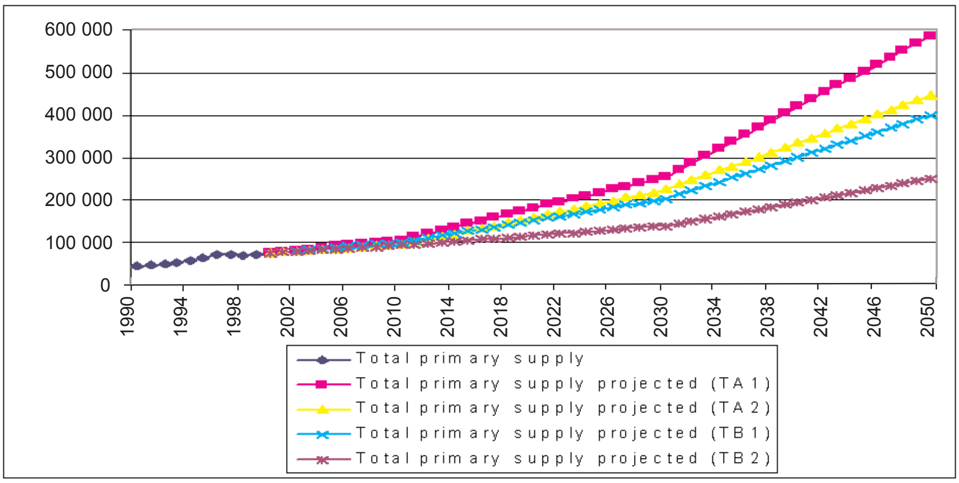
Notes: Expressed in ktco$_2$.

Sources: 1990-2007, data from Enerdata (2009); 2015 and 2050, estimated from data projected by Shresta, Malla and Liyanage (2007).

Comparing now total primary energy supply (TPES) estimated by IEA and Shresta *et al.* (see Fig. 11 and 12), the Thai economy appears to have been more energy consumptive in 2000-2008 than that projected by Shresta *et al*. For instance, "real" TPES is equal to 110,021 ktoe in 2008 compared to between 90,005 ktoe and 100,955 ktoe depending on the scenario considered from Shresta *et al.*

As previously, projections for 2030 by IEA correspond approximately to, but are slightly higher this time than the "more optimistic" scenario of Shresta *et al.* (*i.e.* TB2): 178,542 ktoe against 140,557 ktoe respectively. In 2050, TPES would increase between 280% (TB2) and 581% (TA1), *i.e.*, reaching either 251,739 ktoe or 586,400 ktoe respectively.

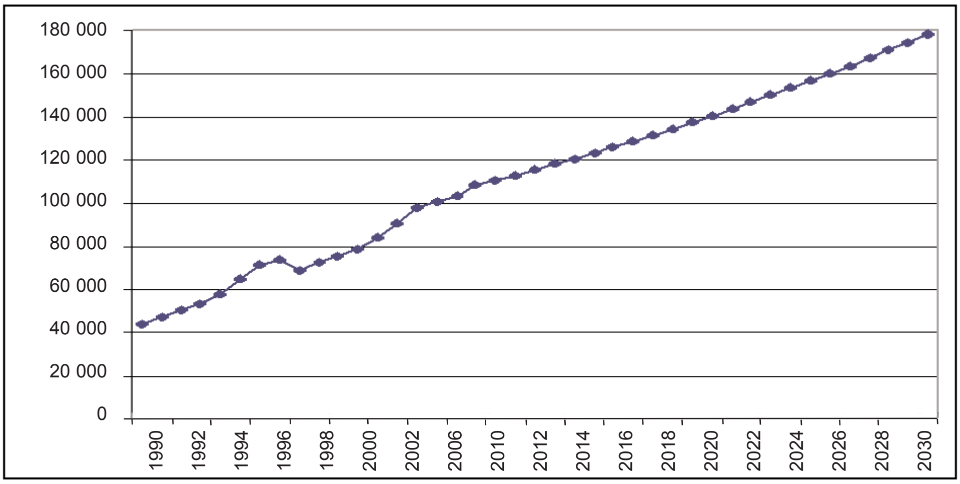
Figure 11 - Total primary energy supply in respect of Scenarios by Shresta, Malla and Liyanage, 1990-2050



Notes: Expressed in ktoe.

Sources: 1990-2007, data from Enerdata (2009); 2015 and 2050, estimated from data projected by Shresta, Malla and Liyanage (2007).

Figure 12 - Total primary energy supply in respect of Baseline Scenario by IEA, 1990-2030



Notes: Expressed in ktoe.

Sources: 1990-2007, data from Enerdata (2009); 2015 and 2030, estimated from data projected by IEA (2009).

Keeping these evolutions in mind, decomposition analysis of CO_2 emissions can proceed, Shresta *et al.* have done so. Comparing the base year 2000 to the targeted year 2050, their results indicate that:

- Energy transformation effect (total primary energy supply/final energy demand) decreases CO_2 emissions by 7%;
- Intensity energy effect decreases CO_2 emissions, but by a more significant margin, *i.e.*, 49%;
- Conversely, the carbon intensity effect contributes to an increase of 20% of CO_2 emissions;
- Population effect equally increases CO_2 emissions by 47%;
- Finally, the activity effect is the principal determinant of CO_2 emissions, contributing to increase it by 782%.

We proceed to the same analysis from projections obtained through the Baseline Scenario by IEA. Table 6 shows the results of this time-series decomposition for the overall economy for 1990-2050 with sub-periods. In the period 1990-2030, CO_2 emissions are expected to increase by 314,404 ktco$_2$. 56.2% of this increase (*i.e.*, 176,536 ktco$_2$) is then anticipated to occur in 2007-2030, which corresponds to 1.3 times their 1990-2007 level.

Table 6: Decomposition analysis - past and prospect (IEA Baseline Scenario)

	C_{effect}	I_{effect}	A_{effect}	POP_{effect}	CO_2 emissions changes
1190-2007	10 092 (7,3)	17 366 (12,6)	87 361 (63,4)	23 050 (16,7)	137 953 (100)
2007-2030	21 392 (12,1)	-69 862 (-39,6)	199 370 (113)	25 552 (14,5)	176 536 (100)
1990-2030	28 680 (9,1)	-22 030 (-7,0)	257 762 (82,0)	49 908 (15,9)	314 404 (100)

The main determinant behind this increase is the A_{effect}, which accounts for 82% of the growth of CO_2 emissions during 1990-2030 (i.e., 257,762 ktco$_2$). The second determinant is the POP_{effect} contributing to increase total CO_2 emissions by 15.9% (*i.e.*, 49,908 ktco$_2$). The third determinant is the C_{effect} (9.1% of total CO_2 emissions changes in 1990-2030). Finally, the I_{effect} is the only determinant that, in the long term, allows for CO_2 emissions savings by 22,030 ktco$_2$ throughout 1990-2030 (*i.e.*, -7%).

Comparing the period 1990-2007 to the period 2007-2030, it is obvious that the A_{effect} remains the main contributor, almost doubling its relative importance (from 63.4% to 113.0%, respectively). The contribution of the C_{effect} increases, passing from 7.3% in 1990-2007 to 12.1% of total CO_2 emissions in 2007-2030. Perhaps more important, Improvement in energy intensity (I_{effect}) is notable between periods: from a positive contribution of 12.6% in 1990-2007, the I_{effect} becomes negative, allowing for a CO_2 emissions savings of 39.6% in 2007-2030. Finally, the impact of the POP_{effect} decreases slightly from 16.7% to 14.5% respectively.

Although not strictly comparable, these results identify the main determinant of CO_2 emissions in the long term to the A_{effect} and POP_{effect} as Shresta *et al.* do. The C_{effect} contributes also to increase CO_2 emissions, while the I_{effect} should generate CO_2 emissions savings.

4. Policies and measures for climate mitigation: a matrix approach

The study on low-carbon initiatives to foster economic growth in Thailand focuses on the economic impact of climate mitigation. Although Thailand is not committed to an internationally binding agreement on climate change mitigation policies, it has already made substantial progress in implementing public policy measures to that effect.

It can be assumed that these measures, in various policy areas, are to be reviewed and updated. They should certainly be upgraded and expanded further, and with new components, if Thailand is to further improve its economic and social development based on a sustainable low-carbon growth path. This will also be consistent with the construction of Nationally Appropriate Mitigation Actions that would be in line with the post-2012 Climate regime. How should these measures be reviewed and a coherent package of measures built?

This part will consider basic principles founding climate change mitigation strategies (4.1), and then review the range of relevant policy tools that are considered in recent reports and economic literature, and present an exploratory approach through design of a matrix of policy options (4.2). Then it will consider its relevance to analyse measures and policies in Thailand and present a preliminary test case (4.3).

4.1 Strategies for climate mitigation

The Green Growth approach outlined above aims explicitly at creating strong policy guidance for governments. In principle, it is therefore beyond the mere listing of recommendations (rarely applied) for policy actions contained in Agenda 21 drawn at the Rio Summit (1992). Besides the various IPCC reports, OECD, for its part, seeks currently to define a "*strategy for green growth*" (OECD, 2010a). In its 2010 report devoted to *Development and Climate Change*, the World Bank reviews the various policy measures that may be useful for promoting green growth in countries of different income levels (World Bank, 2010). UNCTAD does the same in its *Trade and Development Report 2009*, especially in Chapter V addressing "*Climate Change Mitigation and Development*" for developing countries.

The rationale behind reviewing various climate mitigation measures lies, as already indicated, in the presence of multiple market imperfections. This view is largely shared among scholars and international organizations (IPCC, 2001, 2007; UNCTAD, 2009; World Bank, 2010). Imperfections to be addressed have been listed by the OECD in respect of three broad categories:

(i) Imperfections that prevent equalizing marginal abatement costs across all existing GHG emission sources: (a) the global public-good nature of climate that creates a free rider problem, (b) monitoring and enforcement costs that differ among emission sources, (c) information problems which prevent exploiting the right opportunities, and (d) the market power of emitters;

(ii) Imperfections that prevent fostering innovation and diffusion of GHG emissions-reducing technologies: (a) positive externalities (learning-by-using, learning-by-doing, or network externalities), which prevent an appropriation of the full social benefits of innovations; (b) lack of credible commitment devices, which create political uncertainty; and (c) capital market imperfections that constitute a barrier to innovation and the adoption of technologies;

(iii) Imperfections that prevent coping effectively with risks and uncertainties surrounding both climate change and abatement costs: incomplete information on climate change damage and abatement costs (OECD, 2010a, table 2.1, p. 56).

Because the market function is disrupted by not only one of these imperfections, but by all of them simultaneously, and at varying degrees, state interventions should be inclusive. This inclusiveness can also be justified if various policy objectives are pursued. For instance, bio-fuel production and automobile-fuel efficiency can serve to promote energy security and fuel diversity as well as GHG mitigation. In both cases, climate mitigation policy must not be based on only one isolated instrument, but on a combination or package of policies and measures oriented towards meeting precise environmental targets. The different package measures may range from market-based instruments to regulations and standards, and to fiscal and financial incentives (including those to be removed), etc. The broad categories of measures will be further specified in the next section.

Problems arising from the use of a policy package are linked to problems addressed by this package. The combination of various policies and measures should lead *a priori* to improved environmental effectiveness and economic efficiency because it allows combining the strengths, while compensating for the weaknesses, of individual policies and measures that serve identical and/or different purposes (remedy market imperfections and/or reach policy goals). For instance, the specification of a technology standard could upgrade information of producers about the attributes of a particular technology to reduce CO_2 emissions (and/or increase energy security), but it might be insufficient to promote its adoption. Market-based instruments, through carbon pricing, can place a constraint on producers to invest in the particular technology specified. But because the investment cost of technology is high, particularly with regard to "dirty" ones, there can be a need to promote the research and development for the technology specified and the investment cost of producers through financial and/or fiscal incentives (*e.g.*, Aghion, Hemous and Veugelers, 2009). The use of regulatory standards such as eco-labelling and of financial/fiscal incentives can also be needed to promote the use of renewable energies (wind, solar, etc.) in the residential and construction sectors.

A policy mix does not inevitably lead to an improved environmental and economic efficiency. Indeed, taking the above into account, a lot of informational requirements are needed to formulate the right policy package: a good understanding of the environmental issue to be addressed, of the links with other policy areas, of the particulars of each instrument to determine which are most appropriate and of the interactions between the different instruments in the mix (IPCC, 2007, p. 766). For instance, policymakers need to know the distributional impacts of the instruments since those impacts determine the social acceptability of instruments in general. For technology standards, the regulator must have good and reliable information on the abatement costs and options open to each firm, and in return on the economic situation and capacity (financial, technological, human, organizational, and so on) of the firm. An emissions tax needs to be adjusted for changes in external circumstances, such as inflation, technological progress and new emissions sources, etc.

Not only is a policy mix needed, but this portfolio should consist of policies and measures both generic and selective. By generic, one must understand "across-the-board", while selective matches sectoral- and even firm-, product- and/or technology-specific policies and measures. The need for such policies will be explained in section 4.3.

Institutional capacities to administer, implement and coordinate policies and measures chosen are equally necessary. When lacking, they must be developed. For instance, “international scanning” institutional capacity is needed to observe foreign experiences and draw lessons (institutions, instruments and their settings), knowing that any experience of the outside cannot be copied but must be adapted to the national institutional context. To complete information, policymakers can also develop an institutionalized collaboration and coordination with private actors and civil society (Haggard, 2004; Rodrik, 2008). Close links with private actors can create opportunities to elicit information about the existence and location of positive externalities, market failures and constraints that block structural change. This collaboration can serve equally to choose the instrument, to periodically evaluate the situations and outcomes, and to learn from the mistakes being made, such as policy mismanagement (administrative complexity, adequacy of instruments). As a result, policies and measures can be formulated in a pragmatic way. Finally, because the issue is shared among participants, collaboration plays an important role in resolving credibility problems and building trust between the public and private sectors, which eliminate, or at least decrease, problems associated with political uncertainty and reciprocal commitments. Collaboration with civil society too can increase the social acceptability of policies and measures. Without the required capacities and information, the applied policies and measures can produce a worse result.

To summarize, the key points of strategies for climate mitigation are:

- they must be based on a policy mix;
- they must be generic and selective;
- they require a close institutional relationship and trust building between State/public sector, private actors and civil society.

4.2 Identification of policies/measures in Thailand

4.2.1 A tool for screening and evaluating mitigation policies and measures

Here we present a pilot Matrix approach with the aim of using it for Thailand. This matrix serves to classify policies and measures relative to CO_2-emissions-mitigation actions. We consider that the design of a matrix can serve several purposes for a strategic approach:

- screen the range of policy options in a systematic way,
- map out the scope of existing and planned policies and measures,
- identify/select packages of measures,
- identify gaps, loopholes and limits of the climate mitigation commitment,
- pinpoint the cross-sector effect of policies and their potential for extension,
- explore the need for resources or financing tools for mitigation policy.

The implicit assumption behind the matrix is that the use of a single policy and measure cannot be an efficient way for mitigating GHG emissions. As already indicated, the design and implementation of a structured set of mitigation measures lies in the presence of multiple market imperfections, often acting simultaneously. The development of a policy mix can also be justified if various political objectives are pursued. For instance, objectives of energy security and associated policies overlap environmental objectives and associated policies (*e.g.*, the development of new and renewable energy resources).

The matrix is double-entry. On the one hand, it classifies the policies following a sectoral approach (rows in the matrix)[32]. Indeed, reduction targets or emissions limitations and mitigation actions implemented by governments may

[32] Relevant sectors of intervention for mitigation actions are those identified as the backbone of economic and social activities, directly contributing to energy consumption and GHG emissions. Note that the IPCC has considered a comprehensive list of sectors, namely, energy, agriculture, industry, transport, infrastructure, households, and waste management.

affect one or several specific sectors (or sub-sectors), even if the desired aim is to achieve the aggregated environmental objective.

In absolute terms, all human economic activity contributes to a fraction of total CO_2 emissions. As a result, it can be expected that strategies for climate mitigation should encompass all emissions sources, whether proven or potential. But among these sources, some are more important than others, whether they are economic sectors and sub-sectors, fossil fuel consumed, production process used (including equipment), and so on. Similarly, R&D programmes should be developed, but specific technologies are more useful than others given the national needs, capacities (human, institutional, etc.) and objectives. Regarding positive externalities[33], it can be reasonably expected that these are not produced homogeneously in all economic sectors and sub-sectors (and between firms). Specific activities are more prone to produce positive externalities, simply because they have superior technological potential. Similarly, not all activities suffer to the same degree from the market imperfections outlined above. One can say that these examples could be repeated *ad infinitum*. But all point to one direction: generic policies and measures are needed to enlarge the scope and magnitude of environmental effectiveness and economic efficiency, but specific ones must be designed to better respond to specific circumstances and particular activities, which can lead to some discrimination in generic policies and measures.

On the other hand, the matrix lists the various measures that can be included in sectoral policies (columns in the matrix). The measures are then grouped into two main families depending on whether they are regulatory (command and control, soft regulation), or involve the use of market instruments (internationalization of externalities, production externalities).

The actions associated with a "command and control" are based on regulation instead of market instruments. Traditionally, it is considered that these measures are determined by the ruling government and not directly from market forces. The government would therefore play the role of the regulator. Although it is not excluded that the government acts unilaterally in imposing regulations against the will of private actors, the definition of these regulations is often a process of negotiation between the government, which initiates and regents, and private actors concerned, who shall ensure the effective representation of their preferences and concretely implement the measures chosen; also, their role is fundamental in terms of policy effectiveness. These negotiated measures are nevertheless associated with an inflexible regulatory framework, which constrains the behaviour of private actors involved in forcing their acquiescence through laws, rules, norms, standards, and so on, to which inspection programs may be attached. Four types of measures are included in the matrix:

(i) Masterplans,
(ii) Laws and regulations,
(iii) Technical norms and standards,
(iv) Voluntary agreements.

By contrast, measures linked to soft regulations are usually associated with "soft" regulatory frameworks rather than "mandatory and rigid". They encourage actors to behave to meet the objectives set. They can be seen as a complement of most policies envisaged. Soft policy can be based on two sets of tools. *Information instruments* (*e.g.* awareness campaigns) may positively affect environmental quality by promoting informed choices and possibly contributing to behavioural change. Although the impact on emissions has not been measured yet, they are of particular relevance to comprehensive stakeholder participation. *Training and education* covers both the deployment of existing education systems towards issues relevant to climate change (skill generation), and finalized training to foster change of behaviour and to promote the development of know-how (*e.g.*, the use and maintenance of equipment).

[33] In economic theory, an externality exists when a party engages in an activity without considering the costs (negative externality) or gain (positive externality) that could be inflicted on others.

Three types of measures are included in the matrix:

(i) Benchmarking and good practices,
(ii) Education and Training,
(iii) Information.

In addition to these regulations, the government can intervene directly in the economy, using various market instruments. Beyond meeting the environmental objectives, these instruments are designed to meet two different purposes: on the one hand, internalize negative externalities and, on the other hand, generate positive externalities. Both externalities are different from the point of view of their economic effects. First, economic theory explains that negative externalities contract the level of welfare achieved, while positive externalities limit the level of welfare feasible. Secondly, positive externalities are sources of self-sustaining economic growth. They can be generated by different sources, principally innovation, technology and infrastructure, including productive capacities. In spite of these differences, both externalities constitute a strong theoretical argument commonly accepted in favour of direct government intervention in the economy. In principle, this intervention should allow reaching an optimal situation, that is to say a situation where the gap between the private benefit/cost and social private/cost is minimized, and ideally annihilated. The measures included in the matrix are:

1- For internalization of negative externalities:

(i) Levies and taxes,

(ii) Eco taxes,

(iii) Emission quotas,

(iv) Emission certificates.

2- For production of positive externalities:

(i) R&D programmes,

(ii) Technology promotion,

(iii) Investment in infrastructure (including production capacities),

(iv) Fiscal bonus and financial subsidies,

(v) Suppression of market distortions.

Tables 6.1 and 6.2 below reproduce the matrix following the logic of previous explanations.

Table 7.1: Matrix approach regulatory tools (part 1)

Measures / Sectoral policies	TYPES OF REGULATION						
	Command & control				Soft regulation		
	Masterplans	Law & regulations	Technical norms & standards	Voluntary agreements	Bench-marking, good practices	Education & training	Information
Energy / Electricity							
Coal							
Natural gas							
Solar							
Hydro							
Wind							
Biomass							
Nuclear							
Carbon capture & storage							
Electricity (T&D)							
Industry							
All industries							
Energy intensive industry							
Transport							
Road							
Railway							
Air							
Sea / river							
Others							
Building							
Residential							
Services							
Industrial							
Agriculture & Fisheries							
Crops							
Livestock							
Fisheries							
LULUCF*							
Deforestation							
Degradation							
Other							
Water							
Production - Treatment							
Distribution							
Waste							
Urban							
Rural							
Research							
Climate							
Energy							
Information							

** Land Use, Land-Use Change and Forestry*

Table 7.2: Matrix approach regulatory tools (part 1)

Measures / Sectoral policies	MARKETS INSTRUMENTS								
	Internalization of negative externalities				Production of positive externalities				
	Levies & taxes	Eco taxes	Emission quotas (caps)	Emission certificates	R&D	Technology promotion	Investment in infrastructure	Fiscal bonus financial subs.	Supression of mkt distortions
Energy / Electricity									
Coal									
Natural gas									
Solar									
Hydro									
Wind									
Biomass									
Nuclear									
Carbon capture & storage									
Electricity (T&D)									
Industry									
All industries									
Energy intensive industry									
Transport									
Road									
Railway									
Air									
Sea / river									
Others									
Building									
Residential									
Services									
Industrial									
Agriculture & Fisheries									
Crops									
Livestock									
Fisheries									
LULUCF*									
Deforestation									
Degradation									
Other									
Water									
Production - Treatment									
Distribution									
Waste									
Urban									
Rural									
Research									
Climate									
Energy									
Information									

** Land Use, Land-Use Change and Forestry*

4.2.2 A snapshot: New and Renewable Energy policies in Thailand

In this sub-section, we explain through a snapshot how to use the matrix, the structure of which is shown in Table 7. This table provides a mapping of New and Renewable Energy policies applied in Thailand.

The interest here is not to give a detailed reading of Table 7 but only to give some illustrative examples to facilitate its understanding. It must be remembered that the usefulness of this matrix, at this level of development, is only to allow, ideally, the identification of the extensive set of implemented and planned measures; in short, to increase the readability of applied and expected policy actions.

Some examples can be taken from Table 4 for illustrative purposes. Thai authorities actually applied some generic policies and measures for developing new and renewable energies. Some of them aim at internalizing negative externalities: Carbon Credits correspond to the fourth category of measures listed under label 2, “internalization of negative externalities”, that is “emission certificates” (see 2.4. in Table 7). Others are designed to produce positive externalities: *(i)* through technology promotion (3.2.), that is technology transfer; and *(ii)* through fiscal bonus and/or financial subsidies (3.5.), that is financing of adder cost. Soft regulations are equally applied. They are educational and informational, such as technical assistance for project from ESCO Fund (4.2.), and also informational, such as dissemination projects (4.3).

In new and renewable energies, biomass, biodiesel, ethanol, solar and wind sub-sectors are subject to special treatment. As such, each of these sub-sectors benefits from various policies and measures. For instance, biomass production is subject to a regulation of command and control type, more specifically a masterplan (1.1.), or National Biotechnology policy. In addition, it benefits from measures to promote the production of positive externalities, especially the fiscal bonus and financial subsidies (3.5.), that is, promotional packages and tax incentives for research and development. Ethanol production benefits equally from various fiscal bonuses and financial subsidies; and so on.

Obviously, information contained in Table 7 is conditional on the availability of information (we worked on a very limited sample of documents, essentially from public Internet sources or some government agencies). As a result, the matrix is not entirely comprehensive.

Beyond these limits, we now emphasize the different uses of the matrix and how they can assist in policymaking.

First, by taking a thorough mapping of all the measures and policies implemented, more information can be collected to assist and guide decision-making policies; in other words, to facilitate the definition of future policies and measures. A full matrix can put into perspective the sectors requiring policy focus and their relevant forms (*i.e.*, which kinds of measures and policies). As a result, it is possible to map and reveal the existing gaps, in terms of sectors and measures. Moreover, it is possible to identify redundancies in terms of measures and policies already implemented and, ultimately, to reform or delete them. It is also possible to specify what policies hinder environmental objectives (*e.g.*, bad pricing practices or subsidies to polluting fossil fuels). Because of information asymmetry and transparency issues, all this information may not be clearly identified or readable in the decision-making process, particularly when several governmental agencies and/or ministries are involved.

Secondly, beyond the mapping of all Measures and Policies implemented, the integration of some major environmental objectives (to be achieved, in terms of production capacities, CO_2 emissions reductions, etc.), can lead to quantitative assessment. It would then be possible, through modelling, to conduct the evaluation of the comparative effectiveness of policies and measures. Similarly, it would be possible to compare the contribution of each sector to these objectives.

Table 8: The Matrix of New and Renewable Energy policies and measures

Measures Sectoral Policies	Command & Control (1.)	Internalization of negative Externalities (2.)	Production of positive externalities (3.)	Soft regulation (4.)
New and renewable energy		2.4. Carbon credits	3.2. Technology transfer 3.5. Financing of adder cost by term of support 7 years and 10 years for power generation from wind and solar (3 provinces in southern Thailand) 3.5. Soft loan from ESCO fund (limited to 50 million Baht /project, with varying terms and conditions depending on project [equity investment, capital venture, equipment leasing])	4.3. Dissemination project 4.2. Technical assistance for project from ESCO fund
Biomass	1.1. National Biotechnology Policy	2.4. Clean Development Mechanism for specified projects	3.1. Promotional packages and tax incentives for R&D in biotechnology and its applications, particularly those that use agricultural outputs and by-products for alternative energy production 3.3 Thermal generation from biomass	
Biodiesel	1.1. Enforcement used B2 for the whole country 1.2. Announce for use B5 as a standard diesel in case of enough raw material for biodiesel production 1.1. Substitute B100 for 10% diesel		3.1. Intensive R&D on enhancing values of by-products from bio-diesel production Promotion of palm oil and jatropha cultivation 3.5. Fund for promoting biodiesel production from used oil 3.5. Soft loan fund for oil palm plantation 3.3. Community and commercial scale of B100 production and utilization of B5 in the South and the Central part of Thailand 3.6 Biodiesel retail price cheaper than diesel oil by 0.70-1.00 baht/liter	
Ethanol			3.5. Decreased taxes and levies for gasohol E10 3.6. Duty exception for machinery import 3.5. Income tax 8 years 3.6. Free trade of ethanol production for use as fuel 3.6. Liberalization of Ethanol industries 3.6. Gasohol retail price cheaper than gasoline	
Solar			3.5. Awarding and promotion of investment in the manufacture of solar cell modules	
Wind			3.5. Subsidies for electricity produced by wind power, with prices at 2.5 baht per unit (kW/hour)	

Conclusions

From the different insights of this study, several important conclusions can be drawn here regarding climate-change mitigation strategies in Thailand:

- A set of existing policies, mostly focused on the energy sector, has already been implemented. This could be expanded further and diversified.

- The experience of governmental bodies has been built up over the past two decades to identify options, coordinate exchanges of views and implement targeted policies. Some experimentation could be initiated – for example on a preliminary carbon-tax system.

- A national scientific potential is already established, with a diversity of expertise and capacity for nationwide field work. The seminar generated suggestions for further relevant research expansion.

- Coordinated initiatives of the private sector have been diverse, with substantial potential for upgrading in major sectors of activity.

- A growing awareness among civil society is however combined with entrenched attitudes, and resistance to change in everyday life, as in most other countries…

Therefore, one could assume that the national strategy of Thailand will aim at the ambitious goal of reconciling sustainable economic and social development with climate strategy, and that government and public administrations will maintain and even strengthen a proactive attitude in this area. We also consider that Thailand, as a developing nation, is not legally bound by the UNFCC as Annex-1 countries are, but will show its preparedness for new commitments to contribute to the emergence of a post-2012 climate regime - in spite of uncertainties regarding the possible transformation of the UNFCC framework, particularly regarding the extension of the Kyoto Protocol.

List of acronyms

ADB	Asian Development Bank
AFD	Agence Française de Développement
CGN	Chula Global Network at Chulalongkorn University (Thailand)
CNRS	Centre National de la Recherche Scientifique (France)
CO_2	Carbon dioxide
COP	Conference of Parties
DEDE	Department of Alternative Energy Development and Efficiency
EPPO	Energy Policy Planning Office
ESCAP	Economic and Social Commission for Asia and Pacific
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de Recherche pour le Développement
Ktoe	Thousand ton (metric) oil equivalent
Ktco2	Thousand ton (metric) carbon dioxide
LCS	Low-carbon Society
LMD	Logarithmic Mean Divisia index method
NAMA	Nationally Appropriate Mitigation Action
NESDB	National Economic and Social Development Board
TPEC	Total primary energy consumption
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

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