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Fostering low carbon growth initiatives in Thailand

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Figures

PRESENTATION

Ce document propose un cadrage de l'étude « **Fostering low carbon growth initiatives in Thailand** », soutenue par l'Agence Française de Développement et dont le comité scientifique est présidé par le National Economic and Social Development Board de Thailande. Il constitue le papier introductif du séminaire accueilli par l'Université Chulalongkorn – Chula Global Network, de Bangkok.

Le document propose une approche générale sur les thèmes de la croissance verte, des combinaisons de stratégies énergétiques et climatiques, en particulier pour les pays émergents et dans la région Asie. Il développe une analyse des tendances énergétiques et des émissions de CO2 en Thailande. Il détermine les profils d'émission passés et futurs, en utilisant la méthode de la décomposition. La finalité est d'éclairer les enjeux d'une croissance moins intensive en émissions et de contribuer à l'identification des politiques climatiques.

FOREWORD

This document provides a general framework for the study **"Fostering low carbon growth initiatives in Thailand"** sponsored by Agence Française de Développement. It is designed as a background document for the scientific workshop hosted by Chula Global Network at Chulalongkorn University on 25-26 February 2010.

The report is prepared with three main objectives:

i/ Review of general information and scientific literature to be shared with members of the scientific committee and with other contributors to the seminar.

ii/ Analysis of energy trends and carbon emission patterns, and identification of major issues related to low carbon scenarios analysis.

iii/ Exploration of some topics for further debate and analysis.

In the following sections, the background report will be organized along three major lines:

- Overview on the dual climate change and development challenge, with emphasis on the scope for policy options related to the current debate on "Green Growth",

- Retrospective analysis of CO2 emissions profiles in Thailand over 1990-2008,

- Review of methodologies low carbon scenario

The conclusion will address the rationale for Nationally Appropriate Mitigation Actions that could be implemented in the years to come. This report is built on documents and literature published prior to

December 2009 and therefore does not deal with new issues considered as in a 'post Copenhagen Conference' perspective

This document was prepared by LEPII-team[1] and presented at the workshop, with input or comments from other contributors from the Scientific Committee, Chula Gobal Network and Agence Française de Développement.

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– EXECUTIVE SUMMARY –

The development of the study "**Fostering low carbon growth initiatives in Thailand**" **acknowledges a triple priority, with strong bearing on future economic and social development:**

1/ The need to address jointly the challenges associated with current economic crisis issues (short term "economic recovery" targets) with objectives of sustainable strategies (long term economic, social and environmental improvements) through 'Green Growth' oriented policies, which provide a vision that is already high on the international agenda, particularly in the East Asian region.

2/ Low carbon initiatives show particular relevance in rapidly emerging economies. Theses countries experience tremendous transformations and currently require proactive policies to steer the economy towards future growth patterns: in that respect Thailand presents a showcase as Southeast Asian emerging economy, with vibrant energy and carbon emission intensive growth associated with increasingly diversified policy intervention.

3/ The ambition to foster debate, between specialists of various affiliation or origins, with thought provoking workshop bringing more economic insight in existing techno-economic studies and analysis of the impacts of energy and low carbon initiatives on the Thai economy. The paper selected for workshop presentation will focus on several amongst major sectors in terms of green growth potential and Carbon emission reductions.

This background report is organized along three major lines:

   i.   Presentation of the challenges of climate change for the developing world, and particularly debate and current visions in Asia.

   ii.   Retrospective analysis of CO2 emissions profiles in Thailand over 1990-2008,

   iii. Review of methodologies to design and estimate various low carbon scenario, with special consideration to those relevant for Thailand.

The conclusion covers current policies in Thailand and the rationale for Nationally Appropriate Mitigation Actions that could be implemented in the years to come. This report is built mostly on information, documents and literature published prior to December 2009 and therefore does not fully deal with new issues or specific expectations as they rise after the end of the COP15 Copenhagen conference.

1 INTRODUCTION: THE CHALLENGE OF CLIMATE CHANGE AND DEVELOPMENT

Since 1988, when the United Nations initiated the Intergovernmental Panel on Climate Change, global warming has been increasingly perceived as major challenge facing mankind. This has resulted into an internationally negotiated framework first implemented in the Rio Conference (1992) and then developed through the series of Conferences of the Parties, among them Kyoto (1997) and Copenhagen (2009).

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 been upgraded as a paramount element both for debate in civil society and inspiration for fresh scientific investigations in all major scientific areas. In addition, mitigation and adaptations strategies to face the challenge of climate change are now a key component of overall development strategies, which gives ample justification for strengthening exchange 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 evidences 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 over several decades[2]. 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[3]. 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, increased 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 **double rationale for a transition to Low Carbon Economy**: it is expected to increase flexibility and security of supply through a better management of energy requirements and

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[2] Stiglitz, J. Yusuf, S. (2001) Rethinking the East Asian Miracle. World Bank/O.U.P.

[3] Rock, M.T., Angel, D., (2005): Industrial Transformation in the Developing World. Oxford University Press.

sources, and on the other hand it addresses the climate and environmental challenges thanks to cleaner production and transport systems and improved resource management[4].

Thailand is a telling case on these aspects – it has been one of the brightest Newly Industrialized Economies[5] 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. **Thai government has also designed and implemented a range of policy measures ranging from environment protection to energy conservation** and diversification which takes the path towards the so-called Green Growth approach presented below. In addition, the context of the financial crisis and related fiscal stimulus initiative offers additional opportunities for well targeted public sponsored measures that will strengthen the adaptation of Thailand's economy throughout the Tenth National Plan period, and prepare orientations for the next National Plan.

1.1 The relevance of the « Green growth » agenda

We turn here to 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.). It also analyses the relevance of Green Growth in the context of Asia, as seen by international institutions and some selected countries (2.).

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

Over the past decade, thinking on reconciling overall economic growth and environmentally friendly policies has led to coin out 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 or promoters such as J.G. Speth, former Head of the United Nations Development Programme (presently at Yale University), alongside United Nations Secretary General Ban Ki Moon (coining the idea of Green New Deal) and from former United States of America Vice President Al Gore. On a wider level, international institutions, such as various agencies of the UN system, or recently the European Union have also

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[4] For further development see *The Economics of Climate change in Asia – A Regional review* ADB (2009*), How the Energy sector can deliver on a climate agreement in Copenhagen* IEA/OECD October 2009.

5 Muscat, R. (1995) *The fifth Tiger* UNU Wider & M.E. Sharpe ; B. Nidhiprabha, Warr, P.G. (1996) *Thailand's Macroeconomic Miracle* World Bank & Oxford University Press.

increasingly referred to Green Industries and Green jobs as components to 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 has also recently endorsed the concept in its June 2009 ministerial meeting, issuing a "declaration on Green growth" that emphasizes:

i. The need to address jointly the challenges associated to the current economic crisis issues (short term "economic recovery" objective) with the targets of sustainability strategies (long term social and environmental improvements) through 'Green Investment' and policies.

ii. The crucial role of international cooperation to promote low carbon economies, through development of adequate technologies and institutional framework.

iii. The strategic orientation for OECD member countries to encourage Green Investment, related knowledge and training capacities, and to engage into relevant policy reforms.

iv. The willingness to share information, projects as well as strengthening international cooperation with non-OECD member countries.

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 recent 2009 UNCTAD report has also emphasized the need to promote national strategies and international negotiation/cooperation to reconcile growth, economic opening and climate mitigation.

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[6].

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 months. In 2009 in Manila, the International Conference on Green

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[6] See Aghion et alii (2009) No green growth without Innovation (Bruegel think Tank Brussels, Novembre 2009). And also The French Economic Association (see AFSE Newsletter August 2009 special issue on Green Growth and sustainability).

Industry in Asia (UNIDO, Manila declaration 10 September[7]) has 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[8] 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 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 pattern. UNESCAP proposes a Five tracks approach, adopted by the 5th Ministerial Conference on Environment and Development (MCED 2005) 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 '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. Several examples can be mentioned at this stage :

China. Green Growth policy orientation would combine a resource saving society and a new industrial path. China has selected and targeted policies for slowing carbon emissions, develop resource saving and pollution control options. A wide range of measures is being implemented. It is declared that this approach should alleviate environmental damages, reduce costs bearing on

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[7] http://www.iisd.ca/download/pdf/sd/ymbvol166num3e.pdf

[8] 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

activities and human life (e.g. cost of pollution amounting to 3% of GDP in 2004). Recently China Implemented a Fiscal stimulus with 'Green Growth' component: a two year stimulus package of $585 billion (4 trillion Yuan) was introduced late 2008, to cushion the domestic economy against the 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 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. It 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 is also created to assist the commission. The current energy strategy has a 2030 horizon. Other components to be further 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 of Korea, the president believes that green growth will enable Korea to take a lead in the direction of a low carbon society[9]. 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.

To put it in a nutshell, it can be said that the Green Growth Approach provides a convenient framework for Climate Change policies, as it offers different levels of thinking and of action:

    i.   Common perspective for new ideas and strategies against global warming to be shared among Asian countries.

    ii.   Flexible agenda for policy measures in various sectors, with a Low Carbon Economy prospect.

    iii.   Areas for fostering job creation, innovation, and creation of new activities.

    iv.   Preliminary conceptual framework for negotiation and cooperation in climate mitigation actions, relevant for both developed and emerging or developing nations;

1.1.3 The quest for a low carbon economy

The debate on the low carbon economy is growing everywhere in Asia. Recent studies for China [10] show that the more economically advanced provinces in this country are also the least

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

[10] 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 main findings of the report on http://www.undp.org.cn/downloads/copenhagen/key_findings.pdf

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 have to lead to increased greenhouse gas emissions.

As detailed in the following paragraphs in this background paper, Low carbon scenarios may help to envision what could be a low carbon economy. Japan is one of the leading countries promoting Low Carbon Scenarios and founded the LCS R–net[11]. The National Institute for Environmental Studies (NIES), together with other institutes, has developed visions for low-carbon society and roadmaps for several cities in Asia. Modelling research on LCS in Japan suggest that a 70% to 80% reduction in GHGs 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 a LCS. Dr. Mikiko Kainuma, (National Institute for Environmental Studies, Japan)[12]also pointed out that while innovative technology is important to realize a 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 this 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 detailing the different issues at stake and the LCS study for Thailand (Shresta et al., 2009[13]).

In spite of the mixed results of the negotiation at COP-15 in Copenhagen, the debate on LCS will continue to grow in importance and several International Symposium and scientific conferences are going to be organised[14]. 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 to 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.

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: 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.

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[11] 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

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

[13] For a quick overview of the key issues as well as session summaries in the Bologna inaugural meeting, one's can refer to the synthesis report which can be obtained 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). Published in 2009 and prepared by the LCS-RNet Secretariat

[14] The APN and the Hyogo Prefectural Government are organising an International Symposium "Challenge 25 Beyond Borders? Promoting a Low Carbon Society" to be held on 23 January 2010 at the Hyogo Prefectural Museum of Art in Kobe, Japan. http://www.apn-gcr.org/en/indexe.html.

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

In that perspective, the sixth report from the Working Group on Climate Change and Development[15], launched before COP15 argued that the chances of controlling climate change will rise dramatically if people recognise 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 those on lowest incomes getting the fewest benefits and paying the highest costs. A wide range of examples of more positive approaches are given derived from the extensive and practical experience of partners in the coalition. Altogether they paint a picture of more qualitative development, which should not be dependent on further global over-consumption by the already rich, considering false hopes that crumbs of poverty alleviation could benefits those at the bottom of the income pile.

"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 changed 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 each time tailored to local conditions. The aim of this background paper 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 adjusted to Thailand – which 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.

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

1.2.1 Thailand's development: issues, ambitions and visions

Thailand presents a showcase of a Southeast Asian emerging economy. It has experienced six vibrant development decades, faced economic opening and globalization, and achieved tremendous modernization of infrastructures so as a diversification of production systems in major sectors. The current level of satisfaction of basic needs and of human development are also remarkable. These economic and social achievements were actively researched by the Thai

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[15] Featuring contributions from Dr Rajendra Pachauri, Prof. Herman Daly , Prof. Wangari Maathai, Prof. Manfred Max-Neef, Prof. Jayati Ghosh (economist) and David Woodward. See
http://www.neweconomics.org/publications/other-worlds-are-possible

government, in a constant effort of elaboration of public policies, within the framework of the National 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 damages, the sustained growth and transformation of the country have undoubtedly contributed to the increase in energy consumption and hence to higher emissions of greenhouse gas, and 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 placed itself on a high carbon economy course over the past decades. This has also generated constraints on energy import dependence, a burden on external accounts as well as on household expenses, and required consistent policy initiatives to reduce vulnerability. While some actions had been undertaken before, the energy and environmental issues have penetrated deeper into the political agenda with the sixth plan, covering the 1987-1991 period[16]. Since then, these issues remain as key elements of public policy, with recent significant evolutions.

A major stone has been 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* »[17]. This mandate is set to promote energy conservation and energy efficiency in industry, building and commerce. At the same time an important focus has been placed on reforestation. Efforts have also been made to look for solutions to the serious problem of import energy dependency and to increase the 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, these 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[18]. 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 putting at risk the rapid economic growth that the country has experienced over the past. Tellingly though, the Tenth Economic and Social Development Plan calls

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[16] Ministry of Science, Technology and Environment, 2000, *Thailand's Initial National Communication*, 2000.

[17] Ministry of Science, Technology and Environment, 2000, *Thailand's Initial National Communication*, 2000, p. 76.

[18] 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.

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 preservation of environment and natural resources.

Consequently, the 10th Plan advocates the vision of *"... a 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 new growth pattern

Is there a favourable context setting 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, and probably calling for new forms of negotiations and regulations. On the other hand Green Growth orientations could establish a nexus between 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, promote development of low carbon options in various domains could trigger a transition towards a more sustainable development pattern.

Although the Thai government has ratified the United Nations Framework Convention on Climate Change at Rio in 1992, it has not been associated up to now to international commitments to reduce greenhouse gas emissions. Thailand belongs to the list of the Non-Annex 1 of the UN-FCCC. Also, if 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 has announced targets for reducing CO_2 emissions by 15-20 percent[19], compared to a reference projection, or no-policy case. This commitment has been reaffirmed for Copenhagen, the Thai government announcing a target of greenhouse gas emissions reduction in the energy sector by up to 30% from now until 2020[20].

This political statement, clearly oriented toward the control and the reduction of CO_2 emissions, is certainly welcome. Indeed, estimates by World Resource Institute indicate that Thailand's contribution to World CO_2 emissions is non negligible. In 2006, its emissions represented

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

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

0.83 % of World total, ranking in the twenty-fifth place 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 Environment Department of the World Bank: during the 1994-2004 period, while emissions had increased by 72%, Thailand was ranked in the sixth place among 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 the past decades, and a high one by international comparison. In this context, initiatives to better control carbon emission growth, promote development of low carbon options in various domains of life and socio-economic system could trigger the transition toward a low carbon society, while taking the path of a 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 help the political decision-making with the aim of creating a new growth pattern. However, the promises of a new impetus have to be balanced with the obvious difficulties and challenges that will certainly be experienced throughout the process, such as:

i.   Price increases, induced by policy measures such as 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 down 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[21])

iii.   This will imply changes at micro- and macro-economic level and require new policy tools to be analyzed 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.

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[21]Referencehttp://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Events/2009/Green_Industry_Co nference/concep.pdf

2   A RETROSPECTIVE ANALYSIS OF CO_2 EMISSIONS PROFILES IN THAILAND (1990-2008)

The purpose of this section is to analytically clarify what have been 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 a great help for a country like Thailand, which, accordingly to the Bali Action Plan and the conclusions of the Copenhagen conference, will have in the future 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). Result are then presented and commented.

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 then put into perspective in order to choose the most suitable model in order to provide a complete and adequate decomposition (LMD method).

2.1.1 Short review of the literature

At the heart of the problematic of CO_2 emissions decomposition lays 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 CO2 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. 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 have been 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, the energy intensity, the elasticity of energy to GDP, the material flows and dematerialization and the 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 have 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 a growing political concerns concerning 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 US, UK, 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, a less marked interest was given to emerging economies (see, Ang and Zhang, 2000). This discrimination in the interest provided to different countries can be regarded as logical: industrialized countries belong to the Annex I and are thus submitted 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 even who have already developed national policy actions or NAMAs directed towards this purpose[22].

Considering the Thai emerging 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 emissions intensities from three determinants: technology-mix, fuel-mix and fuel intensity. The sector analysed are 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 NOx emissions intensities, fuel intensity being the main one, thanks to efficiency improvements in technology production.

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[22] To give few references focusing on greenhouse gas emissions, see Ang and Pandiyan (1997) for China, Korea and Taiwan, Ang, Zhang and Choi (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.

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

Punyong, Taweekun and Prasertsan explored energy efficiency in Thai industry from 1987 to 2002 (Punyong, Taweekun and Prasertsan, 2008). Punyong and his associates 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 the 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, 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 ktoe in the 1987-2002 period.

ii.   While the mining and construction have saved energy (25.84 ktoe and 145.84, 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) in 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 in 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 analyzed 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 Laspeyres index and Divisia index. Laspeyres index measures the impact of a factor by changing its value, while keeping constant other factors at their respective level for the base year. 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 is the residual value, the more difficult it is to interpret the results, if it is not impossible. The residual appears equally in the Divisia index, where index takes the form of an arithmetic mean. Thus, these two indexes expressed in their conventional form do not satisfy the factor-reversal test (Ang, 2004). The Laspeyres index, as 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. 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 determine which of them should be used to make the CO_2 decomposition analysis. Decomposition can use the multiplicative or additive technique. 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, 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 can not be established as clear-cut under the Laspeyres index. Finally, Ang added that logarithmic mean Divisia index method should also be preferred because of its theoretical foundation and easyness to use and to interpret 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:

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

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 use efficiently the energy resources it consumes. Improved efficiency may come from policies implemented, technological changes and socio-economic behaviors.

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

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:

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

(2)

where E is the total CO2 emissions. When subscript i is added to each effect, this effect is then estimated fo the ith sector. In 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 $L(E_{iT}, E_{i0}) = (E_{iT} - E_{i0}) / \ln(E_{iT} / E_{i0})$ is 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 proceed 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:

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

As proposed first by Sun (1999), preceding equations can be used to assess "theoretical" and "real" CO_2 emissions by sector and for the overall economy. CO_2 emissions 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') and "Real" (R_i') CO_2 emissions by the ith sector then can be written as:

$$T_i' = E_i^0 + A_i' + S_i'$$

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

and for the whole economy:

$$T' = E^0 + A' + POP'$$

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

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 CO2 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 analyzed 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 tons, respectively of CO2 and of oil equivalent (ktCO2 and ktoe). Seven sectors are identified as: agriculture, mining, construction, manufacturing, transport, electricity, residentials and service. Five types of energy are used namely, oil, natural gas, coal and lignite, biomass and electricity.

The GDP is equally collected from Enerdata and is expressed in US$ in constant price and exchange rate 2005. 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 Bath 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 been multiplied by 2.2, increasing from 89 billions US$ (at constant 2005 price and exchange rate) in 1990 to 199 billions US$ in 2008. This growth has thus proceeded at an average annual rate of 4.3 % over the same period. However, as shown in Figure 1, this strong growth process has been repeatedly disrupted. During the first half of the 1990s, the economy is in a dynamic growth process that began in the late 1980s, after a period of structural adjustments. From 1990 to 1996, the economy has grown on average at a rate of 8.2 %. However, the irruption of the Asian financial crisis in July of 1997 has stopped this impulse. Economic activities then undergoes a drastic slowdown: in 1998, all economic sectors show negative growth rates, sometimes after several years of double digit growth, according to the sector considered. As a result, the economy as a whole has recorded negative growth rates of -1.4 % in 1997 and -10.5 % in 1998.

The crisis has been short-lived and the GDP started to pick up since 1999 (4.4 % y.a.g.r.). But the economy is subject to a slowdown in 2001, primarily as a result of the impact of the global slowdown on the industry sector and on exports coupled with sluggish domestic demand (ADB, 2001, 2002). The growth rate has thus decreased from 4.8 %p.a. in 2000 to 2.2 %p.a. in 2001. Growth bounces back in 2002 (5.3 %p.a.) and 2003 (7.1 %p.a.). A further slowdown begins 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, last but not least, rising oil prices (ADB, 2005, 2006). The next period 2005-2007 represents a relatively stable growth era, but the growth rate is substantially slower than in early 1990s, *i.e.*, 4.9 %p.a. on average. Finally, growth fell to 2.6 %p.a. in 2008. This is due to domestic political turbulence, which has aggravated the economic impact of the global recession (ADB, 2009).

Figure 1 - Thailand's GDP, 1990-2008
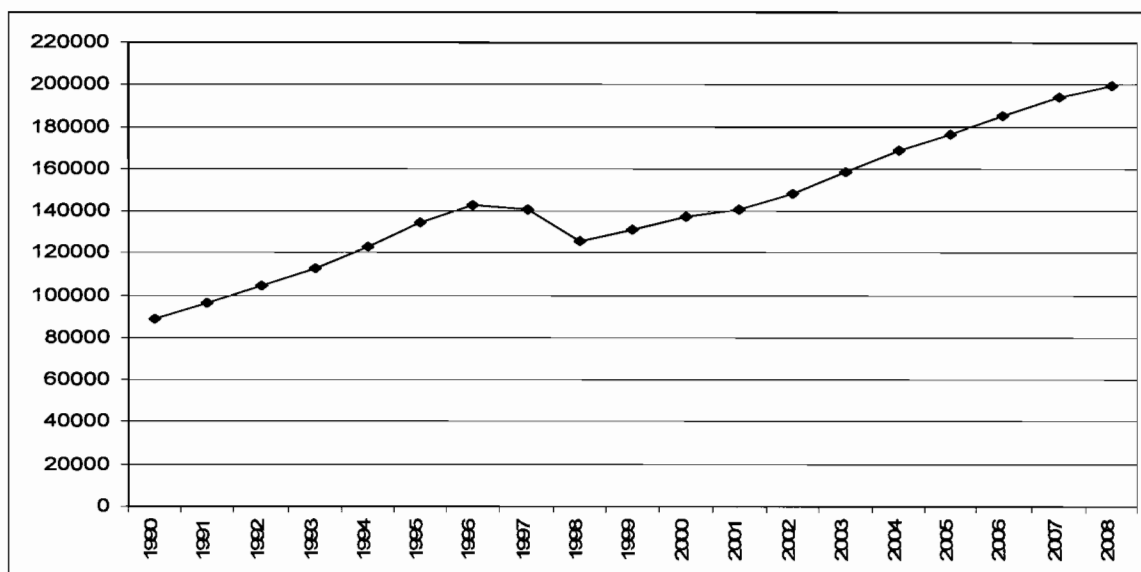
Note: GDP US$ at constant price and exchange rate 2005.

Sources: Enerdata - Global Energy & CO2 Data (2009).

2.2.3 Value-added by sector: strong structural changes

During the disrupted growth process, the economy has undergone major structural changes (see Fig.2). The most notable one is that manufacturing took precedence over the agriculture and service sector in the conduct of economic growth by the turn of the 2000s. This reflects the process of rapid industrialization in Thailand. The contribution of manufacturing has 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 has thus trebled, increasing from 29.2 % in 1990 to 40.1 % in 2008. Its growth has been the most dynamic until 1997 (on average, 7.8 % per annum). However, its growth rate has been halved during the remaining period (4.1 %p.a. in 1997-2008). The growth of manufacturing has occurred primarily at the expense of the residentials and service sector[23]. While this sector was the principal contributor to GDP in 1990, its share is passed from 41.1 % to 33.3 %, because of a low average annual growth rate of 3.2 % (lower than GDP).

Agriculture (excluding forestry) also suffers from Manufacturing Industry growth. Its share has dropped from 11.8 % in 1990 to 8.9 % in 2008. In fact, the share of agriculture has 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.).

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[23] In respect of EPPO classification, Residentials include "Private Households with Employed Persons".

The Electricity sector has contributed little to GDP throughout the period considered, although its share has slightly increased from 2.4 % in 1990 to 3.4 % in 2008. Because of its low level in 1990, this sector has grown at an average annual growth rate of 6.2 %, *i.e.*, slightly higher than Manufacturing Industry. The Mining sector is subject to the same observation. Its share has slightly increased from a low base of 1.6 % to only 2.2 % respectively, but at an annual average growth rate of 6.2 %p.a.. In time, Transportation has contributed to slightly increasing share of GDP from 7.5 % in 1990 to 9.8 % in 2008, at 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 to GDP has been divided by 2.7, decreasing from 6 % in 1990 to 2.2 % in 2008. In fact, the Construction sector has benefited from the real estate and construction boom induce by the high economic growth in the early 1990s. But it has then been 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 has remained relatively stable, at around 2.4 % on average during 2001-2008. Thus, Construction never managed to regain its past momentum.

Figure 2 - Value added by sector, 1990-2008
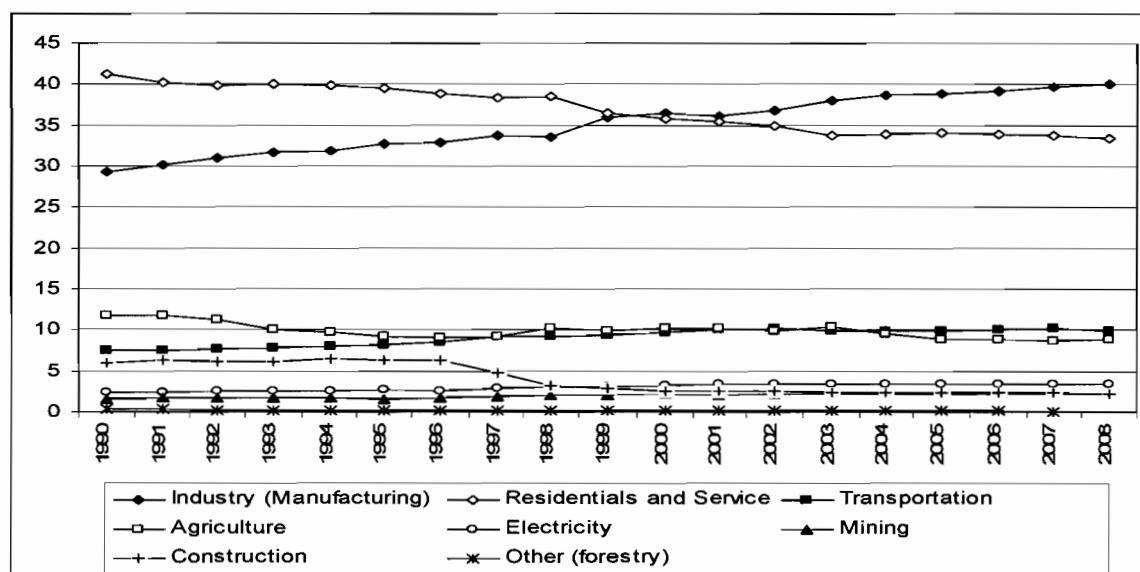
Note: Sectoral share in percentage of GDP.
Sources: 1990-1991, NESDB (2003); 1993-2008, EPPO web site.

2.2.4 CO_2 emissions and CO_2 intensity at the aggregate level

During the 1990-2008 period, CO_2 emissions have been multiplied by 2.7, passing from 83 674 ktCO2 to 226 672 ktco2 respectively (see Fig.3). This increase occurred at an average annual

growth rate of 5.4 %. In the same time, CO_2 intensity has increased from a low base of 0.94 ktCO2/MUS$ (constant price and exchange rate 2005) in 1990 to 1.12 ktCO2/MUS$ in 2008).

CO_2 emissions have increased most significantly and most rapidly until 1997, increasing at an average growth rate of 9.2 % during 1990-1997. Following the Asian crisis and the sharp slowdown in economic activity, CO_2 emissions have declined significantly in 1998 (-9.3 %). The emissions then increase again until 2004, but at a much more 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 increase moderately until new rises in 2007 (4.2 %) and to a lesser extent in 2008 (2.3 %).

Figure 3 - CO_2 emissions and CO2 intensity, 1990-2008
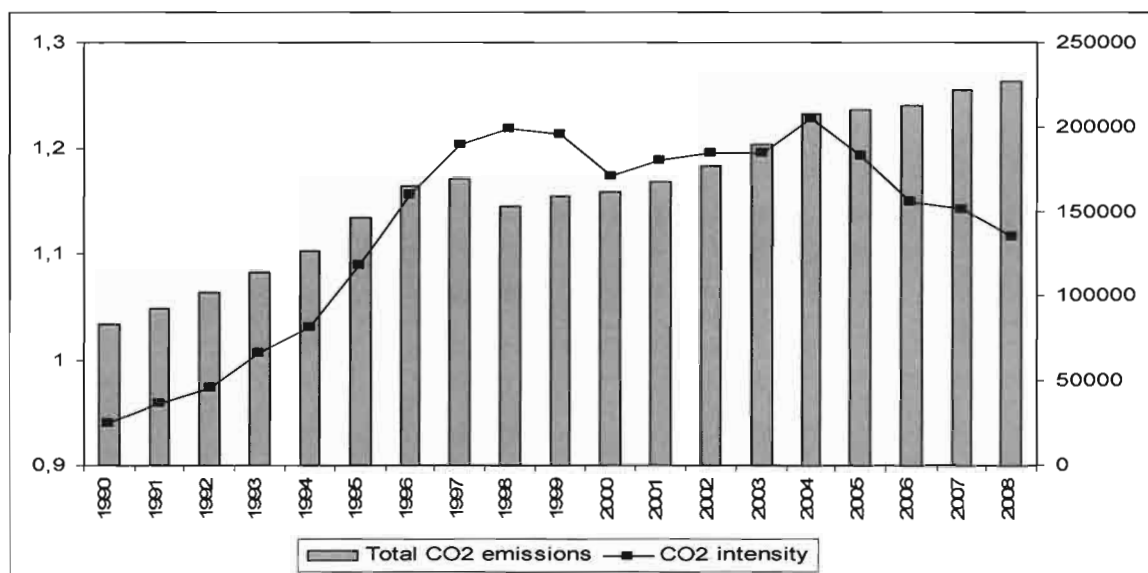
Notes: left axis: CO_2 intensity defined as CO_2 emissions (in ktco2) divided by GDP (at US$ constant price and exchange rate 2005); right axis: CO_2 emissions expressed in ktco2.

Source: See Figure 1.

Regarding CO_2 emissions, growth was more intensive in CO_2 until the Asian Financial crisis, increasing from 0.94 ktco2/MUS (constant price 2005) in 1990 to 1.22 ktco2/MUS (constant price 2005) in 1998. Also, one point of growth has produced on average 1.6 point of percentage of CO_2 emissions during this period (see Tab. 1). During and in the aftermath of the Asian financial crisis (1997-1999), CO_2 intensity remained relatively stable, but dropped significantly in 2000 to 1.17 ktco2/MUS against 1.21 ktco2/MUS in 1999. As CO_2 emissions, CO_2 intensity has grown 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 greater than that of GDP.

In spite of growing CO2 emissions, the end of the period has followed a trend opposite to that prevailing in its early in terms of CO_2 intensity: economic growth has become less and less emission intensive since 2004.

2.2.5 CO_2 emissions at sector level

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

Electricity is the main transmitter 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 1990-2008. While their growth has been striking in 1990-1997 (on average, 9.6 % per annum), the growth rate of CO_2 emissions has significantly reduced in 1997-2004 (0.7%). Although the growth rate remained lower than that prevailing 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. Consecutively to a moderate increase over 1990-2008, increasing at an average annual growth rate of 3.7 %, Transport has become 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 have not increased but 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 CO2 emissions has been 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 have increased at an average annual growth rate of 3.6 % in 1990-2008, their contribution to total CO_2 emissions has decreased slightly from 6.8 % in 1990 to 4.9 % in 2008. The pace of emissions growth has been stronger in 1990-1997 (on average, 4.9 % per annum), and then slowed in 1997-2004 (3.7 %) and in 2004-2008 (0.2 %).

CO_2 emissions from residential and commercial have grown on average by 4.5 % per year in 1990-2008. However, their contribution to total CO_2 emissions has slightly decreased from 2.8 % in 1990 to 2.4 % in 2008. Their growth has been the most dynamic in 1990-1997 (on average, 6.3 % per

annum) and then slowed in 1997-2004. Like for electricity, CO_2 emissions have increased again in 2004-2008, although remaining at a level below that prevailing in 1990-1997 (*i.e.*, 4.1 %)[24].

Finally, construction and mining are the only sectors where CO2 emissions have 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 have decreased from 0.6 % and 0.2 % in 1990 to 0.2 % in 2008 and 0.04 % in 2006 respectively.

Figure 4 - CO_2 emissions by sectors, 1990-2008
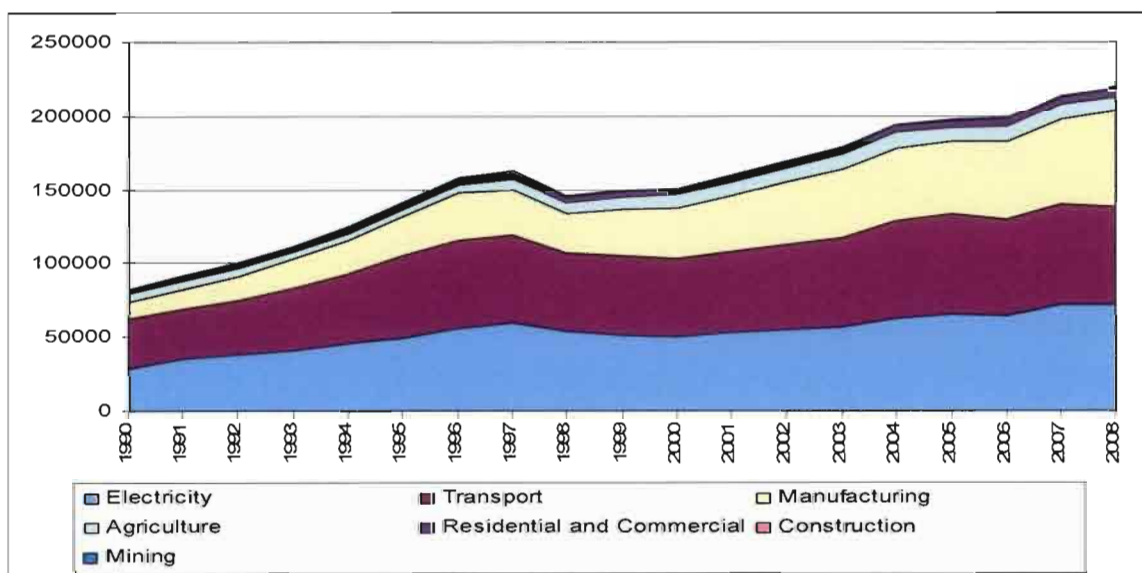
Notes: CO_2 emissions expressed in ktco2. The total in this Figure is not strictly comparable to those of Figure 4 because exclusion of some parts of energy sector (for instance, equivalent to 979 ktco2 in 1990 and 14785 ktco2 in 2008). Electricity corresponds to public electricity and heat production. Manufacturing includes autoproducers and, in 2007-2008, mining.

Source: See Figure 1.

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

Since 1990, total primary energy consumption (TPEC) has significantly increased (see Fig.5). The level of final consumption in 2008 accounted for 2.5 times the 1990 level (from 43899 ktoe in 1990 to 110021 ktoe in 2008). In the same time, energy intensity has raised from 0.49 ktoe/million of US$ in 1990 to 0.55 ktoe/million of US$ in 2008. TPEC increased at an average annual growth rate of

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[24] Note that the data of Enerdata do not take into account the CO_2 emissions from commercial, residential only. 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 biased the results in order to radically change the results obtained from decomposition analysis.

5 % over 1990-2008. However, its growth has considerably reduced after the Asian financial crisis. While TPEC has grown on average at 6.7 % by 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 has decreased during the first half of 1990, passing from 0.49 ktoe/million of US$ in 1990 to 0.47 ktoe/million of US$ 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/million of US$. Energy intensity has thus begun a gradual decline thanks to the faster growth of GDP than TPEC. In 2008, energy intensity has reached 0.55 ktoe/million of US$. This level remains however higher than that prevailed throughout the 1990s.

Thus, in spite of growing TPEC, the end of the period has shown a changing trend in terms of energy intensity: economic growth has become less energy intensive since 2004.

Figure 5 - Total primary energy consumption and energy intensity, 1990-2008
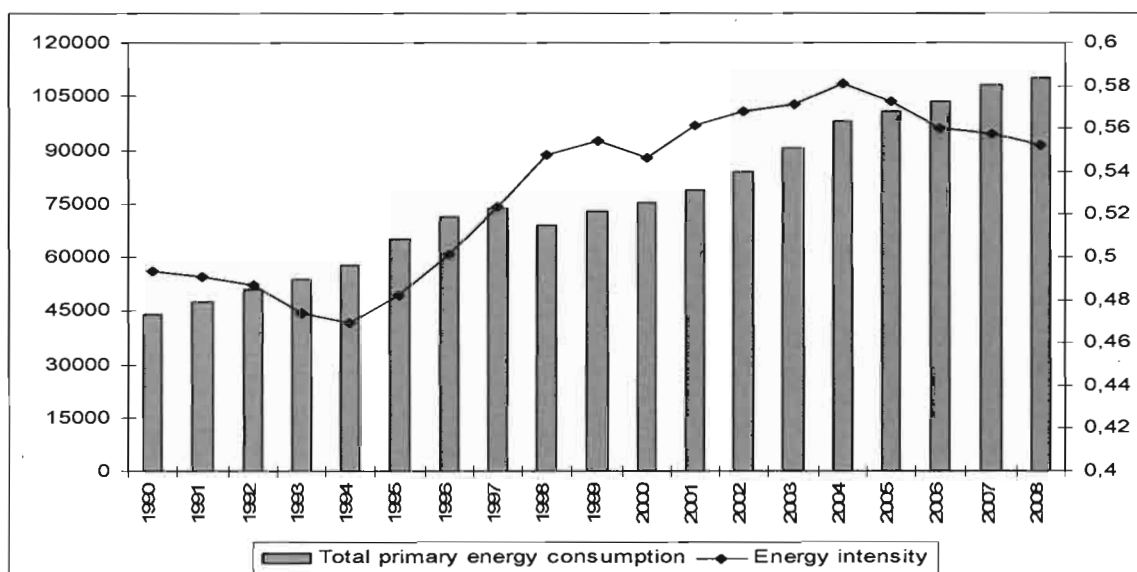
Notes: left axis: total primary energy consumption expressed in ktoe; right axis: energy intensity defined as total primary energy consumption per dollar of GDP (at US$ constant price and exchange rate 2005).

Source: See Figure 1.

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 sectors listed in Figure 6.

While residential and commercial was the principal energy consumer in 1990, representing 25.5 % of TPEC, its share has fallen to 20.2 % in 2008. This decline is attributable to increased consumption by electricity and manufacturing sectors. Indeed, their shares in TPEC have risen from 20.8 % and 18.1 % in 1990 to 24.8 % and 23.6 % in 2008, respectively. As a result, electricity and manufacturing sectors are the first and second largest consumer of energy in 2008. Energy consumption share of residential and commercial has also declined and 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 has been the most dynamic, increasing at an average annual growth rate of 6.4 % in 1990-2008. Electricity has equally increased its consumption rapidly, on average 5.9 % by year in the same period. The growth of consumption by 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 by each sector was most rapid between 1990 and 1997, while a significant slowdown is observed for the period post-Asian Financial Crisis. For instance, the growth rate of consumption of the building fell on average from 12.1 % by year in 1990-1997 to -9.2 % in 1997-2004 and to -8.4 % in 2004-2008. For electricity rate has fallen 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, 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
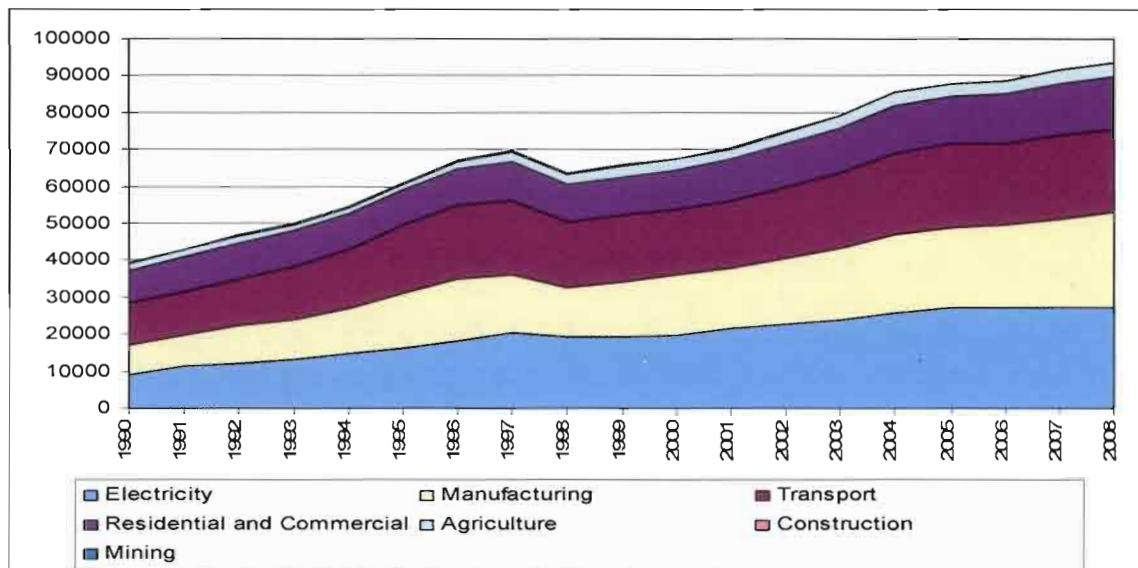
Notes: Energy consumption expressed in ktoe. Electricity corresponds to public electricity and heat production. Manufacturing includes autoproducers and, in 2007-2008, mining.

Source: See Figure 1.

2.3 Assessment of empirical results

In this stage we proceed to the assessment of empirical results. Assessment at sector level are presented first, covering agriculture sector, mining sector, construction sector, industry sector, transport sector, electricity sector, residential and service sector, respectively. Finally the assessment for the overall economy is presented.

2.3.1. Agriculture sector

The empirical results of decomposing CO_2 emissions for the agriculture sector over the period 1990-2008 are presented in Figure 7. This Figure 7 presents, year by year, the cumulative impact on the variation of agricultural CO_2 emissions (expressed in ktco2) of each of the four effects pre-identified. The sum of each of the four effects is added and it corresponds to changes of total CO_2 emissions year by year (adding the variation of CO_2 emissions of a year to the preceding ones).

Between 1990 and 2008, 5501 ktco2 have been accumulated by agricultural sector. This increase has been notable from 1995. Thereafter, the growth of agriculture sector has been carbon intensive, changes of total CO_2 emissions being superior to that of A_{effect}. Since 2005, the situation was reversed, but not significantly as indicated by the small gap between changes of total CO_2 and the A_{effect}.

The Activity effect (A_{effect}) is the most important contributor to increasing CO_2 emissions over the period considered: it increased CO_2 emissions by 6098 ktco2 in 1990-2008. Conversely, thanks to a structural decline, and a corresponding fall of its share of GDP, the Structural effect (S_{effect}) has contributed to CO_2 emissions saving of 1898 ktco2 in 1990-2008, and most particularly since the second half of 2000s.

The Carbon intensity effect (C_{effect}) has been a marginal contributor to CO_2 emissions, generating a decrease of 6 ktco2 over 1990-2008. Conversely, Energy intensity effect (I_{effect}) has increased CO_2 emissions in an important way (1307 ktco2), though it generated CO_2 emissions reduction in the first half of 1990s (1635 ktco2).

Figure 7 - Empirical results of decomposition of CO_2 emissions for agriculture sector, 1990-2008
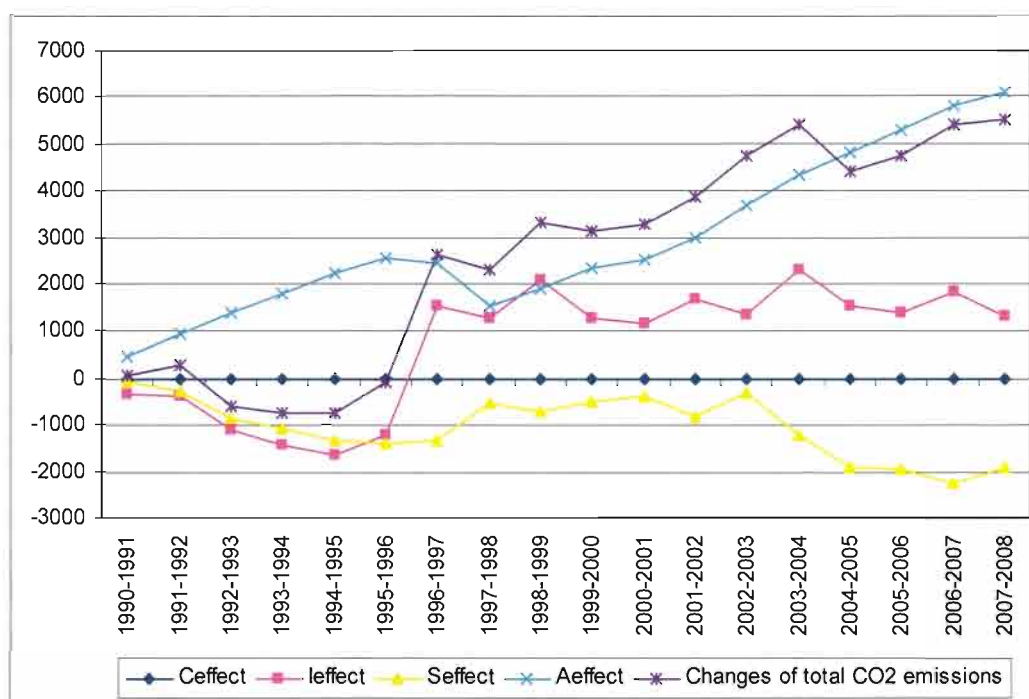
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

Figure 8 shows theoretical and effective CO_2 emissions. Obviously, effective emissions have closely followed theoretical emissions such that no clear upward or downward trend appears. However, summing-up yearly effective emissions for the whole period and comparing it to the sum of yearly theoretical emissions, or the CO2 emissions differential has increased by 1301 ktco2 during 1990-2008.

Figure 8 – Theoretical and real CO₂ emissions for agriculture sector, 1990-2008

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

Source: see Figure 1.

2.3.2. Mining sector

The empirical results of decomposing CO_2 emissions for the mining sector over the period 1990-2008 are presented in Figure 9 as before.

Mining sector was successful in reducing its CO_2 emissions by 86 ktco2 between 1990 and 2008. As a result, its growth has not been carbon intensive, changes of total CO2 emissions being negative for the whole period (except in 1999).

This reduction of CO_2 emissions is entirely due to the I_{effect}. Already negative at the beginning of 1990s, the saving generated by the I_{effect} intensified until 2000 and since then stagnates. Ultimately, the cumulated reduction has been of 210 ktco2 in 1990-2008. The C_{effect} has marginally contributed to reduce CO_2 emissions by 1 ktco2.

Conversely, the A_{effect} has been responsible for an increase of CO_2 emissions by 80 ktco2 during 1990-2008. The S_{effect} equally but its positive impact on emissions began later, from 1997. From 1990 to 2008, this effect has increased CO_2 emissions by 45 ktco2.

Figure 9 - Empirical results of decomposition of CO_2 emissions for mining sector, 1990-2008
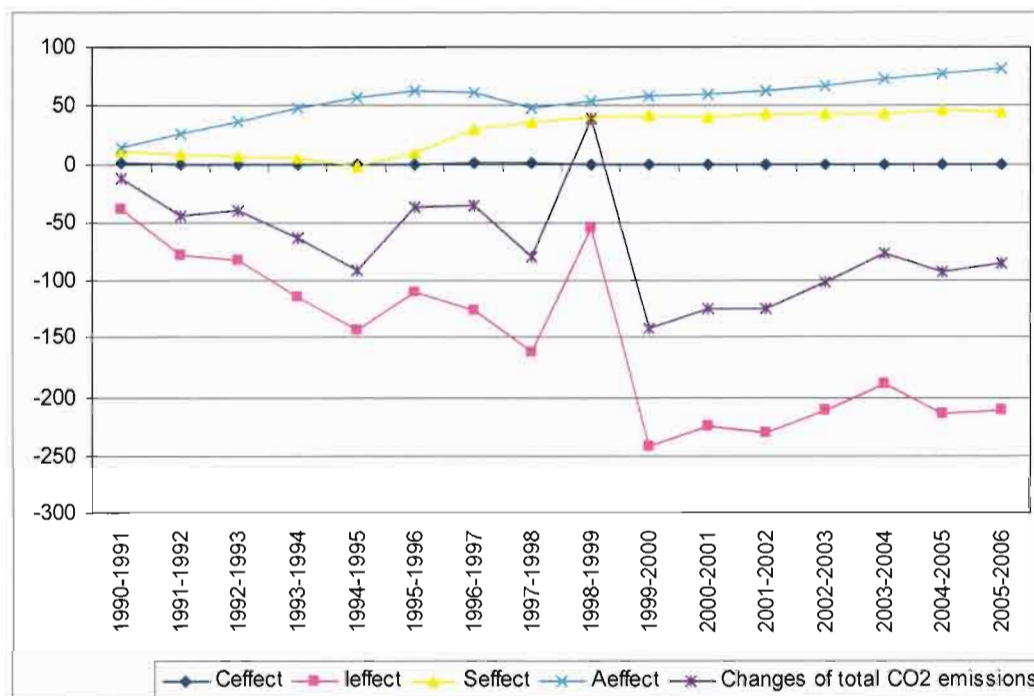
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 10, CO_2 emissions differential has been reduced by a small margin, only 211 ktco2. However, this reduction is more due to changes occurring in the 1990s than to changes in the end of the period where effective CO_2 emissions have tended to be higher than theoretical ones (C_{effect} and I_{effect} inflating CO_2 emission from the economic activity).

Figure 10 - Theoretical and real CO₂ emissions for mining sector, 1990-2008

Notes: Expressed in ktco2. Theoretical and real CO_2 are calculated as described in section 2.1.3.

Source: see Figure 1.

2.3.3. Construction sector

The empirical results of decomposing CO_2 emissions for the construction sector over the period 1990-2008 are presented in Figure 11.

As for mining, construction sector has decreased its CO_2 emissions by 122 ktco2 over the period considered. This decrease is closely related to the collapse of the sector's share in GDP after the Asian financial crisis. As a result, this sector is much less carbon intensive since.

The S_{effect} explains the CO_2 saving in the construction sector: CO_2 emissions have been reduced by -894 ktco2. This is due to its collapse after the Asian financial crisis and its low dynamism thereafter, as already indicated. For its part, the C_{effect} has been neutral, generating no reductions and no increases over 1990-2008.

The A_{effect} is already the most important determinant of increases in CO_2 emissions during the period considered, being responsible for a cumulative increase of 469 ktco2 from 1990 to 2008. The I_{effect} has also contributed positively to CO_2 emissions by 303 ktco2. However, this is due only to the important increase occurring in 1997-1999. Since then, this effect has first stagnated and then allowed small annual CO_2 emission saving.
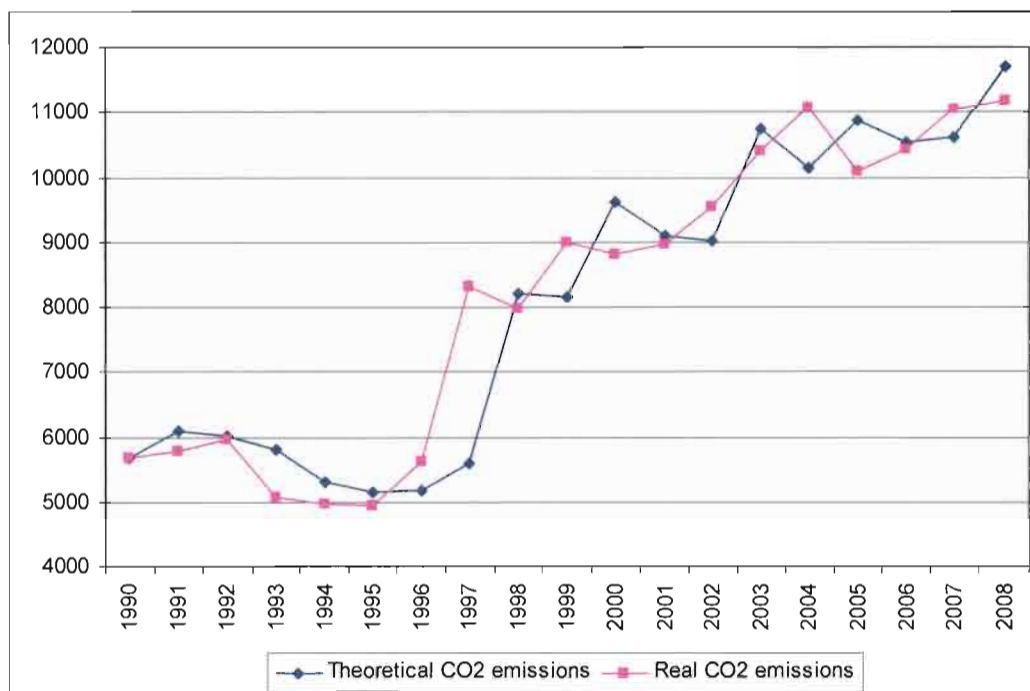
Figure 11 - Empirical results of decomposition of CO_2 emissions for construction sector, 1990-2008
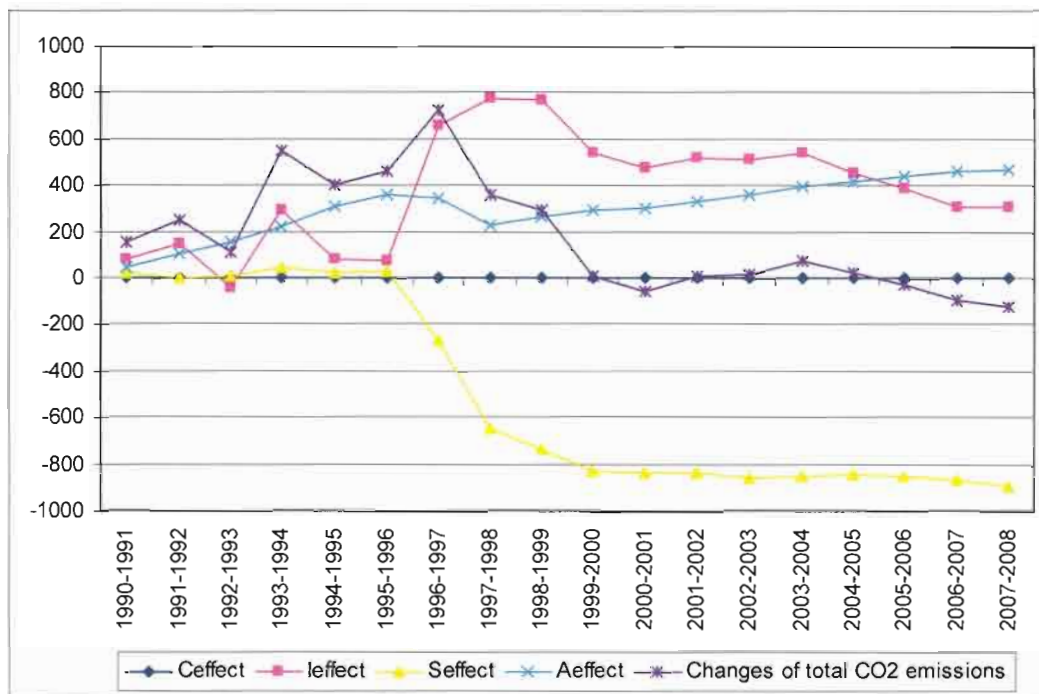
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 12, while effective CO_2 emissions have been higher than theoretical ones during the 1990s, they have been lower during the 2000s, indicating a reduction of emissions generated by the I_{effect} and the C_{effect}. However, since CO_2 emissions differential has increased by 303 ktco2 over 1990-2008, this reduction has been insufficient to compensate earlier increases.

Figure 12 - Theoretical and real CO$_2$ emissions for construction sector, 1990-2008

Notes: Expressed in ktco2. Theoretical and real CO$_2$ are calculated as described in section 2.1.3.

*Source:* see Figure 1.

2.3.4. Industry sector

The empirical results of decomposing CO$_2$ emissions for the industry sector over the period 1990-2008 are presented in Figure 13.

Between 1990 and 2008, industry sector has significantly increased its CO$_2$ emissions by 52955 ktco2. This sector's growth has thus been carbon intensive and each of the effect identified has positively contributed to this increase.

The main contributor has been the A_{effect}, which has increased CO$_2$ emissions by 26153 ktco2 over 1990-2003, its contribution accelerating in particular during the 2000s. The second most important determinant lies in the C_{effect}, generating an increase of 14954 ktco2 in CO$_2$ emissions during the same period.

The S_{effect} also has caused a progressive upsurge of 9822 ktco2. Finally, although contributing positively to CO$_2$ emissions by an amount of 2026 ktco2, the impact of I_{effect} had thus been less marked and remained relatively stable over the period (except around the Asian financial crisis).
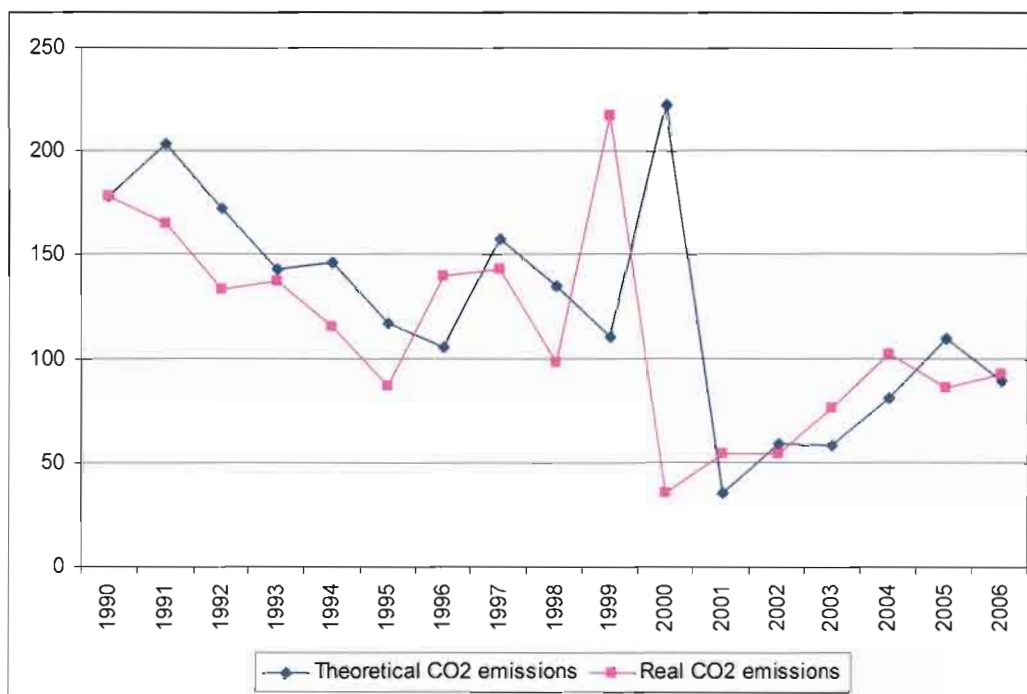
Figure 13 - Empirical results of decomposition of CO_2 emissions for industry sector, 1990-2008
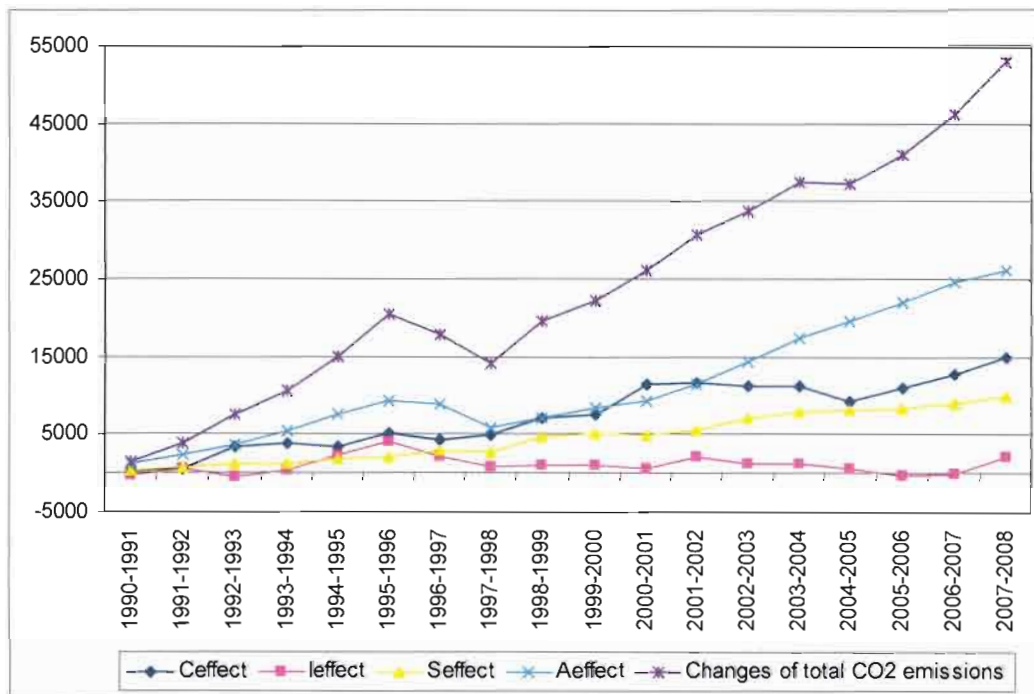
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

Figure 14 indicates that effective CO_2 emissions have been quasi constantly superior to the theoretical CO_2 emissions. As a result, CO_2 emissions differential has increased by 16980 ktco2 from 1990 to 2008.

Figure 14 - Theoretical and real CO_2 emissions for industry sector, 1990-2008

Notes: Expressed in ktco2. Theoretical and real CO_2 are calculated as described in section 2.1.3.

Source: see Figure 1.

2.3.5. Transport sector

The empirical results of decomposing CO_2 emissions for the transport sector over the period 1990-2008 are presented in Figure 15 as before.

Over 1990-2008, CO_2 emissions of the transport sector have increased by 32862 ktco2. Thus, its sectoral growth has been intensive in carbon, except since 2006.

The A_{effect} is the principal determinant for escalating CO2 emissions, being responsible of an increase by 41377 ktco2 over 1990-2008. The S_{effect} equally contributed in non negligible way to the increase of CO_2 emission by 13954 ktco2.

While the C_{effect} has been marginal, allowing for a low CO_2 emissions saving of 180 ktco2, the I_{effect} has been the only determinant which has partially offset emissions arising from the precedent effects. Indeed, from 1997 the I_{effect} has been almost constantly negative. Ultimately, it has contributed to a decrease by 22287 ktco2 of CO_2 emissions over the period 1990-2008.
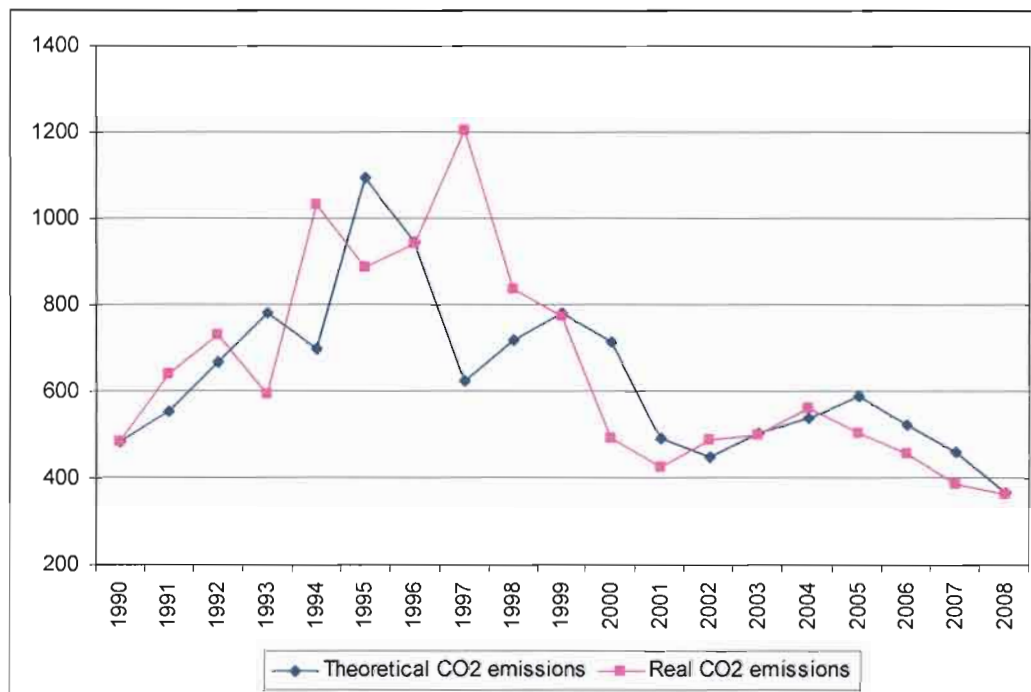
Figure 15 - Empirical results of decomposition of CO_2 emissions for transport sector, 1990-2008
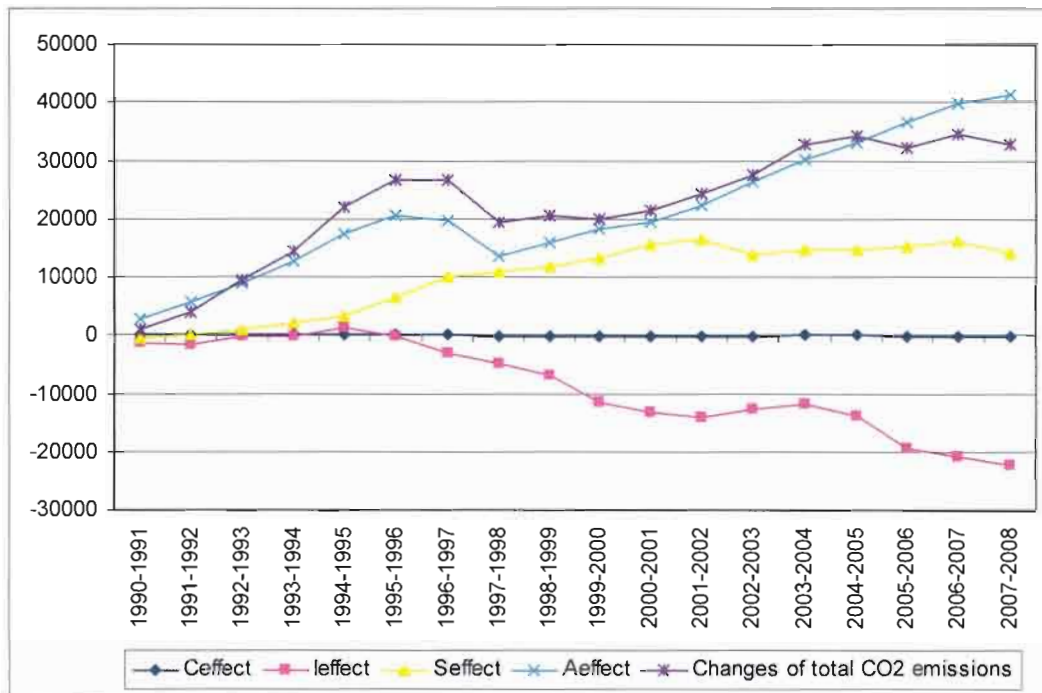
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 16, effective CO_2 emissions have been quasi constantly lower than theoretical ones, particularly since 1996. As a result, CO_2 emissions differential has been decreasing by 22649 ktco2 over 1990-2008.

Figure 16 - Theoretical and real CO_2 emissions for transport sector, 1990-2008
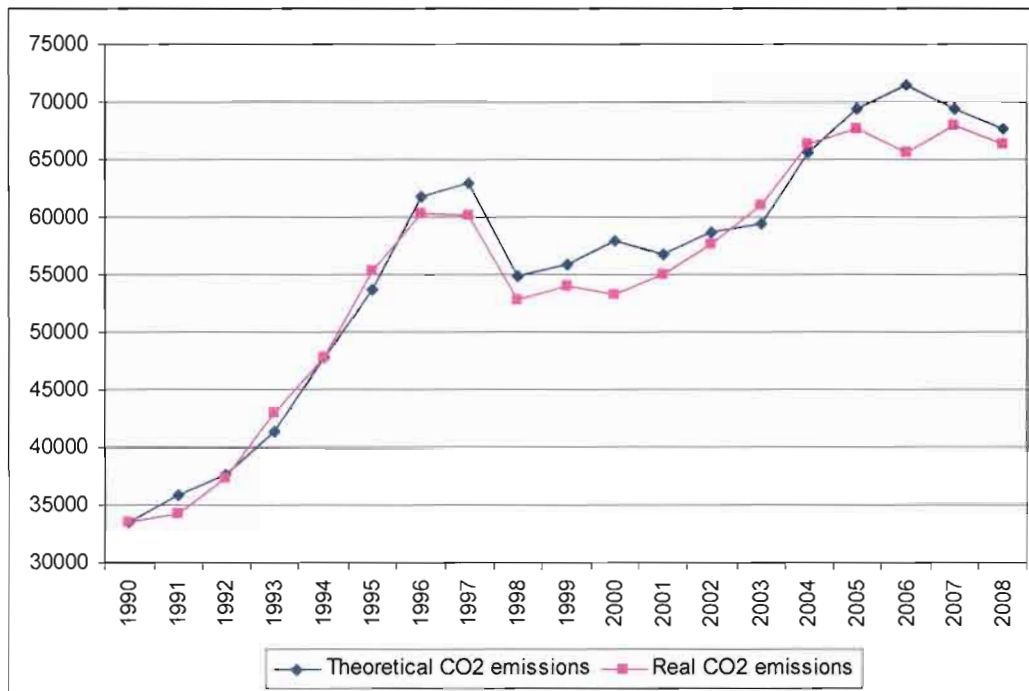
Notes: Expressed in ktco2. Theoretical and real CO_2 are calculated as described in section 2.1.3.

Source: see Figure 1.

2.3.6. Electricity sector

The empirical results of decomposing CO_2 emissions for the electricity sector over the period 1990-2008 are presented in Figure 17.

CO_2 emissions from electricity sector have increased by 43312 ktco2 during 1990-2008. Thus, its sector growth has been carbon intensive, although some improvements can be observed since the 2000 (but the situation is approximately comparable to that of the earlier 1990s).

The A_{effect} and the S_{effect} have been the main determinants of increasing CO_2 emissions. Indeed, the A_{effect} has been responsible of 39441 ktco2, and the S_{effect} 17465 ktco2.

Conversely, the C_{effect} and the I_{effect} have generated CO_2 emissions saving over the period considered. More specifically, while positive until 2005, the I_{effect} took a negative sign from 2006 so that CO_2 emissions saving arising from it (6190 ktco2) is a recent phenomenon. Inversely, the saving generated by the C_{effect} is a more long-term one. Indeed, except some few years (particularly in 2007), this effect has been of a negative sign, allowing a reduction by 7404 ktco2 of CO_2 emissions.
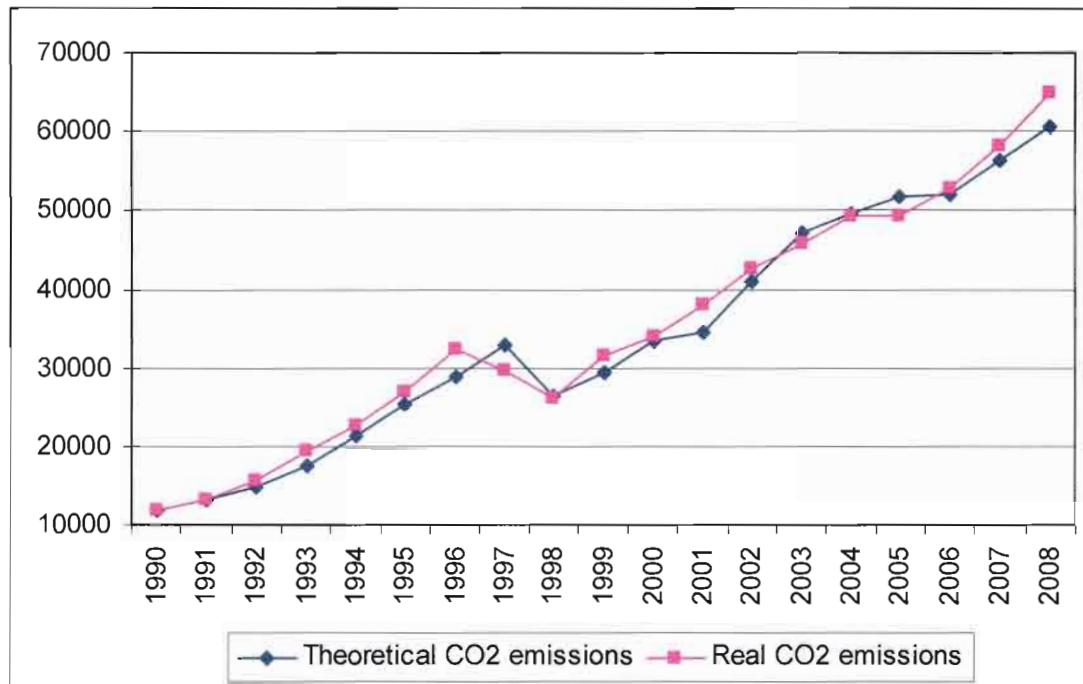
Figure 17 - Empirical results of decomposition of CO_2 emissions for electricity sector, 1990-2008
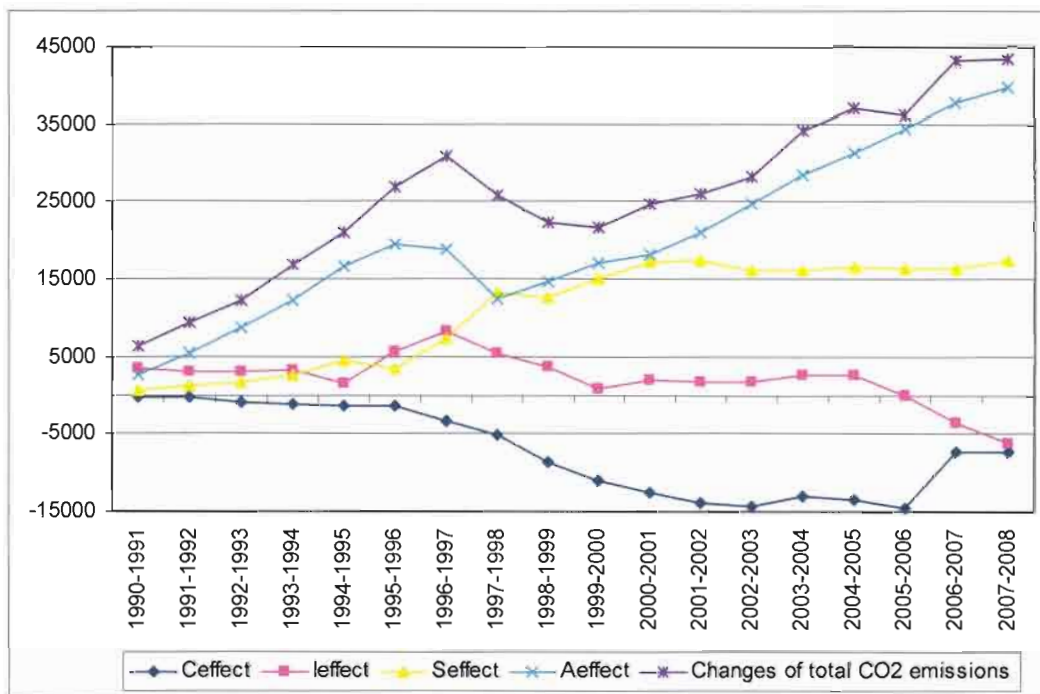
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 18, effective CO_2 emissions have closely followed the theoretical ones. Although CO_2 emissions differential has decreased by 13593 ktco2 over 1990-2008, this decrease took place principally in 1998-2000.

Figure 18 - Theoretical and real CO$_2$ emissions for electricity sector, 1990-2008

Notes: Expressed in ktco2. Theoretical and real CO$_2$ are calculated as described in section 2.1.3.

Source: see Figure 1.

2.3.7. Residential and service sector

The empirical results of decomposing CO$_2$ emissions for the residential and service sector over the period 1990-2008 are presented in Figure 19.

From 1990 to 2008, residential and service sector has increased its CO2 emissions by 3053 ktco2. Also, except for the beginning of the period, this sector has been carbon intensive, although some progress has been made since 2004.

The A_{effect} and the C_{effect} have been the determinants of this increase. The first effect has increased by 2913 ktco2 CO$_2$ emissions, while the second by 1099 ktco2. But while the A_{effect} has progressively increased, the C_{effect} has been more stable over the period considered.

The last two effects, the S_{effect} and the I_{effect}, have generated CO$_2$ emission saving, but in a quite distinctive way. Indeed, the S_{effect} has decreased CO$_2$ emissions by 791 ktco2 over 1990-2008 but progressively from 1995. The saving arising from the I_{effect} has been inferior, *i.e.*, 167 ktco2, but thanks predominantly to the reduction operating in the first half of 1990. Since the 2000s, it has been responsible of CO$_2$ emissions in small quantity however.

Figure 19 - Empirical results of decomposition of CO_2 emissions for residential and service sector, 1990-2008
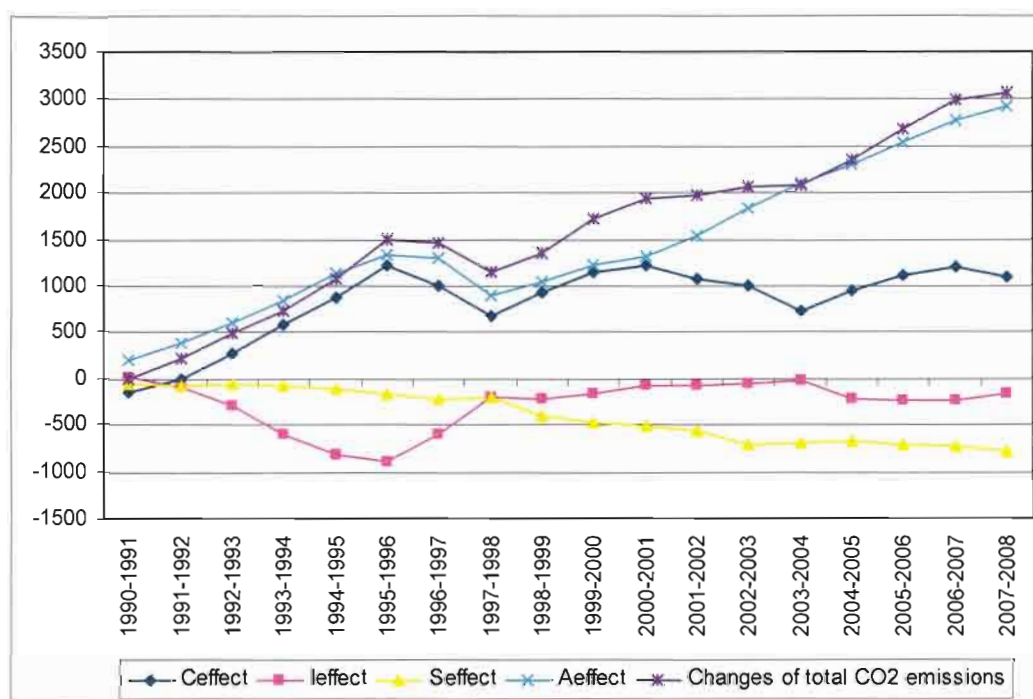
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 20, CO_2 emissions differential has increased by 931 ktco2 over 1990-2008 as the result of the C_{effect} and the I_{effect}. However, no clear downward trend appears.

Figure 20 - Theoretical and real CO_2 emissions for residentials and service sector, 1990-2008
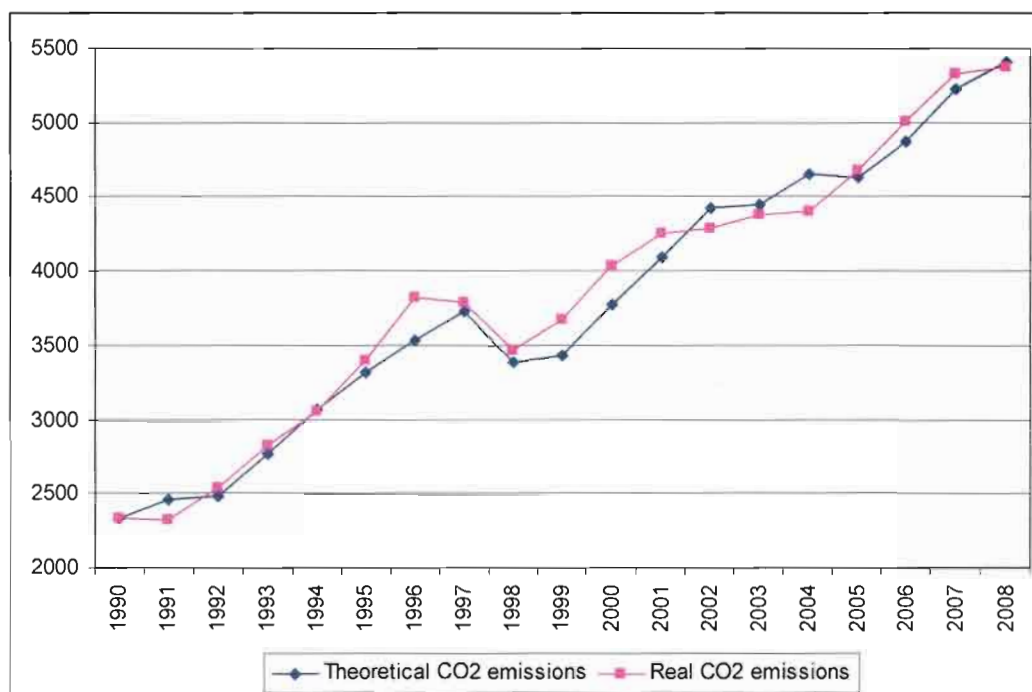
Notes: Expressed in ktco2. Theoretical and real CO_2 are calculated as described in section 2.1.3.

Source: see Figure 1.

2.3.8. 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 95145 ktco2 of CO_2 emissions over the period considered (except around the Asian financial crisis). 66.5 % of total emission increase are thus du 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 ktoco2. Because of a constant increase in population, its contribution has progressively increased along the period observed.

The I_{effect} is the third contributor. It has caused an increase of 18,644 ktco2 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} has decreased thereafter.

Finally, the C_{effect} increased equally CO_2 emissions by 2839 ktco2 (*i.e.*, 2 %) during the period considered. However, this positive contribution has taken place at the beginning of the period, since from 1997 it became negative (except in 2004 and 2008).
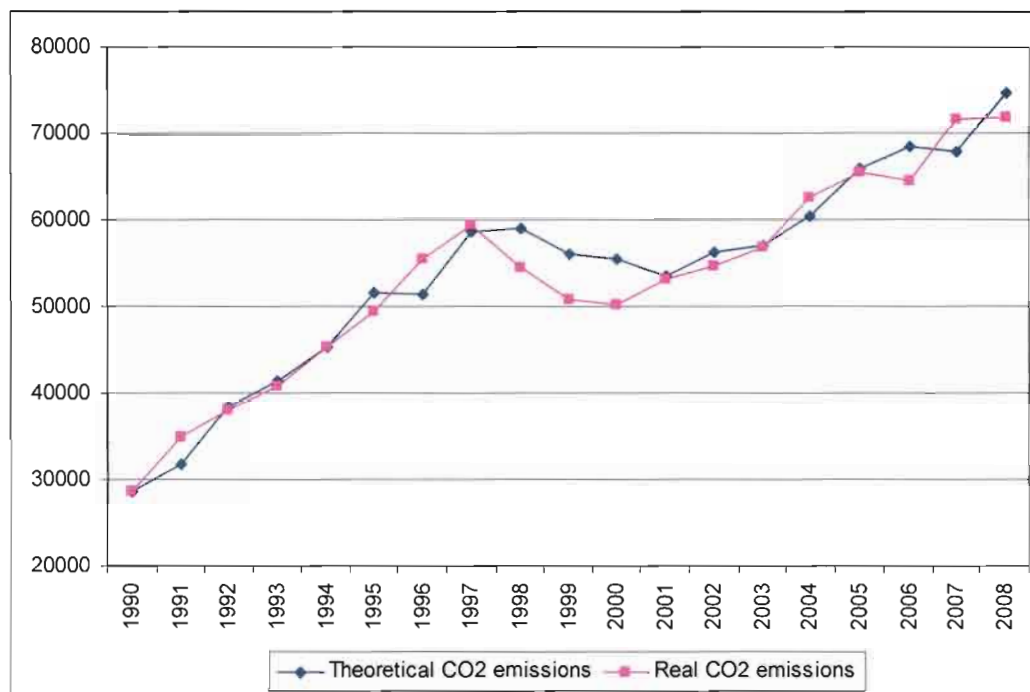
Figure 21 - Empirical results of decomposition of CO_2 emissions for the overall economy, 1990-2008
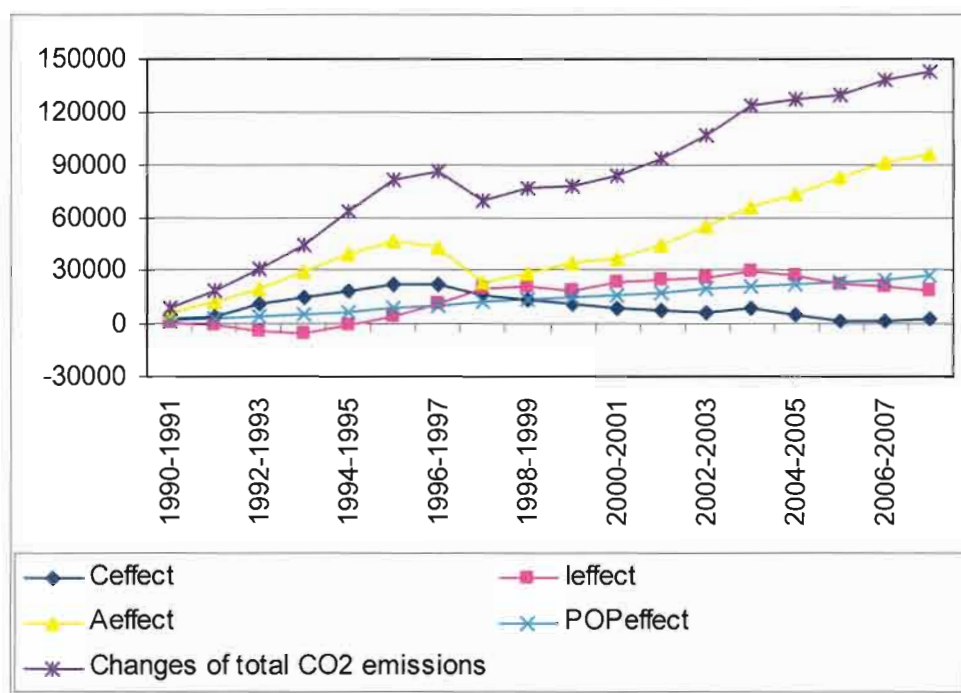
Notes: Expressed in ktco2. Abbreviation: C_{effect}: Carbon intensity effect; I_{effect}: Energy Intensity effect; S_{effect}: Structural effect; A_{effect}: Activity effect. Changes of total CO_2 emissions correspond to the sum of each of the effects considered.

Source: see Figure 1.

As shown in Figure 22, CO_2 emissions differential has increased by 21484 ktco2 from 1990 to 2008. However, comparison of changes in effective emissions and theoretical ones indicates that reductions in CO_2 emissions differential have occurred mostly in the 2000s.

Figure 22 - Theoretical and real CO_2 emissions for the overall economy, 1990-2008
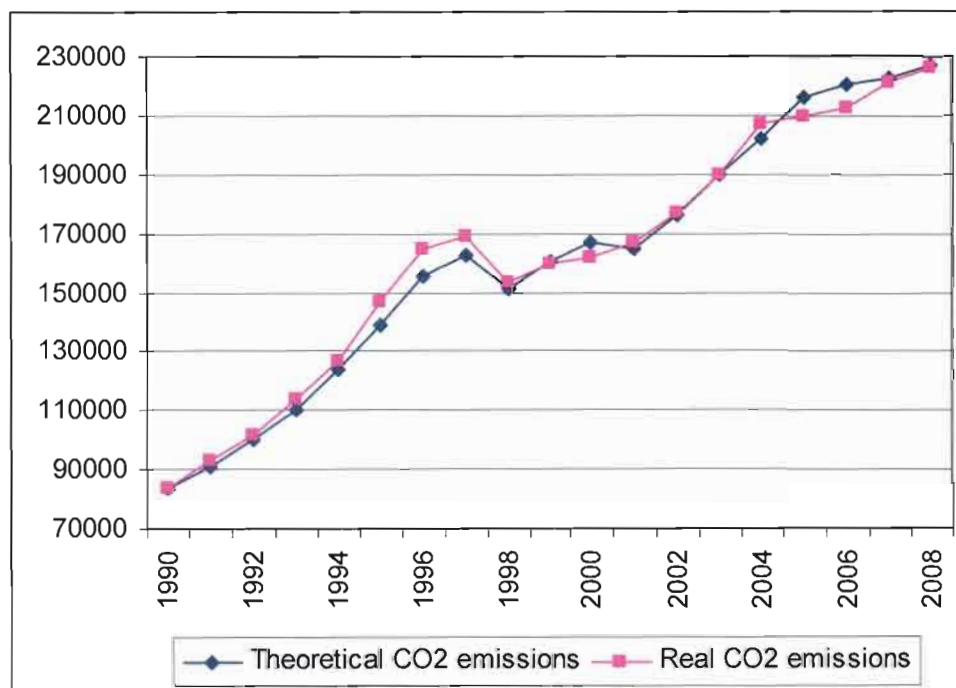
Notes: Expressed in ktco2. Theoretical and real CO_2 are calculated as described in section 2.1.3.

Source: see Figure 1.

2.4 Conclusion and discussions

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

TABLE – 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 ranged 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.*, difference between real (R) and theoretical (T) emissions; cf. section 2.1.3) over 1990-2008.

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

From the point of view of sectors, C_{effect} and I_{effect} have contributed either to CO_2 increases either to CO_2 saving. However, it is noteworthy that these effects have generated CO_2 saving but not in a significant way and/or in a long-lived way, except for the I_{effect} in Mining, Transport and Electricity sectors. These three sectors have also benefited from CO_2 saving coming from the C_{effect} – leading to a decrease in their CO_2 emissions differential has decreased. However, it should be recalled that Transport and Electricity sectors remain the principal polluter sectors. For the Industry sector, it is the only one where C_{effect} and I_{effect} (and the other effects) have contributed to increase CO_2 emissions, without the initiation of a downward trend for one or other of these effects. CO_2 emissions differential has thus increased, industry being an important polluter for which emissions are growing most rapidly. Finally, CO_2 emissions differential in Agriculture, Construction and Residential and service has increased, in spite of reductions generated by C_{effect}, I_{effect} or both.

Consequently, **opportunities exist for political actions**. 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 effectiveness is debated – see already cited analysis by Punyong, Taweekun and Prasertsan which conclude 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.

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 are aiming at exploring the prospects for decarbonisation 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 Research agenda on LCS Scenario

A major agenda for research is focusing on energy demand modelling in developing and emergent economies. Bhattacharyya & Govinda (2009)[25] 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)[26] many models are biased towards industrialized countries, neglecting main characteristics of developing countries, e.g. the role of the informal economy, supply shortages, poor performance of the power sector, structural economic change, electrification, traditional bio-fuels, urban–rural divide and explain that and how they should thus be adjust 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 in 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 stabilisation of greenhouse gas 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. Amongst the most famous, the SRES scenario published by IPCC authors, the UN Millennium Ecosystem Assessment (MEA) and the International Energy Agency (IEA) scenario

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[25] Bhattacharyya, Subhes C. & Timilsina, Govinda R., 2009. "Energy demand models for policy formulation : a comparative study of energy demand models," Policy Research Working Paper Series 4866, The World Bank

[26] F. Urban, R.M.J. Benders, H.C. Moll, Modelling energy systems for developing countries": Energy Policy, Volume 35, Issue 9, September 2007, Page 3473-3482,

exercises (WEO, standing for World Energy Outlook). Looking at radically different future or Low Carbon scenario is relatively new. The use of the concept of Low Carbon Societies really improved the policy discussion in European countries[27]. In the Asia Pacific region NIES (2007)[28] encouraged research on low carbon scenario.

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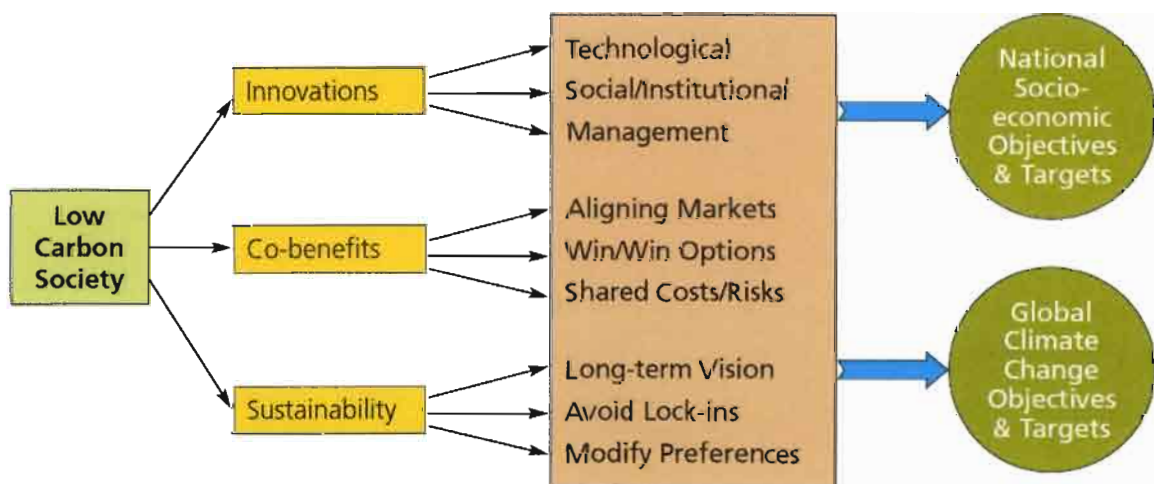
The following definition was proposed by the Steering Committee of the Japan–UK Low-Carbon Society project. It was not intended as a scientific statement but rather as a flexible framework which would allow fruitful discussions, leading to practical actions.

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

[28] NIES (2007). Aligning Climate Change and Sustainability- Scenarios, Modeling and Policy Analysis. Tsukuba: AIM Integrated Model Centre for Global Environmental Research, National Institute for Environmental Studies.

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 CO2 and other greenhouse gases 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 greenhouse gas 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 parameter the different variables such as GDP, energy demand...

3.1.3 Visions for Low Carbon Societies

The methodology of building LCS has its roots in academic and policy oriented exercises on energy prospective, foresight sciences and require strong inter & multidisciplinary competences. This emerging research field takes advantage of LCS-RNet[29], the International Research Network for Low Carbon Societies. Recognising the necessity of the promotion of research in this area and the information exchange to help more countries to develop their own roadmaps towards LCS, participating Environmental Ministers in the G8 Environmental Ministers Meeting (EMM) held in Kobe, May 2008, supported the idea to create an international network of research institutions.

LCS-RNet recognises 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

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[29] The 1st annual meeting was held in October 2009, see http://lcs-rnet.org. LCS-Rnet, is an international network integrating researches and knowledge from 10 of the most important research institutes on climate change in six countries. The international network is an open group willing to grow up and integrate those who will show competences and commitment to sharing the same multidisciplinary goals, putting together scientific research knowledge and political, economic, social and environmental systems.

climate scenarios are defined with contrasted paradigms and visions. The possibility of a low-carbon society into a reality is to develop visions that will be credible and attractive to the general public[30].

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 in that 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 CO2 emissions is achieved by 2050. However, the mix of technologies employed is different (Table 1). In both cases, energy efficiency improves considerably – both in industry and in the home.

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[30] For example, The Japan Low-Carbon Society project envisages a world in which global temperature rise is held below 2°C, global CO2 emissions are cut by 50% by 2050, and Japanese emissions are cut by 70%. The results are presented in Matsuoka (2007; National Institute for Environmental Studies et al., 2007).

TABLE 1 Comparison of CO_2 emission reduction drivers

	Vision A ('Doraemon')	Vision B ('Satsuki 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 system Efficient air-conditioners Efficient water heaters Efficient lighting systems Fuel-cell systems Photovoltaics on the roof	High-insulation dwellings and buildings Eco-life navigation system 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 function Public transportation system 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 vehicle
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).

An international modelling comparison has also been undertaken by nine national teams, with a strong developing-country focus (Stratchan et al., 2009) [31]. The comparison emphasis was to focus on individual model strengths (notably technological change, international emissions trading, non-price (sustainable development) mechanisms and behavioral 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 policy makers do emerge.

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[31] Strachan, Neil; Foxon, Tim; Fujino, Junichi, Policy implications from the Low-Carbon Society (LCS) modelling project, Climate Policy, Volume 8, Supplement 1, 2008 , pp. S17-S29(1)

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 as such as 50% global CO2 emission reduction, most models in this LCS project comparison showed an associated GDP loss in the range 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 $100–330/tCO2[32].

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[33] describes how the costs and benefits of global economic growth have been very unfairly distributed, with those on lowest incomes getting 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. "Other Worlds are Possible" notes that difference between success and failure in the international climate negotiations will be whether governments and financial institutions continue to support old, failed economic approaches, or whether they will move to encourage and replicate new approaches that take account of changed economic and environmental circumstances. This timely report makes the case in compelling terms that there is not one model of economic development; there are many

In another radical but very welcomed essay, Prof. Tim Jackson[34] book consistently emphasizes that a two-fold change is needed to tackle global change challenges in a finite world : in addition to these economic changes, Jackson (2009) calls for social changes and changes in values, especially in developed countries and elites, The book summarizes an essay by the economist Amartya Sen that calls for a shift from an economy that aims at opulence or at utility to an economy that aims at human flourishing.

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 interrelationship between energy use and the environment in Thailand. Various aspects of these studies include sector specific energy planning and

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[32] This greatly exceeds the current price of carbon in the EU Emissions Trading Scheme. However, it is in the same order of magnitude than exstimated costs othe impacts of climate change (Stern, 2006)

[33] Featuring contributions from Dr Rajendra Pachauri, Professor Herman Daly , Professor Wangari Maathai, Professor Manfred Max-Neef, Professor Jayati Ghosh (economist) and David Woodward. See http://www.neweconomics.org/publications/other-worlds-are-possible

[34] The entire book is available to read at http://www.sd-commission.org.uk/publications.php?id=914 ,

Tim Jackson, Prosperity Without Growth, Economics for a Finite Planet, Earthscan Publications Ltd., December 2009 , 160 pp,

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[35], 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 (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. This last sets out a timetable of actions needed to limit the long-term concentration of greenhouse gases 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)[36].. As qualified by Executive Director, Nobuo Tanaka, "the IEA 450 scenario is the energy pathway to Green Growth"[37]. To carry out the assessment, assumptions are made about population, growth, macroeconomic trend, energy prices, technological development and government policies. Energy-related environmental aggregates are then primary energy mix (demand and production), trade and greenhouse gases emissions (CO_2, NO_x, PM2.5, SO_2). Assessments proceeds for the World, by region, by countries (selected, including Thailand), and at the macro- and sectoral- levels.

Shresta et al. (2007) use the bottom up modelling framework based on a cost minimum linear programming approach. Four scenarios are specified[38]. The global market integration scenario (TA1) in which Thai economy is more integrated in the global economy and, consecutively, 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 primary energy supply mix, sector-wise (agriculture, commercial, industry, residential,

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[35] 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

[36] IEA, 2009, *World Energy Outlook*, OECD/IEA, Paris.

[37] 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.

[38] Ram M. Shrestha, Sunil Malla, Migara H. Liyanage, Scenario-based analyses of energy system development and its environmental implications in Thailand, Energy Policy, Volume 35, Issue 6, June 2007, Pages 3179-3193

transport) final energy demand, energy import dependency and CO_2, SO_2 and NO_x emissions over 2000-2050.

Tanatvanit et al (2003) forecast the growth in energy demand and corresponding emissions to the year 2020 for three sectors, namely, residential, industrial and transport sectors by using a model based on the end-use approach[39]. The energy savings from the energy conservation strategies, such as energy efficiency improvement and energy demand management, are assessed and also the implications on electricity generation expansion planning are examined. The integrated resource planning (IRP) model is used to find the least-cost electricity generation expansion plans.

Mulugetta et al (2007) focus on the power sector and scenarios represent the range of opportunities and constraints associated with divergent set of technical and policy options[40]. 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[41]. The three scenarios developed in their paper encompass different story lines for major energy parameters, energy technologies, and energy efficiency and environmental policies and plans. The impacts are assessed in terms of the changes in primary energy supply mix, energy import dependency, and the 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)[42]. 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 study 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).

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[39] Tanatvanit, S., Limmeechokchai, B., and Chungpaibulpatana, S. (2003) Sustainable energy development strategies: implications of energy demand management and renewable energy in Thailand, Renewable and Sustainable Energy Reviews, 7, pp. 367-395

[40] Yacob Mulugetta, Nathinee Mantajit, Tim Jackson, Power sector scenarios for Thailand: An exploratory analysis 2002–2022, Energy Policy, Volume 35, Issue 6, June 2007, Pages 3256-3269

[41] Srichattra Chaivongvilan, Deepak Sharma (University of Technology, Sydney, Long term impacts of alternative energy-environmental scenarios for Thailand, 10th IAEE European Conference Energy, Policies and Technologies for Sustainable Economies, 7 - 10 September 2009 http://www.aaee.at/2009-IAEE/uploads/fullpaper_iaee09/P_583_Chaivongvilan_Srichattra_2-Sep-2009,%2010:47.pdf

[42] 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 setting for analysing a variety of energy issues. In this model, the objective function emphasises the minimization of total energy system cost, subject to a set of pre-specified constraints.

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 hypothesis on technologies costs, the reader should refer to the annex of the published papers.

TABLE 2: 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		5
TB_1	6,5		5,5
TB_2	4		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
	CO2		
(Mt)	2000		2050
TA_1	158		1312
TA_2			1172
TB_1			1035
TB_2			647

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

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)[43] are detailed in the following table.

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[43] Ram M. Shrestha and Shreekar Pradhan, "Measures towards a Low Carbon Society: Case of Thailand", Presented at Japan Low-Carbon Society Scenarios Toward 2050 Project Symposium Path towards Low-Carbon Society: Japan and Asia, February 2009 Tokyo, Japan, assessed via (September 12, 2009), http://2050.nies.go.jp/sympo/S-3_LCS_sympo_WS_2009/S-3_LCS_sympo_2009/presentation/2.4_RamManoharShrestha_ppt.pdf

TABLE 3: Hypothesis for the LCS in Thailand by Shresta & Pradhan (2009)

Base Case Scenario (Business as Usual)	Moderate CO2 Reduction Scenario (LCS20)	Accelerated CO2 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 US\$10/tCO_2 in 2015 to \$100/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 CO2 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 hypothesis used by Chaivongvilan & Sharma (2009), while on-going work by Chaivongvilan & Sharma aims at providing valuable inputs for the estimation of economy-wide impacts of alternative energy-environmental settings.

TABLE 4: Hypothesis for the energy scenarios in Chaivongvilan & Sharma (2009)

Main features in energy scenarios Features	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 to look at evolution of energy consumption by sectors, shifts in the infrastructures and technologies. It is however, difficult to assess the technical or economic feasibility and even acceptability of such scenarios, especially in the light of other competing agendas and 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)[44] and as developed above in section 2 may be used to assess the feasibility of LCS and the realism of the results. Indeed,

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[44]Paolo Agnolucci, Paul Ekins, Giorgia Iacopini, Kevin Anderson, Alice Bows, Sarah Mander and Simon Shackley, Different scenarios for achieving radical reduction in carbon emissions: A decomposition analysis Ecological Economics, Volume 68, Issue 6, 15 April 2009, Pages 1652-1666 special issue on 'Eco-efficiency: From technical optimisation to reflective sustainability analysis'

the realism may be assessed by comparing past rates of economic growth, diffusion of particular technologies, In the scenario presented , the rates of diffusion of different technologies, in particular in the energy sector or road transportation and 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 on the potential of diffusion of energy efficient as well as radical innovations in the manufacturing sector, such as cement, steel, papermaking industries, 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 in 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 recognising the difference between technical and economical potentials as well as the time constants that characterise the diffusion process. Elements such as learning-curves and "niche-markets" have been introduced, which allow for a truly dynamic approach of the development and diffusion of these technologies.
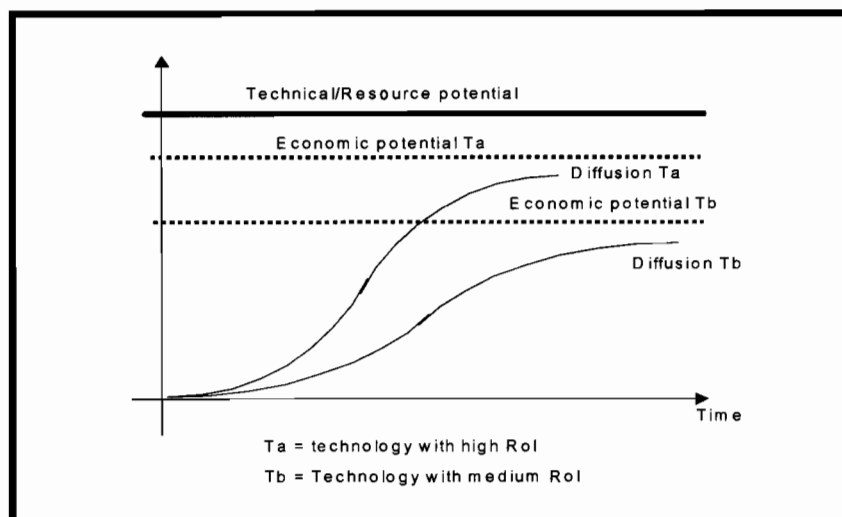
The module that is dedicated to the simulation of new and renewable technologies identifies the generic technologies which are representative of the solutions to be implemented in different types of countries and might have a significant quantitative contribution in the long-term development of energy 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 to 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 alternatives LCS scenario results

From the previous LCS, it is possible to explore the alternatives trajectories which could be taken by Thai economy in the future. This exploration can proceed in two ways. The first is simply to put in perspective, through a graphical representation, 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 23 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 24 reproduces in the same way estimations by Shresta and alii (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 and alii are higher than that of IEA. Indeed, CO_2 emissions estimates by IEA correspond only to, but are slightly lower than, the scenario the "most optimistic" of Shresta and alii (*i.e.*, TB_2). In fact, "real" Thai CO_2 emissions correspond closely to that projected from this TB_2 scenario. For instance, "real" CO_2 emissions are equal to 225709 ktco2 in 2008 comparing to 241494 ktco2 projected through the TB_2 Scenario. Also, Thai economy appears to have followed since 2000 the better alternative trajectory as estimated by Shresta and alii. If this continue, CO_2 emissions would be 397993 ktco2 (Scenario 450) or 461143 ktco2 in 2030 (TB_2 scenario) and 661396 ktco2 in 2050. CO_2 emissions should thus increase by almost 300% by 2050 comparing to 2008. The other trajectories (*i.e.*, other scenarios by Shresta and alii) give rise to increases in emissions significantly higher.

Figure 23 - CO_2 emissions in respect of Baseline Scenario by IEA, 1990-2030
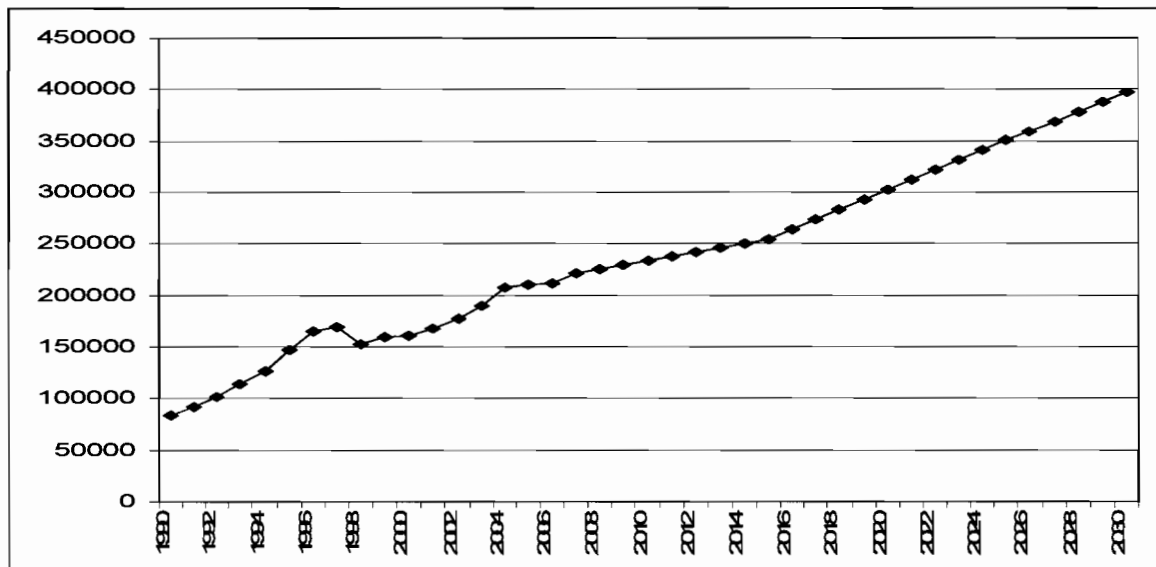
Notes: Expressed in ktco2.

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

Figure 24 - CO_2 emissions in respect of Scenarios by Shresta, Malla and Liyanage, 1990-2050
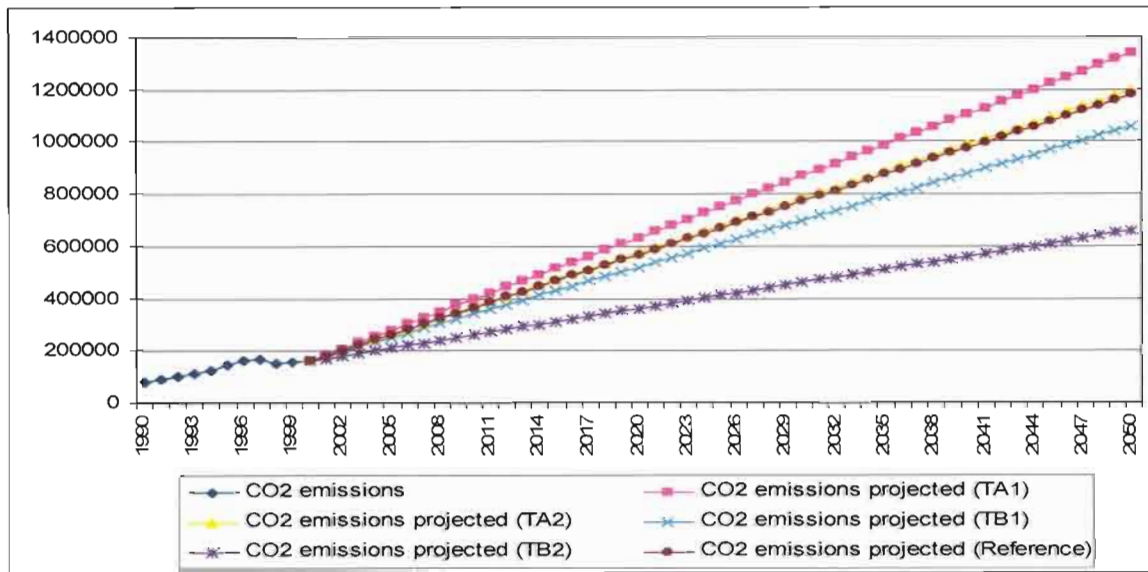
Notes: Expressed in ktco2.

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 and alii (see Fig. 25 and 26), Thai economy appears to have been more energy consumer in 2000-2008 than that projected by Shresta and alii. For instance, "real" TPES is equal to 110021 ktoe in 2008 compared to between 90005 ktoe and 100955 ktoe depending on the Scenario considered from Shresta and alii. As previously, projections for 2030 by IEA correspond approximately to, but are slightly higher this time than, the "more optimistic" scenario of Shresta and alii (*i.e.* TB$_2$): 178542 ktoe against 140557 ktoe respectively. In 2050, TPES would increase between 280 % (TB$_2$) and 581 % (TA$_1$), *i.e.,* reaching either 251739 ktoe or 586400 ktoe respectively.

Figure 25 - Total primary energy supply in respect of Scenarios by Shresta, Malla and Liyanage, 1990-2050
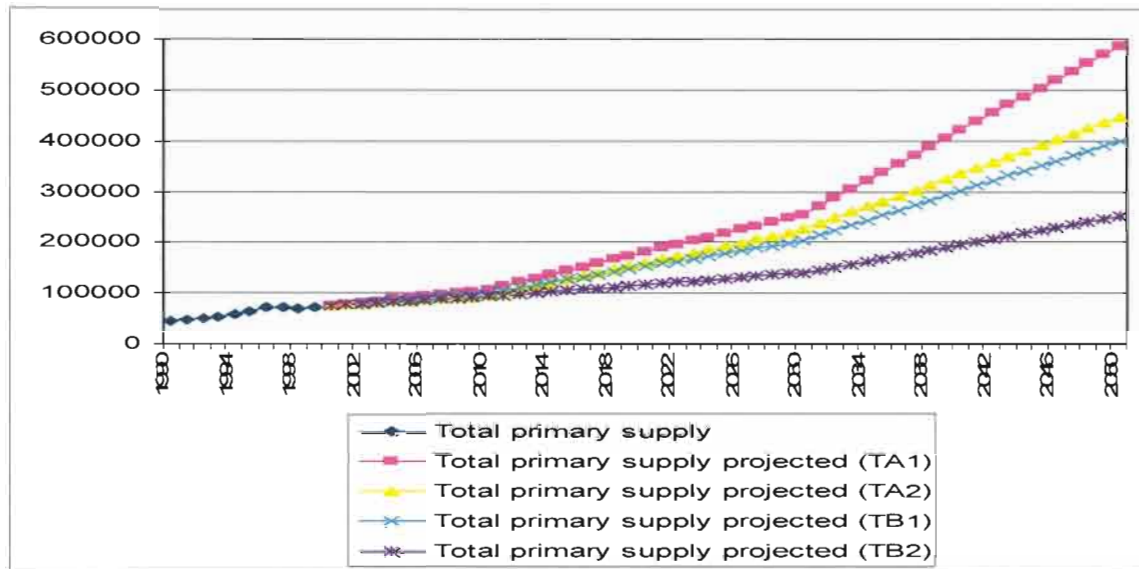
Notes: Expressed in ktoe.

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

Figure 26 - Total primary energy supply in respect of Baseline Scenario by IEA, 1990-2030
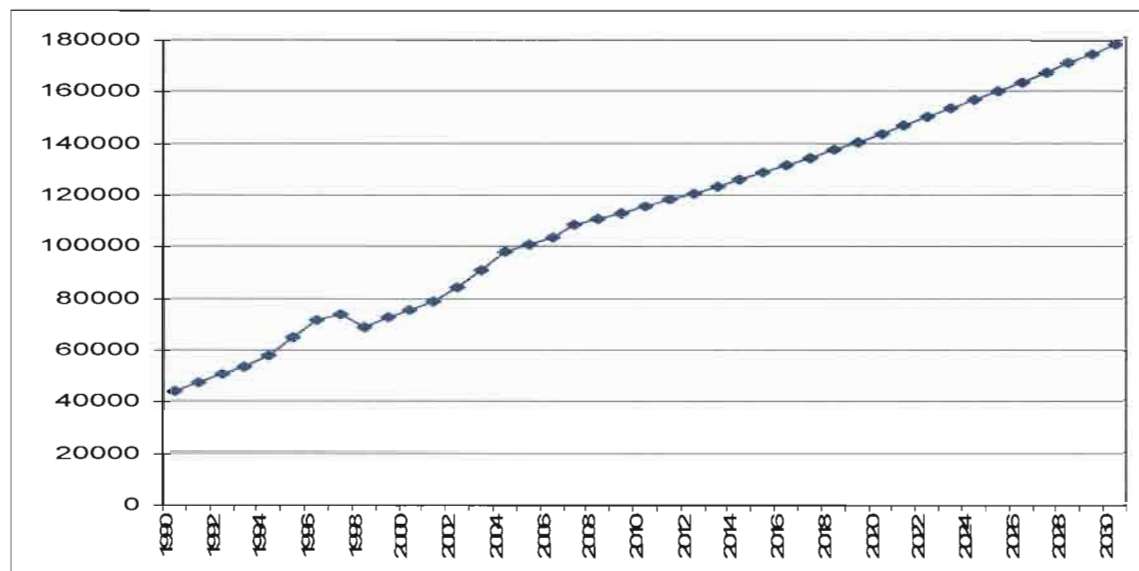
Notes: Expressed in ktoe.

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

Keeping in mind these evolutions, decomposition analysis of CO_2 emissions can proceed. Shresta and alii have realized this analysis. Comparing the base year 2000 to the targeted one 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. The Table 5 shows the results of this time-series decomposition for the overall economy for the period 1990-2050 with sub-periods. During 1990-2030, CO_2 emissions are expected to increase by 314404 ktco2. 56.2 % of this increase (*i.e.*, 176536 ktco2) is then anticipated to occur in 2007-2030, which corresponds to 1.3 times their level in 1990-2007.

The main determinant behind this increase is the A_{effect}, which account for 82 % of the growth of CO_2 emissions during 1990-2030 (*i.e.*, 257762 ktco2). The second determinant is the POP_{effect}, contributing to increase total CO_2 emissions by 15.9 % (*i.e.*, 49908 ktco2). 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 which, in the long term, allows for CO_2 emissions saving by 22030 ktco2 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, doubling almost 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. Maybe more important, Improvement in energy intensity (I_{effect}) is notable between periods: from a positive contribution of 12.6 % in 1990-2007, I_{effect} becomes negative allowing for a CO_2 emissions saving of 39.6 % in 2007-2030. Finally, the impact of 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 and alii do. The C_{effect} contributes also to increase CO_2 emissions, while I_{effect} should generated CO_2 emissions saving.

4   CONCLUSION AND PERSPECTIVES: NAMAS AS A BRIDGE TOWARD LOW CARBON SOCIETIES

In the development of the international climate negotiation, the Bali Action Plan (BAP) recognized the need for substantial developing country participation in order to reach global emission reduction goals, while respecting the UNFCCC principle of common but differentiated responsibility. Consequently the BAP introduced the idea of Nationally Appropriate Mitigation Actions (NAMAs), to promote and recognize mitigation efforts undertaken by developing countries, based on national initiative and characteristics, create a platform and governance that supports these actions, with flexible screening criteria but 'measurable, reportable and verifiable' (the so-called MRV framework).

In the preparation of the COP15, Copenhagen Climate Conference, December 2009, participants in technical discussions were trying to agree on a framework that would encourage developing countries to carry out Nationally Appropriate Mitigation Actions (NAMAs) "in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner"[45], this process being condition for assistance from Annex I countries. Following discussions at Bali and proposal by Korea[46], several studies have recently addressed the question of NAMAs design, such as E3G (2009), CCAP (2009)[47], or Ecofys (2009)[48].

There are still uncertainties on the principles and details of the workable solutions. NAMAs implemented in a MRV manner should be recognized and rewarded with carbon credit, so that project promoters/credit holders could sell these credits and improve commercial viability of their investment in mitigation actions. Beyond financing NAMAs are also envisaged as a vector for technology improvement, such as technology based sectoral NAMAs in China for the cement or steel sectors (RFF, 2009)[49]. In addition, as a new institutional framework they offer channel for both policy public policy promotion and private project targeting; in that respect Pía Zevallos (2009)[50] brings an observer's perspective and argues about the "trust building role" of NAMAs.

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[45] UNFCCC (2007) Bali Action Plan. Decision 1/CP.13

[46] http://unfccc.int/files/meetings/ad_hoc_working_groups/lca/text/plain/non-paper_from_korea.txt

[47] http://www.ccap.org/docs/fck/file/NAMA%20Paper%20July%2010%20Final%20%20draft%20for%20meeting.pdf July 10, 2009

[48] http://www.ecofys.com/documents/NAMAframeworkpresentation_Vieweg.pdf sept 2009

[49] http://rfflibrary.wordpress.com/2009/08/20/technology-based-sectoral-namas-a-preliminary-case-study-of-chinas-cement-and-iron-and-steel-sectors/

[50] NAMAs and the Carbon Market : Nationally Appropriate Mitigation Actions of developing countries, Perspectives 2009, CD4CDM, UNEPR Risoe, Karen Holm Olsen, Jørgen Fenhann, Miriam Hinostroza, (Editors) http://www.cd4cdm.org/Publications/NAMAS&CarbonMarket.pdf

Indeed, in spite of uncertainties on the post-2012 climate regime, NAMAS may be considered as an essential piece of climate policies in the short run and a bridge toward long term Low Carbon Societies. The elaboration of NAMAs in developing countries will indeed provide a consistent framework for the development of policies that reconcile the major target of curbing emissions at global level as soon as possible, and the necessity to foster policies adjusted to the constraints of sustainable development at the national level. It is therefore suggested that further work on this theme could focus on the possibility to improve or refine guidelines in the elaboration of NAMAs in Thailand. Investigations could cover design and implementation of NAMAs, policy framework, market and institutional dimensions, embeddedness in civil society - this could be seen as contribution to the first stage in the development of a low carbon society.

TABLE OF APPENDIX

Appendix 1 – Decomposition of the Changes in CO_2 emissions for the agriculture sector, 1990-2008

	Decomposition of Changes			Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	$R\text{-}T$
1990-1991	2,2	-338,7	-51,2	470,2	82,5	1991	5766,9	6103,4	-336,5
1991-1992	-5,4	-34,8	-212,4	456,1	203,7	1992	5970,6	6010,7	-40,1
1992-1993	-10,5	-726,2	-593,2	437,0	-892,9	1993	5077,7	5814,3	-736,6
1993-1994	9,9	-345,0	-209,6	432,1	-112,6	1994	4965,1	5300,2	-335,1
1994-1995	-2,0	-190,5	-261,1	438,0	-15,6	1995	4949,5	5142,0	-192,5
1995-1996	0,5	427,5	-68,0	302,4	662,4	1996	5611,9	5183,9	428,0
1996-1997	4,7	2717,4	69,8	-94,9	2697,0	1997	8309,0	5586,8	2722,2
1997-1998	-14,7	-234,2	806,7	-903,3	-345,6	1998	7963,3	8212,3	-249,0
1998-1999	24,1	811,9	-170,0	368,6	1034,5	1999	8997,9	8161,9	836,0
1999-2000	-4,3	-819,2	214,2	413,0	-196,2	2000	8801,7	9625,1	-823,5
2000-2001	-5,5	-114,7	97,9	190,5	168,3	2001	8970,0	9090,1	-120,1
2001-2002	-1,1	514,7	-418,0	479,5	575,0	2002	9545,0	9031,5	513,5
2002-2003	-1,4	-322,8	506,9	687,9	870,5	2003	10415,5	10739,7	-324,3
2003-2004	4,2	933,3	-921,6	654,5	670,3	2004	11085,8	10148,3	937,4
2004-2005	-11,3	-761,5	-682,4	464,4	-990,8	2005	10094,9	10867,8	-772,9
2005-2006	3,3	-132,5	-49,2	502,3	323,9	2006	10418,8	10548,1	-129,2
2006-2007	1,9	449,7	-314,0	513,8	651,5	2007	11070,3	10618,7	451,6
2007-2008	-0,8	-527,0	357,0	285,6	114,8	2008	11185,2	11713,0	-527,8
1990-2008	-6,3	1307,5	-1898,1	6097,7	5500,8	1991-2008	149199,0	147897,9	1301,2

Appendix 2 – Decomposition of the Changes in CO_2 emissions for the mining sector, 1990-2006

	Decomposition of Changes				Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	R-T
1990-1991	0,0	-38,4	11,6	14,1	-12,7	1991	177,9	177,9	0,0
1991-1992	-0,1	-39,1	-4,1	11,6	-31,7	1992	165,2	203,6	-38,4
1992-1993	-0,6	-5,4	-1,1	10,7	3,6	1993	133,5	172,7	-39,2
1993-1994	-0,2	-31,0	-1,7	10,8	-22,2	1994	137,1	143,1	-6,0
1994-1995	-0,4	-30,2	-6,8	8,8	-28,5	1995	114,9	146,2	-31,2
1995-1996	0,9	34,1	12,2	6,4	53,6	1996	86,5	117,0	-30,6
1996-1997	0,8	-15,9	19,7	-2,0	2,6	1997	140,0	105,0	35,0
1997-1998	-0,1	-36,6	5,6	-13,2	-44,3	1998	142,6	157,7	-15,1
1998-1999	-1,3	108,3	5,3	6,5	118,8	1999	98,3	135,0	-36,7
1999-2000	-0,4	-186,9	0,7	4,6	-181,8	2000	217,0	110,1	106,9
2000-2001	0,9	17,2	-0,7	0,9	18,4	2001	35,2	222,4	-187,2
2001-2002	-0,1	-5,4	2,8	2,8	0,1	2002	53,6	35,5	18,1
2002-2003	-0,5	18,9	-0,2	4,4	22,6	2003	53,7	59,2	-5,5
2003-2004	-0,2	21,1	-0,7	5,4	25,6	2004	76,2	57,9	18,3
2004-2005	0,1	-23,9	3,8	4,1	-15,9	2005	101,8	80,9	20,9
2005-2006	0,1	3,0	-1,1	4,4	6,3	2006	85,9	109,7	-23,9
1990-2006	-1,2	-210,2	45,2	80,4	-85,8	1991-2006	1819,5	2033,9	-214,5

Appendix 3 – Decomposition of the Changes in CO_2 emissions for the construction sector, 1990-2008

	Decomposition of Changes			Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	$R-T$
1990-1991	0,000	83,5	25,0	45,7	154,2	1991	637,4	553,9	83,5
1991-1992	0,000	59,5	-22,0	53,0	90,5	1992	727,9	668,4	59,5
1992-1993	0,000	-189,1	2,2	52,2	-134,6	1993	593,3	782,3	-189,1
1993-1994	0,000	335,0	36,4	68,2	439,6	1994	1032,8	697,9	335,0
1994-1995	0,000	-210,9	-22,0	84,5	-148,3	1995	884,5	1095,3	-210,9
1995-1996	0,000	-5,0	9,7	52,3	57,1	1996	941,5	946,5	-5,0
1996-1997	0,000	581,2	-302,1	-14,8	264,3	1997	1205,9	624,7	581,2
1997-1998	0,000	118,7	-375,1	-112,2	-368,6	1998	837,2	718,6	118,7
1998-1999	0,000	-7,9	-92,1	35,0	-65,0	1999	772,3	780,1	-7,9
1999-2000	0,000	-221,9	-88,8	28,8	-281,9	2000	490,4	712,3	-221,9
2000-2001	0,000	-66,9	-8,9	9,8	-66,1	2001	424,3	491,2	-66,9
2001-2002	0,000	39,9	0,4	23,6	63,9	2002	488,2	448,3	39,9
2002-2003	0,000	-2,0	-20,6	34,1	11,5	2003	499,6	501,6	-2,0
2003-2004	0,000	23,0	4,1	32,2	59,4	2004	559,0	536,0	23,0
2004-2005	0,000	-84,6	5,3	23,3	-56,0	2005	503,0	587,6	-84,6
2005-2006	0,000	-68,5	-4,2	23,4	-49,3	2006	453,7	522,2	-68,5
2006-2007	0,001	-75,5	-13,5	20,0	-69,0	2007	384,6	460,1	-75,5
2007-2008	-0,001	-5,3	-27,9	9,6	-23,7	2008	361,0	366,3	-5,3
1990-2008	0,0	303,2	-894,2	468,8	-122,2	1991-2008	11796,4	11493,2	303,2

Appendix 4 – Decomposition of the Changes in CO_2 emissions for the manufacturing sector, 1990-2008

	Decomposition of Changes				Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	$R\text{-}T$
1990-1991	341,1	-314,0	337,7	1036,0	1400,9	1991	13330,1	13303,0	27,2
1991-1992	109,6	775,5	417,0	1128,0	2430,1	1992	15760,3	14875,2	885,1
1992-1993	2796,4	-987,1	385,7	1386,7	3581,7	1993	19342,0	17532,6	1809,3
1993-1994	444,9	853,3	99,3	1798,6	3196,1	1994	22538,1	21239,9	1298,2
1994-1995	-368,7	1898,2	597,6	2175,9	4303,1	1995	26841,1	25311,6	1529,5
1995-1996	1804,0	1803,5	183,8	1691,3	5482,7	1996	32323,9	28716,3	3607,6
1996-1997	-1010,7	-1999,8	862,6	-428,3	-2576,2	1997	29747,6	32758,1	-3010,5
1997-1998	748,4	-1229,5	-114,5	-3093,9	-3689,5	1998	26058,1	26539,3	-481,2
1998-1999	2194,2	39,6	1973,5	1248,9	5456,1	1999	31514,3	29280,5	2233,8
1999-2000	418,3	153,9	407,2	1519,7	2499,2	2000	34013,4	33441,2	572,2
2000-2001	4031,4	-468,0	-274,8	772,0	4060,6	2001	38074,1	34510,6	3563,5
2001-2002	224,2	1486,3	688,8	2086,7	4486,0	2002	42560,1	40849,6	1710,5
2002-2003	-473,0	-852,2	1444,9	3043,0	3162,6	2003	45722,7	47047,9	-1325,2
2003-2004	-44,3	-20,2	817,4	2894,2	3647,1	2004	49369,8	49434,3	-64,5
2004-2005	-1965,9	-588,7	259,8	2163,6	-131,2	2005	49238,7	51793,2	-2554,6
2005-2006	1655,6	-898,8	347,9	2498,8	3603,4	2006	52842,1	52085,3	756,8
2006-2007	1859,2	197,7	649,6	2654,0	5360,4	2007	58202,5	56145,6	2056,9
2007-2008	2189,2	2175,9	738,1	1578,1	6681,4	2008	64883,9	60518,8	4365,1
1990-2008	14954,0	2025,7	9821,7	26153,2	52954,6	1991-2008	652362,6	635382,9	16979,7

Appendix 5 – Decomposition of the Changes in CO_2 emissions for the transport sector, 1990-2008

	Decomposition of Changes				Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	R-T
1990-1991	-30,6	-1527,6	-390,5	2783,7	835,0	1991	34318,2	35876,4	-1558,2
1991-1992	-41,7	-257,1	484,7	2781,4	2967,3	1992	37285,5	37584,3	-298,8
1992-1993	56,1	1466,2	915,7	3173,3	5611,3	1993	42896,8	41374,6	1522,3
1993-1994	-3,4	2,5	979,6	3897,8	4876,4	1994	47773,3	47774,2	-0,9
1994-1995	82,8	1562,9	1377,3	4547,2	7570,2	1995	55343,5	53697,8	1645,7
1995-1996	2,5	-1500,7	3080,0	3311,6	4893,5	1996	60236,9	61735,1	-1498,2
1996-1997	-76,3	-2738,9	3605,6	-831,5	-41,0	1997	60195,9	63011,0	-2815,1
1997-1998	-132,7	-1930,7	870,5	-6261,3	-7454,3	1998	52741,6	54805,1	-2063,4
1998-1999	57,8	-1983,1	865,6	2322,5	1262,8	1999	54004,4	55929,7	-1925,2
1999-2000	-38,7	-4554,9	1381,3	2489,4	-722,8	2000	53281,6	57875,1	-4593,5
2000-2001	-31,3	-1830,8	2384,3	1160,4	1682,6	2001	54964,2	56826,3	-1862,1
2001-2002	7,1	-980,9	789,1	2917,9	2733,1	2002	57697,4	58671,2	-973,9
2002-2003	46,9	1600,5	-2417,5	4092,7	3322,5	2003	61019,9	59372,5	1647,4
2003-2004	56,0	647,6	700,2	3874,7	5278,4	2004	66298,3	65594,7	703,6
2004-2005	41,7	-1819,4	134,9	2937,7	1294,9	2005	67593,2	69370,9	-1777,7
2005-2006	-164,7	-5739,6	630,2	3261,0	-2013,2	2006	65580,0	71484,3	-5904,4
2006-2007	-0,4	-1367,9	602,0	3194,9	2428,6	2007	68008,6	69376,9	-1368,3
2007-2008	-11,4	-1336,9	-2039,6	1724,2	-1663,7	2008	66344,9	67693,2	-1348,3
1990-2008	-180,2	-22289,0	13953,5	41377,3	32861,7	1991-2008	1005584,3	1028053,5	-22469,2

Appendix 6 – Decomposition of the Changes in CO_2 emissions for the electricity sector, 1990-2008

	Decomposition of Changes				Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	R-T
1990-1991	-237,3	3403,7	533,3	2598,8	6298,4	1991	34901,0	31734,6	3166,4
1991-1992	18,1	-521,5	750,3	2830,9	3077,8	1992	37978,8	38482,2	-503,4
1992-1993	-722,6	86,6	356,1	3122,4	2842,4	1993	40821,2	41457,2	-636,1
1993-1994	-267,4	202,9	804,3	3700,9	4440,6	1994	45261,8	45326,3	-64,5
1994-1995	-196,6	-1783,2	2041,9	4183,8	4245,8	1995	49507,6	51487,5	-1979,9
1995-1996	-45,0	4122,2	-1119,6	3006,4	5963,9	1996	55471,5	51394,4	4077,1
1996-1997	-2005,6	2711,2	4003,8	-792,7	3916,6	1997	59388,1	58682,6	705,6
1997-1998	-1657,9	-2900,7	5919,2	-6315,5	-4954,9	1998	54433,2	58991,8	-4558,6
1998-1999	-3425,9	-1788,9	-666,0	2289,7	-3591,1	1999	50842,1	56056,9	-5214,8
1999-2000	-2544,4	-2818,6	2396,3	2345,0	-621,6	2000	50220,5	55583,5	-5363,0
2000-2001	-1570,6	1241,3	2156,4	1108,0	2935,1	2001	53155,5	53484,8	-329,3
2001-2002	-1263,7	-362,1	327,9	2792,5	1494,7	2002	54650,2	56276,0	-1625,8
2002-2003	-425,8	98,1	-1340,2	3843,5	2175,6	2003	56825,8	57153,5	-327,7
2003-2004	1239,9	919,9	6,4	3634,5	5800,6	2004	62626,5	60466,7	2159,8
2004-2005	-363,9	-11,0	417,7	2810,4	2853,2	2005	65479,7	65854,5	-374,9
2005-2006	-1015,2	-2800,5	-308,9	3183,9	-940,6	2006	64539,0	68354,7	-3815,7
2006-2007	7133,0	-3305,6	87,5	3255,9	7170,8	2007	71709,8	67882,4	3827,4
2007-2008	-53,0	-2683,7	1098,5	1843,3	205,1	2008	71914,9	74651,5	-2736,7
1990-2008	-7404,1	-6189,8	17464,7	39441,5	43312,3	1991-2008	979727,3	993321,2	-13593,9

Appendix 7 – Decomposition of the Changes in CO_2 emissions for the residentials and service sector, 1990-2008

	Decomposition of Changes				Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	S_{effect}	A_{effect}			R	T	R-T
1990-1991	-145,3	6,4	-58,9	190,8	-7,1	1991	2319,6	2458,5	-139,0
1991-1992	149,8	-93,6	-22,5	188,8	222,6	1992	2542,2	2485,9	56,3
1992-1993	261,3	-211,3	17,1	212,4	279,5	1993	2821,7	2771,7	50,0
1993-1994	314,9	-316,2	-16,0	252,8	235,5	1994	3057,2	3058,5	-1,3
1994-1995	298,3	-214,6	-29,3	284,8	339,3	1995	3396,5	3312,7	83,7
1995-1996	348,7	-68,0	-66,1	206,6	421,2	1996	3817,6	3536,9	280,7
1996-1997	-232,2	290,2	-43,0	-52,5	-37,5	1997	3780,1	3722,2	57,9
1997-1998	-322,5	399,1	10,5	-402,0	-314,9	1998	3465,2	3388,6	76,6
1998-1999	251,4	-14,3	-192,5	155,1	199,8	1999	3665,0	3427,8	237,2
1999-2000	216,9	56,6	-76,2	178,7	375,9	2000	4040,9	3767,4	273,4
2000-2001	74,4	89,4	-38,2	88,9	214,5	2001	4255,4	4091,7	163,8
2001-2002	-142,6	8,2	-54,5	221,3	32,5	2002	4287,9	4422,3	-134,4
2002-2003	-65,1	1,3	-143,8	298,9	91,3	2003	4379,2	4443,0	-63,8
2003-2004	-287,8	36,5	10,6	267,5	26,7	2004	4406,0	4657,3	-251,4
2004-2005	227,2	-188,9	31,0	199,2	268,5	2005	4674,5	4636,1	38,3
2005-2006	163,0	-27,4	-35,9	237,1	336,7	2006	5011,2	4875,7	135,6
2006-2007	97,3	-0,7	-30,4	247,1	313,3	2007	5324,6	5227,9	96,7
2007-2008	-109,0	79,9	-53,0	137,4	55,2	2008	5379,8	5408,9	-29,1
1990-2008	1098,7	-167,3	-791,2	2913,0	3053,1	1991-2008	70624,5	69693,2	931,3

Appendix 8 – Decomposition of the Changes in CO_2 emissions for the overall economy, 1990-2008

	Decomposition of Changes			Total CO_2 emissions changes		Real CO_2 emissions	Theoretical CO_2 emissions	CO_2 emissions differential
	C_{effect}	I_{effect}	A_{effect}	POP_{effect}			R	T	$R\text{-}T$
1990-1991	2117,0	-380,5	6174,2	1058,8	8969,6	1991	92643,4	90906,9	1736,6
1991-1992	2309,2	-816,1	6411,2	1136,1	9040,4	1992	101683,8	100190,8	1493,0
1992-1993	6500,8	-2986,0	7296,0	1234,3	12045,1	1993	113728,9	110214,2	3514,7
1993-1994	4111,3	-1155,7	8985,0	1364,5	13305,2	1994	127034,1	124078,4	2955,7
1994-1995	3762,2	3806,3	10530,5	1540,3	19639,3	1995	146673,3	139104,9	7568,5
1995-1996	3283,1	5935,9	7166,6	1753,3	18138,8	1996	164812,2	155593,2	9219,0
1996-1997	-646,3	7251,1	-4175,8	1870,5	4299,4	1997	169111,6	162506,8	6604,8
1997-1998	-5280,3	7358,8	-19643,5	1756,9	-15808,1	1998	153303,5	151225,0	2078,5
1998-1999	-2523,0	1821,6	5191,7	1611,3	6101,6	1999	159405,1	160106,5	-701,4
1999-2000	-3038,6	-2299,7	5920,6	1525,8	2108,1	2000	161513,2	166851,4	-5338,3
2000-2001	-2243,7	4411,9	2104,9	1418,8	5691,9	2001	167205,1	165036,9	2168,2
2001-2002	-1019,2	1975,5	7563,2	1353,0	9872,5	2002	177077,7	176121,3	956,3
2002-2003	-1057,5	1047,5	11304,6	1338,4	12632,9	2003	189710,5	189720,6	-10,1
2003-2004	1935,6	3477,4	10683,2	1395,1	17491,3	2004	207201,8	201788,8	5413,0
2004-2005	-3110,0	-3035,5	7703,1	1455,5	3013,1	2005	210214,9	216360,4	-6145,5
2005-2006	-3426,1	-4581,7	8878,4	1474,6	2345,2	2006	212560,1	220567,9	-8007,8
2006-2007	-297,4	-1101,2	8863,7	1518,0	8983,1	2007	221543,2	222941,8	-1398,6
2007-2008	1462,0	-2085,2	4187,6	1564,5	5128,9	2008	226672,1	227295,3	-623,1
1990-2008	2839,1	18644,5	95144,9	26369,8	142998,3	1991-2008	3002094,5	2980610,9	21483,6

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