Global Warming, Energy Efficiency and the Role of the Built Environment

by

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Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development

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Abstract

This thesis attempts to explore the relationships between the Buildings Sector, energy efficiency and global warming. Through a qualitative analysis the author illustrates the connection between these three areas and shows how both energy efficiency, as a key policy measure, and the Buildings Sector, as the key recipient of such policies, can act together to significantly mitigate the effects of global warming and resulting climate change.

First, the reader is given the tools to understand the issues surrounding global warming and climate change. This is accomplished through an overview of related science, history and environmental and economic impacts. Future climate scenarios are explained and mitigation options are offered. Second, an overview of energy efficiency as the primary mitigation option for global warming is given. Terminology, history and mitigation potential of energy efficiency and how it applies across market sectors are reviewed. Barriers to implementation of energy-efficiency projects and the need for strong policy are also explored. Third, the Buildings Sector, showing the most promise for greenhouse gas mitigation through energy-efficiency investments, is analyzed. This analysis focuses on the current consumption patterns of buildings, on available energy-efficient technologies, and on the characteristics of efficiency projects in buildings and how they support the goals of broader climate change policy. The analysis concludes with a review of the barriers to such projects along with an overview of the policies in place meant to overcome these barriers. Finally, the author summarizes her research and offers her conclusions.

Thesis Supervisor: Brian A. Ciochetti, PhD
Title: Professor of the Practice of Real Estate

Dedication

This thesis is dedicated to my mother, Sheila Scott. Without her help I never could have finished. And to my advisor Tony Ciochetti, whose enthusiasm, encouragement and patience guided me through the process and kept me moving forward.

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Chapter 1: Overview

1.0 Goals & Motivations

Global warming is a serious threat that impacts the earth's environment, global economic stability, and human health. Though not obvious to most, the link between the Buildings Sector and global warming does exist. The Buildings Sector has the potential to significantly contribute to the mitigation of this threat through investments in energy-efficient technologies that reduce the use of energy, thereby reducing the burning of fossil fuels that create greenhouse gas emissions which enhance the effect of global warming.

This thesis explores the link between global warming and the Buildings Sector by providing a brief history of global warming, highlighting the factors that have contributed and are currently contributing to it, and discussing the primary strategies for mitigating the damages associated with it. One of these key strategies is energy efficiency, which is widely believed to have the greatest potential for mitigation in the short-term. The thesis investigates the facets of energy efficiency – how it works, where it originates, its potential – and discusses how it can be applied across all market segments. In doing so, the Buildings Sector is identified as offering the greatest potential for efficiency gains. These gains translate directly and indirectly into greenhouse gas emissions savings. The thesis elucidates the qualities inherent in energy-efficiency projects within the Buildings Sector that make them an attractive means of addressing global warming for policy makers.

The goal of the thesis is to educate the reader by advancing his/her knowledge of the threat of global warming, the importance of energy efficiency and the certainty of greenhouse gas mitigation through energy-efficiency projects within the Buildings Sector.

My interest in the topic evolved from my study of sustainability and the delivery chain process in a spring class at MIT. The environmental issues discussed and how all industries negotiate them in the course of doing business sparked my interest in the issue of energy efficiency. As a home builder, I applied this interest in energy efficiency to the built environment by studying energy-efficiency projects in buildings. That led to the investigation of energy efficiency as a larger policy measure and the topic of global warming. During this process of exploration, I recognized that a link between global warming and the Buildings Sector existed but had yet to be exploited. This thesis is a culmination of my research. It addresses this knowledge gap and attempts to bridge it.

1.1 Structure

The thesis is comprised of five chapters.

Chapter one offers an overview of the thesis. This chapter briefly describes the subject matter the thesis explores, the author's goals for the thesis and the origins of her interest in the topic. It also gives an overview of how the thesis is structured.

Chapter two reviews the basic science of global warming and its link to anthropogenic greenhouse gas emissions. It explains the history of global warming and how human activity has exacerbated it since the beginning of the industrial age. The chapter explores the international response to the awareness of global warming's effects on the environment and the economic development of society. Finally, the chapter concludes with a discussion of the primary ways in which to mitigate the effects of global warming through the reduction of greenhouse gas emissions.

Chapter three explores energy efficiency as the best short-term means of addressing global warming. It begins by clarifying the assorted ways of defining energy efficiency and its potentials. The chapter exposes the link between energy efficiency and greenhouse gas emissions and discusses the ways in which energy efficiency can be applied across energy-consuming and energy-producing market sectors. The chapter reviews the history of energy efficiency improvements and discusses the barriers that currently block further implementation of such improvements. Finally, the chapter concludes with a discussion of the policy measures available to address these barriers.

Chapter four examines the Buildings Sector and its role as the greatest contributor to mitigating global warming in the short-term through the use of energy efficiency. This chapter explores the consumption patterns of buildings and the mitigation potential of greenhouse gases through the implementation of energy-efficient projects in buildings. It also explains how such projects support the goals of broader climate change policy. The chapter examines the energy-efficient technologies currently available that apply to the Buildings Sector and reviews the barriers in place that block the implementation of such technologies. The chapter ends with a discussion of the policy measures currently available and in place that help to overcome these barriers.

The thesis concludes with chapter five, which summarizes the research and exposes the author's conclusions.

Chapter Two: Global Warming & Climate Change

2.0 Global Warming

Global warming and the climate changes it brings, threatens the natural cycles we depend on for our health and livelihoods. Rising global temperatures jeopardize human health by increasing the spread of disease. Such temperatures shift weather patterns causing an increase of extreme weather like hurricanes and heat waves. They damage global economies by reducing the productivity of industries such as fishing or skiing. And they harm Earth's ecosystems causing the loss of plant and animal species worldwide. Global warming is more urgent and its dangers are more fundamental than most people realize. Global warming is believed to be the most serious environmental challenge of our time.[1]

2.1 The Greenhouse Effect

Understanding global warming requires a basic understanding of the science which underlies it. The most fundamental component of this science is a process known as the greenhouse effect. The greenhouse effect is the warming that Earth experiences because certain gasses in its atmosphere trap and radiate energy from the sun. Simply put, when sunlight enters Earth's atmosphere it passes through a blanket of gases. As it reaches Earth's surface, much of its energy is absorbed by the land, water and biosphere resulting in surface warming. Once absorbed, much of this energy is eventually re-radiated back into the atmosphere. Some of this energy passes into space, but much of it is absorbed by certain gases in the atmosphere that re-emit the energy as heat back towards Earth's surface, thus helping Earth to maintain its temperature.[2] This warming or greenhouse effect is a natural process where absorbed energy is closely balanced by energy radiated back into space   It is this delicate balance that enables Earth's temperature to remain in a steady state and what makes Earth's climate suitable for human existence.

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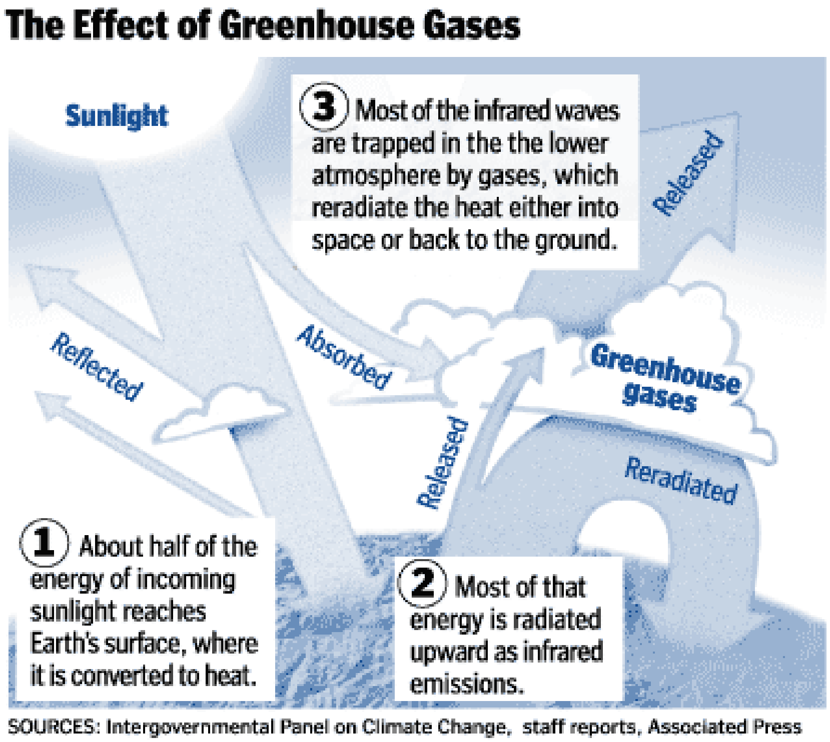
[1] *Environmental Defense Fund: About Us*. Retrieved from http://www.fightglobalwarming.com/page.cfm?tagID=137

[2] *United States Environmental Protection Agency: Greenhouse Effect*. Retrieved from http://epa.gov/climatechange/kids/greenhouse.html

Figure 1: The Effect of Greenhouse Gases



2.2 Greenhouse Gases

The blanket of naturally occurring gases, referred to as greenhouse gases, is comprised primarily of water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20). Though these trace gases make up less than 1% of Earth's atmosphere, it is these greenhouse gases that give Earth its insulation.

In addition to naturally occurring greenhouse gases, human activities produce and add to the atmospheric concentration of these gases. Man-made chemicals such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) act as greenhouse gases contributing to the greenhouse effect and the warming of the Earth. The burning of fossil fuels such as coal or gas mainly used in energy production and land use changes such as deforestation and urbanization, produce greenhouse gases and contribute to the warming effect as well.

The contribution of human-induced, or anthropogenic,[3] greenhouse gases and the incremental warming they contribute to Earth's natural process can influence changes in global climate patterns. Though

[3] 'Anthropogenic' is defined as the effects, processes, objects, or materials that are derived from human activities, as opposed to those occurring in natural environments without human influences.

"global warming can occur from a variety of causes, both natural and human induced …in common usage, 'global warming' often refers to the warming that [occurs] as a result of increased emissions of greenhouse gases from human activities."[4]

Next to water vapor, CO_2 is the most abundant greenhouse gas in the atmosphere. Though carbon dioxide on a molecule basis is not as adept at trapping heat as methane or nitrous oxide, its atmospheric concentrations are far greater and it remains in the atmosphere far longer. CO_2 once emitted will linger in the atmosphere for centuries perpetuating the warming effects.

2.3 Greenhouse Gas Measurements

"The standard unit of measurement of greenhouse gases is the *metric ton of carbon dioxide equivalent* (tCO_2e), the global warming impact of one metric ton of atmospheric carbon dioxide. This measure allows gases that exacerbate global warming to be converted to a common unit. *Figure 2* lists several greenhouse gases and their relative Global Warming Potential (GWP) compared to CO_2."[5]

Figure 2: Global Warming Potential of Various Gases[6]

Gas	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	23
Nitrous Oxide (N_2O)	296
HFC-152a	120
HFC-134a	1,300
HFC-143a	4,300
HFC-23	12,000
Perfluoromethane (CF_4)	5,700
Sulfur Hexafluoride (SF_4)	22,200

[4] *United States Environmental Protection Agency: Climate Change*. Retrieved from http://www.epa.gov/climatechange/basicinfo.html
[5] Aaron G. Binkely, "Real Estate Opportunities in Energy Efficiency and Carbon Markets," diss., Massachusetts Institute of Technology, 2007, 8.
[6] "Carbon Trading Fact Sheet," Clifford Chance. March 2006.

This is an important concept to understand because it can create much confusion when reviewing available data. Different reports and institutions switch off between speaking of global warming in terms of CO_2e or simply CO_2. When the term 'greenhouse gases' is used it's referring to CO_2e and all gases that contribute to global warming. Some reports simply speak of CO_2, which comprises the largest share of greenhouse gases representing 77% of total anthropogenic greenhouse gases in 2004.[7]

A common unit used for measuring CO_2e is the giga-tonne (Gt). A giga-tonne is equal to one billion metric tonnes of CO_2e. One giga-tonne is written as GtCO_2e.

2.4 Global Warming and Resulting Climate Change

Scientists have used ice core data to analyze global temperature changes that have occurred over the past 800,000 years[8]. These studies have revealed the tightly correlated relationship between global temperature changes and fluctuations in CO_2 levels in Earth's atmosphere.

In addition to exposing the relationship between atmospheric CO_2 levels and global temperature, these studies have also revealed the fact that atmospheric CO_2 concentrations have been on an unprecedented upward climb since the beginning of the Industrial Revolution.

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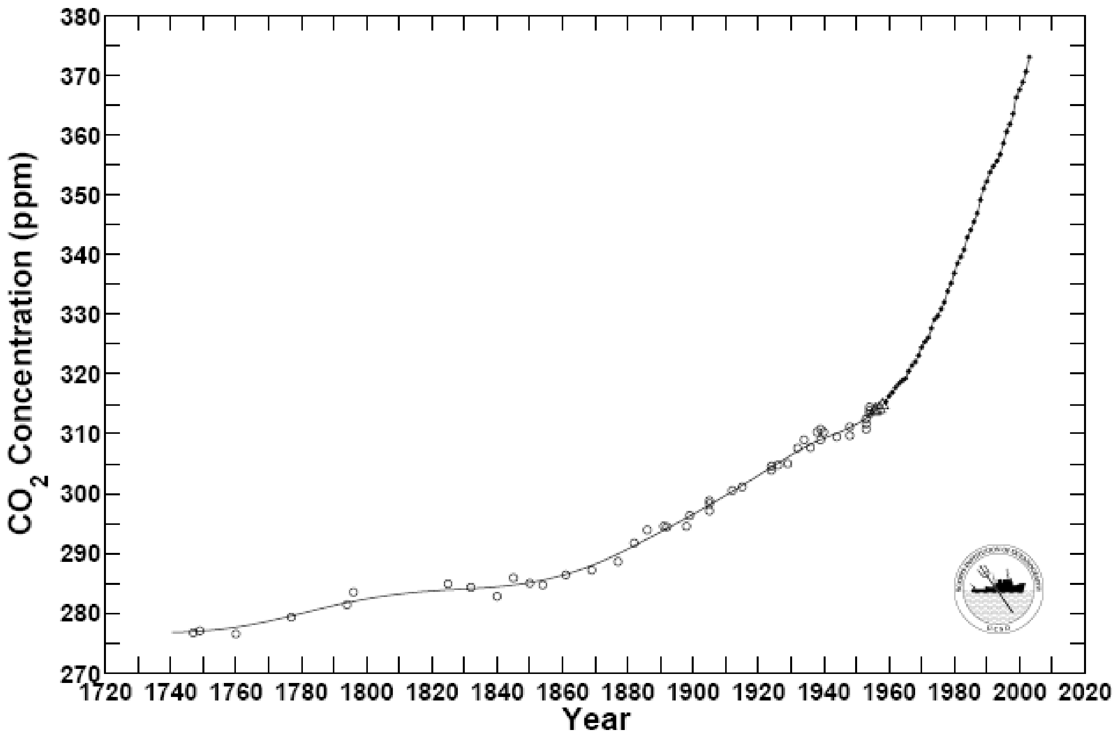
[7] IPCC, Fourth Assessment Report, Climate Change 2007: Mitigation of Climate Change; Summary for Policymakers (2007) 3.

[8] Jonathan Amos, "Deep ice tells long climate story," BBC News 4 September 2006. Retrieved from http://news.bbc.co.uk/2/hi/science/nature/5314592.stm

Figure 3: Trend in Atmospheric CO_2 Concentrations over the Industrial Era[9]



Today, levels of atmospheric CO_2 concentrations are substantially higher than they've been in the past 800,000 years. The sharp rise in CO_2 levels over the past 200 years along with a corresponding increase in the global mean surface temperature of between 1.0 and 1.7 degrees Fahrenheit since 1850[10] is widely believed to be anthropogenic. In its fourth assessment report released in February 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."[11]

Though controversy surrounding global warming and its causes still exists in the public press, there is general consensus by the scientific community that global temperatures are increasing and climate change is occurring. Climate change, defined as the change in average weather patterns over time for a given region, can include changes in temperature, wind patterns and precipitation.

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[9] Source: Scripps CO_2 Program. Retrieved from http://scrippsco2.ucsd.edu/graphics_gallery/graphics_gallery.html
[10] *United States Environmental Protection Agency: Temperature Changes*. Retrieved from http://www.epa.gov/climatechange/science/recenttc.html
[11] Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report: Climate Change 2007 (2007)

Primary environmental impacts resulting from global warming and concurrent climate change include:[12]

- Rising Temperatures
- Sea Level Rise
- Intensification of the Hydrologic Cycle (precipitation, droughts, floods)
- Health Effects, such as malaria from rising mosquito populations
- Dramatic Effects on Ecosystems

2.5 Acceptance of Anthropogenic Global Warming

Though a prime topic of conversation and debate in recent years, human involvement in global warming is not a new discovery. The first theory on global warming that linked it to human activity was published in 1896 by the Swedish scientist Svante Arrhenius[13] in his paper 'On the influence of carbonic acid in the air upon the temperature of the ground'. His research proposed a relationship between atmospheric CO_2 concentrations and temperature. Arrhenius postulated that as humanity burned fossil fuels such as coal, adding CO_2 to Earth's atmosphere, the planet's average temperature would rise. His was just one of many theories on climate at the time and not thought to be the most believable or significant. Popular belief was that if the theory indeed had merit, human influences were insignificant compared to natural forces and any resulting atmospheric change would not occur for tens of thousands of years.

Since Arrhenius' time scientists have diligently worked to understand the delicate relationships that exist within Earth's atmosphere. The technological advances and scientific research conducted over the course of the following century shed new light on the relationship between CO_2 and temperature gains, supporting Arrhenius' theory. Despite increasing acceptance in certain circles, scientific uncertainties and the sheer complexity of climate relationships was cause for continued skepticism in others. Inconclusive and unreliable scientific data further supported skeptic's beliefs.

It wasn't until1957 that American scientist Charles David Keeling initiated the Scripps CO_2 Program and began tracking CO_2 in Earth's atmosphere. His precise measurements, taken from Mauna Loa Observatory in Hawaii and the South Pole, produced a notable data set which highlighted the build-up of CO_2 concentrations in the world's atmosphere and eventually led to the tracking of greenhouse gases

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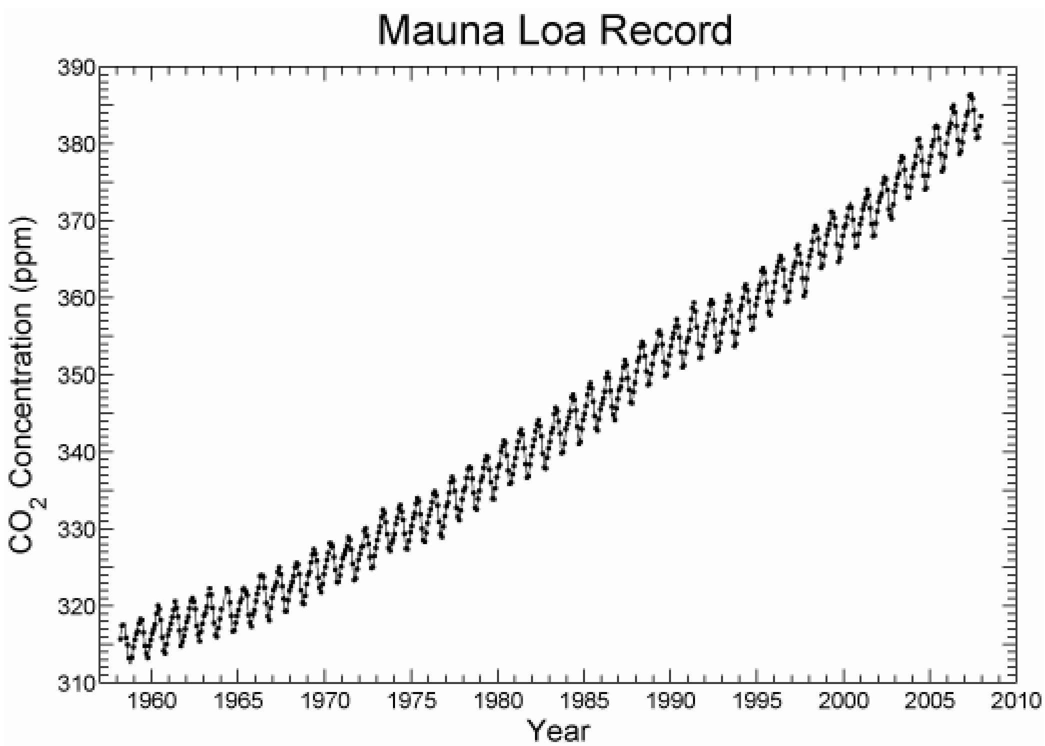
[12] *Woods Hole Research Center: Warming of the Earth, Potential Outcome.* Retrieved from http://www.whrc.org/resources/online_publications/warming_earth/potential_outcome.htm
[13] S.M.Enzler, "History of the greenhouse effect and global warming," Lenntech. Retrieved from http://www.lenntech.com/greenhouse-effect/global-warming-history.htm

worldwide.[14] Keeling's research provided the first real indication that atmospheric CO_2 levels were rising. Through his research, what came to be known as the Keeling Curve was developed. The Keeling Curve is shown in *Figure 4*. This iconic graph, which measures the number of parts per million (ppm) by volume of CO_2 in the atmosphere (number of molecules of CO_2 for every million molecules in the air), served as the basis for the global debate on climate change and created further belief that global warming was anthropogenic. Eventually Keeling's work was picked up by the National Oceanic and Atmospheric Administration (NOAA), a US federal agency. By the late 1970's NOAA had begun monitoring CO_2 levels worldwide.

Figure 4: The Keeling Curve[15]



By the late 1970's it was clear that global temperatures had begun to rise and the scientific community warned against the effects of rising greenhouse gases. However, it wasn't until 1988 that scientists' claims about climate change first drew wide public attention. Against a backdrop of the hottest summer on record till then[16], scientist James Hansen of the NASA Goddard Institute for Space Studies testified

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[14] Helen Briggs, "50 years on: The Keeling Curve legacy," BBC News 2 December 2007. Retrieved from http://news.bbc.co.uk/2/hi/science/nature/7120770.stm
[15] Source: Scripps CO_2 Program. Retrieved from http://scrippsco2.ucsd.edu/graphics_gallery
[16] Spence Weart, "The Discovery of Global Warming," June 2007. Retrieved from http://www.aip.org/history/climate/summary.htm

before a US Senate committee that he could state with 99% confidence that a "recent, persistent rise in global temperature was occurring".[17] In 1988 it was finally publicly acknowledged that the climate was warmer than in any period since 1880.

Years prior to Hansen's testimony certain international organizations were already acting on their concern over the probable connection between human activity and the changing climate. One such organization was the United Nations' World Meteorological Organization (WMO) which in 1979 organized the first World Climate Conference (WCC). This conference called for "global cooperation to explore the possible future course of global climate and to take this new understanding into account in planning for the future development of human society." The conference appealed to the nations of the world "to foresee and to prevent potential man-made changes in climate that might be adverse to the well-being of humanity."[18]

Over the following decade the link between greenhouse gas concentrations and climate change became clearer and the vital need for timely data became apparent. This issue was eventually addressed in 1987 by the 10th Congress of the WMO with its recognition of the need for "objective, balanced, and internationally coordinated scientific assessment of the understanding of the effects of increasing concentrations of greenhouse gases on the earth's climate and on ways in which these changes may impact socio-economic patterns."[19] It was proposed that an intergovernmental mechanism be created to provide scientific assessments of climate change and so in 1988, the same year that James Hansen stood before the US Senate, the WMO and the United Nations Environment Program (UNEP) created the Intergovernmental Panel on Climate Change (IPCC).

2.6 Intergovernmental Panel on Climate Change (IPCC)

Established in 1988 by the WMO and UNEP, the Intergovernmental Panel on Climate Change (IPCC) was created to address the need for an internationally coordinated scientific assessment of the global effects of climate change. The IPCC consists of more than 2,500 scientific and technical experts from

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[17] Andrew C. Revkin, "Special Report: Endless Summer-Living with the Greenhouse Effect," Discover 23 June 2008. Retrieved from http://discovermagazine.com/1988/jun/23-special-report-endless-summer-living-with-the-greenhouse-effect

[18] Intergovernmental Panel on Climate Change, 16 Years of Scientific Assessment in Support of the Climate Convention (Geneva: 2004) 2. Retrieved from http://www.ipcc.ch/pdf/10th-anniversary/anniversary-brochure.pdf

[19] IPCC, 16 Years 2.

more than 60 countries all over the world. It has been referred to as the largest peer-reviewed scientific cooperation project in history and is believed to be the world's leading authority on climate change.[20]

"The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for mitigation."[21]

Simply put, the aims of the IPCC are to assess current, peer-reviewed, published scientific literature relevant to:

- Human-induced climate change
- The impacts of human-induced climate change
- Options for adaptation and mitigation

The IPCC does not conduct original research. Instead, it compiles and assesses the most up-to-date climate change research available and releases its findings in the form of assessment reports. Since the IPCC's inception in 1988, four assessment reports have been released. The most recent report, the Fourth Assessment Report (AR4), was released in 2007.

Each assessment report consists of three volumes with each volume covering a different area of exploration related to climate change. The three areas are:

I. Available scientific information on climate change
II. Environmental and socio-economic impacts of climate change
III. Formulation of response strategies

Each volume is produced by a separate committee, referred to as a Working Group.

Since the IPCC is an intergovernmental body, review of IPCC documents involves both peer review by scientific experts and review by governments. This rigorous review is an essential part of the IPCC process and enhances the credibility of all IPCC reports released.

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[20] "A guide to facts and fictions about climate change," The Royal Society March 2005. Retrieved from http://royalsociety.org/downloaddoc.asp?id=1630
[21] IPCC, 16 Years (Foreword)

Though IPCC assessment reports are meant to be neutral with respect to policy, their objective analysis of scientific, technical and socio-economic factors has become the basis for the creation of climate change-related policy.

The most significant policy resulting from an IPCC report was initiated by the United Nations General Assembly (UNGA) in 1990.[22] After noting the findings of the IPCC's First Assessment Report, the UNGA initiated the negotiation of a global treaty which would create international cooperation on climate change and adopt effective measures to mitigate the damages associated with it in order to preserve the global climate.

The IPCC's First Assessment Report served as the scientific basis for this negotiation and in 1992 the United Nations Framework Convention on Climate Change (UNFCC) was adopted. Today, IPCC reports remain the UNFCC's primary source for the scientific, technical and socio-economic information it uses to make decisions and formulate global policy.

2.7 United Nations Framework Convention on Climate Change (UNFCCC)

On June 12, 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was signed by 154 countries at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. For the first time, this treaty created an overall framework for intergovernmental efforts to deal with the global issues that climate change presented.

Under the UNFCCC, governments agreed to:

- Gather and share information on greenhouse gas emissions, national policies and best practices
- Launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries
- Cooperate in preparing for adaptation to the impacts of climate change[23]

[22]IPCC, 16 Years 4.
[23] *United Nations Framework Convention for Climate Change: UNFCCC.* Retrieved from http://unfccc.int/essential_background/convention/items/2627.php

Upon ratification of the treaty, participating governments committed to a voluntary goal of reducing atmospheric concentrations of greenhouse gases so as to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[24] As originally framed, the treaty set no mandatory limits on greenhouse gas emissions for individual nations and hadn't any enforcement provisions. Its commitments were legally non-binding.

Recognizing member countries "common but differentiated responsibilities and respective capabilities and their social and economic conditions,"[25] emission-reducing actions of the treaty were aimed primarily at industrialized countries. Though other goals of the treaty were the responsibilities of all parties, the near term stabilization of greenhouse gas emissions was left to industrialized nations. According to the UNFCCC, these nations were required to reduce their emissions of greenhouse gases below their 1990 levels by the year 2000.

Though somewhat controversial, the rationale for this decision is mainly reflected in the following excerpt from the treaty.

> "Noting that the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs."[26]

The excerpt says two things: (1) That current atmospheric greenhouse gas levels can primarily be attributed to the development that industrialized countries have undergone, and (2) that developing countries should be allowed to continue to develop and that with this development will come increasing per capita emissions. They should not be penalized for this.

Almost two years after the treaty's original signing, the UNFCCC entered into force on March 21, 1994. Today its membership is nearly universal, reflecting 192 countries. Since its inception the parties to the treaty have been meeting annually in Conferences of the Parties (COP) to assess the progress made in dealing with climate change. Beginning in the mid 1990s, negotiations began to establish legally binding obligations for developed countries to reduce their greenhouse gas emissions. These negotiations eventually led to the principle update to the UNFCCC known as the Kyoto Protocol.

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[24] United Nations, United Nations Framework Convention on Climate Change (UNFCCC), (1992) 4.
[25] United Nations, UNFCCC 1.
[26] United Nations, UNFCCC 1.

2.8 Kyoto Protocol

The Kyoto Protocol was adopted on December 11, 1997 in Kyoto, Japan and entered into force seven years later on February 16, 2005. To date, 181 nations have ratified the treaty. The European Community, acting on behalf of the European Union, has signed the treaty as well.

The major distinction between the Kyoto Protocol and the UNFCCC is that while the UNFCCC encourages industrialized countries to stabilize greenhouse gas emissions, the Kyoto Protocol legally commits them to do so. Under international law, the Kyoto Protocol sets binding emission reduction targets for the 37 industrialized countries that have ratified the protocol.

Reduction targets cover emissions of the six main greenhouse gases, namely: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and Perfluorocarbons (PRCs).[27]

Each participating country adheres to the individual reduction target negotiated during the creation of the treaty. These targets are set as a percentage decrease in a country's future emissions against their 1990 emissions level. *Figure 5* provides an overview of these reductions. Committed countries have through the end of the first phase of the treaty, 2008 to 2012, to meet their reduction targets.

[27] *United Nations Framework Convention for Climate Change: Kyoto Protocol*. Retrieved from http://unfccc.int/kyoto_protocol/items/3145.php

Figure 5: Baseline Emissions, Percentage Reduction, Absolute Cutbacks[28]

Region	Baseline Emissions (MtC)[a]		Nominal Reduction (% wrt 1990)	Effective Reduction (% wrt 2010)	Absolute Cutback (MtC wrt 2010)
	1990	2010			
AUN	88	130	-6.8	27.7	36
CAN	127	165	6.0	27.7	46
EUR	929	1041	7.8	17.7	184
JPN	269	331	6.0	23.6	78
EEC	301	227	7.1	-23.2	-53
FSU	1036	713	0.0	-45.3	-323
Total U.S. out[b]	2750	2607	5.0	-0.7	-32
USA	1347	1809	7.0	30.8	556
Total U.S. in[c]	4097	4416	5.0	11.9	525

Key: AUN – Australia and New Zealand, CAN – Canada, EUR - OECD Europe (incl. EFTA), JPN – Japan, EEC - Central and Eastern Europe, FSU - Former Soviet Union (incl. Ukraine).

[a] Source: International Energy Outline (IEO 2001) - reference case
[b] Annex B without U.S. compliance
[c] Annex B with U.S. compliance

For example, Japan has committed to emissions reductions of 6% below its 1990 level. The targeted average worldwide reduction in emissions across all industrialized nations amounts to 5% below 1990 levels (Total U.S. out).

Under the Protocol, countries must attempt to meet their targets primarily through national measures. However, the Kyoto Protocol offers countries additional means of meeting their targets by way of three market-based mechanisms.

- Emissions Trading (commonly referred to as "carbon trading")
- The Clean Development Mechanism (CDM)
- Joint Implementation (JI)

As discussed, industrialized countries committed to reducing their emissions have agreed to individually negotiated reduction targets. In other words, these countries have agreed to cap their greenhouse gas

[28] Source: Chistopher Bohringer and Carsten Vogt, "Dismantling of a Breakthrough: The Kyoto Protocol – Just Symbolic Policy!" Center for European Economic Research (ZEW) (2002) 4.

emissions at specified levels over the course of the compliance period, 2008 to 2012. These amounts of allowed emissions are broken into assigned amount units (AAU) and spread across the five year period. Under the treaty, those countries that emit less than their allotted cap can sell their excess AAUs to committed countries who have exceeded their allotted cap. In this way the Kyoto Protocol created a new commodity: the commodity of avoided greenhouse gas emissions. The market for this commodity is referred to as the carbon market.

Article 17 of the Kyoto Protocol sets forth the parameters for emissions trading. In addition to AAUs, these parameters allow Emission Reduction Units (ERU) and Certified Emissions Reductions (CER) to be traded. ERUs and CERs are not based on emissions allowances but are created through the offset of greenhouse gas emissions. Offsets are typically created through emissions reducing projects such as renewable energy. Both ERUs and CERs are created using the Kyoto Protocol's other market-based mechanisms, the Clean Development Mechanism (CDM) and Joint Implementation (JI).

Under the Clean Development Mechanism (CDM) an industrialized country can sponsor a greenhouse gas reduction project in a developing country where the cost of implementing greenhouse gas reduction projects is generally lower. In this scenario, the industrialized country would be given credits towards meeting its emission reduction targets, while the developing country would benefit from the investment of capital and the transfer of clean technology. Emissions units generated through CDM projects are known as Certified Emissions Reductions (CER). An example of a CDM project is the hydroelectric generation plant that was built in 2005 by Finland in Honduras. This plant, which produces clean hydroelectric power, reduces CO_2e emissions and contributes to the reduction of Honduran petroleum imports. This CDM project is estimated to avert 17,800 metric tonnes of CO_2e per year, with each metric tonne of CO_2e avoided being equal to 1 CER. Finland, as the industrialized country that sponsored the project, gets the CER credits the project produces, while Honduras, the host country, gets the technology.

Under Joint Implementation (JI) an industrialized country with relatively high costs of domestic greenhouse reduction would set up a project in another developed country where the cost of project implementation is lower. Again, in this scenario the country making the investment earns credits towards its emission reductions target while the host country benefits from an infusion of capital and the transfer of clean technology. The emissions units generated through a JI project are known as Emission Reduction Units (ERU).

Both CDM and JI measures support the carbon market since surplus offsets generated by participating countries can be traded on the carbon market for profit.

The Kyoto Protocol contains measures to assess performance and progress. These measures include strict guidelines that govern the creation of emissions tracking systems in member countries, the release of regularly scheduled reports by member countries demonstrating their compliance with the Protocol and the review by teams of experts who continually assess activities and information provided by the member states. The Protocol also contains some penalties. Countries that fail to meet their emissions targets by the end of the first compliance period (2012) must make up the difference plus a penalty of 30% of emissions in the second commitment period. The ability to sell credits under emissions trading for these countries would also be suspended.[29]

As an expansion of the underlying UNFCCC, and in accordance with the principle of "common but differentiated responsibilities", the Kyoto Protocol places the heaviest financial burden on industrialized nations in its aim to reduce global greenhouse gas emissions. This emphasis is one of the primary reasons it took seven years to implement the treaty.

Under the terms of the treaty, the Kyoto Protocol would not take effect until 90 days after it was ratified by at least 55 countries who were parties to the UNFCCC. A second and more difficult condition was that these ratifying countries had to represent at least 55% of the world's total greenhouse gas emissions for 1990. Since the United States and Russia were responsible for 36% and 17%, respectively, of 1990 greenhouse gas emissions, these two countries were seen as key supporters, with the ratification of at least one of the two countries essential for implementation of the protocol.

The first condition was met in May 2002, when Iceland became the 55th country to ratify the Kyoto Protocol. The second took longer to satisfy and was met two years later when Russia finally ratified the agreement in November 2004. The Kyoto Protocol entered into force 90 days later in February 2005.

As the largest emitter of greenhouse gases, the United States still has not ratified the Kyoto Protocol. It is the only industrialized nation yet to join. Though the U.S. helped to shape the treaty, President Bush withdrew U.S. support shortly after he took office in 2001. His main criticism was that treaty requirements would harm the U.S. economy, costing hundreds of billions of dollars and millions of jobs. He also objected to the practices of the protocol, believing them to be ineffective and discriminatory.

[29] "Kyoto and beyond," CBC News 14 February 2007. Retrieved from http://www.cbc.ca/news/background/kyoto/#s8

President Bush is not alone in his criticism of the Kyoto Protocol. Other critics of the treaty feel that it doesn't go far enough to reduce greenhouse gases. They question the effectiveness of its practices and feel the treaty doesn't address other factors that contribute to global warming, believing the Kyoto Protocol to be an anti-industrial agenda. Some critics still attack the science underlying the treaty, claiming no evidence exists that proves rising temperatures are due to human activity.

Even advocates of the treaty acknowledge that the Kyoto Protocol will not by itself reduce atmospheric warming noticeably. The Woods Hole Oceanographic Institution (WHOI), the world's largest private, non-profit ocean research, engineering and education organization, estimates that even if the Protocol achieved the 5% reduction of greenhouse gas emissions below 1990 levels, the resulting reduction in anthropogenic emissions would decline from around 7.2 $GtCO_2e$ (billion metric tonnes) per year to about 6.8 $GtCO_2e$ per year. [30] From an environmental perspective, this agreement falls far short of the measures needed to reverse global warming. Even if we accomplish the 5% reduction, we will still be 1.8 $GtCO_2e$ above the level needed to stabilize emissions.[31]

Supporters of the Kyoto Protocol acknowledge the difficult realities it faces, but argue that the real impact of the Protocol is not tangible. Its greatest value is symbolic. It is a step in the right direction, fostering multinational collaboration on global warming. This global consensus is imperative to address the complex issue of climate change.

With the first phase of the agreement set to expire in 2012, talks on how to proceed beyond this first phase have been an ongoing part of the UNFCCC process. A successor to the Kyoto Protocol is currently being outlined. One possible aspect of this plan includes a global emissions trading system that would apply to both industrialized and developing nations.

2.9 Stern Report & Economic Impacts of Climate Change

While the international community has worked towards consensus on greenhouse gas reductions and has developed policy to implement them, research continues on the effects of global warming. Though scientific data modeling the environmental impacts of climate change make a convincing case for countries to reduce the greenhouse gases they emit, the economic story is no less compelling.

[30] *Woods Hole Oceanographic Institute: About WHOI.* Retrieved from http://www.whoi.edu

[31] Sir Nicholas Stern, "Stern Review on the Economics of Climate Change; Executive Summary". Office of Climate Change, UK. 30 October 2006 x.

‘The Stern Review on the Economics of Climate Change’ was commissioned in 2005 by Gordon Brown, then the Chancellor of the Exchequer in the United Kingdom, and was released on October 30, 2006 by economist Lord Stern of Brentford. Though not the first report to put global warming into economic terms, it is the most widely known. This 700 page report discusses the effects of global warming and climate change on the world economy.

The Stern Review creates a business as usual (BAU) scenario which it uses as the basis for its estimates of the economic costs of climate change. This BAU scenario models the impacts of climate change if the global community were to continue its current patterns of consumption. Against this scenario, the report forecasts the physical impacts of climate change on human life, on the economy and on the environment. It creates economic models to estimate the financial implications of climate change as well as examines the costs and effects of transitioning to a low-carbon economy.

Key economic findings of the Stern Review include:

- Extreme weather such as hurricanes, flooding and heat waves could reduce global gross domestic product (GDP) by up to 1%. (For example, as listed by the CIA World Factbook, global GDP in 2007 was US $53,640 billion. A loss of 1% of GDP would translate to a loss of US $536 billion.)
- A 2 to 3 degrees Celsius rise in temperatures could permanently reduce global GDP by up to 3%
- A 5 to 6 degree Celsius rise in temperatures could result in the loss of up to 10% of global GDP with the poorest countries losing more than 10% of their GDP
- Costs over the next two centuries of climate change associated with business as usual (BAU) emissions involves impacts and risks equivalent to an average permanent reduction in global per-capita consumption of between 5% and 20%
- To remain at manageable levels, greenhouse gas emissions would need to stabilize in the next 20 years and fall between 1% and 3% after that. This would cost 1% of global GDP.

The difficulties faced in modeling the overall economic impact of climate change are formidable. The lags that exist between action and effect are very long and pose challenges to the underlying quantitative analysis. Stern openly discloses his assumptions as well as acknowledges the complexity of interpreting the results of such a long-range modeling exercise.

Though the Stern Review has received much positive attention and been used by many as a call to arms against anthropogenic global warming, it has its critics as well. Its controversial assumptions, criticized by some economists as over-estimating the impacts of climate change while under-estimating the positive impacts of development and adaptation, have caused much debate. Other critiques include its double counting of risks, its discounting assumptions, and its sensationalized “fear-mongering arguments”.[32]

Many involved in this discussion lie between the two extremes. These players feel that while certain assumptions in the report are open for debate, its fundamental conclusion is justified: That ignoring climate change will eventually damage global economic growth and that the benefits of decisive, early action will far outweigh the costs.

On June 25, 2008, due to faster than expected global warming, Lord Stern of Brentford increased his estimate of the predicted cost to reduce carbon emissions from 1% of GDP to 2% of GDP. For the UK alone, 2% of GDP represents roughly £28 billion a year.[33]

2.10 Emissions Trends & Stabilization

While the world has slowly awakened to the realities of global warming and deliberated and debated over who’s to blame and courses of action to take, the concentrations of greenhouse gas emissions in the atmosphere have steadily continued to rise. The clock has continued to tick.

There is real cause for concern here. Despite the scientific community’s persistent warnings that Earth may enter un-chartered territory if its temperatures continue to increase, greenhouse gas emissions continue to grow. The realities of species loss, rising sea levels, severe weather patterns and the increased spread of disease don’t seem to be creating the sense of urgency needed to actually address the underlying cause of these issues. Possibly the most upsetting aspect of this reality is the seeming lack of concern on the part of the general public.

What scientists and government officials know that most people don’t understand is that the emissions we are releasing may stay in the atmosphere for centuries. This means that the CO_2 we emit today will affect our climate through the end of this century and into the next. There is inertia in the climate system. This inertia disconnects the act of polluting from the ultimate impact of the pollution. It may be the lag between action and effect that lulls people into a state of complacency and reduces their sense of urgency.

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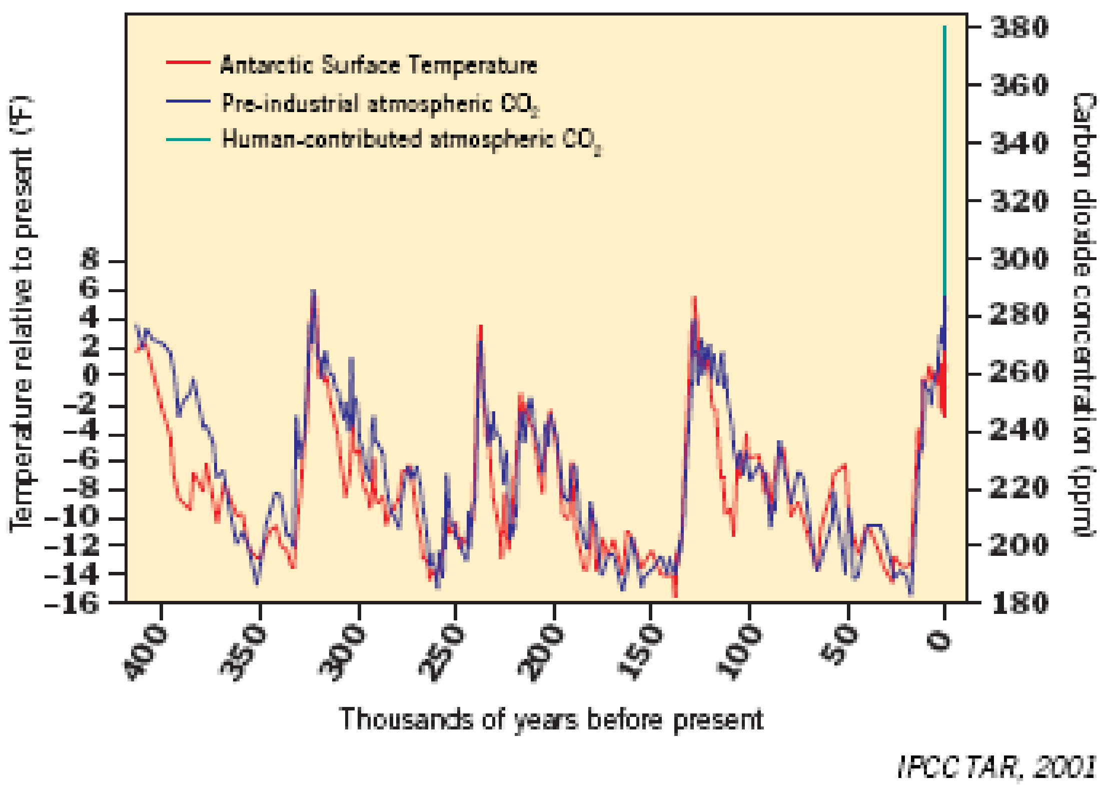
[32] Bjorn Lomborg, “STERN REVIEW, The dodgy numbers behind the latest warming scare.” The Wall Street Journal 2 November 2006. Retrieved from http://www.opinionjournal.com/extra/?id=110009182

[33] Juliette Jowit and Patrick Wintour, “Cost of tackling global climate change has doubled, warns Stern,” The Guardian 26 June 2008. Retrieved from http://www.guardian.co.uk/environment/2008/jun/26/climatechange.scienceofclimatechange

Today atmospheric concentration of CO_2 as measured by the Scripps CO_2 Program is at 384 ppm and rising by 2 ppm per year. Concentration prior to the Industrial Revolution was at 280 ppm.[34] This increase in concentration has already caused the world to warm by more than half a degree Celsius and will lead to at least a further half degree of warming over the next few decades.[35] The 37% jump in atmospheric concentration over the industrial era is alarming but what's more alarming is that the majority of this increase has occurred since 1970. The period 1970 to 2004 alone saw a 70% increase in greenhouse gas emissions.[36] The eight warmest years on record since 1850 have all occurred since 1998, with the warmest year being 2005. Today's atmospheric concentration of CO_2 is considerably higher than the scientific record has ever shown. As illustrated in *Figure 6*, pre-industrial global concentrations of CO_2 over the last 400,000 years have never exceeded 300 ppm.

Figure 6: Historical Global Concentrations of CO_2



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[34] *Scripps CO_2 Program: FAQ*. Retrieved from http://scrippsco2.ucsd.edu/faq/faq.html
[35] Stern iii.
[36] IPCC, Fourth Assessment Report, Climate Change 2007: Mitigation of Climate Change; Summary for Policymakers (2007) 3.

General consensus among scientists seems to be that concentration of greenhouse gases in the atmosphere needs to stabilize between 450 and 550ppm if major environmental damage is to be avoided. Stabilizing at or below 550ppm would require global emissions to peak in the next 10 to 20 years and then fall at a rate of 1% to 3% per year.[37] At a stabilized concentration of 550ppm, there is a 77% to 99% chance, depending on the climate model used, of global average temperature rise exceeding 2 degrees Celsius above pre-industrial levels. Though this may not sound significant, current temperatures are only 5 degrees Celsius above what they were during the last ice age.[38] If a 5 degree Celsius increase in temperature can move Earth from an ice age to its present environmental state, consider the effect an additional 2 degrees Celsius or more would have on our environment. Furthermore, considering that the annual flow of emissions is accelerating as developing countries employ carbon-intensive infrastructure and demand for energy and transport increases world-wide, the stabilization level of 550ppm CO2e may be somewhat aggressive. This level of concentration could be reached as early as 2035 if immediate steps are not taken to slow emissions trends.

What is stabilization and how do we achieve it? According to the Stern Review, stabilization is the level of annual CO_2e emissions that balances the earth's natural capacity to remove greenhouse gases from the atmosphere. In the long-term, annual global emissions will need to be reduced to below 5 $GtCO_2e$, the maximum level that Earth can absorb without adding to the concentration of greenhouse gases in the atmosphere. This is more than 80% below the absolute level of current annul emissions. The longer our CO_2e emissions remain above this natural level, the higher the final stabilization level will be.[39]

2.11 Mitigation of Climate Change

Strong, early action is needed to stabilize emissions and to mitigate the effects of climate change. If such steps are immediately taken, much, though not all, of climate change-related risk can be reduced. In regards to developing such a policy, the four main ways to cut greenhouse gas emissions have been identified as: Reducing Demand for Emissions-intensive Goods and Services; Switching to Lower-carbon Technologies for Power, Heat and Transportation; Action on Non-energy Emissions, such as Avoiding Deforestation; and Increased Energy Efficiency**.**

[37] Stern xi.
[38] Stern iv.
[39] Stern xi.

Reducing Demand for Emissions-Intensive Goods and Services

Reducing demand for emissions-intensive goods and services is, in the broadest sense, a behavioral change. Successful mitigation ultimately requires that consumers and investors shift demand away from emissions-intensive products and services to those that are based on low-carbon technologies. An example of this would be a consumer choosing to sell his sport utility vehicle (SUV) that gets 15 miles to the gallon so that he can buy a hybrid vehicle that gets 40 miles to the gallon. Assuming the consumer maintains the same driving behavior, he will consume less fuel and release fewer emissions for each mile traveled. In this way changes in consumers' consumption patterns that move them away from emissions-intensive goods and services and towards goods and services that emphasize resource conservation contributes to lowering global greenhouse gas emissions.

Switching to Lower-carbon Technologies for Power, Heat and Transportation

According to the Stern Review, "Large-scale uptake of a range of clean power, heat and transport technology is required for radical emission cuts in the medium to long term. The power sector around the world will have to be at least 60%, and perhaps as much as 75% de-carbonized by 2050 to stabilize at or below 550ppm CO_2e."[40]

Considering that power generation is the primary source of global CO_2 emissions and that world electricity demand is projected to increase by 50% by 2030[41] a host of opportunity exists to reduce emissions through lower-carbon technologies in the power sector now and into the future. Opportunities for de-carbonizing the power sector include increasing the use of clean, renewable energy technology such as solar, wind or hydroelectric; increasing the use of nuclear energy; and increasing the use of clean coal technologies and the use of carbon capture and storage (CCS).

Efficient heating can be provided through combined heat and power (CHP) technology. As opposed to conventional thermal power plants where two-thirds of the primary energy used to generate electricity is lost in the form of heat, CHP plants capture the heat generated during electricity production and use it for district heating, for use in commercial buildings as heat or for use in industrial processes. Current CHP designs can boost overall conversion efficiency to over 80%, leading to cost savings and to significant carbon-emissions reductions.[42]

[40] Stern xiii.
[41] United States, Energy Information Administration, International Energy Outlook 2008: Highlights (Washington, 2008) 1.
[42] United Nations Environment Program (UNEP), Human Development Report 2007/2008; Chapter 3 Avoiding dangerous climate change: strategies for mitigation (2007)

Opportunities exist for changing the fuel-mix within the transport sector as well. Hybrid technology and vehicles that run on biofuels or compressed natural gas (CNG) all contribute to reducing greenhouse gas emissions.

Action on Non-energy Emissions, such as Avoiding Deforestation

Non-energy emissions such as those created by man-made refrigerants or those attributed to the agricultural sector or the process of deforestation make up one-third of total global greenhouse-gas emissions.[43] Deforestation by itself accounts for about one-fifth of global emissions.[44] Because forests store carbon (as much as 500 tCO_2 per hectare[45]) every inch of forest lost adds to greenhouse gas emissions. According to the United Nations Development Program (UNDP), between 1990 and 2005 shrinkage of the global forest stock is estimated to have added around 4 $GtCO_2$ to Earth's atmosphere each year. The UNDP also states that between 2000 and 2005, net forest loss world-wide averaged 73 thousand square kilometers a year; an area the size of a country like Chile.[46] Taking measures to avoid deforestation would make an important contribution to mitigating climate change.

Increased Energy Efficiency

The technical potential for energy efficiency improvements to reduce energy consumption and resulting emissions is substantial. Scenarios developed by the International Energy Agency (IEA) point to the potential for energy efficiency savings to cut global emissions by 16% in OECD[47] countries by 2030.

Increased energy efficiency can be applied across all market sectors that consume energy (Power, Industry, Buildings and Transport). For example, in the Power sector, available efficient technology for coal-fired power plants has the capacity to generate more power using less coal thereby creating fewer emissions. The most efficient coal plants today have attained efficiency levels of around 45% as compared to 33% for older technology.[48] In the end-use sectors of Industry, Buildings and Transport, energy efficiency improvements have the capacity to dramatically curtail consumption and emissions. A prime example of this is the energy savings achieved through the adoption of energy efficient lighting technology. It is estimated that today 20% of global electrical energy production is used for lighting.

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[43] Stern xiii
[44] UNEP, Human Development 158.
[45] A 'hectare' is unit of area equal to 10,000 square meters. One hectare is equal to 2.47 acres.
[46] UNEP, Human Development 158.
[47] OECD stands for the Organization for Economic Cooperation and Development. See *Appendix A* for a detailed explanation.
[48] UNEP, Human Development

Studies estimate that the implementation of Light Emitting Diode (LED) technology, currently available on the market, could save 30% of today's consumption for general lighting by 2015 and as much as 50% by 2025.[49] Other examples of currently available, energy-efficient technologies in the end-use sectors are profuse. Such examples include: the use of energy efficient appliances, the adoption of hybrid technology and improved fuel efficiency and emissions standards in vehicles, and the installation of insulation and the use of high thermal performance windows in buildings.

As full of opportunity for reducing greenhouse gas emissions as each of these mitigation approaches is, none of them is without its problems. Each approach faces a different set of barriers and adheres to a different time frame for implementation.

For example, the current energy mix in OECD countries is heavily dominated by fossil fuels. Changing this mix in favor of low-carbon energy would certainly lead to cuts in emissions but energy systems cannot be transformed overnight. Such transformations require large up-front investments and long-term planning horizons. In addition, renewable technologies are currently underexploited because they are not cost-competitive with the traditional use of fossil fuels. And nuclear energy, though a zero-carbon alternative, raises difficult questions for most communities in regards to safety. Though, CCS technology is believed to possess significant opportunity for the stringent mitigation of carbon emissions in coal-fired power generation, uncertainties remain with this technology and very few CCS plants actually exist. CCS technology is projected to come on-line very slowly with just 11 plants in operation by 2015.[50]

In regards to deforestation, the Stern Review claims that "a substantial body of evidence suggests that action to prevent further deforestation would be relatively cheap compared with other types of mitigation if the right policies and institutional structures were put in place."[51] This may be true but enforcing these policies and structures could be another story. Laws put in place to protect international forests are often not respected or enforced. The motivations surrounding deforestation are complex and the forces driving deforestation are difficult to control. In some cases poverty is the driver, with populations collecting wood for fuel or expanding into forests with subsistence agriculture. In most other cases deforestation is driven by commercial pressures. The international expansion of markets for products like soybeans and beef has created strong incentives for deforestation. Commercial logging, often times illegal, also puts forests under pressure. With croplands, pastures, plantations and logging expanding into forests around

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[49] European Union, European Commission, Action Plan for Energy Efficiency: Realizing the Potential (2006) 5.
[50] UNEP, Human Development 145.
[51] Stern xiii.

the globe, commercial pressures are unlikely to disperse any time soon. Tackling deforestation is a complicated task that will take many years to overhaul of incentives.

Though energy efficiency as a mitigation strategy is not without its obstacles, it offers the greatest potential of all strategies discussed as a means of reducing greenhouse gas emissions in the short-term. This potential stems from the fact that an abundance of energy-efficient technology currently exists and that this technology has already proven to deliver significant energy savings once implemented. These proven savings make increased energy efficiency the lowest-cost option for carbon mitigation. In addition, energy efficiency technologies are diverse and can be implemented across all energy-related market sectors. This wide variety and application of efficient technology creates additional opportunity for energy, emissions and cost savings.

Though energy-efficient technologies have been around and improving for decades, the possibilities for further savings from energy efficiency are far from tapped. This wealth of unfulfilled potential is the result of ingrained market barriers that have blocked the adoption of energy-efficient technology over the years. Such barriers include the lack of available information on the benefits of efficient technology or subsidies that artificially lower the cost of energy, making energy savings less financially appealing to consumers. Deep-rooted as these barriers are, many of them can be removed through the use of public policy. Public policies that work to enhance consumer awareness of efficiency measures or that prohibit or create strong disincentives for practices that drive down efficiency and drive up carbon emissions will significantly improve the adoption of efficient technologies worldwide.

Considering that global emissions need to peak in the next 10 to 20 years to stabilize atmospheric concentrations of CO_2e at 550ppm, immediate steps need to be taken to reduce greenhouse gas emissions. Energy efficiency is the only option that realistically offers this immediate response. Whereas the other mitigation approaches discussed will take decades to fully implement, energy-efficiency technology is something that can be put into practice without delay. It is our best short-term bet.

Chapter Three: Energy Efficiency

3.0 Why Energy Efficiency?

The promotion and implementation of energy efficiency measures in recent years has become an area of focus for governments world-wide. These measures are seen as playing a critical role in addressing global environmental issues.

On July 9, 2008, the International Energy Agency (IEA) released the results of its three year study on energy efficiency policies. This study was requested by the G8 Heads of State in their effort to address the challenges of climate change. In its report the IEA cites the following "compelling" reasons to focus on an energy efficiency strategy[52].

- It is the least cost strategy that can have an immediate impact
- Implementing energy efficiency will buy governments time while they configure their economies for a low-carbon future
- Energy efficiency policies have already proven to deliver significant energy savings[53]

Beyond these reasons, the IEA goes on to discuss the untapped, cost-effective potential for energy savings that existing energy efficiency technology possesses.[54]

The IEA is not alone in its opinion on the potential savings that a strong energy efficiency strategy would provide. Many organizations echo these same thoughts, describing energy efficiency as a low-cost option that can be immediately implemented using existing technologies with proven results. They also endorse the belief that the potential for energy savings is large and that this potential has yet to be exploited.

In addition to the energy savings and climate protection that energy efficiency investments provide, these investments offer additional social and economic opportunities as well. Some of the commonly referenced benefits of energy efficiency include:[55]

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[52] International Energy Agency (IEA), Energy Efficiency Policy Recommendations (Paris 2008).
[53] Study published in Energy Use in the New Millennium (IEA, 2007) cited an analysis of 14 major economies from 1990 to 2004 which showed a decrease in energy demand of 14% from projected levels due to energy efficiency improvements implemented over this period.
[54] IEA cites two studies: (1) Cool Appliances (IEA, 2003) finds current energy efficiency policy only exploits one third of energy savings potential from improving the efficiency of household appliances. (2) Lights Labor Lost (IEA, 2006) finds that global cost-effective lighting energy savings potential is 38%.

- **Improved Energy Security** – Decreased dependence on fossil fuels results from consuming less energy. In most developed countries like the US or the EU, a sizeable percentage of the fossil fuels used for energy production or transport are imported. This dependence on fuel imports poses economic risk that strong energy efficiency policy would help to mitigate.
- **Cost savings** – Increasing energy efficiency means large cost savings to a country's economy thereby rerouting money to other areas.
- **New Business Opportunities** – Improving energy efficiency creates new business opportunities for innovative businesses.
- **Employment Creation** – It is estimated that investments in energy efficiency will have a positive impact on employment and the creation of jobs both directly and indirectly.

Of all the reasons mentioned for using energy efficiency as a means of addressing global warming and climate change, possibly the most important is the speed with which energy efficiency improvements could be implemented. According to global warming experts we are on borrowed time and immediate action needs to be taken to reduce greenhouse gas emissions to avoid a potentially unmanageable climate situation. Because proven energy efficient technologies already exist, they are an expedient way to reduce growing greenhouse gas emissions over the short-term.

3.1 Defining Energy Efficiency

Though the practice of energy efficiency has been around for decades, there is still much confusion surrounding this term. Depending on who is using it, an engineer, a scientist or an economist, the definition and calculation may vary.

In the most basic sense energy efficiency is a reduction in the energy used to provide a given service (lighting, heating, etc.) or level of activity. In this way, people can enjoy a consistent level of service without compromise while utilizing less energy in the process. Energy efficiency should not be confused with 'energy conservation', which is adopting behavior that results in the use of less energy. Energy efficiency means doing more with less not doing without.

The calculation of energy efficiency is simply output divided by input, where energy is an input. Engineers calculate this ratio in physical terms, where output is the amount of mechanical work or energy

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[55] Corinna Klessmann et al., "Making Energy-Efficiency Happen: From Potential to Reality". EcoFys International (25 May 2007) 17.

(measured in watts or joules) resulting from the process and input is the quantity of mechanical work or energy used to run the process.[56] Economists calculate this ratio in monetary terms, where output is the economic activity (usually measured as gross domestic product (GDP)) which results from a given level of physical input.

To engineers, energy efficiency and the resulting reductions in energy consumption are usually associated only with technological improvements such as using energy efficient fluorescent lights instead of less energy efficient incandescent lights to attain the same level of illumination. To economists, energy efficiency has a much broader definition. In approaching energy efficiency, economists consider all changes to an economy that result in decreasing the amount of energy used to produce one unit of economic activity (e.g. GDP). They include not only technological changes in their calculations but behavioral and economic changes as well.[57] For example, a structural change in an economy like a shift from heavy industries that consume a lot of energy to a services-based economy that consumes far less energy would decrease the input side of an economist's energy efficiency calculation. This, in turn, would decrease the ratio of energy used to produce one unit of GDP.

Another bit of terminology worth touching on is the concept or calculation of the 'potential' efficiency gains realized from implementing energy efficiency strategies. Many different types of 'potential' exist within the energy efficiency discussion. The main 'potentials' for efficiency gains, in order of greatest to least, have been identified as:

- Theoretical potential (up to the maximum permitted by the laws of physics)
- Technical potential (offered by current available technologies)
- Economic potential based on social value
- Economic potential based on private internal value
- Actual uptake not blocked by market failures or barriers
- Spontaneous potential (what happens if no effort is made to accelerate efficiency gains)

These terms and their resulting quantities are often not clearly distinguished and can make comprehending energy efficiency literature a challenge.

[56] http://en.wikipedia.org/wiki/Energy_efficiency
[57] "Energy Efficiency Policies Around the World: Review and Evaluation," World Energy Council (2008) 9.

Energy efficiency definitions and descriptions of the various types of efficiency potential can be looked at from multiple perspectives. These terms do not always have consistent meanings and their sometimes subtle differences can create confusion when digesting the information provided.

Though inconsistencies do exist, the majority of reports released (when estimating achievable savings) on energy efficiency mainly focus on the technical efficiency currently available for implementation as well as the technical potential of this type of efficiency.

3.2 Energy Conversion Chain & End-Use Efficiency

Energy efficiency happens along a chain of energy conversions that takes primary energy[58] in the form of raw fuel like oil, coal or gas through a process of conversion and transmission and delivers it to the end-user to power appliances or equipment that provide energy-related services such as heat, light, music, transportation, etc.

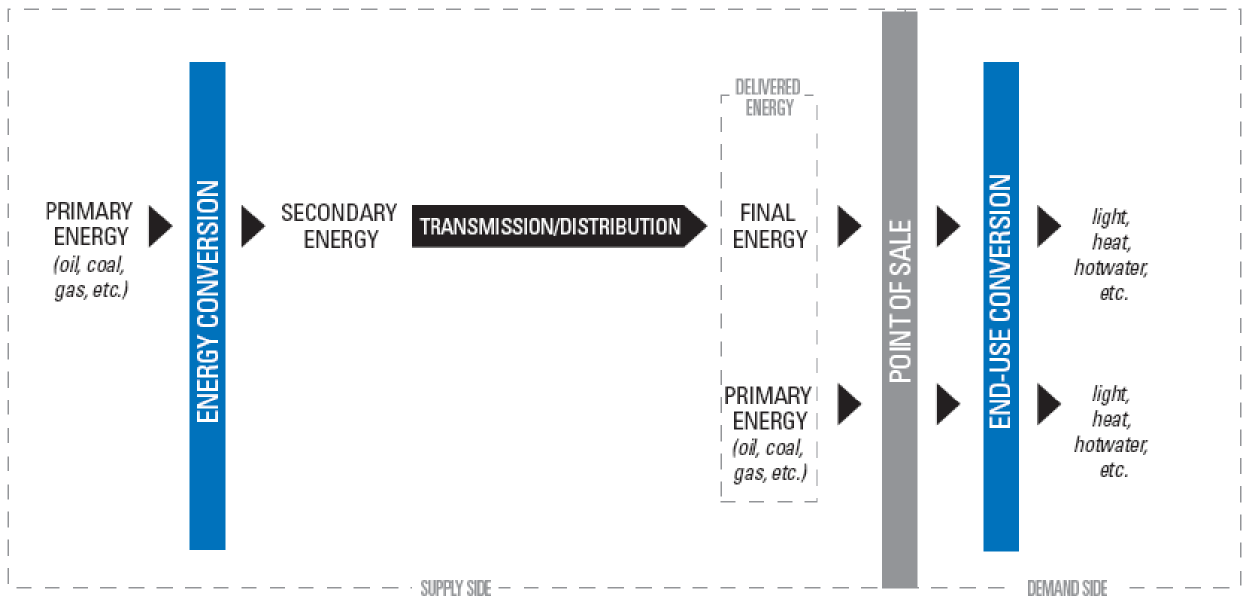
Most of this efficiency is technical, relying on the efficiency of the system or technologies in place. For example the technology that converts primary energy to secondary energy is not 100% efficient and consumes and loses as much as 70% of its energy in the process of conversion. The energy loss reflects the conversion efficiency of this process. As this secondary energy moves from the point of conversion to the point of end-use, up to another 9% of energy is lost as it is transmitted or distributed. The energy loss reflects the distribution efficiency of this process. The secondary energy created at the point of conversion is greater than the secondary energy delivered to the end-user due to these losses. This delivered secondary energy has also been referred to as 'final energy'. The term 'delivered energy' refers to more than just delivered electricity. It refers to all energy consumed at the point of sale or the point it enters a home or a commercial establishment and can include both final energy and primary energy. For example, in residential buildings a consumer could heat her home using primary energy such as natural gas or oil through a furnace or a boiler in addition to consuming secondary energy in the form of electricity that powers other equipment and appliances. Both secondary energy and primary energy are used, the combination of which is known as 'delivered energy'.

Just beyond the point of delivered energy, another conversion occurs. This end-use conversion happens though equipment or appliances that use the delivered energy to power heating systems, hot water heaters, computers, freezers, etc. As the delivered energy is converted into desired energy services such as heat,

[58] Primary energy refers to the supply of energy before it has been converted or transformed for use. It includes raw materials like coal, crude oil, natural gas, etc.

hot water, internet searches or ice, more energy is lost in the conversion. The amount of loss depends on the equipment being used and reflects the end-use conversion efficiency of this process. *Figure 7* displays this conversion and transmission process in its entirety.

Figure 7: The Energy Conversion Chain[59]



The whole chain can be split into two sides: the supply side and the demand side. The supply side refers to the processes relating to the generation, transmission and distribution of energy and is controlled by energy suppliers. Basically, the supply side relates to everything that happens along the chain up to the point of sale of the delivered energy. The demand side is the part of the energy chain that is associated with final energy users. This part of the system is normally not controlled by energy suppliers. The demand side starts beyond the electric meter, gas meter or oil fill and consists of energy consuming appliances, equipment and other related installations.

Energy demand is determined by the energy users' need for energy-related services such as light or a specific indoor climate. Energy produced on the supply side is a function of this energy demand.

59 Graphic produced by Deanna DiBona.

The product of the three efficiencies described (conversion efficiency, distribution efficiency and end-use efficiency) represents the technical efficiency of energy use. Of these, end-use efficiency is believed to hold the greatest potential gains for energy savings.

3.3 Market Segments

Energy efficiency improvements can be applied in many ways to various market segments. Though studies may break the segments of the market apart in a variety of ways, referring to them as 'priority areas' or 'market sectors', the most common groups identified where energy efficiency investments would make the largest impact include:

- Energy Supply or Utilities
- Transport
- Industry
- Buildings[60]

Transport, Industry and Buildings are referred to as end-use market sectors.

Within each sector the main energy-efficiency technologies currently available have been identified for investment. They are outlined in *Figure 8*.

[60]The 'Buildings' category includes residential, commercial and other structures such as schools, government structures, hospitals, etc. In some reports this sector is broken apart into the 'Residential' and 'Services' sectors. Certain reports refer to the 'Services' sector as the 'Tertiary' sector. Additionally, certain reports break the categories of 'Appliances' and 'Lighting' our separately from the larger 'Buildings' category though more commonly these categories are included within the larger 'Buildings' category.

Figure 8: Commercially Available Energy-Efficiency Technologies

Sector	Technologies currently commercially available
Energy Supply	• Improve energy-efficiency of power generation by retrofit of existing power plants • Replacement of inefficient power plants with new efficient power plants • Increased use of Combined Heat and Power (CHP) generation
Transport	• Improve energy-efficiency of cars and trucks through increased use of hybrid vehicles and fuel cell vehicles
Industry	• More efficient end-use electrical equipment • Heat and power recovery
Buildings	• Use of energy-efficient lighting and day-lighting • Use of more efficient electrical appliances and heating and cooling devices • Improved insulation • Passive and active solar design for heating and cooling

3.4 Energy Efficiency and Greenhouse Gas Emissions

Though the contribution of many technologies is needed to stabilize the climate, according to the IPCC, "Energy efficiency plays a key role across many scenarios for most regions and time scales."[61] As noted in *Figure 9*, energy efficiency measures (available technologies) coupled with energy conservation measures (changing behavior) are projected to make the greatest contribution to emissions reductions until 2030. The year 2030 is the end date of the phrase "short-term" as it relates to climate change.

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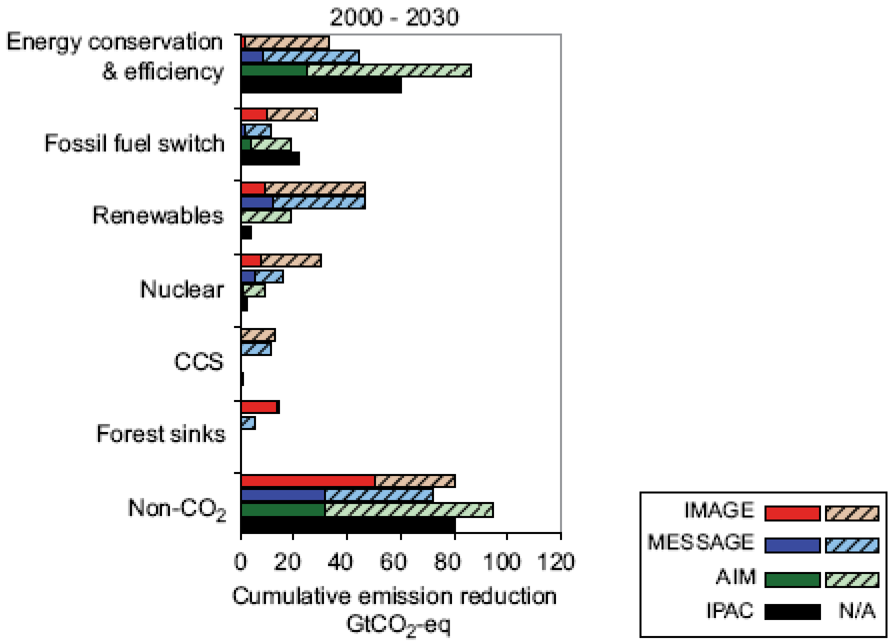
[61] IPCC, Climate Change 2007: Mitigation of Climate Change; Summary for Policymakers (2007) 25.

Figure 9: Cumulative Emissions Reductions by Mitigation Approach[62,63]



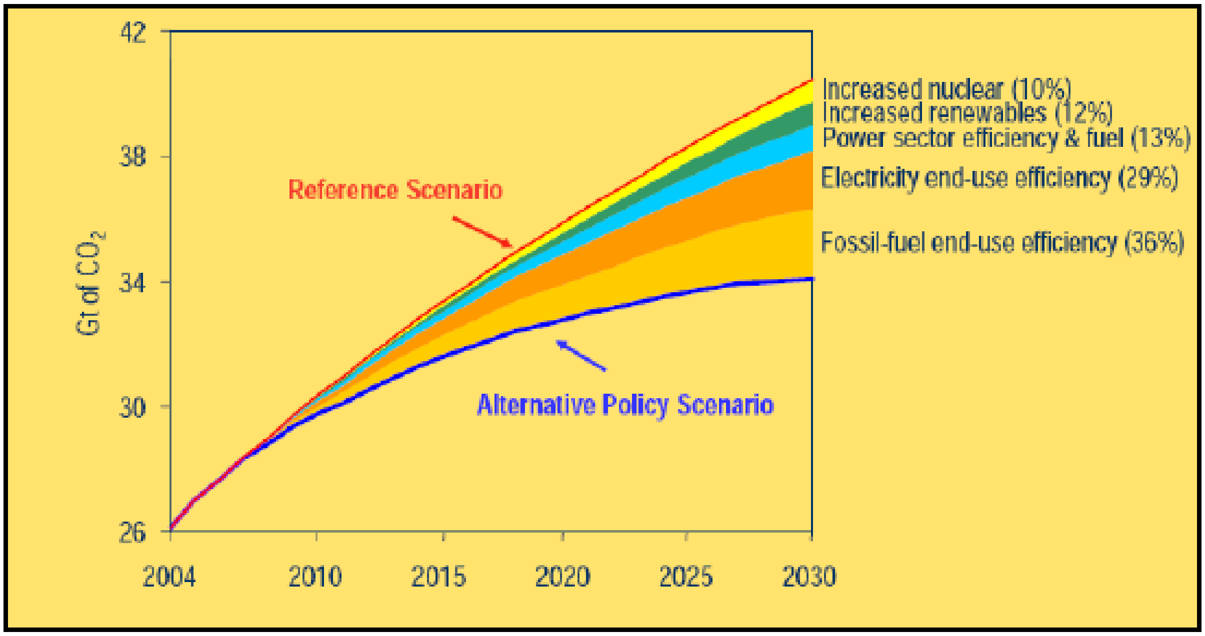
The graph reflects cumulative emissions reductions for alternate mitigation measures for the short-term period 2000 to 2030. It illustrates scenarios from four models, each denoted by a different colored bar. Solid bars denote reductions for a target of 650 ppm CO_2e by 2030 and striped bars denote the additional reductions necessary for a target of 490-540 ppm CO_2e by 2030. Across the portfolio of options shown, energy efficiency and energy conservation measures are modeled to provide the greatest emissions reductions of the energy-related emissions categories.

Looking specifically at energy production and the proposed ways of reducing primary energy demand and emissions, it's apparent that efficiency measures play a major role. *Figure 10*, taken from World Energy Outlook (WEO) 2006, an annual report released by the International Energy Agency (IEA), displays two carbon emissions scenarios projected to the year 2030. The *Reference Scenario* assumes a business as usual course of action where world governments stick to the energy related policies currently in place. The *Alternative Policy Scenario* assumes a course of action where world governments implement the policies and measures they are currently considering in the fields of energy efficiency, renewable energy

62 IPCC, Summary 26.
63 'CCS' stands for Carbon Capture and Storage. 'Non-CO_2' reflects reductions in certain man-made chemicals and deforestation.

and nuclear power. As illustrated by the *Alternative Policy Scenario*, the estimated impact of these policies and measures results in a savings of 6.3 $GtCO_2$ below the *Reference Scenario* by 2030.[64] Energy efficiency improvements account for 78% of this savings. Broken down, this reduction amounts to a savings of 13% from supply-side power sector efficiency, 29% from electricity end-use or demand-side efficiency and 36% from fossil fuel end-use or demand-side efficiency.[65]

Figure 10: Global Savings in CO_2 Emissions, World Energy Outlook 2006[66]



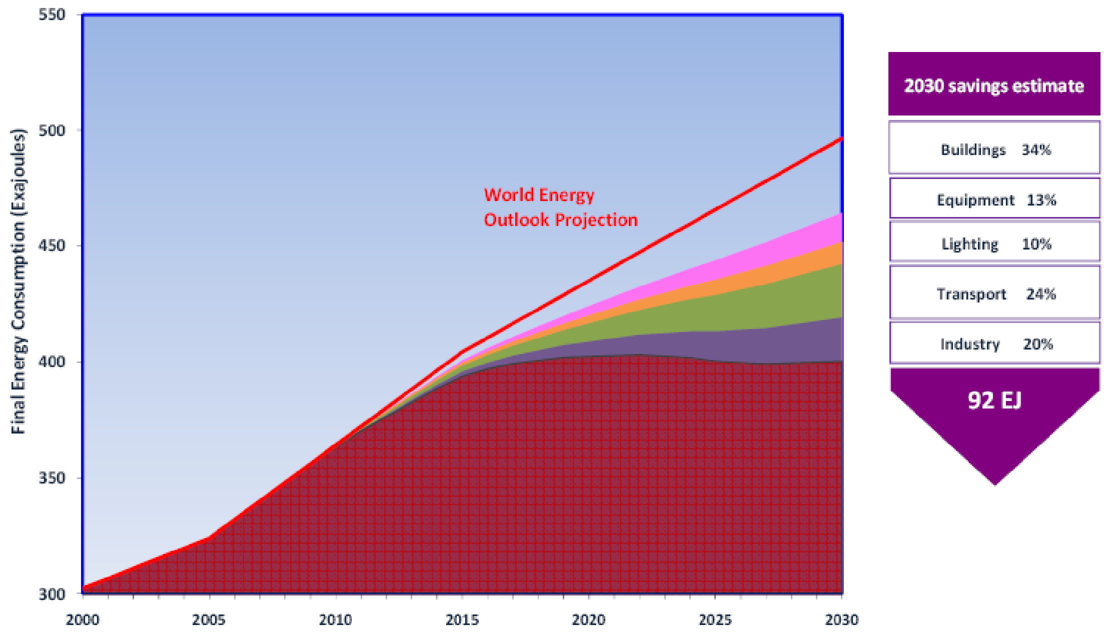
Focusing specifically on end-use or demand-side energy efficiency improvements across the market sectors of Transport, Industry and Buildings, the energy and carbon savings are substantial as seen in *Figure 11*.

In its most recent report titled 'Energy Efficiency Policy Recommendations', the IEA recommends specific energy efficiency policy measures across 25 fields of action and 7 priority areas. Of these, a significant number apply to the end-use areas of Buildings, Equipment, Lighting, Transport and Industry. The IEA chooses to create separate end-use categories for Equipment and Lighting though these two categories are commonly included within the Buildings Sector.

[64] This emissions savings reflects only CO_2 from the burning of fossil fuels.
[65] International Energy Agency (IEA), World Energy Outlook (WEO) 2006 (Paris 2006) 188.
[66] IEA, WEO 2006 192.

The IEA creates a future energy projection that would result if all proposed policies were to be implemented and compares it to the WEO 2007 *Reference Scenario.* In this way the IEA identifies potential energy savings by end-use area. These savings are illustrated in *Figure 11*.

Figure 11: Impact of Energy Efficiency Policy Recommendations, IEA 2006-2008[67]



As shown in the graph, the Buildings Sector accounts for the largest end-use savings in energy consumption. Though the IEA shows this number to be 34%, if the end-use categories of Equipment and Lighting were to be included, as is commonly the case, the true reduction designated to Buildings would be 57%. The IEA estimates that the proposed 25 fields of action, if implemented globally without delay, could save approximately 8.2 $GtCO_2e$ per year by 2030.

Energy efficiency investment will provide the greatest energy and emissions savings in the short-term. However, whether looking at the potential for emissions savings within energy efficiency strategies or across all proposed mitigation strategies, one message is consistently repeated: There's no single answer. Proposed approaches to reduce energy usage and emissions at all levels must be implemented jointly to achieve the kinds of savings needed to maximize emissions reductions over the long-term.

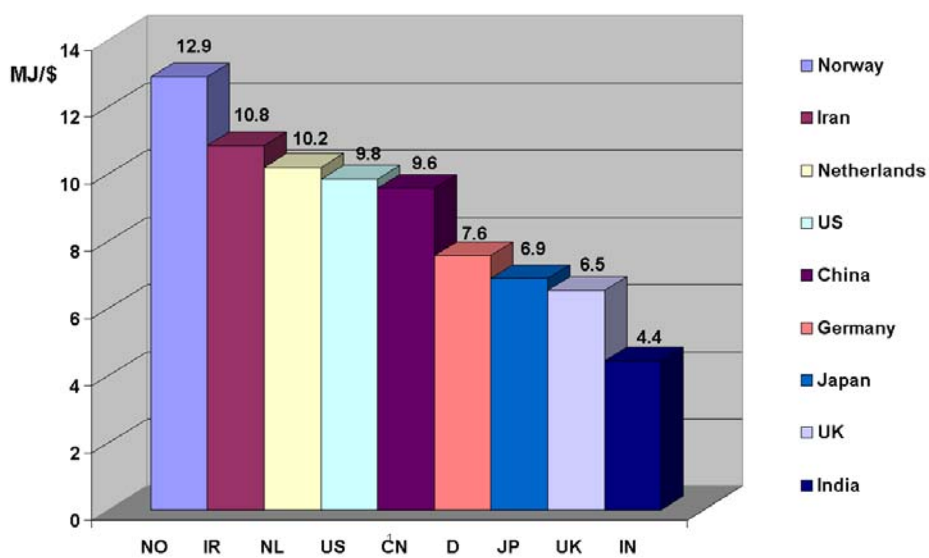
[67] IEA, Policy Recommendations 7.

3.5 Energy Intensity

Energy intensity is an economic ratio used as the primary indicator to assess changes in the energy efficiency of a country's economy. It is defined as the number of units of energy expended for each unit of GDP. Energy intensity is simply the reverse of the energy efficiency ratio. Essentially, energy intensity measures the amount of energy used to produce one dollar of GDP. High energy intensities indicate a high cost of converting energy into GDP whereas low energy intensities indicate the opposite.[68] Energy intensity can be used to measure either the aggregate energy efficiency of a nation's economy or can be applied to specific market sectors (i.e. industry, transport, buildings, etc.).

Many factors can influence the energy intensity of a nation's economy. Things like climate, fuel-mix, transportation preferences, behavior, the nature of economic activity and standards of living all impact the overall energy intensity of a country. Trends in energy intensity are influenced by the shifts in these factors as new technologies are adopted and economies mature and change.

Figure 12: Energy Intensity of Different Economies[69]



For example, *Figure 12* displays the energy intensities of nine countries. This graph shows the amount of energy it takes to produce one US dollar of GDP where GDP in this case is based on 2004 purchasing power parity (PPP) and 2000 US dollars adjusted for inflation. As can be seen from the chart, Norway

[68] http://en.wikipedia.org/wiki/Energy_intensity
[69] This chart was created by Frank Van Mierlo from 2004 data supplied by the IEA in their 2006 report, url: http://www.eia.doe.gov/pub/international/iealf/tablee1p.xls

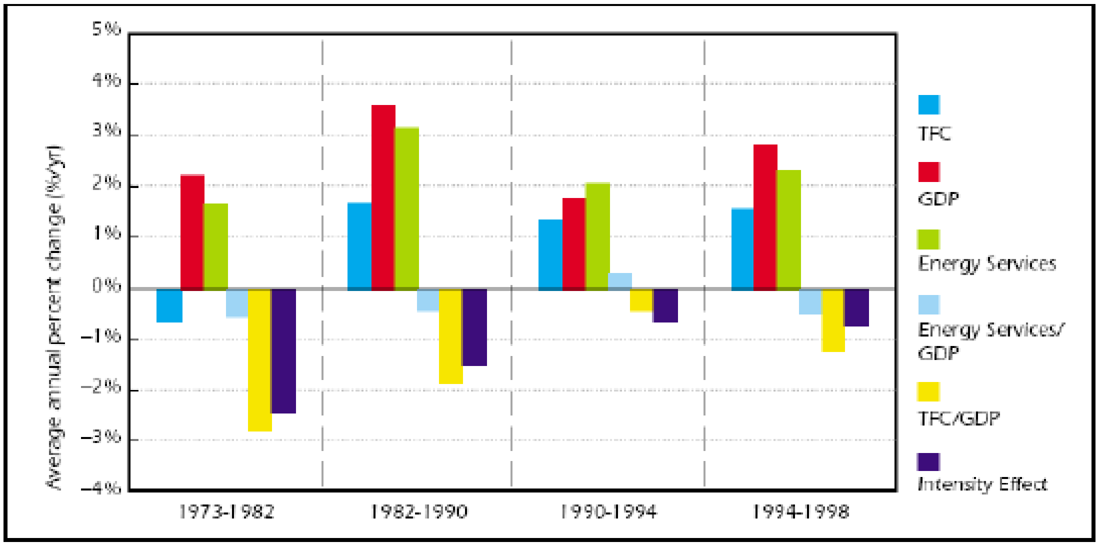
has the highest energy intensity making it the least energy efficient of all countries shown whereas India has the lowest energy intensity making it the most energy efficient.

3.6 Historical Context of Energy Efficiency

Energy efficiency is not a new notion and has been a topic of discussion and debate between engineers, physical scientists and economists for decades.

Since the oil crisis of the early1970s energy efficiency in the global economy has increased due to government policies, supply uncertainties, energy price increases and technological improvements. *Figure 13* provides an overview of changes in TFC (Total Final energy Consumption)[70], GDP and energy service demand and intensities across four time frames for the period 1973 to 1998. This graph illustrates that significant decreases in energy intensity were achieved through the 1980s but since 1990 energy savings rates have decreased far less. This is partly the result of a waning focus on energy efficiency policies.

Figure 13: Total Final Energy Consumption (TFC), GDP, Energy Services and Intensities 1973 – 1998[71]



Despite the positive strides in energy intensity made in the 1970s and 1980s, during that time the full potential of available energy efficient technology was still far from realized.

[70] Total Final energy Consumption (TFC) covers energy supplied to the final consumer's door for all energy uses. It is calculated as the sum of final energy consumption from all sectors (industry, transport, households, services and agriculture). TFC is measured in thousand tonnes of oil equivalent (ktoe).
[71] Ecofys International 2.

According to Amory Lovins, CEO of the Rocky Mountain Institute, by the early 1980s detailed engineering studies had exhaustively documented the scope for improving energy efficiency. These studies, published for industrialized as well as certain developing countries, compellingly showed that the majority of energy use was inefficient. The studies also claimed that the same or better services could be provided using significantly less energy by fully installing, wherever possible and practical, the most energy efficient technologies then available. Lovins explains that such studies continued and their findings remained largely consistent across borders. For example, European studies found that technology in the1980s could save three-fourths of the electricity used in Danish buildings, or half of all Swedish electricity consumed, or four-fifths of the electricity consumption in German homes. [72]

Lovins references another, more recent study, conducted by the American Council for an Energy Efficient Economy (ACEEE). This study estimates that just moderate adoption of the top five conventional US opportunities for energy efficiency (industrial improvements, light-vehicle standards, cogeneration, better building codes, and improved central air conditioning standards) could save 530 million tonnes of oil equivalents (Mtoe) per year in the US. Considering that the US' primary energy consumption in 2007 was 2,361.4 Mtoe, adopting such energy efficiency improvements would result in a decrease of 22.4% in the US' primary energy demand.[73]

Though reports such as these continue to surface, energy efficiency remains an untapped resource. In its recent report titled, "Worldwide Trends in Energy Use and Efficiency", the IEA states that despite efficiency gains over the past few decades, there still remains a large potential for energy savings across all market sectors resulting from energy efficiency investments. For example, in the Industry Sector alone the IEA estimates that the application of proven technologies and best practices on a global scale could save between 18% and 26% of current primary energy use in this sector. This savings represents between 1.9 and 3.2 $GtCO_2$ of associated carbon emission per year.[74]

Projected savings such as these are rampant in the historical and current literature that's publicly available on energy efficiency. So the question remains, if so many opportunities for energy savings exist through efficiency improvements why haven't they been exploited?

[72] Amory B. Lovins, 'Energy End-Use Efficiency' Rocky Mountain Institute (September 19, 2005) 8.
[73] British Petroleum, BP Statistical Review of World Energy (June 2008) 40.
[74]International Energy Agency (IEA), Worldwide trends in energy use and efficiency (Paris 2008) 10.

3.7 Barriers to the Implementation of Energy-Efficiency Investments

The existence of such unrealized opportunities in energy efficiency implies that there are numerous market barriers or failures.

Market barriers, or failures, which refer to obstacles that contribute to the slow adoption of energy efficient technologies, are diverse and can be classified in a variety of ways. These obstacles block economically optimal investments in energy efficient technologies through a series of distortions and market failures. Commonly referenced market barriers include: Weak Price Signals; Information Barriers; Economic Barriers; Institutional Barriers or Organizational Failures; Lack of Interest in Energy Efficiency Improvement and Split Incentives.

Weak Price Signals

Possibly the biggest market barrier in place until recently has been the artificially low price of energy leading to a weak price signal.[75] Since most energy efficiency investments are ultimately an economic decision, weaker price signals (occurring in some economies more than others) have interfered with the implementation of these investments.

Cost related decisions concerning energy efficiency, at the individual or firm level, are essentially based on a trade-off between the immediate cost of the energy efficiency investment and the expected future decrease in energy costs resulting from the investment. Therefore, the higher the energy price, observed or expected, the greater the projected savings and the more attractive the energy efficiency investment becomes. Weak price signals distort this relationship and remove incentives for energy efficiency investments. The World Energy Council (WEC) in a recently released report explains that, "In market economies, where most energy prices to final consumers are deregulated, prices should normally reflect fairly accurately the supply costs. However, for several reasons, they often reflect only a part of the overall costs of fuels and electricity. They include none, or just a few, environmental externalities and long run marginal development costs. As a result, decisions made by final consumers when purchasing equipment or making an energy efficient investment (e.g. retrofitting of dwelling) often do not reflect the drive towards global economic optimization, creating a gap between the actual achievements in energy

[75] Per Wikipedia, a 'price signal' is a message sent to consumers and producers in the form of a price charged for a commodity. This price is seen as indicating a signal for producers to either increase or decrease supply and for consumers to either increase or reduce demand. A low price charged for a commodity would signal consumers to consume more of the product and producers to supply more of it. (http://en.wikipedia.org)

efficiency and what could be achieved through an accurate price system accounting for all costs involved."[76]

Information Barriers

Consumers are often poorly informed about the types and costs of energy efficiency improvements applicable to them. This lack of information, or in many cases misinformation, creates confusion and misunderstanding on the consumer's end. This uncertainty underlies their need for extremely high returns for buying efficiency or discourages their investment altogether. Another information barrier is referred to as the "hassle factor", which is when people are just too busy to bother to educate themselves on their energy use. In this way, people avoid making energy efficient "micro-decisions" in their day to day lives because they are simply not informed.

Economic Barriers

Energy efficiency options don't necessarily satisfy the profitability criteria set by firms. This may be due to an emphasis on simple payback to assess the potential energy savings as opposed to using a discounted cash-flow analysis that calculates the value of an energy efficiency investment over its lifetime. This slant leads to absurdly high hurdle rates and extremely short payback periods. This approach is especially true for home owners who generally demand a high return on investment of around 30% and a payback period of two to three years.[77] Another economic barrier can be lack of capital for investment or the fact that old equipment is not yet depreciated. Or financing for energy efficiency improvements may be difficult to secure.

Institutional Barriers or Organizational Failures

This generally falls under the category "old habits die hard" where the pressure and pace of day-to-day business rewards status quo over innovation. Because of this mentality few firms have structures for carrying out energy efficiency investments or measuring how their buildings and processes actually work. The organization of a company can create cultures where departments can't or don't cooperate and rewards for cutting energy costs don't exist.

Lack of Interest in Energy Efficiency Improvement

Similar to Institutional Barriers is the lack of interest in making energy efficiency improvements. In many instances energy expenditure is such a small share of the total operating costs of firms or

[76] World Energy Council 9.
[77] "The elusive negawatt," The Economist (8 May 2008). Retrieved from http://www.economist.com/displaystory.cfm?story_id=11326549

households that energy efficiency investments are paid little attention. Though savings do exist, they may be too small to properly create incentives for firms or households to implement the projects necessary to capture them.

Split Incentives

This barrier is representative of a group of barriers that relate to the fact that the one carrying out the energy efficiency investment (e.g. the owner of an office building) may not be the one who reaps the financial operating benefits of that investment (e.g. the user of the office building who pays the energy bill). Though most often thought of as a landlord-tenant issue, this issue is ubiquitous and occurs in a multitude of industries. Situations such as these limit energy consumers' choices by substituting intermediaries who don't bear the cost of their poor decisions.

3.8 Energy-Efficiency Policy Measures

The multitude of barriers currently hindering the implementation of energy-efficient technologies highlights the magnitude of the market failures in place and the need for strong action on the part of policy makers. In order to realize the full potential that energy-efficient technologies offer in terms of energy and emissions savings, strong measures must be taken to break down market barriers. Innovative and effective energy-efficiency policy is needed.

Energy-efficiency policy at the broadest level includes all public interventions, referred to as policies or measures, which are aimed at improving the energy efficiency of a region. Energy-efficiency improvement can be accomplished in many ways, some of which include: the adequate pricing of energy, regulations and economic or fiscal incentives.

The adequate pricing of energy is generally accomplished through taxation. Governments use this method to control weak price signals at the consumer level. By inflating artificially low market prices, taxation can be used to create a clear price signal that influences the energy-using behavior and purchasing decisions of consumers.

Though an important component, clear price signals alone are not enough to create a heightened awareness of energy use. Additional energy-efficiency policies and measures are necessary to complement the role of prices and to help remove the usual barriers to energy efficiency. The main objective of these "non-price" measures is to create the necessary conditions to speed up the development and deployment of energy-efficient technologies, through: Improved Information Sharing with Final

Consumers; Risk Sharing with Producers and Distributors of Energy Efficient Equipment; Supporting R&D and the Dissemination of Expertise in the Field of Energy Efficiency; Deployment of Specific Financing Mechanisms and Regulating the Efficiency of Products and the Continuous Monitoring of Energy Efficiency.[78]

Improved Information Sharing with Final Consumers

This approach involves increasing final consumers' awareness about the wide range of benefits that energy efficiency offers them. By doing this the overall costs of all energy-efficient options become transparent, enabling consumers to make better informed purchasing decisions.

Risk Sharing with Producers and Distributors of Energy-Efficient Equipment

Risk sharing here can take several forms: loans, subsidies, tax credits, etc. The main objective of this measure is to overcome the commercial barriers that the developers of efficient technologies encounter.

Supporting R&D and the Dissemination of Expertise in the Field of Energy Efficiency

This approach involves using public funds to support R&D and the dissemination of energy-efficient technologies. Its aim is to speed up the market penetration of such technologies as well as decrease their costs once on the market.

Deployment of Specific Financing Mechanisms

Making financing available for energy-efficiency projects at the consumer level removes the financial constraints that create market imbalances. This measure is meant to steer people towards cost-effective energy-efficient solutions that have higher investment costs but lower operating costs and away from less efficient technologies that have lower investment costs but higher operating costs. On the commercial end, such financing measures help suppliers to implement the production and/or the distribution of energy-efficient products and/or services.

Regulating the Efficiency of Products and the Continuous Monitoring of Energy Efficiency

Such regulations aim to remove the least efficient products (appliances, equipment, buildings, etc.) from the market and to introduce mandatory actions (maintenance, reporting, auditing) that promote improved energy efficiency.

[78] World Energy Council 9.

Taken together these measures work to create a market where energy-efficient technology is not only plentiful, but actually sought by consumers.

Chapter Four: Buildings

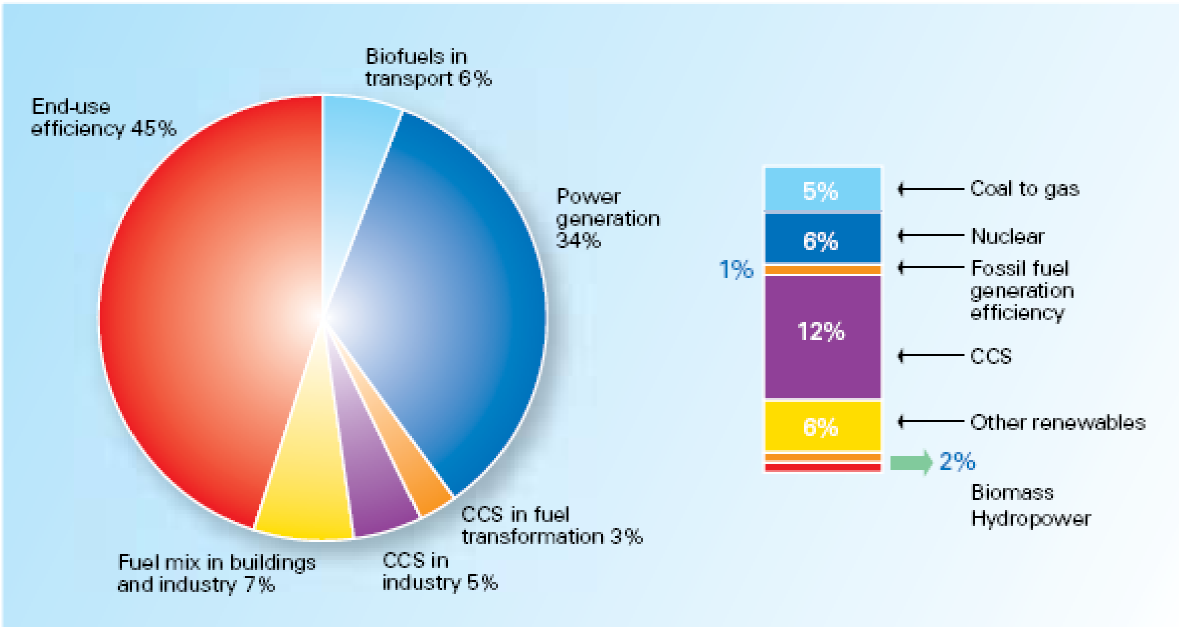
4.0 End-Use Efficiency and the Buildings Sector

The increasing focus on energy efficiency as a means of combating global warming has brought a deeper understanding of the most effective ways to implement energy efficiency across markets. This deeper understanding of implementing and achieving energy efficiency has led to the discovery that some market segments and the energy-efficient technologies they utilize will provide greater emissions savings than others.

The energy-related segments of the market can be broken down into two distinct sides: the supply side, which includes the Energy Utility Sector, and the demand side, which includes the Industry, Transport, and Buildings Sectors. Taken together, the demand-side sectors are known as end-use markets and the energy-efficient technologies applied in these markets create end-use efficiency.

End-use efficiency is believed to offer the greatest near-term potential for energy efficiency gains and carbon mitigation. Potential exists for reducing energy-related emissions on the supply side through the adoption of low-carbon technologies such as renewable energy. However, the potential for carbon mitigation that end-use efficiency offers leads all other options. Two added benefits of end-use efficiency are (1) that efficient end-use technologies are readily available, and (2) these technologies can be implemented immediately. In fact, technologies such as LED lighting, high-efficiency refrigerators and other appliances and high performance windows are already in use. *Figure 14* illustrates that end-use efficiency accounts for 45% of potential reductions in CO_2 emissions.

Figure 14: Potential Reductions in CO_2 by Technology Area[79]



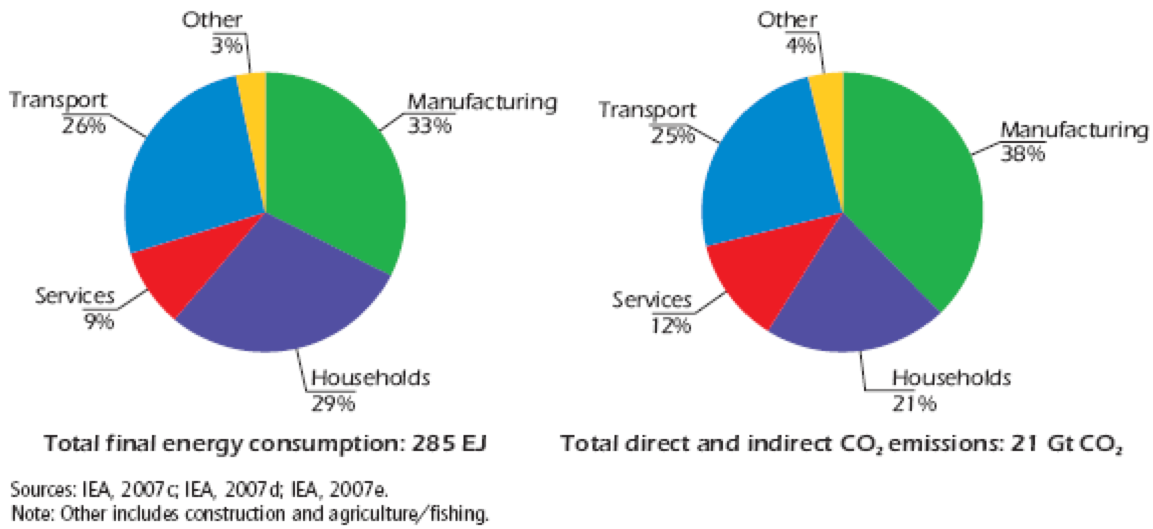
Of the end-use sectors, the Buildings Sector offers the greatest potential for greenhouse gas mitigation. The Buildings Sector includes residential buildings, commercial buildings and other structures such as public buildings, hospitals, and schools. It also includes the appliances and equipment that are housed and installed within buildings. In a recent report, the IEA recommended specific energy-efficiency policy measures spread across the three end-use sectors. This portfolio of options has the potential to reduce carbon emissions by 8.2 $GtCO_2e$ annually over current levels by 2030. The Buildings Sector alone accounts for 57% of this decrease, representing potential emissions reductions of roughly 4.7 $GtCO_2e$ annually by 2030.[80] The potential for mitigation that this sector offers is significant.

4.1 Energy Consumption and Carbon Emissions from the Buildings Sector

The Buildings Sector is the largest consumer of energy of all end-use sectors as illustrated below in *Figure 15*. According to the IEA, the Buildings Sector, which is represented in *Figure 15* as the combination of 'Households' and 'Services', accounts for roughly 40% of primary fuel used in most countries. This primary energy consumption accounts for 33% of CO_2 emissions worldwide.

[79] King Sturge, European Property Sustainability Matters (London 2007) 25.
[80]See Figure 11.

Figure 15: Global Final Energy Consumption and CO_2 Emissions by Sector, 2005[81]



The European Union is a perfect example of this level of consumption, where "almost half of its energy is used by its more than 160 million buildings." Through the implementation of practical energy-efficiency measures in new and existing buildings, it is estimated that 450 million tCO_2e could be saved annually. This savings alone is equal to roughly one-eighth of Europe's current carbon dioxide emissions.[82]

Because the Buildings Sector is such a large consumer of energy and emitter of greenhouse gases, there are ample opportunities here for mitigation.

4.2 Buildings: The Best Fit for Climate Change Policy

One of the key aspects of the Kyoto Protocol is that initial CO_2 reduction targets have been set over a relatively short compliance period (2008-2012). In light of this, two factors have emerged as critical in the development of appropriate climate change policy:

1. The speed at which any policy is to have an effect, and
2. The cost of the action necessary to implement the policy.

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[81] IEA, Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis (Paris 2008) 17.

[82] Andrew Warren, "Energy End-Use Efficiency," Metering International Issue 1 (2005). Retrieved from http://www.euroace.org/articles/A_050331.pdf

Accordingly, in order to maximize these two measures, policy options need to be prioritized with particular emphasis on those options which are already available and proven, have relatively low investment costs, provide good cost effectiveness over their lifetime and can be widely applied.

Potential policy options that have received attention as a means of reducing energy-related CO_2 emissions and meeting Kyoto targets are:

- Renewable Energy
- Combined Heat and Power (CHP)
- Energy Efficiency in Transportation
- Energy Efficiency in Power Generation and Fuel Switching
- Energy Efficiency in Industry
- Energy Efficiency in Buildings (industrial, commercial, public sector and residential)[83]

In order to evaluate these options a qualitative analysis of each was conducted by the European Union (EU) in 1999. This analysis assessed the potential impact of each option in light of the criteria mentioned above. The results of this study are summarized in *Figure 16*.

[83] Please see pages 21-26.

Figure 16: Qualitative Assessment of the CO2 Savings Options within the EU[84]

Category	Sub-Category	Available /Proven	Low Investment	Good Cost – Effectiveness	Potential Impact	
					Short	Long
Renewables	Wind	✔ ✔	✔ ✔	✔ ✔	✔	✔ ✔ ✔
	Hydro	✔ ✔ ✔	✔	✔ ✔ *	✔	✔ ✔
	Solar	✔	✔ ✔	✔	✔	✔
	Nuclear	✔ ✔	✔	✔ ✔ *	✔ ✔	✔
	Biomass	✔	✔ ✔	✔ ✔	✔	✔ ✔ ✔
Transport	Fuel Efficiency	✔ ✔	✔ ✔	✔ ✔ ✔	✔ ✔	✔ ✔
	Less Usage	✔	✔ ✔ ✔	✔ ✔ ✔	✔	✔ ✔
	Alt. Fuels	✔	✔ ✔ ✔	✔ ✔	✔	✔ ✔
	Intermodal	✔	✔	✔ ✔ *	✔	✔ ✔
Fuel Switching & Generating Efficiency	Gas	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔	✔
	Other	✔ ✔	✔ ✔	✔ ✔	✔ ✔	✔ ✔
CHP	Industrial	✔ ✔	✔ ✔	✔ ✔ *	✔ ✔	✔ ✔
	Commercial	✔ ✔	✔ ✔	✔ ✔ *	✔ ✔	✔ ✔
	District Heat	✔ ✔	✔ ✔	✔ ✔ *	✔ ✔	✔ ✔
Industrial Efficiency	Process	✔ ✔	✔ ✔	✔ ✔ *	✔ ✔	✔ ✔ ✔
	Ancillary	✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔	✔
Building Efficiency	Industrial	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔
	Commercial	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔
	Public Sector	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔ ✔	✔ ✔
	Domestic	✔ ✔ ✔	✔ ✔ ✔	✔ ✔	✔ ✔ ✔	✔ ✔

* Cost-effectiveness depends on treatment of depreciation.

✔ ✔ ✔ = Strong ✔ ✔ = Moderate ✔ = Weak

The results of this study clearly show that Building Efficiency in industrial, commercial, public sector and domestic areas scores the highest across all categories. Not only are the technologies that promote building efficiency available and proven, they represent a low-cost investment, thereby demonstrating a high level of cost-effectiveness and they provide the strongest potential for emissions savings in the short-term. This study illustrates that Building Efficiency has the best chance of meeting the priorities of policy makers in regards to initial CO_2 reduction targets.

4.3 Projected Carbon Emission Mitigation in Buildings

The global potential for carbon emissions reductions through energy-efficiency improvements in the Buildings Sector is sizeable. Projections of these reductions can be found in the Working Group III (WGIII) Report 'Mitigation of Climate Change' which is a section of the IPCC's Fourth Assessment

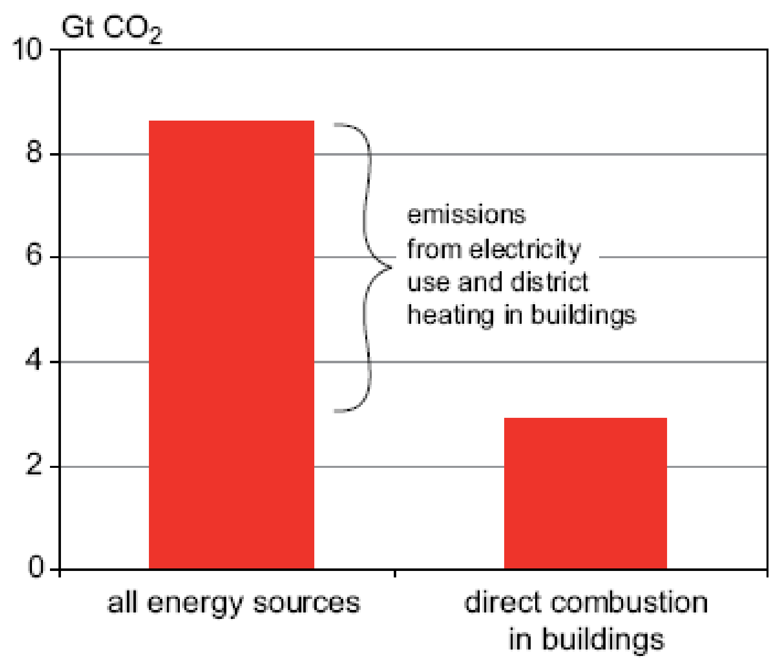
[84] Paul Ashford et al. "The cost implications of energy efficiency measures in the reduction of carbon dioxide emissions from European building stock," The European Alliance of Companies for Energy Efficiency in Buildings (EuroACE) (December 1999) 6.

Report (AR4) 'Climate Change 2007'. 'Mitigation of Climate Change' is one of the most recent reports available on the subject and was released by the IPCC on May 4, 2007.

Chapter six of the WGIII report is titled 'Residential and commercial buildings'. This chapter discusses the potential for greenhouse gas mitigation in the Buildings Sector. In this chapter, high and low economic growth scenarios and the resulting carbon emissions in the Buildings Sector are examined. These scenarios are then adjusted to reflect the mitigation potential that energy-efficiency technologies in the Buildings Sector possess.

According to the report, 2004 global emissions from the Buildings Sector alone were 8.6 $GtCO_2$ per year. As illustrated in *Figure 17*, these building emissions include both emissions from electricity use as well as emissions from the direct combustion of fossil fuels in buildings.

Figure 17: Carbon Dioxide Emissions from the Buildings Sector, 2004[85,86]



[85]IPCC, Climate Change 2007: Mitigation of Climate Change; Chapter 6:Residential and commercial buildings (2007) 391.
[86] Per Wikipedia, district heating is a system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant. (http://en.wikipedia.org)

The IPCC projects the low growth scenario for building-related emissions to trend at 1.5% annually and to reach 11.4 $GtCO_2$ annually by 2030. In its high growth scenario, building-related emissions are projected to trend at 2.4% annually and to reach 15.6 $GtCO_2$ annually by 2030. In both instances, building-related emissions grow to represent an approximate 30% share of total CO_2 emissions from all sectors by 2030. IPCC and IEA projections differ; the IEA estimates a higher fraction of CO_2 emissions due to buildings.

To estimate the CO_2 mitigation potential in buildings, the IPCC reviewed 80 recent studies on building-related energy-efficiency projects. These studies spanned 36 countries, 11 country groups and all inhabited continents. Using these reports, the IPCC aggregated a baseline scenario for building-related emissions. This baseline scenario was projected to be 14.3 $GtCO_2$ annually by 2030 as illustrated in *Figure 18*.

Against the baseline scenario, the IPCC then analyzed emissions mitigation potential across three carbon cost categories[87]: cost-effective ($0/$tCO_2$), low-cost ($20/tCO_2) and high-cost ($100/$tCO_2$). These studies suggest that globally at least 31% of projected baseline emissions can be mitigated cost-effectively ($0/$tCO_2$) by 2030 in the Buildings Sector. It was also estimated that an additional 4% of baseline emissions can be avoided at costs up to $20/$tCO_2$ and 5% more at costs up to $100/$tCO_2$. These mitigation potentials will result in a reduction of approximately 4.5, 5.0 and 5.7 billion tonnes of CO_2 at $0, $20, and $100 respectively in 2030. The bottom line of *Figure 18* labeled *Global* displays these findings. The emissions reductions of the different cost categories are additive. For example, the figure of 5.7 billion tCO_2 at $100/ tCO_2 is the sum of 4.5, 0.5 and 0.7. While the figure of 5.7 billion tonnes of CO_2 is impressive, *Figure 18* clearly shows that cost-effective options, where the cost of mitigating carbon emissions is zero or in many cases even negative, have the potential to save the largest amount of $GtCO_2$.

[87] The terms ‘cost-effective’, ‘low-cost’ and ‘high-cost’ refer to the life-time cost of the investment.

Figure 18: CO_2 Mitigation Potential the Buildings Sector in 2030 ($GtCO_2e$)[88]

			Potential at costs at below 100 US$/$tCO_2$-eq		Potential in different cost categories		
					<0 US$/$tCO_2$	0-20 US$/$tCO_2$	20-100 US$/$tCO_2$
Mitigation option	Region	Baseline projections in 2030	Low	High	<0 US$/tC	0-73 US$/tC	73-367 US$/tC
Electricity savings[a]	OECD	3.4	0.75	0.95	0.85	0.0	0.0
	EIT	0.4	0.15	0.20	0.20	0.0	0.0
	Non-OECD/ EIT	4.5	1.7	2.4	1.9	0.1	0.1
Fuel savings	OECD	2.0	1.0	1.2	0.85	0.2	0.1
	EIT	1.0	0.55	0.85	0.20	0.2	0.3
	Non-OECD/ EIT	3.0	0.70	0.80	0.65	0.1	0.0
Total	OECD	5.4	1.8	2.2	1.7	0.2	0.1
	EIT	1.4	0.70	1.1	0.40	0.2	0.3
	Non-OECD/ EIT	7.5	2.4	3.2	2.5	0.1	0.0
	Global	14.3	4.8	6.4	4.5	0.5	0.7

The IPCC also looked at all market sectors, including non-end-use sectors, to identify the mitigation potential for greenhouse gas emissions in different cost categories. *Figure 19* compares the estimated mitigation potential across all market sectors. The information in *Figure 19* is displayed in $GtCO_2e$. The lines labeled *Global* that are found under the *Region* column for each sector should be compared. An analysis of the data reveals that of all sectors studied in the IPCC report, the Buildings Sector shows the greatest potential for mitigation at the lowest cost.

[88] Please see *Appendix A* for an explanation of OECD. EIT stands for 'economies in transition' which is used to describe former soviet bloc countries that are transitioning to a market economy.

Figure 19: CO_2 Mitigation Potential at a Sectoral Level in 2030 ($GtCO_2e$)[89, 90]

Sector	Mitigation option[a)]	Region	Economic potential <100 US$/$tCO_2$-eq[c)]		Economic potential in different cost categories[d), e)]			
			Cost cat. US$/$tCO_2$-eq		<0	0-20	20-50	50-100
			Cost cat. US$/tC-eq		<0	0-73	73-183	183-367
			Low	*High*				
			Gt CO_2-eq					
Energy supply[e)] (see also 4.4)	All options in energy supply excl. electricity savings in other sectors	OECD	0.90	1.7	0.9		0.50	0
		EIT	0.20	0.25	0.15		0.06	0
		Non-OECD/EIT	1.3	2.7	0.80		0.90	0.35
		Global	2.4	4.7	1.9		1.4	0.35
Transport[b), e), g)] (see also 5.6)	Total	OECD	0.50	0.55	0.25	0.25	0	0
		EIT	0.05	0.05	0.03	0	0	0.02
		Non-OECD/EIT	0.15	0.15	0.10	0.03	0.02	0
		Global[b)]	1.6	2.5	0.35	1.4	0.15	0.15
Buildings (see also 6.4)[f), h)]	Electricity savings	OECD	0.8	1.0	0.95	0.00	0	
		EIT	0.2	0.3	0.25	0	0	
		Non-OECD/EIT	2.0	2.5	2.1	0.05	0.05	
	Fuel savings	OECD	1.0	1.3	0.85	0.15	0.15	
		EIT	0.6	0.8	0.2	0.15	0.35	
		Non-OECD/EIT	0.7	0.8	0.65	0.10	0.01	
	Total	OECD	1.8	2.3	1.8	0.15	0.15	
		EIT	0.9	1.1	0.45	0.15	0.35	
		Non-OECD/EIT	2.7	3.3	2.7	0.15	0.10	
		Global	5.4	6.7	5.0	0.50	0.60	
Industry (see also 7.5)	Electricity savings	OECD	0.30		0.07		0.07	0.15
		EIT	0.08		0.02		0.02	0.040
		Non-OECD/EIT	0.45		0.10		0.10	0.25
	Other savings, including non-CO_2 GHG	OECD	0.35	0.90	0.30		0.25	0.05
		EIT	0.20	0.45	0.08		0.25	0.02
		Non-OECD/EIT	1.2	3.3	0.50		1.7	0.08
	Total	OECD	0.60	1.2	0.35		0.35	0.20
		EIT	0.25	0.55	0.10		0.25	0.06
		Non-OECD/EIT	1.6	3.8	0.60		1.8	0.30
		Global	2.5	5.5	1.1		2.4	0.55
Agriculture (see also 8.4)	All options	OECD	0.45	1.3	0.30		0.20	0.30
		EIT	0.25	0.65	0.15		0.10	0.15
		Non-OECD/EIT	1.6	4.5	1.1		0.75	1.2
		Global	2.3	6.4	1.6		1.1	1.7
Forestry (see also 9.4)	All options	OECD	0.40	1.0	0.01	0.25	0.30	0.25
		EIT	0.09	0.20	0	0.05	0.05	0.05
		Non-OECD/EIT	0.75	3.0	0.15	0.90	0.55	0.35
		Global	1.3	4.2	0.15	1.1	0.90	0.65
Waste (see also 10.4)	All options	OECD	0.10	0.20	0.10	0.06	0.00	0.00
		EIT	0.10	0.10	0.05	0.05	0.00	0.00
		Non-OECD/EIT	0.20	0.70	0.25	0.07	0.10	0.04
		Global	0.40	1.0	0.40	0.18	0.10	0.04
All sectors[i)]	All options	OECD	4.9	7.4	2.2	2.1	1.3	1.1
		EIT	1.8	2.8	0.55	0.65	0.50	1.0
		Non-OECD/EIT	8.3	16.8	3.3	3.6	4.1	2.4
		Global	15.8	31.1	6.1	7.4	6.0	4.5

[89] IPCC, Climate Change 2007: Mitigation of Climate Change; Chapter 11: Mitigation from a cross-sectoral perspective (2007) 632.

[90] Table 11 uses the WEO 2004 baseline to calculate CO_2 emission reductions while the table presented in Table 10 uses the baseline constructed on the basis of the reviewed studies. For this reason, the $GtCO_2$ savings in both tables do not match; however, the potential estimates as a percentage of the baseline are the same in both cases.

4.4 Energy-Efficient Technology in Buildings

If the buildings sector has the greatest potential for energy and carbon savings, how exactly are these savings achieved?

An extensive assortment of technologies exists that can be applied to reduce energy use and greenhouse gas emissions in new and existing buildings. These technologies are used to support big-picture design strategies where the building is examined as an entire system. This 'systems approach' can lead to design solutions which maximize cost as well as efficiency. This approach in turn requires an integrated design process (IDP), in which the building's performance is optimized through an iterative process that involves all members of the design team. This process ensures that the building's architectural elements and engineering systems work together effectively. Key elements of these design strategies include[91]:

- Utilizing a systems approach to building design
- Considering building form, orientation and related attributes
- Reducing heating, cooling and lighting loads
- Utilizing active solar energy and other environmental heat sources and sinks
- Increasing efficiency of appliances, heating and cooling equipment and ventilation
- Implementing commissioning to improve operations and maintenance
- Changing occupant and owner behavior

A selection of the technologies and practices used to fulfill these design strategies and make buildings more energy efficient are outlined in *Figure 20*. These options are only some of the technologies currently available.

[91] IPCC, Chapter 6 394.

Figure 20: **Commercially Available Energy Efficiency Technologies for Buildings**

General Category	**Available Technologies & Practices**
Thermal Envelope	• Insulation including cavity wall insulation, spray foams, rolled loft insulation • Windows with high thermal performance (multiple glazing layers, low-conductivity gases like argon between layers, low-emissivity coatings, framing materials with low conductivity. • Control Air Leakage through weather stripping or installation of walls with a continuous impermeable barrier.
Lighting	• Use of natural lighting (day-lighting) • Use of ambient/task lighting • Use of most efficient lighting devices available • Occupancy and daylight sensors to control lighting use
Heating, Ventilation and Air Conditioning (HVAC)	• Use of variable-air volume (VAV) systems to minimize simultaneous heating and cooling of air • Use of heat exchangers to recover heat or cold from ventilation exhaust air • Minimize fan and pump energy consumption by controlling rotation speed • Use of a demand-controlled ventilation system where ventilation airflow changes with building occupancy • Maximize use of natural ventilation • Correctly size all components of selected HVAC system
Appliances	• Use of equipment that conforms to Energy Star requirements[92] • Use of equipment with low power ratings in operating, low power, sleep and off modes
Operational Management	• Controls systems • Commissioning • Operation, maintenance and performance benchmarking

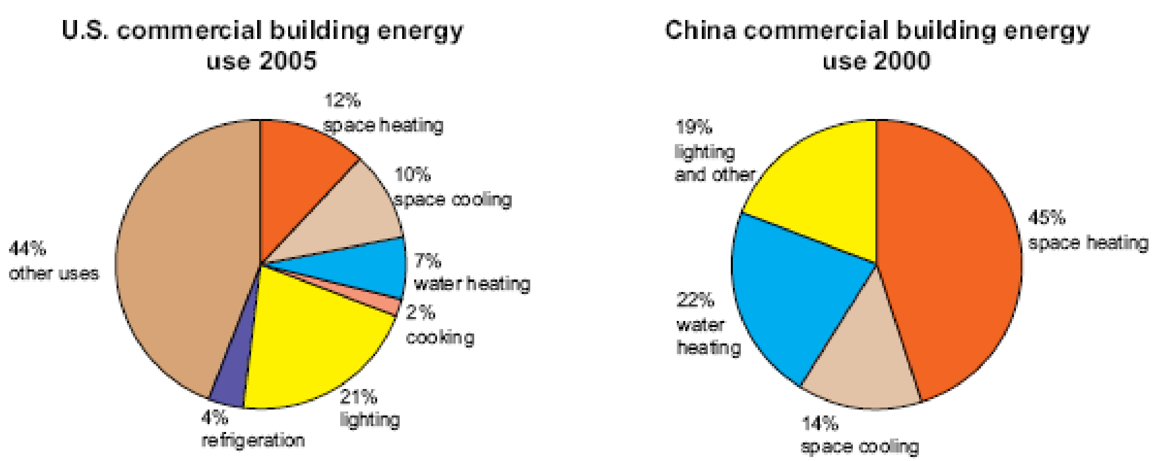
[92] Energy Star is an internationally recognized standard for energy efficient consumer and commercial products.

On-site Energy Generation	• Solar • Co-generation (Combined Heat and Power (CHP)) • Wind

Not all of these technologies when applied produce the same results. The appropriateness of a specific technology varies depending on the economic, cultural and climatic conditions of a particular region. These conditions largely determine the applicability, energy savings and mitigation capacity of the technology in question.

Understanding how energy is used highlights the most effective strategies for reducing its consumption. In comparing the energy use in commercial buildings between the United States in 2005 and China in 2000 (the last year for which figures are available), it is clear that each country favors different end-use technologies. As shown in *Figure 21*, in the United States 22% of energy consumption in commercial buildings is relegated to space heating and cooling whereas in China space heating and cooling are 59% of building energy consumption. Therefore, on a relative basis, the energy saving impact of implementing efficient HVAC technology in China would be greater than in the United States.

Figure 21: Commercial Building Energy Use in the US and China[93]



[93] IPCC, Chapter 6 393

4.5 Barriers to the Implementation of Energy-Efficiency Investments in Buildings

Despite the availability of proven energy-efficient technologies, CO_2e emissions rates in the Buildings Sector continue to rise. Since 1999, the average increase in global CO_2e emissions resulting from energy use in buildings has increased from 2% per year to 2.7% per year.[94] Considering the abundance of mitigation opportunities in this sector, ingrained market barriers continue to block the implementation of such projects.

All of the barriers to the implementation of energy-efficient technologies described in Chapter 3 apply to the Buildings Sector. Distorted price signals, information barriers, organizational failures, economic barriers and split incentives all work towards hindering the implementation of energy-efficient technologies in buildings.

In addition to these more general categories, barriers exist that relate more specifically to the Building Sector. Such barriers include Limitations of the Traditional Building Design Process and Fragmented Market Structure; Small Project Size, Transaction Costs and Perceived Risk; and Culture, Behavior and Lifestyle.[95]

Limitations of the Traditional Building Design Process and Fragmented Market Structure

The linear nature of the design process hinders maximizing a building's energy efficiency across all systems. A building is made up of complex systems and while the building design process is generally sequential, minimizing energy use requires optimizing these systems as a whole. Creating an energy-efficient building requires an integrated design process where a building's form, orientation, envelope, and mechanical and electrical systems are planned concurrently to optimize the building's energy efficiency.

In addition to the barriers to efficiency that the linear nature of the design process presents, the fragmentation of the trades within the building industry limits the energy efficiency of buildings as well. The division of responsibilities that typically occurs during a building's design and construction contributes to suboptimal results due to the varying priorities and narrow focus of the stakeholders, or subcontractors, involved.

[94] IPCC, Chapter 6 391
[95] IPCC, Chapter 6 418

Small Project Size, Transaction Costs and Perceived Risk

In many instances energy-efficiency projects in buildings are too small to attract the attention of investors and financial institutions. Small project size coupled with disproportionately high transaction costs can prevent the implementation of energy-efficiency projects.

For more affluent residential investors, the relatively small share of their disposable income that energy expenditures represent and the opportunity costs involved with the time spent researching and implementing energy efficient opportunities can limit incentives for such projects in the residential sector. Similarly, commercial enterprises often receive higher returns on their investments in marketing or other business-related activities than they do when investing their resources in energy-related projects.

Additionally, the traditional and conservative lending practices of financial institutions, a limited understanding of energy-efficiency technologies, and the volatility of fuel prices all increase the perception of market and technology risk making efficiency projects less attractive to capital.

Culture, Behavior and Lifestyle

Variation across countries in the quantity of energy used per capita can be explained only partly by weather and wealth. These variations are also affected by culture, tradition and lifestyle; attributes which significantly impact energy use in buildings. For example, the differences in behavior associated with distinct cultures such as nighttime lighting preferences, average room temperatures considered comfortable, preferred temperatures of food and drink, and the size and composition of households all impact energy consumption and the types of efficiency projects, if any, considered for investment.

4.6 Policies that Promote Greenhouse Gas Mitigation in Buildings

Though an official study has yet to be completed, it has been inferred that the Buildings Sector faces the most and the largest barriers to the implementation of energy-efficient technology. Though numerous policies aimed at reducing and eliminating these barriers exist and are currently in use, more ambitious policy-making may be needed to more fully capture the benefits of energy efficiency in this sector.

Existing policies vary widely, reflecting the diverse characteristics of the Buildings Sector and the countless energy-efficient technologies and practices that apply to it. Of all policies currently in use, only a few are aimed directly at buildings. Other policies influence the adoption of energy-efficient technologies and practices in buildings but are not specific to the Buildings Sector. Buildings-specific policies in this discussion are given special attentions since their impacts are more easily observed when evaluating the progress of energy efficiency in the Buildings Sector. Such direct policies include: Building Codes; Building Certification and Labeling Schemes; Standards & Labeling (appliances, office equipment & lighting systems) and Voluntary Agreements.

Building Codes

The use of strong building energy codes poses, quite possibly, the best opportunity to ensure the inclusion of energy-efficient technology in buildings. This is because the optimal time to maximize the efficiency of a building's envelope, equipment, and lighting technology is when the building is being built, or in the case of existing buildings, when those elements are replaced or upgraded during a major renovation. In addition to being the best time to incorporate efficient technologies, the most cost-effective time to incorporate energy-efficient technology into a building is during original construction or a major renovation.

Though originally designed to regulate issues relating to occupant safety, building codes have expanded their influence to include areas relating to the energy efficiency of structures. Building codes as they relate to energy efficiency can be classified in two main ways:[96]

1. **Overall performance-based codes –** These require compliance with an annual energy consumption level or energy cost budget, which is calculated using a standard prescribed method. This type of code provides flexibility but requires well-trained professionals for implementation.
2. **Prescriptive codes** – This style of codes sets separate performance levels for major envelope and equipment components, such as minimum thermal resistance of walls, maximum window heat loss/gain and minimum boiler efficiency. In some instances codes monitoring electricity demand exist as well.

Though prescriptive codes are generally easier to enforce and therefore more prominent than performance-based codes, performance-based codes are increasingly being adopted worldwide. This trend reflects the fact that the flexibility of performance-based policies allows for the optimization of integrated design and the inclusion of innovative technologies.

An example of how building energy codes create energy efficiency and save money comes from the U.S. Department of Energy's (DOE) Building Energy Codes Program. The DOE program works with other government agencies, national code organizations and state and local regions to help states adopt,

[96] IPCC, Chapter 6 421

implement and enforce stronger building codes. The DOE estimates that its $37.5 million investment in the program has resulted in energy savings of nearly $1 billion per year.[97]

Another example that illustrates how public policy is addressing energy efficiency through the use of building energy codes is the European Directive on the Energy Performance of Buildings (EPBD). Article 4 of this directive requires member states to ensure that minimum energy performance requirements for buildings are set. The article also requires that member states review these requirements at regular intervals to reflect the technical progress in energy efficiency that's continually being made.[98]

As can be seen from the EPBD, there is a continual need for the further upgrading of building energy codes to reflect the continuous stream of improvements in energy-efficient technology.

Building Certification and Labeling Schemes

Building certification and labeling schemes can be used to address many of the barriers that block the implementation of energy efficient technologies. Possibly the biggest barrier that such schemes help to overcome is the barrier relating to the lack of information available regarding the energy efficiency of a building.

Building and certification schemes provide owners, prospective buyers and tenants with an overview of the energy consumption patterns of a building's thermal envelope and installed equipment. In some instances they provide an assessment of the building's environmental impact as well. Though the exact detail and types of information may vary by scheme, the broader idea is to provide the consumer with a benchmark or tool for evaluating the overall energy efficiency of a structure. This benchmark can be use by a consumer as a way of identifying energy-efficient improvements to implement or, in the case of a prospective buyer or tenant, as a means of evaluating and comparing potential buildings to buy or spaces to rent. Certification and labeling schemes can be either mandatory or voluntary.

Possibly the best example of a building certification and labeling scheme comes from the EPBD. A primary component of this European directive uses mandatory energy performance certificates as a means of identifying the energy efficiency of buildings in the EU. According to article 7 of the Directive, energy performance certificates are required when buildings are constructed, sold or rented and must be made

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[97] *United States Department of Energy: Building Energy Codes Program*. Retrieved from http://www.energycodes.gov/whatwedo

[98] Rod Janssen et al., "Towards Energy Efficient Buildings in Europe," EuroACE (June 2005) 26.

available to the owner, prospective buyer or tenant. The article also states that "Member States shall take measures to ensure that for buildings with a total useful floor area over 1,000 m^2 occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public."[99]

Another well-known certification and labeling scheme is the voluntary Energy Star Buildings rating. According to Energy Star, in 2007, more commercial buildings than ever before qualified for the Energy Star label. This brought the total to more than 4,000 commercial buildings representing over 740 million square feet. Due to their highly efficient energy performance, these buildings use on average 35% to 50% less energy than typical buildings.[100]

There are many benefits to certification and labeling schemes. Such schemes are an effective way to ensure compliance with building energy code requirements and may even encourage the attainment of higher energy performance levels than the codes require. The most significant impact by far of these schemes has been to place a financial value on energy efficiency through a well-informed marketplace. Through the use of certificates and labels, consumers are now able to evaluate the energy performance of buildings and use this information to make purchasing decisions. Labels and certificates take the evaluation of buildings beyond shape and location. Attaching a value to the energy efficiency of a building has become an additional tool for marketing and is a way for consumers to compare options, thereby giving energy efficiency dollar value. It is this ability to create financial value and the desire for building owners to remain competitive in the marketplace that will work to break down barriers and encourage investment in energy efficiency.

Standards & Labeling (appliances, office equipment & lighting systems)

Energy efficiency performance standards and labels (S&L) for appliances, office equipment and lighting are increasingly proving to be effective measures for influencing the adoption of energy efficient technologies. Products subject to S&L are diverse, covering all end-uses and fuel types though their primary focus is on energy consuming products.

[99] Janssen 27.
[100] United States, Environmental Protection Agency, Energy Star Overview of 2007 Achievements (Washington 2008) 3. Retrieved from http://www.energystar.gov/ia/partners/publications/pubdocs/2007%20CPPD%204pg.pdf

Labels applied fall into three general categories:

1. **Endorsement Labels** – Such labels are similar to giving a product a stamp of approval. The giving of this stamp defines a product as being efficient when it meets a specified set of criteria.
2. **Comparison Labels** – These labels provide detailed, factual information about the energy performance of a specific product.
3. **Categorical Labels** – Such labels categorize the overall energy performance of a product using letters (ABC) or numbers (1 – 10).

Each system of S&L has it advantages and disadvantages but all are effective measures for promoting the energy efficiency of products. This effectiveness can be seen in the results that these programs have achieved. According to the IPCC, past and future achievements include examples such as:[101]

- The US Energy Star endorsement label program estimates savings of 13.2 million tCO_2e occurred in 2004, and projects that the program will save 0.7 G tCO_2e over the period 2003 to 2010 and as much as 1.8 G tCO_2e over the period 2003 to 2020.
- Estimates by the IEA claim that greenhouse gas abatement through appliance S&L in Europe by 2020 will be achieved at a cost of -$191 per tCO_2e thus highlighting the cost-effectiveness of such measures.
- A study of China's energy-efficiency standards estimates savings from 17 endorsement labels and concludes that during the first 10 years of implementation these measures will save 250 million tCO_2e in aggregate.

As with the certification and labeling of buildings, S&L measures create a market for energy efficient appliances, equipment and lighting. Such standards and labels increase consumer awareness and knowledge about the energy use of certain devices. In turn, this deeper understanding enables consumers to make informed choices and creates demand for energy efficient products. Though S&L measures have been successful at reducing energy consumption and carbon emissions, it is believed that even greater savings could be achieved if existing policy measures were strengthened. Stronger measures could be a means of aggressively improving energy efficiency.

[101] IPCC, Chapter 6 424

Voluntary Agreements

Like S&L, voluntary agreements apply to the energy efficiency of appliances, equipment and lighting, though voluntary agreements target the producer side of the market as opposed to the consumer side. Voluntary agreements are negotiated between governments and manufacturers and revolve around reducing the energy consuming properties of goods produced for sale. In this way governments and manufacturers agree on a mutually acceptable level of energy use per product in order to improve the energy efficiency of marketed appliances, equipment and lighting.

Energy Star programs are a perfect example of voluntary agreements. Manufacturers voluntarily improve the energy efficiency of products and apply for Energy Star approval for these products. Manufacturers do this because they understand the market potential for energy efficient products that labeling schemes such as Energy Star have created.

Voluntary agreements regarding the energy efficiency of products are generally more appealing to manufacturers than being locked into mandatory legislation. Policy makers favor voluntary agreements, as well, since they are often easier and faster to implement than legislated requirements. The success of voluntary agreements generally depends on a few factors:

- That manufacturers involved in the agreements are responsible for producing the majority of the product in question
- The agreements are quantified and efficiencies are implemented over a reasonable time period
- An effective monitoring process is put in place to ensure compliance

Voluntary agreements are considered to be most useful when combined with other policies that encourage energy efficiency.

The policies discussed relate most directly to buildings by focusing on improving the energy-efficiency of the physical structure of buildings or the energy-consuming devices utilized within them. Other policies exist that indirectly influence the implementation of energy-efficient technologies in buildings as well. These include policies that may pertain to other market segments or have a universal impact. Such policies may support:

- Taxation or subsidies which alter energy prices
- Utility demand-side management programs

- Energy-efficiency obligations and tradable energy-efficiency certificates
- Energy performance contracting and the promotion of Energy Service Companies (ESCO)

Figure 22 organizes the various policy instruments aimed at directly and indirectly mitigating greenhouse gas emissions in the Buildings Sector into four general categories. A detailed table outlining the impact and effectiveness of these measures can be found in *Appendix B.*

Figure 22: Various Policy Instruments Aimed to Mitigate GHG Emissions in the Buildings Sector[102]

Policy Category	**Policy Instruments**
Control and Regulatory Mechanisms	• Appliance standards • Building codes • Procurement regulations • Mandatory labeling and certifications programs • Energy efficiency obligations and quotas • Utility demand-side management programs
Economic and Market-based Instruments	• Energy performance contracting • Cooperative procurement • Energy efficiency certificate schemes • Kyoto Protocol flexible mechanisms (JI, CDM & International Emissions Trading)
Financial Instruments and Incentives	• Taxation on CO_2 or household fuels • Tax exemptions/reductions • Public benefit charges • Capital subsidies, grants, subsidized loans
Support, Information and voluntary Action	• Voluntary certification and labeling • Voluntary and negotiated agreements • Pubic leadership programs • Awareness raising, education/information campaigns • Mandatory audit & energy management requirement • Detailed billing and disclosure programs

[102] IPCC, Chapter 6 432-434

Though the current policies in place are working to break down the barriers to accessing the benefits of energy efficiency in the Buildings Sector, these policies are far from adequate when the diverse nature of this sector is considered.

Not only are there thousands of energy-efficient technologies available that can be applied to the millions of heterogeneous buildings around the world, but there are millions of players involved – home owners, investors, lenders, tenants, building managers, trades-people, government officials etc. – that are making daily decisions which directly impact the energy efficiency of these buildings. Each of these participants has a role to play in tapping the potential for energy and emissions savings in this sector.

There is an encouraging opportunity here but none of these policies on its own can realize it. A diverse portfolio of measures is needed to create awareness in these decision-makers of the environmental and financial benefits that energy efficiency offers.

Chapter Five: Summary & Conclusions

5.0 Summary

Global warming is a problem that requires immediate action. It threatens the environmental future of our planet, the economic futures of our societies and the physical well-being of all species, including humans. It is imperative that the emissions of anthropogenic greenhouse gases be severely reduced over the coming decades to mitigate the damage that global warming and resulting climate change presents.

My research examined the involved relationships between global warming, energy efficiency and the Buildings Sector to understand the impact that energy-efficient investments in the Buildings Sector could have on reducing energy-related emissions, thereby helping to mitigate the damages associated with global warming. This research lay bare:

- Energy-efficiency improvements provide the most immediate means of reducing energy-related emissions.
- Energy-efficient technologies are diverse and can be applied across all energy-related market sectors with the most potential for savings coming from the demand-side or end-use sectors of Transport, Industry and Buildings.
- Of all sectors studied, the Buildings Sector adheres most closely to the goals of policy-makers in reducing greenhouse gas emissions in that its technologies are the most readily available and proven, are the most cost-effective, require the lowest investment cost, and can be quickly implemented for immediate effect.
- Of all sectors studied, the Buildings Sector offers the greatest emissions reducing potential at the lowest cost in the short-term.
- The reduction of these emissions within the Buildings Sector relates directly to the abatement of global warming.

The research confirms that an immense opportunity does exist within the Buildings Sector to abate greenhouse gas emissions through the use of a diverse array of energy-efficient technologies accompanied by changes in consumer behavior. Before the emissions savings potential of the Buildings Sector can be unlocked, the barriers that block the investments that would lead to such savings must be addressed through the strengthening of policy instruments aimed to mitigate the consumption of energy and the emissions of greenhouse gases in this sector.

5.1 Conclusion

The Buildings Sector is complex, including a wide range of building types that house a diverse range of uses and cover a broad range of geographic locations. This diversity makes understanding how energy is used in buildings a complicated task. Buildings are not simply a sum of their parts; they are integrated systems where all of the different pieces interact, creating efficiencies or inefficiencies in energy consumption. Though most of the research discussed focuses on energy savings stemming from the implementation of energy-efficient technologies, much of energy consumption in this sector is a direct result of human behavior and this key element is often brushed over in the literature.

Energy efficiency is directly tied to individual behavior and reflects the rationale of energy consumers. Though energy-efficient technologies can be implemented in buildings, many of them will only conserve energy if building occupants use them in appropriate and prescribed ways. People think they're being energy efficient because they install compact fluorescents light bulbs in their homes but then they leave every light on in the house. Having the most energy-efficient cooling equipment will not save energy if a building occupant leaves the windows open on a hot day. Similarly, if the building manager doesn't prioritize the maintenance of this energy-efficient cooling equipment, it will lose a significant percentage of its energy-saving potential. In the above instances the energy-saving ability of the technology is compromised by human behavior. Energy-efficient technology by itself is obviously not the answer. Human behavior plays a major role. This behavioral aspect is what makes energy efficiency such an elusive and complicated concept because achieving it relies not just on the science of efficient-technology but on understanding how to motivate and control the behavior of consumers.

Motivating behavioral change in the Buildings Sector would seem to present a more significant challenge than is currently described in energy-efficiency literature. This sector encompasses millions of buildings with the energy-efficiency of each being driven by multiple decision makers on a daily basis. These participants include owners, investors, occupants, building managers, sub-contractors, government officials, etc., all of whom have different incentives influencing their decisions.

Possibly the biggest challenge to changing consumer behavior and capturing the benefits of energy-efficiency improvements in the Buildings Sector is altering the value that consumers attach to energy-efficiency investments. Value associated with such investments could be financial, relating directly to their energy cost savings, or social, relating to the benefits they pose to society such as greenhouse gas abatement. Either way, based on the amount of untapped potential for energy-efficiency savings in the

Buildings Sector that is believed to exist, many consumers simply don't value energy efficiency enough to pursue it.

There is good reason for this. The barriers to the implementation of these types of projects are very real. Most consumers aren't educated about the energy-efficient options available to them and don't understand or believe in the cost-savings these projects promise. More importantly, it seems consumers have yet to make the connection between energy consumption and global warming. Most consumers do not think about how the energy they consume contributes to global warming through the burning of fossil fuels. This concept has simply not occurred to them because energy is an invisible commodity. It's difficult to gauge its usage and even more difficult to gauge the indirect and direct greenhouse gas emissions that are generated through its production.

Because of the deeply ingrained nature of these barriers, raising awareness of energy consumption and its direct relationship to global warming is a difficult prospect. Encouraging the adoption of energy-efficient technologies and behaviors that reduce this consumption thereby mitigating its impact on global warming is a challenge as well. The measures currently in place to accomplish these goals such as building codes, public leadership programs and voluntary labeling programs are not enough. Governments need to find more forceful and appropriate incentives, financial and non-financial, to persuade consumers to modify their consumption behavior and implement energy-efficiency in their buildings. Where persuasion is not appropriate, legislation is necessary. More noise simply needs to be created surrounding these issues.

Complacency is not an option. A paradigm shift is required to change behavioral patterns and consumer attitudes. Individuals, governments and the private sector all need to do more to promote energy efficiency in buildings to abate greenhouse gas emissions. Though the impediments to the implementation of these measures as described in my thesis are exceptionally complex due to the dynamic nature of the Buildings Sector, I believe they pose an even greater challenge than is estimated. As counterintuitive as this may seem, this represents an opportunity. If higher than assumed barriers exist in the Buildings Sector, then more unrealized potential exists for energy savings through energy-efficiency projects and changes in behavior, thus creating further opportunity to reduce the emissions of greenhouse gases.

Appendix A: OECD[103]

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.

[103] IEA, WEO 2006 2.

Appendix B: Impact and Effectiveness of Policy Instruments in the Buildings Sector[104]

Policy instrument[a]	Examples of countries	Effectiveness[b]	Energy or emission reductions for selected best practices	Cost-effectiveness	Cost of GHG emission reduction for selected best practices[c]	Special conditions for success, major strengths and limitations, co-benefits	References
Control and regulatory mechanisms							
Appliance standards	EU, US, JP, AU, BR, CN	High	JP: 31 M tCO_2 in 2010; CN: 240 $MtCO_2$ in 10 yrs; US: 2.5% of electricity use in 2000 = 65 $MtCO_2$, 6.5% = 223.87 $MtCO_2$ in 2010.	High	AU: –15 $/$tCO_2$ in 2012; US: –65 $/$tCO_2$ in 2020; EU: –194 $/$tCO_2$ in 2020.	Factors for success: periodical update of standards, independent control, information, communication and education.	IEA, 2005; Schlomann *et al*. 2001; Gillingham *et al*., 2004; ECS, 2002; World Energy Council, 2004; Australian Greenhouse Office, 2005; IEA 2003a; Fridley and Lin, 2004.
Building codes	SG, PH, DZ, EG, US, GB, CN, EU	High	HK: 1% of total electricity saved; US: 79.6 $MtCO_2$ in 2000; EU: 35–45 $MtCO_2$, max 60% energy savings in new buildings.	Medium	NL: from –189 $/$tCO_2$ to –5 $/$tCO_2$ for end-users, 46–109 $/$tCO_2$ for society.	No incentive to improve beyond target. Only effective if enforced.	World Energy Council, 2001; Lee & Yik, 2004; Schaefer *et al*., 2000; Joosen *et al*., 2004; Geller *et al*., 2006; ECCP, 2001.
Procurement regulations	US, EU, CN, MX, KR, JP	High	MX: 4 cities saved 3.3 $ktCO_2$-eq in one year; CN: 3.6 $MtCO_2$ expected; EU: 20–44 $MtCO_2$ potential.	Medium	MX: $1Million in purchases saves $726,000/yr; EU: <21 $/$tCO_2$.	Success factors: enabling legislation, energy efficiency labelling & testing, ambitious energy efficiency specifications.	Borg *et al*., 2003; Harris *et al*., 2005; Van Wie McGrory *et al*., 2006.
Mandatory labelling and certification programmes	US, CA, AU, JP, MX, CN, CR, EU	High	AU: 5 M tCO_2 savings 1992–2000; DK: 3.568 $MtCO_2$.	High	AU: –30 $/$tCO_2$ abated.	Effectiveness can be boosted by combination with other instrument and regular updates.	World Energy Council, 2001; OPET network, 2004; Holt & Harrington, 2003.
Energy efficiency obligations and quotas	GB, BE, FR, IT, DK, IE	High	GB: 1.4 $MtCO_2$/yr.	High	Flanders: –216 $/$tCO_2$ for households, –60 $/tCO2 for other sector in 2003; GB: –139 $/$tCO_2$.	Continuous improvements necessary: new energy efficiency measures, short-term incentives to transform markets etc.	UK government, 2006; Sorell, 2003; Lees, 2006; Collys, 2005; Bertoldi & Rezessy, 2006; Defra, 2006.
Utility demand-side management programmes	US, CH, DK, NL, DE, AT	High	US: 36.7 $MtCO_2$ in 2000.	High	US: Average costs approx. –35 $/$tCO_2$.	DSM programmes for commercial sector tend to be more cost-effective than those for residences.	IEA, 2005; Kushler *et al*., 2004.
Economic and market-based instruments							
Energy performance contracting	DE, AT, FR, SE, FI, US, JP, HU	High	FR, SE, US, FI: 20–40% of buildings energy saved; EU:40–55$MtCO_2$ by 2010; US: 3.2 $MtCO_2$/yr.	Medium	EU: mostly at no cost, rest at <22 $/tCO2; US: Public sector: B/C ratio 1.6, Priv. sector: 2.1	Strength: no need for public spending or market intervention, co-benefit of improved competitiveness.	ECCP, 2003; OPET network, 2004; Singer, 2002; IEA, 2003a; World Energy Council, 2004; Goldman *et al*., 2005.

[104] IPCC, Chapter 6 432-434

Policy instrument[a]	Examples of countries	Effectiveness[b]	Energy or emission reductions for selected best practices	Cost-effectiveness	Cost of GHG emission reduction for selected best practices[c]	Special conditions for success, major strengths and limitations, co-benefits	References
Co-operative procurement	DE, IT, GB, SE, AT, IE, JP, PO, SK, CH	High	Varies, German telecom company: up to 60% energy savings for specific units.	High	0: Energy-efficient purchasing relies on funds that would have been spent anyway.	Success condition: energy efficiency needs to be prioritized in purchasing decisions.	Oak Ridge National Laboratory, 2001; Le Fur 2002; Borg *et al.*, 2003.
Energy efficiency certificate schemes	IT, FR	Medium	IT: 3.64 Mt CO_2 eq by 2009 expected.	Medium	n.a.	No long-term experience yet. Transaction costs can be high. Monitoring and verification crucial. Benefits for employment.	OPET network, 2004; Bertoldi & Rezessy, 2006; Lees, 2006; Defra, 2006.
Kyoto Protocol flexible mechanisms[d]	CN, TH, CEE (JI & AIJ)	Low	CEE: 220 K tCO_2 in 2000.	Low	63 $/$tCO_2$.	So far limited number of CDM & JI projects in buildings.	ECS, 2005; Novikova. *et al.*, 2006.
Financial instruments and incentives							
Taxation (on CO_2 or household fuels)	NO, DE, GB, NL, DK, CH	Low	DE: household consumption reduced by 0.9%.	Low		Effect depends on price elasticity. Revenues can be earmarked for further efficiency. More effective when combined with other tools.	World Energy Council, 2001; Kohlhaas, 2005.
Tax exemptions / reductions	US, FR, NL, KO	High	US: 88 $MtCO_2$ in 2006.	High	Overall B/C ratio – Commercial buildings: 5.4 – New homes: 1.6.	If properly structured, stimulate introduction of highly efficient equipment and new buildings.	Quinlan *et al.*, 2001; Geller & Attali, 2005.
Public benefit charges	BE, DK, FR, NL, US states	Medium/ low	US: 0.1–0.8% of total electricity sales saved /yr, average of 0.4%.	high in reported cases	From –53 US$/ tCO_2 to –17 $/$tCO_2$.		Western Regional Air Partnership, 2000; Kushler *et al.*, 2004.
Capital subsidies, grants, subsidized loans	JP, SI, NL, DE, CH, US, HK, GB	High	SI: up to 24% energy savings for buildings, GB: 3.3 $MtCO_2$; US:29.1 Mio BTU/yr gas savings.	Low	NL: 41–105 US$/ tCO_2 for soc; GB:29 US$/$tCO_2$ for soc, –66 $/$tCO_2$ for end-user.	Positive for low-income households, risk of free-riders, may induce pioneering investments.	ECS, 2001; Martin *et al.*, 1998; Schaefer *et al.*, 2000; Geller *et al.*, 2006; Berry & Schweitzer, 2003; Joosen *et al.*, 2004; Shorrock, 2001.
Support, information and voluntary action							
Voluntary certification and labelling	DE, CH, US, TH, BR, FR	Medium/ high	BR: 169.6 $ktCO_2$ in 1998, US: 13.2 $MtCO_2$ in 2004, 2.1 bio tCO_2-eq in total by 2010; TH: 192 tCO_2.	High	BR: US$ 20 million saved.	Effective with financial incentives, voluntary agreements and regulations.	OPET network, 2004; Word Energy Council, 2001; Geller *et al.*, 2006; Egan *et al.*, 2000; Webber *et al.*, 2003.

Policy instrument[a]			Energy or emission reductions for selected best practices	Cost-effectiveness	Cost of GHG emission reduction for selected best practices[c]	Special conditions for success, major strengths and limitations, co-benefits	References
Voluntary and negotiated agreements	Mainly Western Europe, JP, US	Medium/ High	US: 88 $MtCO_2$-eq/yr UK: 15.8 $MtCO_2$	Medium	GB: 54.5–104 US$/$tCO_2$ (Climate Change Agreements).	Can be effective when regulations are difficult to enforce. Effective if combined with financial incentives and threat of regulation.	Geller *et al*., 2006; Cottrell, 2004.
Public leadership programmes	NZ, MX, PH, AR, BR, EC	High	De: 25% public sector CO_2 reduction over 15 years.	High	US DOE/FEMP estimates 4 US$ savings for every 1 US$ of public funds invested.	Can be used to demonstrate new technologies and practices. Mandatory programmes have higher potential than voluntary ones.	Borg *et al*., 2003; Harris *et al*., 2005; Van Wie McGrory *et al*., 2006; OPET, 2004.
Awareness raising, education / information campaigns	DK, US, GB, CA, BR, JP	Low/ Medium	GB: Energy Efficiency Advice Centres: 10.4 K tCO_2 annually.	High	BR: –66 US$/ tCO_2; GB: 8 US$/ tCO_2 (for all programmes of Energy Trust).	More applicable in residential sector than commercial.	Bender *et al*., 2004; Dias *et al*., 2004; Darby, 2006; IEA, 2005; Lutzenhiser, 1993; Ueno et al. 2006; Energy Saving Trust, 2005.
Mandatory audit & energy management requirement	US, FR, NZ, EG, AU, CZ	High, but variable	US: Weatherization Program: 22% saved in weatherized households.	Medium	US Weatherization Program: BC-ratio: 2.4.	Most effective if combined with other measures such as financial incentives	World Energy Council, 2001
Detailed billing and disclosure programmes	ON, IT, SE, FI, JP, NO, CL	Medium	Up to 20% energy savings.	Medium	n.a.	Success conditions: combination with other measures and periodic evaluation. Comparability with other households is positive.	Crossley *et al*., 2000; Darby 2000; Roberts & Baker, 2003; Energywatch, 2005.

Notes:
Country name abbreviations (according to the ISO codes except California, Ontario, Central and Eastern Europe and European Union): DZ – Algeria, AR – Argentina, AU – Australia, AT – Austria, BE – Belgium, BR – Brazil, CL – California, CA – Canada, CEE – Central and Eastern Europe, CN – China, CR – Costa Rica, CZ – Czech Republic, DE – Germany, Denmark – DK, EC – Ecuador, EG – Egypt, EU – European Union, FI – Finland, FR – France, GB – United Kingdom, HK – Hong Kong, HU – Hungary, IN – India, IE – Ireland, IT – Italy, JP – Japan, KR – Korea (South), MX – Mexico, NL – Netherlands, NO – Norway, ON – Ontario, NZ – New Zealand, NG – Nigeria, PH – Philippines, PO – Poland, SG – Singapore, SK – Slovakia, SI – Slovenia, CH – Switzerland, SE – Sweden, TH – Thailand, US – United States.

a) For definitions of the instruments see: Crossley et al. (1999), Crossley et al. (2000), EFA (2002), Vine et al. (2003) and Wuppertal Institute (2002).

b) Effectiveness of CO2 emission reduction: includes ease of implementation; feasibility and simplicity of enforcement; applicability in many locations; and other factors contributing to overall magnitude of realized savings.

c) Cost-effectiveness is related to specific societal cost per unit of carbon emissions avoided. Energy savings were recalculated into emission savings using the following references for the emission factors: Davis (2003), UNEP (2000), Center for Clean Air Policy (2001). The country-specific energy price was subtracted from the cost of saved energy in order to account for the financial benefits of energy savings (Koomey and Krause, 1989), if they were not considered originally.

d) Kyoto flexible mechanisms: Joint Implementation (JI), Clean Development Mechanism (CDM), International Emissions Trading (includes the Green Investment Schemes).

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