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The Climate Emergency and the Need for Global Climate Stabilization: The Role of Energy Efficiency in Climate Policy

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THE CLIMATE EMERGENCY AND THE NEED FOR GLOBAL CLIMATE
STABILIZATION: THE ROLE OF ENERGY EFFICIENCY IN CLIMATE POLICY

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ABSTRACT

Global climate change is a worldwide challenge requiring a coordinated, international policy response. However, political pressures and disagreements between developed and developing countries have obstructed past climate negotiations and have stalled the adoption of binding greenhouse gas emission reduction targets. Despite slow-moving international climate negotiations and comprehensive climate policies, many countries have turned to energy efficiency as a politically feasible tool to lower energy use and greenhouse gas emissions. Economists debate the effectiveness of energy efficiency policies due differing perspectives regarding the relationship between energy use and economic growth.   Because of this fundamental disagreement, economists often come to different conclusions as to whether energy efficiency routinely leads to either a reduction in energy use or leads to an economy-wide increase in energy use. Even when accounting for the rebound effect, many studies indicate that energy efficiency remains a highly cost-effective energy resource in the near future.   Energy efficiency policies also offer an immediate and politically feasible policy tool to encourage the adoption of more comprehensive climate policies.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

In the capitalist global economy, increasing standards of living are pursued through economic growth, which historically require increased energy consumption. As the global economy remains dependent on fossil fuels as its main source of energy, large quantities of greenhouse gases, primarily carbon dioxide (CO_2), are emitted into the atmosphere. Driven primarily by developed countries, such as the United States, energy consumption and greenhouse gas emissions continue to rise to unprecedented levels. However, climate change remains a global issue; the largest percentage of global emissions attributed to a single country is only 26 percent (Council on Foreign Relations, 2013). As a result, international agreements and global emission reduction goals become crucial components when attempting to lower global emissions.

The consequences of unchecked energy consumption are severe, including air and water pollution, natural resource depletion, electric grid failures, rising energy insecurity, and global climate change.[1] Climate scientists warn that humanity has interfered with the Earth's climate system and has crossed critical thresholds, referred to as planetary

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[1] The International Energy Agency defines energy security as the uninterrupted availability of energy sources at an affordable price (IEA, 2013). Thus, energy insecurity includes both an interruption in supply as well as extreme price spikes and volatility.

boundaries (Rockström, 2009).[2] The World Wildlife Fund's annual Living Planet Report

(2012) warns that humanity is placing dangerous pressures on the Earth and is destroying

finite, natural biosystems. Specifically, human consumption is depleting natural

resources at an unsustainable rate, creating biodiversity imbalances with unknown long-

term impacts. The Living Planet Report, which is published annually by the World

Wildlife Fund, studies the state of the planet through three measurements: the Living

Planet Index, the Ecological Footprint, and the Water Footprint of Consumption.[3] The

2012 results of the Living Planet Index signified that global biodiversity health had

declined by 30 percent between 1970 and 2008. The Ecological Footprint indicated that

in 2012 the world economy exceeded the planet's biocapacity by 50 percent. Since the

1970s, an emerging gap has been observed between the global ecological footprint and

the Earth's biocapacity, creating an ecological deficit. This implies that the world

economy has accumulated an ecological debt, meaning that as a whole, the Earth has

exceeded its global biocapacity to absorb human impacts on natural resource cycles. The

majority of this debt is related to carbon emissions. Overall, this finding provides a clear

indication that the current rate of natural resource consumption is unsustainable.

Additionally, the Water Footprint of Consumption, measuring freshwater availability,

found that in 2008, 2.7 billion people lived in areas that experienced severe water

[2] Planetary boundaries refer to critical boundaries or set thresholds coordinating with the planet's biophysical subsystems and processes that should not be crossed in order to maintain a safe operating space for humanity to interact with the Earth's climate system. Climate change parameters include atmospheric carbon dioxide concentration and change in radiative forcing.

[3] The Living Planet Index is a measurement for biodiversity. Using a data set of over 9,000 wildlife-monitoring surveys, biodiversity levels are calculated using population size for species in different regions to determine the average changes in abundance. The Ecological Footprint measures overconsumption by analyzing the Earth's biocapacity or the Earth's ability to produce renewable resources, while absorbing CO_2 emissions. The Water Footprint of consumption measures freshwater availability.

shortages for at least one month per year (WWF, 2012). Despite the alarming evidence, the report concludes that the current state of the planet can be reversed through significant changes in how humanity uses its natural resources.

Acknowledging the degradation of the environment and accelerating climate change, several economic and climate studies have attempted to define critical thresholds of atmospheric carbon dioxide concentrations (measured in parts per million, ppm) that should not be crossed to prevent the acceleration of positive feedback loops.[4] Positive feedback loops associated with the carbon cycle have the potential to initiate irreversible climate change, such as the sudden collapse of ice sheets, a disruption of ocean currents, changes in ecological systems, and changes in the distribution of vegetation (Rockström, 2009). The mainstream view claims that in order to prevent positive feedback loops, the global average temperature must not rise more than two degrees Celsius from pre-industrial levels. However, climate scientists differ in their estimations of carbon dioxide concentrations that should not be exceeded to prevent cataclysmic climate change. The first prominent economic analysis of climate change sponsored by the British government, the Stern Review, stated that carbon dioxide must stabilize between 450 to 550 ppm to allow the Earth to maintain its natural capacity to remove greenhouse gases from the atmosphere.[5] According to the Stern Review, to achieve carbon dioxide stabilization within this range, global carbon emissions must peak between 2016 and 2026, and then, must continue to decline one to three percent per year (Stern, 2006).

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[4] The National Oceanic and Atmospheric Administration (NOAA) define positive feedback loops as "an initial change that will bring about an additional change in the same direction."

[5] While the Stern Review currently is considered outdated, it was the first major economic analysis to warn of the impending climate and economic crisis resulting from human interference within the climate system. From a historical perspective, it is important to discuss its findings.

However, in 2009, Stern stated that his estimations in the Stern Review were overly optimistic and warned that global climate change is accelerating faster than anticipated. As a result, Stern cautioned that the costs of inaction and risk associated with climate change are even greater than he predicted in 2006 (Stern, 2009). In 2008, the Intergovernmental Panel on Climate Change (IPCC), which is the most prominent international organization working on climate change, published its fourth assessment report on global climate change. This report set the safety threshold at 445 to 490 ppm. To achieve this safety threshold, global emissions must peak by 2015, and be reduced 50 to 85 percent by 2050 (Solomon, et al., 2007). However, some scientists suggest that the above thresholds are too conservative. European climate scientist, Johan Rockström (2009), United States' climate scientist, James Hansen (2008), and Australian climate scientists, David Spratt and Philip Sutton claim that in order for humanity to remain within a stable environmental state, carbon dioxide concentration should not have exceeded 350 ppm. Current carbon dioxide concentrations have already exceeded this threshold, suggesting that the climate system is in a state of altered energy balance (Hansen, et al., 2008).[6] The 'Physical Science Basis Report' of the fifth IPCC assessment published in 2013 introduced the concept of a carbon budget.[7] The report stated that no more than 1,000, 1,210, and 1,570 tonnes of carbon could be released into the atmosphere to achieve a 66 percent, 50 percent, and 33 percent chance, respectively, of limiting

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[6] NOAA's March 2014 recording of average atmospheric CO_2 was 399.65 ppm.

[7] The most recent IPCC report was released on April 14, 2014. The report includes a policy summary further indicating that carbon emissions must be reduced beyond current commitment levels. Due to the timing of the report, its findings are not included within this thesis.

global warming to the two degrees Celsius target.[8]   The report also revealed that since

2011, 531 tonnes of the proposed budget had already been used; meaning the carbon

budget only has 469, 679, and 1039 tonnes left, depending on the scenario (Stocker, et.al,

2013).

Because carbon dioxide emissions are the main driver of the human-induced

climate change, emissions reduction strategies are critical to a successful climate

response. Even if emissions of carbon dioxide were discontinued today, a clearly

hypothetical scenario, future generations would still feel the effects of climate change due

to past emissions.[9] Without significant efforts to limit greenhouse gas emissions,

additional warming and changes to the climate system will be exacerbated for current and

future generations (Stocker et.al, 2013). While uncertainty remains regarding an exact

threshold of atmospheric carbon dioxide concentration that will induce significant climate

instability, projections based on climate modeling suggest that current carbon dioxide

concentrations are dangerously close to tipping points.[10]

As the largest single-source of carbon dioxide emissions, the energy sector is

viewed as a leading cause of global climate change. Unchecked carbon dioxide

emissions resulting from energy consumption will intensify the effects of climate change,

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[8] One tonne of carbon equates to 2.13 ppm.

[9] This effect is known as climate lag and is primarily attributed to thermal inertia, which creates a longer
lag-time as in rising air temperatures permeate through the thermal mass of the oceans.

[10] Tipping points refer to irreversible, abrupt changes of the climate system. The effects of irreversible
climate change include a loss of major ice sheets, accelerated sea level rise, and abrupt shifts in forest and
agricultural systems (Rockström, 2009).

with the possibility to even trigger cataclysmic or runaway climate change.[11] In 2012,

global energy-related carbon dioxide emissions increased by 1.4 percent, reaching a

historic high of 31.6 gigatonnes (IEA, 2013). To address the global climate crisis, energy

efficiency is often viewed as a primary strategy to reduce carbon emissions to reach

climate policy goals. According to the IPCC, energy efficiency is the largest single-

source instrument to reduce carbon emissions to a level that achieves climate stabilization

(Solomon, et al., 2007). Additionally, to address swelling energy demand, energy

efficiency acts as an emissions-free energy resource that should be fully utilized before

large capital investments are initiated to increase energy supplies.[12] Studies indicate that

energy efficiency is a low-cost energy resource (averaging approximately 3

cents/kilowatt hour) to address global warming and to absorb additional electricity

demand (Pimental, et al., 2003). As an example, Pimentel et al. (2003) found that

through the adoption of energy conservation behaviors and energy efficient technologies,

approximately 33 percent of United States energy consumption could be saved, equating

to a savings of $438 billion dollars. Further, a 2009 United States study released by

McKinsey & Company suggested that an 'energy efficiency gap' exists and argued that

cost-effective efficiency gains remain untapped, creating a large potential to reduce

greenhouse gas emissions and reduce total electricity consumption. The study proposed

that by 2020, the United States has the potential to yield gross energy savings of $1.2

trillion and to reduce energy consumption by 23 percent of projected demand (9.1

quadrillion Btus).

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[11]Long-term feedback mechanisms could warm the planet to levels that would not support ecosystems and
would threaten the survival of human societies (Rockström, 2009).

[12] However, this implies that energy efficiency gains must occur at a faster rate than economic growth.

While many researchers promote public programs encouraging energy efficient behaviors and technologies, an ongoing debate exists regarding whether energy efficiency is, in fact, an effective instrument to reduce overall energy consumption. Some theoretical arguments predict that energy efficiency creates a rebound effect resulting in increased energy consumption. Historically, this phenomenon was first introduced as the Jevons Paradox. During the nineteenth century coal era, economist William Stanley Jevons wrote that increasing the efficiency of an energy resource will only result in an increased demand for that resource (Jevons, 1866). Thus, improved efficiency results in economic expansion and increased energy consumption. Empirical studies suggest that a 'rebound effect' does exist, but may not entirely negate the intended reduction in energy consumption. Rather, the rebound effect, while difficult to quantify, is commonly estimated to reduce intended conservation levels by approximately 10 – 30 percent (Gillingham, Newell, Palmer, 2009; Sorrell, 2007). However, other studies suggest that the rebound effect could be larger than 100 percent, making energy efficiency policies counterproductive. Regardless of the disparity in empirical estimates, the rebound effect should be considered when attempting to understand the relationship between energy efficiency and consumer behavior and when creating public policies to address rising energy demands and consumption.

In addition to the rebound effect, market barriers, such as imperfect information, exist within the energy sector resulting in consumer decision-making that is not as efficient as predicted by mainstream economic theory. Studies have shown that inter-temporal choice and individual discounting significantly affect energy-use decisions (International Energy Agency, 2007). Moreover, energy companies are often regulated

7

monopolies. As a result, prices are not exclusively market driven and may not equate to

marginal costs. Energy prices often are kept artificially low due to subsidies and public

utility commissions' authority to set prices. Consequently, price signals are distorted,

and as economic theory predicts, consumer behavior is directed away from a socially

efficient allocation (Linares and Labandeira, 2010). Additionally, Borenstein (2009)

found that consumers do not choose energy consumption levels based on the observed

price per billing period, even when utilities use tiered-rate pricing blocks. By analyzing

utility pricing data, Borenstein found that the elasticity for energy consumption is low

and in the range of -0.1 to -0.2. Thus, even if prices were set "correctly" though

appropriate public policies, a lack of information, poor understanding of future prices,

and a low-elasticity for energy consumption by consumers would continue to perpetuate a

socially inefficient allocation of resources. Energy efficiency policies are intended to

counteract the market distortions found within the energy industry.

Ultimately, the effectiveness of energy efficiency as a climate policy is affected

by the perceived relationship between energy consumption and economic growth.

Mainstream and ecological economists differ in their view of this relationship and the

ability for energy use to decouple from economic growth.   Mainstream economists view

energy as a minor factor affecting economic growth, and therefore, energy efficiency can

continually lower the energy use per unit of GDP in order to perpetuate economic

growth. However, ecological economists caution that energy is a main factor affecting

economic growth, and as such, energy decoupling from economic growth may be

overestimated and limited.

This thesis will analyze the role of energy efficiency in climate policy to address the global environmental crisis and to reduce emissions associated with energy consumption. Chapter 2 discusses the global climate problem, its projected impact, and policy challenges associated with the need to stabilize the climate. Chapter 3 will analyze the theoretical debate of the role of energy efficiency as a mechanism to achieve climate stabilization. Chapter 4 discusses the United States' as case study of a major contributor to the global climate problem. This chapter also focuses on the historical pattern of energy consumption and the role of energy efficiency policies in the United States. Chapter 5 discusses the public policy implications of energy efficiency, and ultimately the impact of energy efficiency on climate policy goals. Chapter 6 concludes by examining potential future scenarios associated with the adoption of greater energy efficiency.

CHAPTER TWO: THE GLOBAL CLIMATE PROBLEM

2.1   Introduction

The IPCC (2007) warns that global warming is unequivocal and primarily caused by human interference through emissions of greenhouse gases. The primary greenhouse gas associated with human activities is carbon dioxide (CO_2), followed by methane (CH_4) and nitrous oxide (N_2O). The foremost human activity that emits greenhouse gases is the combustion of fossil fuels [coal, natural gas, and oil] used for electricity, transportation, and industrial processes (EPA, 2013). Since the Industrial Revolution began in the 1750s, global emissions of carbon dioxide, methane, and nitrogen oxide have increased by 40 percent, 150 percent, and 20 percent, respectively (Stocker et.al, 2013). The U.S. Global Change Research Program (2009) supports this argument too. It found a widespread, scientific consensus claiming that increasing emissions are altering the balance of the Earth's climate system and primarily are a result of the burning of fossil fuels, industrial agriculture, and land-use change due to urbanization. Many of the Earth's biophysical systems are non-linear, meaning changes could be abrupt once tipping points are reached. As a result, the consequences of added human pressures on the climate system may be unnoticed or gradual, until abrupt impacts and escalating costs occur rapidly. Future effects of climate change will be unavoidable due to the long lag-time and long lifespan of greenhouse gases that were emitted in past years (Rockström, 2009). According to the IPCC, 15 to 40 percent of emitted carbon dioxide will remain in

the atmosphere for at least the next 1,000 years (Stocker et.al, 2013). To reverse current trends and reduce the risk of crossing irreversible thresholds, greenhouse gas emissions must be reduced through a global effort to move toward low-carbon economies. This chapter aims to present the current status of the global climate change crisis and to demonstrate the urgent need for international action and public policies to stabilize the global climate.

2.2   The Impact of Climate Change

Since 1900, the global average temperature has risen 1.5 degrees Fahrenheit, and 80 percent of this increase can be attributed since 1980 (Solomon, et al., 2007). Rising temperatures will severely affect economic arrangements and environmental systems, both locally and globally. Climate scientists project a rise in extreme weather patterns such as increased drought periods, heavy downpours, intense hurricanes, more frequent flooding events, and more frequent and severe wildfires (Solomon, et al., 2007). Impacts arising from an increase in extreme weather patterns will negatively affect multiple sectors such as agriculture, transportation, and public health, among others.

Increasing temperatures and heat waves are expected to cause public health emergencies in which vulnerable groups such as low-income, elderly, and children will face disproportionate risks and difficulties. Changing disease patterns interacting with shifts in trade and travel may cause an increase in illness and in diseases that spread quickly in dense, urban environments (Solomon, et al., 2007). Decreased water quality due to rising temperatures and decreased air quality due to a rise in ground-level ozone may create public health risks that can rapidly increase medical costs. Water supplies will

be stressed through increased consumption and decreased supply. Additionally, longer, more frequent drought periods are expected to occur creating concerns of more frequent wildfires that have the potential to damage watersheds (USGCRP, 2009). Additionally, extreme variability in rainfall, resulting in droughts or flood events, will deplete crop yields, diminish livestock productivity, and exacerbate and generate food insecurities globally. Many small and subsistence farmers will lack the adaptive capacity and monetary ability to manage the negative effects of lower crop yields or continual drought (Easterling, et al, 2007).

Many of these stressors create the impetus for the emergence of 'environmental migrants,' which refers to involuntary mobility due to environmental factors. As a result, many countries and policymakers are attempting to predict future migration patterns and the effects of migration due to climate change. Research can both prepare regions that are most likely to see an influx of environmental migrants and can help identify stressed populations in need of resources for climate adaptation and advanced planning (Warner et.al, 2012).

As these impacts accumulate, historic habitats and ecosystems will become stressed or depleted, adversely affecting biodiversity. For example, as sea levels rise, wetland habitats will be eroded or eliminated. The IPCC estimates that 20 to 30 percent of global species will become high risk for extinction. In 2010 Ridgwell and Schmidt estimated that the rate of ocean acidification is the fastest in 65 million years due to the absorption of carbon dioxide. The effects of ocean acidification include extinction of ocean floor organisms, ocean dead zones, and the destruction of coral reefs (Ridgwell &

Schmidt, 2010). Due to increased drought and shifting climates, many forests, important agents for absorbing carbon dioxide, will dwindle and shrink in size (WWF, 2012). Climate scientists often raise concerns regarding arctic ice melt resulting in a release of large quantities of freshwater into the ocean (USGCRP, 2013). In addition to sea level rise, thawing of the permafrost may release immense quantities of trapped methane deposits into the atmosphere, generating the potential for accelerated climate change effects. In sum, the IPCC warns that many ecosystems will be stressed beyond repair, overwhelming the natural resiliencies of ecosystems and habitats. The long-term and immediate consequences of a continual loss of biodiversity are unknown due to unprecedented changes and the high concentration of emissions within the atmosphere. While the debate continues regarding the severity and magnitude of climate change impacts, many climate scientists warn that, without action, climate change presents a substantial threat to the survival of human civilization in the long-term.

2.3   The International Emissions Debate: Developed vs. Developing Countries

While emissions are released locally, the impact of climate change has a global effect. Researchers agree that poorer, developing countries will endure more severe and detrimental impacts of climate change than wealthier, developed countries. Additionally, low-lying island countries and mountainous populations will continue to face threats of displacement due to rising sea levels and a loss of snow and ice caps, respectively. Furthermore, poorer countries are not able to restore disrupted resources such as water and food supplies, energy infrastructure, and transportation systems damaged during extreme weather events as quickly or efficiently as developed countries (Wilbanks et.al,

13

2007). This disparity has created a dispute between developed and developing countries over how and to what level emissions should be reduced by individual countries. The United Nations Framework Convention on Climate Change (UNFCC) became effective in 1994 to provide a framework for international negotiations on global climate change and efforts to stabilize global greenhouse gas emissions. Since international emission reduction negotiations began, agreements between developed and developing countries have been difficult. International climate negations initially only involved developed countries and urged voluntary actions towards reducing emissions, of which most countries failed to make any changes. As countries recognized a need for further action, the Kyoto Protocol was created in 1997 and for the first time involved developing countries within international climate negotiations. However, only developed countries, referred to as Annex I countries, agreed to binding emission reduction targets during the period from 1997 to 2012. Developing countries successfully argued that they were not responsible for a large percentage of past global carbon emissions and should not be burdened with the same binding targets. However, this logic does not hold true today. While developed countries such as the United States and China are still the greatest emitters of greenhouse gases, Figure 2.1 on the next page shows that developing countries are projected to account for the greatest increase in emissions in the future and in 2010, accounted for 60 percent of greenhouse gas emissions (Bodansky, 2010). Thus, the role of developing countries in regards to greenhouse gas emissions has changed dramatically since the Kyoto Protocol.

Figure 2.1: Absolute Emissions: Developed vs. Developing Countries (1990-2012)[13]
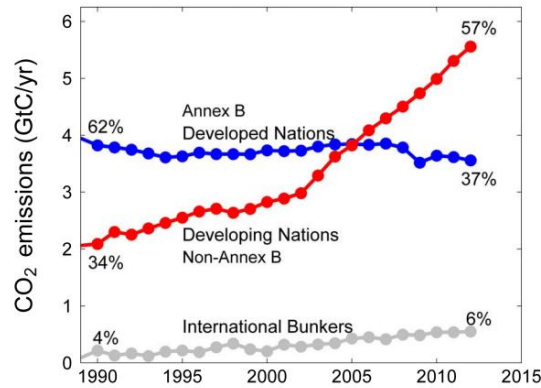
Source: The Global Carbon Project, 2013

Further, Figure 2.2 demonstrates that 58 percent of global carbon emissions can be attributed to four entities: (1) China, (2) United States, (3) the European Union, and (4) India.

Figure 2.2: Cumulative Emissions from Fossil Fuels and Cement (1870-2012)
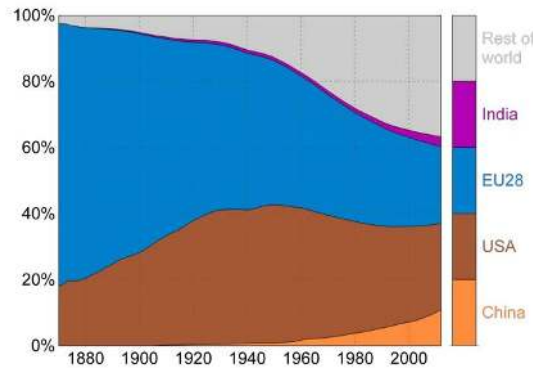
Source: The Global Carbon Project, 2013

Finally, Figure 2.3 illustrates the trends of the top four emitters in per capita terms since 1880, further showing the growing role of developing countries as carbon emitters.

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[13] Annex B countries refer to industrialized countries and Non-Annex B countries refer to developing countries. Annex B countries were associated with the first commitment period under the Kyoto Protocol. International bunkers refer to emissions attributed to fuels used for international aviation and shipping.

Figure 2.3: Per Capita Emissions: USA, China, EU28, India, and World
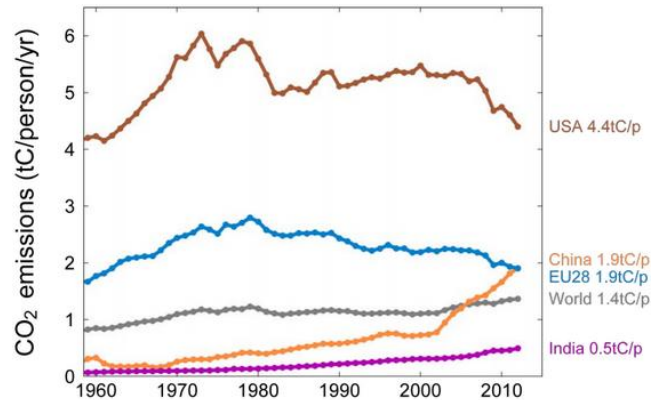
Source: The Global Carbon Project, 2013

Although it is clear that developing countries are playing a greater role in generating carbon emissions, many developing countries argue that curbing emissions will significantly weaken their development efforts. To aid in climate mitigation efforts, developing countries are demanding financial assistance and the transfer of technology from developed countries to reach international emission reduction goals as compensation for developed countries' past emissions and degradation of the global climate system.

2.3.1 Recent International Climate Negotiations

When the Kyoto Protocol expired in 2012, the world was left without any emission reduction targets for both developed and developing countries. The U.N. Climate Change Conference met in Copenhagen in 2009 to reach a new international climate treaty outlining new emission reduction targets for both developing and developed countries. The meeting failed to produce a new climate agreement and simply produced the "Copenhagen Accord," which urged nations to submit emission reduction plans and to continue the targets of the Kyoto Protocol to 2020. The conference agreed

on a target of limiting the global average temperature increase to no more than two degrees Celsius above pre-industrial levels (Bodansky, 2010). However, the resulting actions from the Copenhagen Accord were disappointing, as only 32 countries submitted emission reduction plans. In addition, the 2013 Emissions Gap Report, completed annually by the United Nations Environmental Programme, warned that current emission reduction targets would fall short of the 2020 emission reduction goal from the continuation of the Kyoto Protocol. By failing to meet the targets and by continuing to widen the emissions gap, the report cautioned that a least-cost pathway to climate stabilization may no longer be attainable, and rather, costlier and riskier methods will have to be undertaken to stabilize emissions.

The most recent international negotiations of United Nations Framework Convention on Climate Change took place in Warsaw, Poland in November 2013 to begin planning for an updated international climate agreement scheduled for 2015. The dispute between developed and developing countries continued, as developing countries campaigned for promises of climate aid from developed countries to compensate for 'loss and damage' from climate change impacts. After hours of emotional discussions, the conference agreed on a timeline to finalize a global climate treaty at a meeting in Paris in 2015 and to enforce the treaty by 2020 (Harvey, 2013). However, the longstanding issues between developed and developing countries continued to remain at the forefront of negotiations.

2.4   Climate Policy Approaches

Multiple climate policy approaches have been debated to address global climate change. The debate often focuses on whether climate policies are both economically and politically feasible in a specific country, region, or internationally. This section will begin by discussing the role of discount rates within climate policy. Additionally, this section will discuss three prominent policy tools that frequently enter the climate policy debate: (1) sustainable technology; (2) carbon taxation; and (3) cap and trade programs.

2.4.1   Discount Rates

From a neoclassical economic perspective, the impacts of climate change can be viewed as a market failure requiring government intervention. Removed from political interference, government intervention would seek to internalize the negative externalities and force market agents to address the environmental costs borne by society (Harris and Roach, 2009). However, in addition to large political pressures, traditional economic valuation tools are failing to accurately depict the level of government intervention needed to address climate change. Specifically, a disparity exists between long-term environmental goals and short-term economic gain. The choice of the discount rate used in economic models and cost-benefit analyses has a large determinant effect on policy choices and proposals (Ackerman, 2007; Dietz, Hepburn, and Stern, 2008). Often, the future is de-valued due to the use of a high discount rate. Some economists support the discount rate used in the Stern Review, averaging 1.4 percent or a near zero discount rate. Ackerman (2007) argues that due to the long-term, complex nature of climate change, a discount rate of greater than 3.5 percent removes justification for climate policy action in

the present period, as costs outweigh the predicted benefits. Furthermore, economists

advocating for a low discount rate also provide an ethical argument, citing the need for

intergenerational equality. In contrast, Nordhaus (2007) argues that the discount rate

used for climate change analysis should follow the real return on capital at approximately

6 percent. Commonly used discount rates (between 5-10%) reduce the severity and risk

of long-term damages indicating that a decision towards minimal government

intervention within the present period would be the most efficient choice. However, there

is no scientific rule specifying a discount rate for climate policy, and different discount

rates can provide a very different indication of what climate policy should be adopted.

2.4.2 Sustainable Technology

The impact of human activities on the environment has been characterized using

the IPAT equation, an equation of environmental impact resulting from the interaction

between three variables: total population (P), income per person or affluence (A), and the

level of technology (T) (Chertow, 2001).[14] When first developed, the use of the equation

was intended to isolate the variables that were most environmentally damaging. Thus,

technology was initially viewed as an input to environmental degradation. However, the

role of technology as a detrimental input to environmental impact began to be debated.

Economists began to revise their initial position of viewing technology as negative

mechanism towards a beneficial mechanism that can reverse and reduce environmental

impacts. Thus, a shift occurred in which the technology term in the IPAT equation was

now believed to be able to offset the negative impacts associated with population and

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[14] In the 1970s, economists Ehrlich and Holden introduced the IPAT equation I = P x A x T to quantify
environmental impact, while highlighting multiple factors that contribute to unsustainability.

affluence (Chertow, 2001). Sachs (2008) agreed by stating that, historically, the role of technology has been a detriment to environmental impact explaining, "When T is high, the kind of technology being used imposes a high environmental burden" (p. 29). To overcome the detrimental burden of technology on the environment, Sachs claims that the technology term can and must be changed to 'S,' defined as sustainable technology. Sustainable technology will allow for increased prosperity and lower environmental impacts (Sachs, 2008). Through sustainable technology, environmental impact, theoretically, could become positive. Therefore, Sachs emphasizes the essential role of public policy to elevate the utilization of sustainable technologies to create behavioral change that relies less on consumption and more on coexistence within planetary bounds. Under this approach, public policy must intervene to align profit-maximizing interests of today with the interests of future generations that currently are unrepresented in the market (Sachs, 2008, p. 40). Therefore, energy efficiency technology can be viewed as a form of sustainable technology that would take the form of the 'S' term in the newly termed, "IPAS" equation.

In contrast, other policymakers and economists claim that green technology will fail to create a lower environmental impact. Rather, some economists state that increases in energy efficiency technology will further stimulate economic growth, which concurrently creates an increase in energy consumption.   As a result, some economists advocate for 'degrowth economics,' which refers to a shift away from the capitalist goal of perpetual economic expansion to qualitative goals focused on measures of well-being and quality of life.   Economists supporting this theory declare that a complete shift away

20

from the capitalist economic system must occur because market forces, alone, will not create the behavioral change needed to alter perceptions of economic growth and to promote sustainable technologies (Foster, 2011). However, while economic degrowth, also referred to as a steady-state economy, has been offered as a solution to the global environmental crisis, such a transition would be an insurmountable feat.

2.4.3   Carbon Tax

One method of government intervention is the adoption of a carbon tax. A carbon tax aligns with mainstream economic theory by intending to include environmental costs into the market equilibrium price. A tax would be placed on each ton (or per-unit) of carbon emitted by a firm with a goal of raising the price of the produced commodity and decreasing demand. Thus, the negative externality associated with carbon emissions would be internalized to ensure that the market price of carbon is socially optimal (Harris and Roach, 2009). The effect of the tax policy will depend on the elasticity of the market for fossil fuels. Economic studies have estimated the short-term elasticity of the fossil fuel market to be approximately -0.25 such that a 10 percent increase in the price of a fossil fuel commodity would result in a 2.5 percent decrease in demand. Other studies have calculated the long-term elasticity to be -0.64 such that an increase in the price of a fossil fuel, such as gasoline, by 48 cents would decrease demand by 10 percent (Harris and Roach, 2009, p. 24). However, carbon taxes tend to be regressive and disproportionately affect low-income populations. Therefore, climate scientist and activist, James Hansen (2009) advocates for a carbon tax and dividend. This policy redistributes the revenue gained from the carbon tax to the public on a per capita basis.

Therefore, households with low consumption, theoretically, could gain income as the dividend would exceed the tax. The dividend would offer a public incentive to reduce carbon-intensive energy use, while providing the cash flow to offset the tax and would provide income intended to finance the transition towards purchasing products that are less-carbon intensive (Hansen, 2009). However, those opposed of a carbon tax cite the inherent difficulties when attempting to monetize the price of carbon to calculate an efficient amount of taxation that accurately reflects the social costs of carbon emissions (Leggett, 2011). As a result, a carbon tax has been politically less appealing. Thus, while a carbon tax could provide an economically efficient outcome, it is often eliminated from climate policy discussions due to political reasons.

2.4.4 Cap and Trade Program

An alternative policy option is to create a market for carbon through a cap and trade program. A cap and trade program sets an initial cap on carbon emissions, and firms can trade carbon permits. Emissions are viewed as commodities, bought and sold within a market that sets the prices of the emissions. This market mechanism offers greater flexibility within individual emission reductions by firms as long as emissions do not exceed the overall cap (Leggett, 2011). While some proponents of cap and trade emphasize that its flexibility increases efficiency and equity, others, such as climate scientist James Hansen (2009), argue that cap and trade programs are disguised as "tax and trade." Hansen argues that cap and trade programs fail to decrease emission levels enough, skew towards special interests, and are susceptible to price volatility and speculation. Moreover, Schiller, et al. (2008) argue that cap and trade programs

22

incentivize an emission level equal or right below the overall cap. This behavior results

from the economic incentive to sell unused emission allowances for other sources to emit.

In the context of energy efficiency, cap and trade programs are counterintuitive. By

reducing energy consumption levels and energy intensity, energy efficiency programs

simultaneously increase a firm's unused emissions allowances that can be sold for a

profit. As such, the overall cap must be carefully determined, and may also fall victim to

inherent inaccuracy.

Efforts to create a national cap and trade program within the United States have

failed in Congress. In contrast, the European Union has successfully implemented a cap

and trade program, named the EU Emissions Trading System (EU ETS). The program

began in 2005 and operates within 28 EU countries as well as in Iceland, Liechtenstein,

and Norway (European Commission, 2013a). The program covers approximately 45

percent of the EU's greenhouse gas emissions, but the program has been criticized for

releasing too many permits, and thus, the carbon prices are too low. While most likely

aided by the economic downturn, the EU has experienced an absolute reduction to its

carbon emissions (Plumer, 2013). Furthermore, a cap and trade program has been the

only climate policy discussed during international climate negotiations; implementing a

carbon tax has never been discussed internationally. The EU proposes that an

international carbon trading market is feasible through a bottom-up approach of linking

multiple, smaller emissions trading systems such as those in Australia, Japan, New

Zealand (European Commission, 2013b).

2.5 Conclusion

While climate science provides compelling evidence to support aggressive climate mitigation strategies, economic approaches used to analyze climate change policy responses frequently are plagued by political interference. The denial of such a global crisis through climate policy inaction puts the global economy, citizens, and future generations at risk and represents a large failure of the public sector.   Broad political and international support will be essential to implement aggressive climate policy actions. To effectively respond to global climate change, policies must incentivize large reductions in carbon dioxide emissions and must promote the transition towards renewable energy generation.

CHAPTER THREE: ENERGY EFFICIENCY AS A CLIMATE MITIGATION STRATEGY

3.1   Introduction

Addressing climate change is a multi-faceted issue that requires a greater reliance on renewable energy resources, but also requires reduced energy consumption and increased energy efficiency to support the transition toward a low-carbon future. Proponents of energy efficiency believe it is an effective mechanism to lower carbon emissions and alleviate natural resource pressures associated with energy use. Most often, energy efficiency targets one main contributor to climate change: the electricity sector. Electricity use and electric power generation account for the largest single source of both energy use and carbon emissions (IEA, 2013).   As a component of the absolute reduction in energy use, energy efficiency policies also eliminate unnecessary energy waste. Defined as the energy efficiency gap, economists and policy analysts have identified that a substantial amount of energy waste exists and could be eliminated using current technologies proven to be cost-effective (Howarth and Andersson, 1993).

Energy waste most often occurs in wealthy, developed countries, such as the United States. In contrast, developing countries are referred to as 'energy poor' for three reasons: (1) average per capita energy consumption is low, between one-fifth and one-twentieth of developed countries; (2) only portions of populations have access to energy services; and (3) the costs of energy services are too high for large portions of the

population relative to other needs (Banuri, 2009). Rather than eliminating energy waste, developing countries should transition inefficient processes into more efficient processes using available technologies to realize large gains in efficiency.

Pacala and Socolow (2004) argue that humanity possesses the technology, knowledge, and tools to solve the climate and carbon crisis in the next half-century. By implementing a portfolio of existing strategies, countries could slow the trajectory of atmospheric carbon dioxide emissions and remain within planetary boundaries. Pacala and Socolow refer to these actions and the resulting effect as 'stabilization wedges' within the 'stabilization triangle.' Each wedge represents a policy or activity that can successfully reduces greenhouse gas emissions from fossil fuels. Figure 3.1 below shows how widespread adoption of energy efficiency policies and actions could eliminate the predicted growth of fossil fuel emissions. Pacala and Socolow emphasize that addressing climate change involves a choice between action or delay rather than being stalled by technological barriers that do not exist.

Figure 3.1: Stabilization Triangle
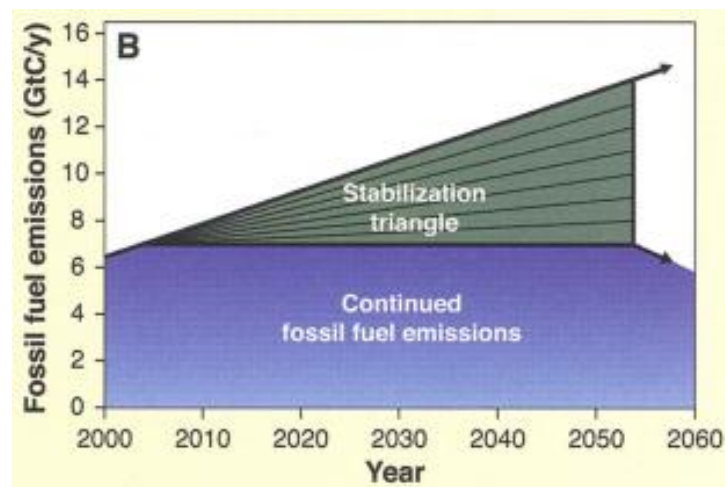
Source: Pacala and Socolow, 2004, p. 969

In addition, the UNFCCC emphasizes that energy efficiency is a low-cost climate mitigation strategy and an essential component to achieving global climate stabilization and sustainable development. Leading up to the UNFCCC's Copenhagen climate negotiations, the *Natural Resources Forum*— A *United Nations Sustainable Development Journal* published a special issue urging members of the UNFCCC to adopt an agreement focusing on four programme areas that would promote "an ambitious, science-based, and equitable agreement to address climate change" (Banuri, 2009, p.257). One of the four programme areas included: "A global technical assistance programme in energy efficiency" (p. 257). In the past, energy efficiency was viewed as a beneficial strategy to achieve energy productivity growth and energy reduction goals. However, energy efficiency recently has emerged as a vital component towards achieving global climate stabilization.

Section 2 explores the theoretical foundations of energy efficiency to analyze how energy efficiency affects energy consumption and carbon emissions associated with energy use. Section 3 discusses the positive benefits associated with energy efficiency, and Section 4 provides a critique of these opportunities. While energy efficiency is often heralded for producing numerous positive benefits, some economists critique that this view is overstated. Therefore, this chapter examines the different viewpoints in economic literature debating the legitimacy of energy efficiency as an effective mechanism to achieve climate stabilization.

3.2 Theoretical Foundation

A microeconomic analysis of energy efficiency and energy savings involves multiple parameters such as energy services, energy consumption, technology, and behaviors. Gillingham, Newell, and Palmer (2009) note that, on a micro scale, energy must be discussed as an input into desired energy services such as lighting, heating, or motion. Additionally, energy efficiency should also be thought of as a characteristic of a product bundle, similar to attributes such as product cost. Further, energy consumption, while also an important variable, can be viewed as exogenous from changes in energy efficiency. For example, short-run reductions in energy use typically account for changes in energy consumption, while long-run changes can include improvements to energy efficiency due to technological advancement (Gillingham, Newell, and Palmer, 2009). To account for both energy efficiency and energy consumption, Oikonomou et al. (2009) introduced a basic model analyzing the combined effect of energy efficiency and conservation actions. The model begins with the following equation, which shows that energy services are a function of energy consumption:

(1)　$Q_s = f(Q_e)$;　Q_s = energy services, Q_e = final consumption of energy

In equation (1), existing technology, behavior, and physical setting determine the final consumption of energy.

To view energy consumption as a function of energy services, Oikonomou et al. (2009) refers to equation (2) and (3):

(2)　$Q_e = f^{-1}(Q_s)$

(3) $Q_e = \beta Q_s$ where β is a technological parameter associated with the conversion of

energy efficient technologies. (Oikonomou et al. assume linearity)

Equation (3) examines the effect of energy efficient technology on the provision of

energy services. However, the model is incomplete as it only addresses energy efficient

technology and fails to acknowledge the effects of human behavior on final energy

consumption. To add in an exogenous term to represent human behavior, Oikonomou et

al. (2009) add the variable, v, in equation 4.

(4) $Q_e = \beta Q_s + v$; v = exogenous variable representing human behavior and

organizational processes

This model expresses final energy consumption as dependent upon both technological

parameters and social behaviors. Thus, to affect energy consumption, attention must be

placed on both variables. Energy consumption is typically addressed through term v, and

energy efficiency is typically addressed through term β. Public policies often target

term v by attempting to incentivize energy efficient behaviors. Additionally, term β can

be affected by new investments in energy efficient technology, which can also account

for subsequent gains in energy efficient technologies. These gains would be captured

endogenously through the model (Oikonomou, 2009). Further, this model indicates that

both market conditions and behavioral decisions will affect final energy consumption.

Gillingham, Newell, and Palmer (2009) also discuss the role of investment

decisions within energy efficiency by describing the balance between high capital costs

and lower operating costs. Individual consumers make energy efficiency investment

decisions by weighing capital costs against expected benefits or future savings. When

attempting to make a rational decision, Gillingham, Newell, and Palmer cite that

consumers form expectations by estimating variable costs such as future energy prices,

operating costs, equipment lifetime, and future cash flows.   Through a production

function, Figure 3.2 and Figure 3.3 show the relationship of capital and energy as inputs

within the provision of energy services. The isoquants represent the different

combinations of energy and capital inputs that create the same level of energy services

output. The straight lines represent isocost lines, which denote the combinations of

capital and energy inputs that equate to the same expenditures or same budget constraint.

The optimal decision lies at the point of tangency when marginal increases in capital

costs and associated energy reduction is equal to the relative price.

Figure 3.2: Substitution Effect   **Figure 3.3:** Technological Advancement
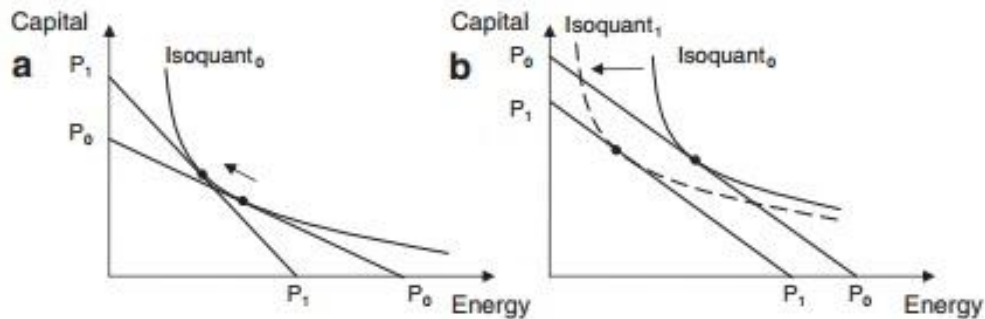
Source: Gillingham, Newell, and Palmer, 2009, p.5

Figure 3.2 demonstrates the substitution effect between capital and energy by moving

along the energy-services isoquant and moving from the relative price of P_0 to P_1 in

which energy is substituted for a greater reliance on capital. The new equilibrium point

represents the same level of production of energy services, but also depicts a higher

relative price of energy when compared to the relative price of capital. Therefore, the

substitution effect indicates that a greater reliance on capital and a lower reliance on

energy can produce the same output. Figure 3.3 demonstrates a shift due to technological

change in which the isoquant shifts left, depicting a gain in energy efficiency and a lower

need for energy services. The isocost line also shifts left, meaning a reduction in total

expenditures. The new equilibrium point demonstrates an absolute decrease in the

production of energy services. Thus, market forces can drive changes in energy

efficiency in multiple ways. However, this theoretical framework assumes perfect

competition and does not consider market failures and barriers that may distort consumer

decisions.

Theories supporting energy efficiency are not new, but were first discussed

prominently beginning in the 1970s. Prompted by the oil shock, Lovins' (1976)

landmark article, "Energy Strategy: The Road Not Taken," advocated for a serious

commitment toward energy efficiency. Lovins argued that, in theory, long-term, technical

fixes could improve the United States' energy efficiency by a factor of at least three to

four. In the early 1990s, Howarth and Andersson (1993) and Grubb (1990) argued that

the transition to achieve an optimal level of energy efficiency is a two-step system.

Figure 3.4 depicts a simple supply and demand diagram, in which the curve 'S'

represents the marginal private cost of producing energy and the curve 'D' represents the

marginal private benefit of purchasing energy. Howarth and Andersson (1993) state that

energy prices must include social costs by internalizing negative externalities, such as

pollution. Thus, the effect of a pricing policy is represented by the curve 'S*,' which

now represents the marginal social cost of energy. Howarth and Andesson state that

public policies must also address market failures and barriers within the energy industry. The effect of public policies removing the market barriers for consumers is displayed using curve 'D*,' which represents the marginal social benefit. Therefore, the new equilibrium point, 'E*', represents the socially efficient allocation of energy, in which a lower quantity would be demanded and the price of energy would be higher.

Figure 3.4: Two-Step System to Achieve Optimal Energy Efficiency
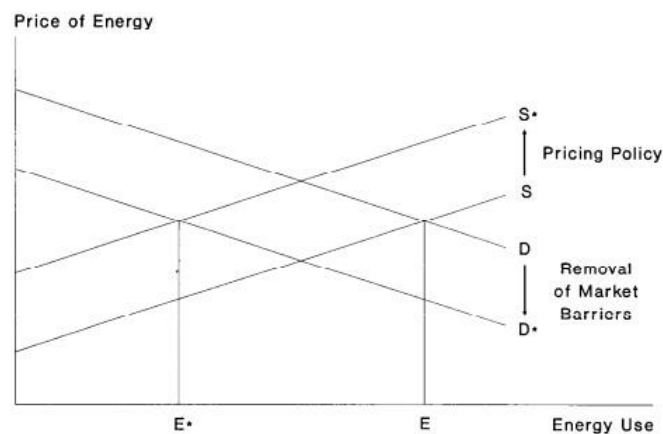
Source: Howarth and Andersson, 1993, p. 263

To achieve a socially optimal level of energy use, both processes must be implemented simultaneously.   However, the interaction of market barriers and consumer behavior has stimulated considerable debate in regards to how well the theories discussed in the beginning of this chapter translate into empirical results. Thus, the next two sections of this chapter will explore the two sides of the debate within economic literature.

3.3   Opportunities and Benefits Associated with Improved Energy Efficiency

As global climate change continues to become a rising concern in the global economy, many countries have implemented public policies to incentivize both investments and behaviors that reduce energy consumption. Energy efficiency has been

popularly nicknamed, 'the fifth fuel,' due to its ability to save energy at cheaper costs than producing energy from coal, oil, natural gas, or uranium, and continues to be an attractive, bipartisan policy mechanism, especially in the United States (The Economist, 2008). This section will discuss the current literature supporting the role of energy efficiency as a climate mitigation strategy by discussing the following positive benefits: (1) substantial potential exists to eliminate energy waste and reduce energy consumption; (2) energy efficiency is a low-cost resource relative to other forms of energy generation; (2) energy efficiency offers multiple secondary benefits; and (4) public policies have been effective at stimulating investments in energy efficiency and incentivizing behaviors that reduce energy consumption.

3.3.1 Energy Efficiency Gap

Proponents of government intervention to promote energy efficiency believe that an energy efficiency gap exists within energy markets in which energy is over-consumed. Additionally, the diffusion of energy efficiency products, technologies, and behaviors has occurred at a sluggish pace, resulting in a gap between energy use and energy efficiency opportunities that are financially beneficial to both producers and consumers. Thus, the "energy efficiency gap," as it is popularly named, indicates that market-driven energy use is consumed beyond a socially efficient level. Consumers could realize cost-effective savings by investing in energy efficiency equipment, which would delay higher costs associated with new generation of energy supplies (Golove and Eto, 1996).

Golove and Eto (1996) suggest that the energy efficiency gap occurs for two primary reasons: (1) high implicit discount rates of consumers prevent investments in

energy efficiency, and (2) energy is mispriced due to regulatory or pricing failures that do not consider negative externalities. To close the gap, several studies indicate that increased investments and public policies could exploit the unused energy efficiency potential. Eichhammer et al. (2009) estimate that by 2020 the EU27 could realize a 15 percent reduction in energy by using a low policy intensity scenario, a 22 percent reduction by using a high policy intensity scenario, and a 29 percent reduction by using the technical potentials currently available, but at a more expensive cost.[15] In the United States, researchers estimate that investments in energy efficiency could yield gross energy savings of $1.2 trillion and could reduce end-use energy consumption by 23 percent of projected demand (9.1 quadrillion Btus) (McKinsey, 2009). Thus, proponents suggest that public policies creating incentives for greater energy efficiency can help close the energy efficiency gap by correcting the multitude of market barriers and failures to achieve the positive gains associated with energy efficiency that are attainable with existing technologies.

3.3.2 Low-Cost Resource

When analyzing the costs of generating new energy supplies, energy efficiency can yield substantial amounts of additional energy supply through saved energy at a low cost. When comparing energy efficiency to other forms of electricity generation, Laitner et al. (2012) found that energy efficiency investments cost between 3 to 5 cents per saved kWh, while the next low-cost alternative, wind energy, costs between 8 to 11 cents per

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[15] Eichhammer et al. (2009) define the low policy scenario as "continued high barriers to energy efficiency, a low policy effort to overcome the barriers and high discount rates for investments in energy efficiency". A high policy scenario is defined as "removing barriers to energy efficiency, a high policy effort to overcome the barriers and low discount rates for investments" (p. 8).

produced kWh. Eto et al. (2000) analyzed 40 of the largest energy efficiency programs

implemented by utilities in the United States and found that programs saved energy at an

average cost of 3.2 cents/kWh.   Eto et al. also estimated that direct, avoided costs by the

utility resulting from the energy savings exhibited a benefit-cost ratio of 3:1. Friedrich et

al. (2009) analyzed the energy efficiency programs in 14 states within the United States

found costs of saved energy ranging from 1.6 to 3.3 cents/kWh and an average cost of 2.5

cents/kWh.   As shown in Figure 3.5, new electricity supply from conventional sources

cost between 7.0 to 14.0 cents per kWh. Therefore, energy efficiency reduces the

economic burden associated with climate stabilization due to its low cost relative to other

energy resources (National Action Plan for Energy Efficiency, 2009).

Figure 3.5: Electricity Generation Cost Estimates
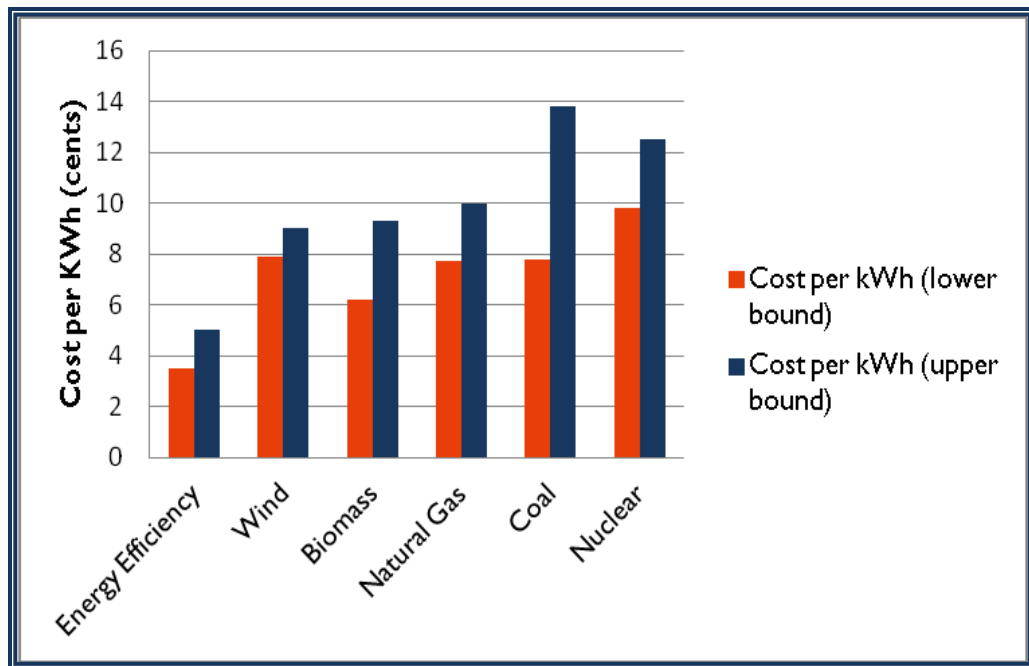
Source: Data from Laitner, et al., 2012

While conventional energy prices are notoriously volatile, prices associated with energy efficiency tends to be more stable in the short- and long-term. This is because energy efficiency investments realize benefits at a more rapid pace than the generation of new energy supplies (National Action Plan for Energy Efficiency, 2009). Due to the cost-effectiveness and low-cost of energy efficiency investments relative to the generation of additional energy supplies, proponents believe that energy efficiency investments should be optimized before expensive capital investments to increase energy supply are initiated.

3.3.3 Secondary Benefits

Energy efficiency investments also create significant secondary benefits that impact economies on a macroeconomic scale. Secondary impacts, also referred to as positive externalities, include job creation, reduced energy-related public expenditures, increased energy security, and macroeconomic effects, such as increased GDP (International Energy Agency, 2013). Analyzing Great Britain's energy efficiency policies using an input-output model, Barker and Foxon (2007), found that between 2005 and 2010 Great Britain's GDP rose 10 percent due to indirect effects related to energy efficiency programs and policies. By increasing the disposable income of consumers, energy efficiency investments created a multiplier effect, spurring both job creation and consumer spending.

According to the International Energy Agency (2007) estimates, energy efficiency can stabilize energy prices, promote development, and support social goals in addition to reducing global greenhouse gas emissions. As energy services become more efficient,

standards of living can increase without proportional increases to energy-related

emissions, also referred to as "green growth". However, energy efficiency projects must

become more attractive to investors. In 2011, the global economy spent $260 billion in

investments toward clean energy, but only seven percent were investments in energy

efficiency (Holmes and Mohanty, 2012). Thus, Holmes and Mohanty (2012) suggest that

governments should initiate energy efficiency projects and supplement costs to facilitate

private investments.

3.3.4   Effectiveness of Demand-Side Management Policies

Studies indicate that policies promoting energy efficiency have been successful at

lowering energy consumption and energy intensity.[16]   World Bank researchers, Stuggins,

Sharabaroff, and Semikolenova (2013), found that the energy intensity of Central Asia

(ECA) and the EU-15 was reduced by 32 percent between 1990 and 2007. The

reductions in energy intensity primarily were attributed to structural reforms promoting

energy efficiency, such as removing energy subsidies and thus, removing perverse

incentives related to low energy prices. In 2005, the Chinese government announced a

goal to reduced energy intensity by 20 percent by 2010 (Zhou, Levine, & Price, 2010).

Due to aggressive energy efficiency policies focusing on pricing, information, and

regulations, the Chinese government was close to its goal and set higher standards for its

next five-year plan from 2011-2016. In the United States, appliance standards have

saved consumers approximately $30 billion dollars between 1987 through 2000, and

since 2007, the federal Energy Star standards and labeling program has saved 1,790

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[16] Energy intensity refers to total energy consumption per dollar of GDP.

trillion Btus (McKinsey, 2009).[17] Also in the United States, Horowitz (2004) analyzed

commercial sector electricity intensity in 42 states to model the effect of energy

efficiency programs. The results from the fixed effects panel model indicated that energy

efficiency programs reduced the rate of growth in electricity sales from 1989 to 2001 by

approximately 11 percent. Resulting from past success and projections of future success,

many countries continue to set goals to reduce energy intensity and to rely on energy

efficiency as a main source of energy into the future.

3.4   Critiques of Energy Efficiency

Proponents of energy efficiency claim that such policies have successfully

reduced energy consumption and carbon emissions. However, critiques of energy

efficiency cite that a rebound effect occurs in which energy efficiency policies are

counterproductive. As a result, the role of energy efficiency as an effective climate

policy tool continues to be debated. While many economists agree that energy

consumption is associated with economic growth, the causal relationship is debated: Is

energy consumption a direct cause of economic growth or is economic growth a direct

cause of increased energy consumption? (Sorrell, 2009). A third argument suggests that

there is no link between the two. Thus, this section will examine the critiques of energy

efficiency policies by discussing the rebound effect and the perspectives on economic

growth.

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[17] EnergyStar is a federal program run by the U.S. Environmental Protection Agency that aims to reduce
energy consumption through a voluntary labeling program of energy efficiency products and buildings. For
more information refer to www.Energstar.gov.

3.4.1 Rebound Effect

The Jevons Paradox, created by William Stanley Jevons in 1865, first introduced the concept of the rebound effect predicting that gains in energy efficiency ultimately lead to increased energy consumption. Since its introduction, many economists have been debating whether the rebound effect negates the positive impacts of energy savings predicted to result from energy efficiency improvements. Within a neoclassical economic framework, technological change should shift the supply curve outward resulting in a lower the price of the product and an increase in the quantity demanded (Madlener and Alcott, 2009). In other words, improvements in energy efficiency should reduce the marginal cost for a product; thus, the demand and consumption for that product would be expected to increase (Sorrell, 2009). While this concept is often defined as the direct rebound effect, indirect rebound effects may occur on a macro level or within secondary markets. Sorrell (2009) discusses five additional indirect rebound effects associated with increases in energy efficiency:

(1) *Embodied energy effects:* Energy used to install or manufacture new energy efficiency technologies will offset a portion of the energy saved by the new technology;

(2) *Re-spending effects:* Monetary savings resulting from energy efficiency actions or investments will be re-spent by consumers on other products that also consume energy and will offset the initial energy efficiency savings;

(3) *Output effects:* Producers will use energy savings to invest in more capital, labor, and materials to increase output. As a result, the price of the commodity

produced may decrease, and thus, the demand for the commodity may rise. Both

result in increased energy use;

(4) Energy market effects: Large-scale reductions in energy demand resulting from

energy efficiency improvements may result in lower energy prices, thereby

increasing real income and stimulating increased energy demand and

consumption;

(5) Composition effects: As energy efficiency improvements stimulate a reduction in

energy prices, the price of energy-intensive products will be lowered and will

become more available to consumers, stimulating demand for these products.

Based on these considerations, energy efficiency clearly creates both an income and

substitution effect. Van Den Bergh (2011) explains the rebound effect by distinguishing

two sequential consequences of energy efficiency improvements: (1) technical-

engineering improvements result in energy savings; and (2) energy savings motivate

behavioral and economic responses, which often lead to increased energy consumption.

Due to both direct and indirect influences, Madlener and Alcott (2009) suggest that

energy efficiency policies may be excellent strategies to stimulate economic growth and

affluence, but may not achieve the intended outcomes of environmental or climate policy

goals.

While many economists agree that a rebound effect exists, the magnitude of the

rebound effect is widely disputed. The rebound effect is measured as the percentage of

energy savings countered by an increase in energy consumption associated with either an

income or substitution effect (Madlener and Alcott, 2009). Empirical studies estimate a

wide range of rebound effects between 0 to over 100 percent. Modeling the rebound

effect relies on multiple assumptions, different modeling techniques, and differing data

sets. Thus, the wide variation amongst results fuels a continued debate.

Evidence also indicates that the rebound effect may be larger in developing

countries, which are in the process of development and may be rapidly accumulating and

consuming energy-intensive technologies (Van Den Bergh, 2011). Historical analysis of

early advances in energy efficiency in now developed countries suggest that energy

efficiency in the early stages of development led to an economic expansion and a more

widespread use of energy-using technologies among households. For example, the

introduction of the fluorescent light bulb in Great Britain caused per capita consumption

of lighting to increase at a much faster rate than per capita GDP (Sorrell, 2009).   Many

historical examples of energy efficiency indicated that it spurred widespread diffusion of

other technologies. Two prominent examples are the introduction of the steam engine

and the Bessemer steel production process. Increases in the efficiency of the steam

engine led to greater production and transportation of coal, which further led widespread

increases in productivity. Increases in the efficiency of steel making through the low-

cost, Bessemer process created positive feedback loops that spurred the creation of a

railway network, and thus, stimulated additional demand for more steel (Sorrell, 2009).

These examples illustrate how early efficiency gains in once energy-intensive processes

stimulated further innovations, economic growth, and increased energy consumption

during the process of development.

3.4.2 Perspectives on Economic Growth

From a neoclassical perspective, energy is a minor factor affecting economic growth due to its low cost of production relative other costs, such as capital and labor. Additionally, energy can alternately be viewed as a sub-sector of capital (Stern, 2011). Gains in energy efficiency are also labeled as technological progress and thus, could be labor-augmenting or capital-augmenting (Saunders, 1992). Greening et al. (2000) caution that within the constant elasticity of substitution production function, the impact of improvements in energy efficiency depends on the elasticity of substitution between energy and other factors inputs. Agreeing with both Solow and Saunders, Greening et al. states that if the elasticity of substitution is less than one, energy efficiency improvements can still result in lower energy consumption.

Ecological economists interpret economic growth theory differently than neoclassical economists. Ecological economists believe that the quality of energy inputs can significantly affect economic growth. According to this viewpoint, improvements in energy quality have stimulated technological change, and subsequently, economic productivity and growth. High-quality energy sources have been a necessary component within historical rises in economic output and productivity. In addition, the ecological perspective assumes that capital, labor, and energy inputs are interdependent and have multiplicative effects rather than being independent and additive as neoclassical theory suggests (Sorrell, 2009). Using a Cobb-Douglas production function, Saunders (1992) offers two reasons why energy consumption increases due to gains in energy efficiency: (1) the effective price of energy is decreased and capital becomes a substitute for labor,

and (2) technical progress increases economic growth, and increases overall energy consumption. Thus, ecological economists suggest that there is a direct correlation between quality-adjusted energy use and economic output. Therefore, high-quality energy sources could significantly stimulate economic growth and potentially negate some of the benefits associated with energy efficiency.

3.5 Conclusion

While numerous benefits associated with energy efficiency motivate the discussion of using energy efficiency as an effective tool within broader climate strategies, critics suggest that the optimism related to the potential benefits of energy efficiency may be over-estimated. Critics of energy efficiency policies are concerned that the impact of the rebound effect may be greater than unity meaning that government investments or subsidies devoted toward energy efficiency improvements may be counterproductive to achieving climate policy goals. As a result, energy efficiency policies must also focus on incentives to promote energy conservation in order to limit the size of the rebound effect. Thus, the unintended consequences of energy efficiency should be carefully analyzed, and the resulting rebound effect should be considered when devising energy efficiency policies that are intended to be a component of broader climate and environmental policy goals. The policy implications of energy efficiency and the opposing views of mainstream and ecological economists will be discussed in further detail in Chapter 5.

CHAPTER FOUR: CLIMATE AND ENERGY EFFICIENCY POLICY IN THE UNITED STATES

4.1 Introduction

As the world's second largest emitter of carbon dioxide in absolute terms and the largest emitter in per capita terms, the United States is a crucial component to the success of global climate stabilization (The World Bank, 2014). The United States consumes more energy in per capita terms than China, India, and the European Union. In 2012, the United States consumed approximately 95.7 quadrillion British thermal units (Btus) in total energy use. In 2012, total worldwide energy consumption was approximately 540 quadrillion Btus, meaning the U.S. consumed approximately 18 percent of the world's energy consumption (EIA, 2012a). Further, in 2011, an average person in the United States consumed 312 million Btus compared to the world average of 74 million Btus (EIA, 2013a). Additionally, fossil fuels such as oil, natural gas, and coal are the primary energy resources used in the United States, meaning large quantities of carbon emissions are released into the atmosphere largely related to its energy consumption. In 2011, the United States released 17 percent of world's energy-related carbon dioxide emissions (EIA, 2012a). As such, the world places significant attention on United States to act as a leader towards climate change mitigation due to its very high-energy consumption and associated carbon emissions.

Since Kyoto to the present, United States' public policy has failed to enact large-scale solutions to address climate change. The climate policy debate began in the United States in 1992 with the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) by 187 countries, including ratification by the United States. However, in 1997, the Kyoto Protocol was not signed by the United States citing that the emission reduction targets would harm the U.S. economy. Currently, the United States remains the only developed country in the world that has not ratified the Kyoto Protocol. In addition to failing to sign the Kyoto Protocol, the lack of climate legislation in the United States further delayed global climate treaties during the 2009 Copenhagen climate conference and has stalled recent climate negotiations. Developing countries are unwilling to agree to binding emission reduction targets until the United States demonstrates leadership and action within its domestic climate policy goals. However, the United States is hesitant to commit to significant emission reductions goals, until other large emitters, such as China, also commit to significant and binding emission targets (Hovi, et al., 2013).   Due to these demands by the United States and developing countries, international climate negotiations remain deadlocked.

This chapter evaluates the role of energy efficiency within United States climate policymaking. Section two presents the current level of energy consumption in the United States and projections of future trends. Section three examines former and current energy efficiency policies in the United States to discuss how these policies have contributed to broader energy and climate policy goals. Section four discusses the past and present challenges occurring in the United States in its attempt (or lack of attempt) to

enact far-reaching climate policies, such as a carbon tax or a national cap and trade

program. To conclude, section five examines the current evidence surrounding the

decoupling of energy use and economic growth in the United States.

4.2   Current Energy Consumption in the United States and Future Trends

According to the U.S. Energy Information Administration (EIA) (2013b), the

major energy resources consumed in the United States are petroleum (oil), natural gas,

coal, nuclear, and renewable energy. As shown in Figure 4.1, fossil fuels represent 82

percent of energy resources consumed in the United States.

Figure 4.1: Primary Energy Use by Source, 2012

Nuclear Electric Power 9%
Renewable Energy 9%
Petroleum 37%
Coal 18%
Natural Gas 27%
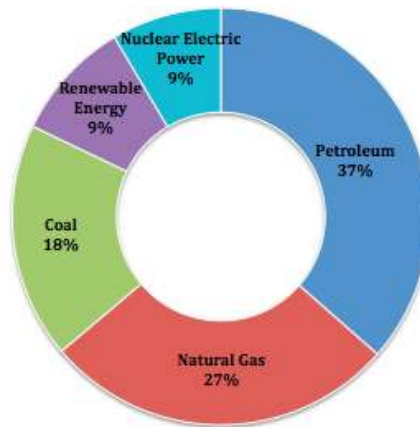
Source: U.S. Energy Information Administration, 2012b

Energy consumption of these resources can be categorized as primary energy

consumption or total energy consumption. Primary energy consumption refers to the

consumption of energy resources before any transformative process. Total energy

consumption refers to how energy resources are used following any transformative

process by each end-use sector.

Figure 4.2: Primary Energy Consumption, 2012
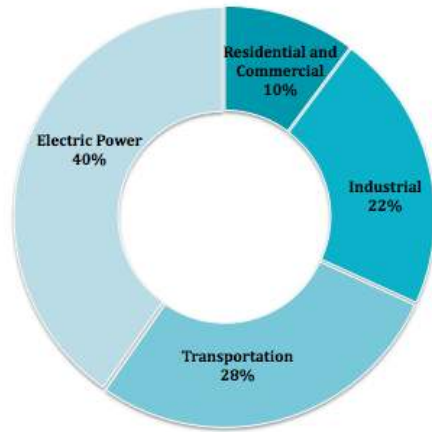
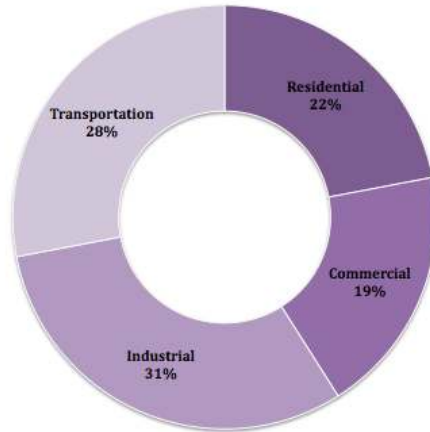
Figure 4.3: Total Energy Consumption by End-Use Sector, 2011

Source: U.S. Energy Information Administration, 2012b

Source: U.S. Energy Information Administration, 2012b

As shown in Figure 4.2, 40 percent of energy consumed in the United States is used to produce electricity. Among end-use sectors, industrial energy users consume 31 percent of energy, followed by the residential, transportation, and commercial sectors.

As shown in Figures 4.4 and 4.5, primary and total greenhouse gas emissions can be attributed to a similar mix of sectors as primary and total energy consumption. In 2009, the United States' energy sector released 98 percent of carbon dioxide emissions (EIA, 2014). As shown in the Figure 4.4, electricity production accounts for the greatest percentage of primary greenhouse gas emissions. Approximately 70 percent of electricity is generated through the combustion of fossil fuels, which is a significant driver of greenhouse gas emissions associated with electricity production. (EPA, 2013).

Figure 4.4: Primary Greenhouse Gas Emissions, 2011

Figure 4.5: Total Greenhouse Gas Emissions by End-Use Sector, 2009
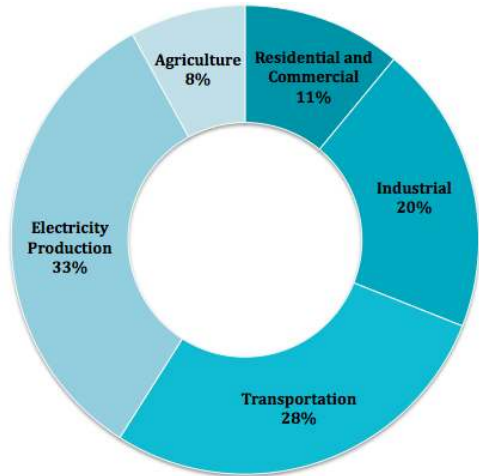
Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011
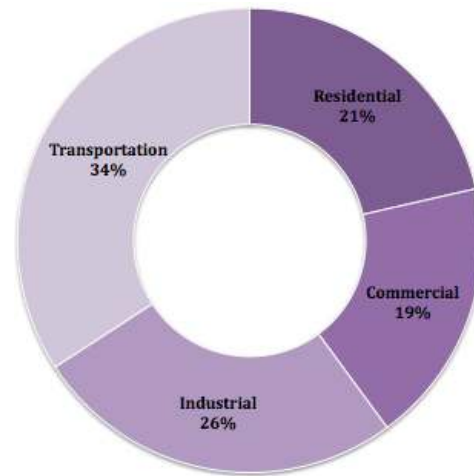
Source: U.S. Energy Information Administration, Emissions of Greenhouse Gases in the U.S., 2009

Because electricity production accounts for the greatest primary source of energy use and greenhouse gas emissions, the data indicate that efficiency and conservation within the energy sector could significantly reduce greenhouse gas emissions.

The United States has experienced a steady increase in total energy consumption. Additionally, the Congressional Research Service found that electricity use has increased at a faster rate than total energy use. While total United States energy consumption had increased over three times since 1950, total electricity power generation has increased almost ten times from the amount generated in 1950 to 2010 (Behrens and Glover, 2011). Figure 4.6 shows both the increase in electricity generation as well as the historical change in the source of electricity generation over time. Coal continues to be the dominant resource used to produce electricity. However, 2010 data indicate that the percentage of electricity generated by coal may be declining as electricity generated by

nuclear, natural gas, and renewable energy resources increase. Additionally, the EIA

estimates that electricity generated by coal will decline by 7.9 percent in 2040 due to the

retirement of coal-fired power plants and an increased reliance on natural gas and

renewables (EIA, 2014).

Figure 4.6: U.S. Electricity Generation by Source: 1950-2010
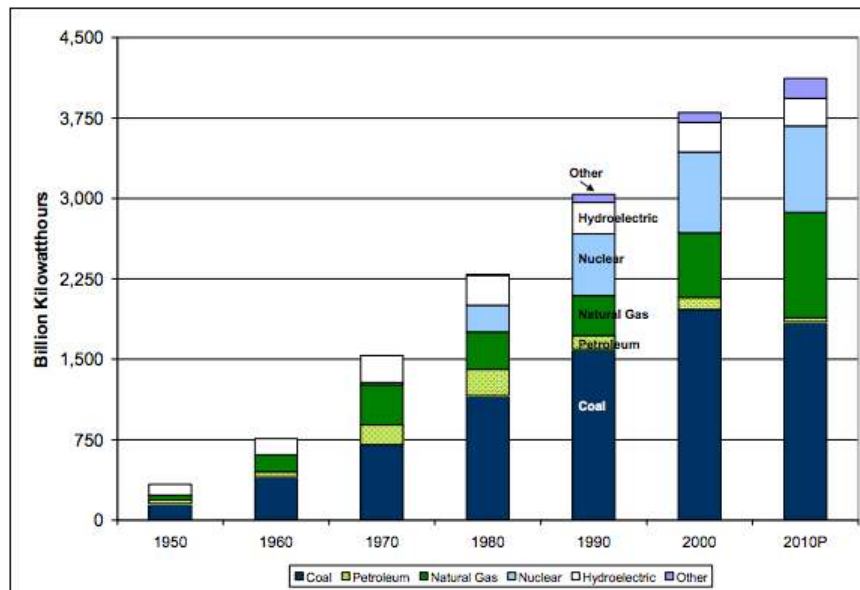
Source: Behrens and Glover, 2011, p. 19

The United States' extremely high energy consumption and associated

greenhouse gas emissions can be associated with its social culture of consumerism. This

claim prompted Bin and Dowlatabadi (2005) to model how consumer activities affect

energy use and environmental impacts. By creating an input-output model using

consumer expenditure data, the authors estimated the total energy use and greenhouse gas

emissions associated with consumer activities in the United States. Using their model

called the "Consumer Lifestyle Approach", Bin and Dowlatabadi (2005) found that

through direct and indirect sources, over 80 percent of energy use and carbon dioxide

emissions in the United States could be attributed to consumer demand for products or

services. Aligning with this perspective, the Brookings Institute refers to the United

States as an "always-on" digital economy in which consumers demand a reliable power

supply at all times. This new paradigm has elevated the demand for a resilient power

source that is immune to power outages and electric grid failures (Ebinger and Banks,

2013). As a result, public policies attempting to curb energy consumption and increase

energy efficiency must address the underlying social standard of consumerism that

creates excessive energy consumption.   However, this raises the question—if

consumption in the United States were to decrease, what would become an alternative

engine of economic growth in the United States?

While total energy use and electricity generation has continued to rise, energy use

per capita has begun to level off in the United States. Figure 4.7 and 4.8 compare total

U.S. energy consumption and total U.S. energy consumption per capita from 1949 to

2012.

Figure 4.7: Energy Consumption, 1949-2011   **Figure 4.8:** Energy Consumption per Capita,
1949-2011
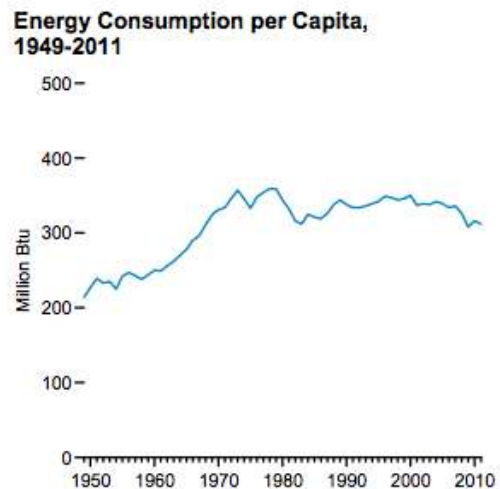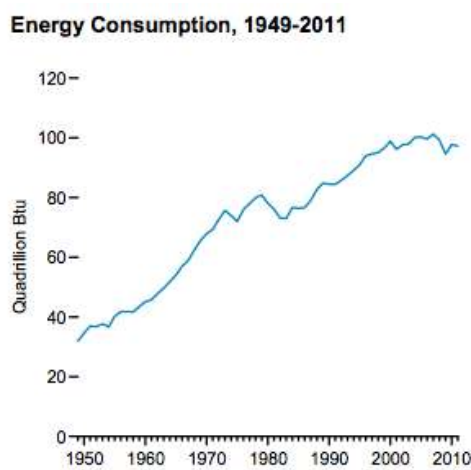
Source: Energy Information Administration, 2012b

50

The EIA projects a decline in average energy use per capita from 2011 to 2040. The

projected decline is largely due to gains in energy efficiency, a corresponding decline in

energy intensity, and a movement away from energy-intensive industries (EIA, 2014). [18]

However, during this same time period, the number of households is projected to increase

by 32 percent and total residential square footage is projected to increase by 41 percent.

The EIA concludes that gains in energy efficiency will likely offset the increases in

energy demand related to population gains and larger building infrastructure. Without

the expected gains in energy efficiency, the projections of energy use, both in absolute

and per capita terms, could be higher.

4.3   Energy Efficiency Policy in the United States

The role of energy efficiency policy has changed over time, but has remained an

essential component within United States energy policy. Laitner, et al. (2012) found that

advancements in energy efficient technologies have allowed the United States to absorb

additional energy demands associated with population growth and economic expansion.

Since 1970, the United States economy has tripled, and as a result, the demand for energy

has continued to rise. However, over 75 percent of the energy demand projected in 1970s

for the current period was absorbed through advances in energy efficiency rather than

through additional energy supplies (Laitner, et al., 2012). Many economists predict that

energy efficiency will continue to play a growing role in coping with additional economic

expansion and population growth.

Energy efficiency policies are implemented within different levels of government

in the United States varying between the federal, state, and local governments. Federal

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[18] Energy intensity is defined as energy use per dollar of GDP.

energy efficiency policies typically consist of broad, uniform efficiency standards, while

state and local policies are tailored toward the individual needs of the state or local

community. To describe the role of energy efficiency policy in the United States, this

section will discuss past and current energy efficiency policy beginning with its

introduction in the 1970s.

The 1970's oil crisis shattered the United States' notion of cheap, abundant

energy. As a result, the United States designed energy policies to cope with the oil

depletion, which at the time seemed imminent. The oil crisis spurred bi-partisan energy

policy focused on conservation and renewable resources, and consumers responded by

reducing energy consumption levels. In the 1970s, energy data indicate that a significant

change occurred within United States energy consumption patterns. Since 1973, the

United States has observed almost a 50 percent reduction in energy intensity, and during

the same time period, carbon emissions decelerated from a growth rate of 4.5 percent to a

current growth rate of 0.4 percent per year (Ross, 2013). Many economists and historians

believe that without the oil crisis, United States' energy consumption levels would have

accelerated and exacerbated current environmental problems.

Spurred by the oil crisis, Congress enacted the National Energy Act in 1978,

which included the Public Utilities Regulatory Policies Act (PURPA) and the National

Energy Conservation Policy Act (NECPA). PURPA was designed to enhance efficiency

and renewable energy generation within electricity generation. PURPA required state

Public Utility Commissions to consider energy efficiency programs when setting

electricity prices, which stimulated the rise of demand-side management energy

efficiency programs implemented by utilities (Gillingham, Newell, and Palmer, 2004). Since 1978, utilities have been spending an increasing amount on demand-side management programs, focusing on the promotion of energy efficiency as well as energy conservation (Arimura et al., 2012). However, spending on energy efficiency programs by utilities peaked in the mid-1990s as state Public Utilities Commissions began to restructure the utility industry. Restructuring allowed for increased competition within the electricity production industry. As a result, spending on energy efficiency programs began to decline as utility companies reduced discretionary costs due to competitive pressures (Arimura, et al., 2012). Following this decline, energy efficiency spending by utilities has resurged in the United States since the late 2000s, as these programs are now viewed as a cost-effective solution to generate additional energy supplies and reduce carbon dioxide emissions (Laitner, et al., 2012).

NECPA created mandatory, federal energy efficiency appliance standards. Since NECPA, continued federal legislation such as the Energy Policy Act of 1992, the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 have updated federal energy efficiency standards (ASE, 2013). Gold et al. (2011) analyzed savings resulting from appliance standards created or updated by the Energy Policy Act of 1992, the Energy Policy Act of 2005, and the Energy Independence and Security Act of 2007 and found that appliance standards have lowered United States energy consumption by 3.6 percent in 2010. The most recent energy policy act was included within the American Recovery and Reinvestment Act of 2009 of the federal stimulus package.

ARRA invested $25 billion for energy efficiency grants, rebates, and other state-level energy programs (ASE, 2013).

Examples of energy efficiency policies implemented at the state and local level include building code standards, public benefit funds, and energy efficiency resource standards. The State of California is well known for its leadership in regards to energy efficiency polices, especially within its building and appliance standards. California was the first state to adopt energy efficiency appliance standards in 1974 and continues to adopt stringent energy efficiency standards above federal levels (Tonn and Peretz, 2007). Due to its progressive energy efficiency policy, California has experienced impressive energy reduction results. As shown in Figure 4.9, while per capita electricity consumption continued to increase in the United States, California's remained flat since the 1970s.

Figure 4.9: Per Capita Electricity Consumption: 1960-2011
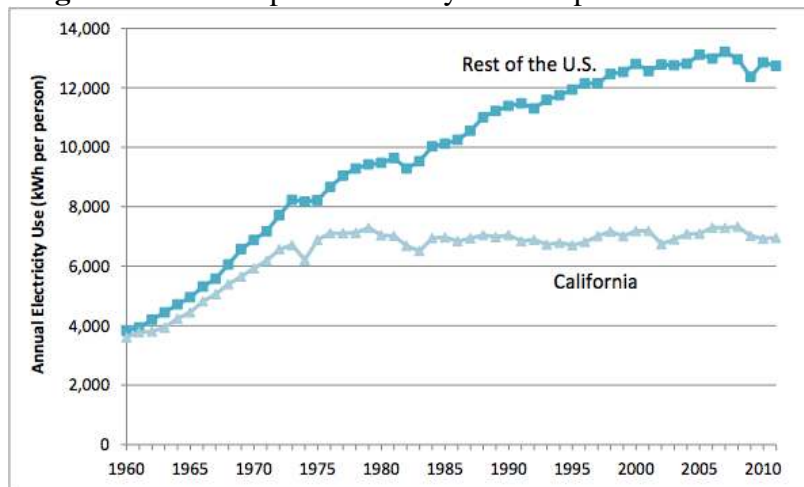
Source: Cooley, et al., 2013, p. 3

Other states, such as New York and Massachusetts, also have recognized the importance of energy efficiency policies and are beginning to see similar results. Each year, the

54

American Council for an Energy-Efficient Economy (ACEEE) compiles a State Energy

Efficiency Scorecard Ranking, which ranks states based on their policy and program

efforts related to energy efficiency.[19] Figure 4.10 below graphs per capita energy use for

the top five states ranked for their energy efficiency policy and the lowest five ranked

states.[20] Not surprisingly, the top ranked states for energy efficiency policies also have

lower per capita energy consumption levels relative to both the lowest ranked states and

total U.S. energy consumption per capita. The comparison indicates that states with

higher energy consumption per capita could potentially lower this measurement by

investing in additional energy efficiency policies.[21]

Figure 4.10: 2011 per Capita Energy Consumption
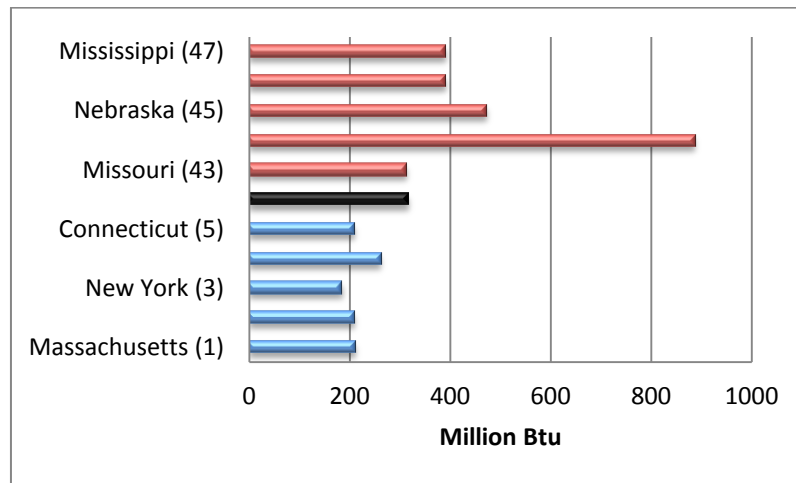
Source: Author's processing of EIA data, 2013c

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[19] Specifically, the scorecard analyzes six policy areas: (1): utility and public benefit policy programs; (2) transportation policies; (3) buildings energy codes and compliance; (4) combined heat and power policies; (5) appliance and equipment standards; (6) state government-led initiatives.

[20] Some states were eliminated due to low populations.

[21] This comparison does not consider differences in climate or household size.

In addition to building and appliance standards, states also have developed funding streams and long-term energy efficiency goals. As of 2012, 21 states and the District of Columbia have developed public benefit funds to publicly finance energy efficiency programs.[22] Typically, the states levy a small surcharge on resident electricity consumption to be deposited into the fund. States are using these funds to invest in energy efficiency and renewable energy generation.   The fund levels vary by state from approximately $1 million in Pennsylvania to over $400 million in California (DSIRE, 2012). In addition to creating revenue streams, as of July 2013, 23 states have adopted Energy Efficiency Resource Standards (EERS). The standards identify long-term goals for energy savings by utility or non-utility energy efficiency programs. According to an analysis by the American Council for an Energy-Efficient Economy (2013), the United States could save an equivalent to 6.3 percent of electricity sales in 2011 if each state reaches its energy efficiency target by 2020.

Local governments and cities also play a role in energy efficiency policy. Most often, cities target building codes to encourage a greater level of energy efficiency above the federal or state standards. For example, the mayors of ten major cities announced in January 2014 their participation in the City Energy Project to increase energy efficiency within its building infrastructure.[23] According to the Project, this effort could cumulatively reduce greenhouse gas emissions to an equivalent of removing 1.5 billion

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[22] Some public benefit funds are operated at the municipal level. For example, the State of Colorado does not have a statewide public benefit fund, but the City of Boulder collects an excise tax from electricity customers.

[23] The cities include Atlanta, Boston, Chicago, Denver, Houston, Kansas City, Los Angeles, Orlando, Philadelphia, and Salt Lake City.

passenger vehicles or taking three to four power plants offline (NRDC, 2014). Rather than targeting energy reduction goals, the program specifically targets climate policy goals of reducing greenhouse gas emissions, further indicating that energy efficiency policies are increasing being viewed as a mechanism to achieve climate policy goals.

4.4 Climate Policy Challenges: The State of the Debate in the United States

Broadly, the United States climate policy debate consists of two primary arguments: an insurance approach consisting of robust regulations and taxes, and a technocratic approach consisting of limited government intervention, also known as a 'research and wait-and-see method' (Leggett, 2011). Within an insurance approach, climate change is viewed as a national threat. While the probability of cataclysmic climate change is uncertain and may be unlikely, the potential damage could cause extremely large amounts of destruction and financial costs. Essentially, an insurance approach reduces the risk of such losses, while understanding the high uncertainty of the risks (Leggett, 2011). In contrast, some decision-makers (and arguably United States' climate change policy thus far) advocate for additional research until more certain results emerge. Proponents of the 'wait-and-see' policy approach view immediate mitigation action as preemptive and believe that resources will be more efficiently spent when climate science becomes more conclusive and technology continues to advance. Aligning with the technocratic approach, Nordhaus (2007) recommends a "climate policy ramp" in which modest actions are taken in the short-term, and actions increase in the medium- and long-terms. Nordhaus bases his rationale on the productivity of tangible, technological, and human capital in the short-term. According to this approach, capital

should be utilized for research and development of low-carbon technologies because this investment would yield the highest return in the present period. Nordhaus states that increasing climate mitigation is only efficient when damages associated with climate change rise relative to the return on investment of capital (Nordhaus, 2007).

While the Intergovernmental Panel on Climate Change (IPPC) reports that climate change is unequivocal and is directly a result of human interference, the United States government has not reached a consensus regarding an appropriate climate policy response and has yet to enact comprehensive climate policies, such as a carbon tax or a national cap and trade emissions program. Rather, United States climate policy is best known for regulations and standards to address climate change (Leggett, 2011). These policies target specific sectors of greenhouse gas emissions. When examined individually, these policies, alone, may not significantly reduce total greenhouse gas emissions. Such policies incrementally reduce greenhouse gas emissions through source-by-source regulations by addressing specific sources of emissions, such as air pollution (Leggett, 2011). Many policy analysts criticize United States climate policy, accusing the United States of exhausting all alternatives until crisis moves policy toward long-term solutions (Bodansky, 2010). In 2009, the House of Representatives passed the American Clean Energy and Security Act, which proposed a nationwide cap and trade program. However, the bill never reached the Senate floor due to a lack of votes, and thus, ultimately, did not become law (The Library of Congress, 2009). The current partisan gridlock in Congress further stalls federal climate policy legislation, making policies such as enacting a carbon tax or cap and trade program politically unattainable, as these

policies are labeled extreme and burdensome by the private sector. As a result,

comprehensive climate policy reform has been under the purview of individual states or

regulatory agencies, such as the Environmental Protection Agency. To achieve progress

within climate policy reform, President Obama and Congress have identified energy

efficiency as a politically feasible mechanism to address the global climate change.

President Obama further elevated energy efficiency in his February 2013 State of the

Union address when he announced the Administration's goal to eliminate energy waste

by doubling energy productivity by 2030 (The White House, Office of Press Secretary,

2013). Since this announcement, interest in energy efficiency as a climate mitigation

strategy has gained national attention.

4.5   Current Efforts to Decouple Energy Use and Economic Growth

After announcing the Obama Administration's goal of doubling United States

energy productivity by 2030, the Alliance Commission on National Energy Efficiency

Policy, comprised of United States legislators, private sector representatives, and research

experts, was formed to determine the policy efforts needed to achieve this goal. The

Commission narrowed the effort to three main policies: (1) increased financial

investments; (2) increased modernization of infrastructure and regulations; and (3)

increased education to engage consumers, workers, and governments leaders in an effort

to become more energy efficient (ASE, 2014). Specifically, the Commission estimated

that households, businesses, federal, state and local governments would need to invest

$166 billion per year in energy efficient improvements associated with buildings,

vehicles, industrial equipment, and transportation systems. While the investment appears

substantial, the effort is predicted to create total net benefits of $327 billion by 2030

(Rhodium Group, 2013). Most importantly, the Commission indicates that if energy

productivity doubled by 2030, economic growth and energy demand would continue to

decouple. Evidence suggests that energy may already be decoupling from economic

growth. The BP Annual Energy 2035 (2014) released the data represented in Figure 4.11

and found that world energy consumption is growing less rapidly than the world GDP.

Figure 4.11: Energy Decoupling Projections
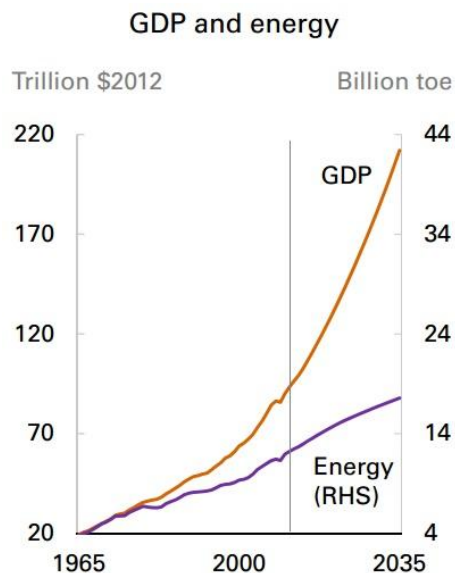
Source: BP, 2014

Before discussing decoupling in further detail, it is important to distinguish

between relative and absolute decoupling. Relative decoupling, in the context of energy

use, implies a reduction in the amount of energy needed per unit of GDP, as shown in

Figure 4.11. However, this does not imply that total energy use is decreasing, which is

referred to as absolute decoupling. Jackson (2009) describes the distinction between

relative and absolute decoupling by stating, "Impacts may still increase, but do so at a

slower pace than growth in GDP" (p. 48). Figure 4.11 shows clear evidence of relative

decoupling in the global economy, mostly driven by a reduction in energy intensity in

developed, OECD countries. However, the global economy is not demonstrating

evidence of absolute decoupling. For example, while the energy use per unit of GDP is

declining, absolute carbon emissions related to energy use continue to rise. Therefore,

Jackson and other economists argue that climate stabilization cannot occur until absolute

decoupling is achieved. In order to achieve both absolute decoupling, technological

efficiencies must improve at a faster rate than economic growth, which would be

unachievable under current business-as-usual scenarios (Jackson, 2009). Current trends,

such as increasing global carbon emissions, are not indicating that the global economy is

close to achieving absolute decoupling.

Some researchers caution that relying on the gains in relative decoupling as a

solution to climate change may be too optimistic based on the observation that economies

are still very dependent on energy to achieve economic growth. Stern (2010) notes that

financial economists faithfully study the relationship between oil prices and economic

growth in the United States due to the historical correlation between oil prices and

economic stability. Multiple economists cite the pattern of increased oil prices followed

by recessions, high inflation, and lower economic growth in the United States (Hamilton,

1983; Heinburg, 2011). Similarly, a 2014 Oxford report indicated that volatile oil prices

currently act as a barrier to economic growth and stability. The report projects that this

barrier to economic growth will only worsen as unconventional oil supplies are depleted

(King, et al., 2014).

To explain the evidence of decoupling in the United States, some economists believe that the United States economy shifted to higher quality energy resources rather than simply decreasing energy intensity. Under this perspective, energy resources are not equal substitutes because some resources achieve greater productivity gains than other resources (Stern, 2010). Stern (2004) defines energy quality as "the relative economic usefulness per heat equivalent unit of different fuels and electricity" (p. 25). As an example of the differing productivity levels of energy resources, Stern (2010) notes that while electricity can power computers, other energy resources such as coal or oil cannot directly power a computer and contribute to the same productivity levels.[24] To account for energy quality and differences in productivity, economists weight each energy resource by its average price. As shown in Figure 4.12 on the following page, when energy use is adjusted for energy quality, the evidence of energy decoupling is less compelling, and United States' energy use correlates with economic growth to a greater degree.[25]

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[24] While coal and oil and other energy resources are used to produce electricity, electricity is viewed as a stand-alone fuel. For example, coal, alone, cannot power a computer, but the generation of electricity from coal or other energy resources creates a new, end-use fuel.

[25] The broader policy implications of this perspective will be discussed in further detail in Chapter 5 of this thesis.

Figure 4.12: U.S. Energy Decoupling with Quality Adjusted Energy Use

Source: Heinburg, 2011, p.167

Therefore, Stern (2010) argues that decoupling in the United States was largely driven by a structural shift toward the reliance on higher quality energy resources. However, if the United States continued to be successful in decoupling energy use and economic growth, energy use and economic growth would diverge, and the current trajectory of energy use and associated greenhouse gas emissions could flatten or even decrease. As a result, the gap between GDP and primary energy in Figure 4.12 would continue to widen.

4.6   Conclusion

While the United States has failed to enact comprehensive climate policies, the United States' increasing reliance on energy efficiency policy may be valuable first step toward achieving climate policy goals. As discussed in this chapter, evidence suggests that United States energy use per capita is expected to decline and could decline further if energy efficiency efforts are strengthened. However, the United States' reliance on energy efficiency as a prominent climate policy tool may not send a strong enough message to developing countries waiting to see the United States demonstrate leadership

within its climate policy platform. Additionally, energy efficiency policy as the main

climate policy mechanism in the United States may not achieve large enough reductions

in emissions to achieve United States' climate policy goals. In 2009, the United States'

committed to achieve a 17 percent reduction in greenhouse gas emissions compared to

2005 levels by 2020. In President Obama's current climate action plan, the

Administration aims to achieve a 3 billion metric tons cumulative reduction in carbon

pollution by 2030; over half of the carbon pollution produced by the U.S. energy industry

annually (The White House, Executive Office of the President, 2013). Therefore,

implementing a comprehensive climate policy, such as a carbon tax, may still be the most

efficient policy option to achieve the broader policy outcome of global climate

stabilization. In regards to comprehensive climate tools, a carbon tax is likely to be a

more effective policy tool than cap and trade program. Specifically, Hansen (2009)

argues that a carbon tax and dividend offers a transparent and simple policy approach that

can target the entire economy and increase the price of energy. As the price of energy

increases, the market will influence decisions toward energy efficiency behaviors,

investments, and innovations. In contrast, cap and trade programs often fall to political

pressures and loopholes. Ideally, the United States would adopt a carbon tax and

dividend, which would also increase the effectiveness of energy efficiency policies.

CHAPTER FIVE: POLICY IMPLICATIONS

5.1   Introduction

Ultimately, the relationship between energy use and economic growth will determine the success of energy efficiency policies. Mainstream economists and ecological economists disagree on the role energy plays in economic growth, and consequently have different perspectives on whether energy efficiency policies can successfully reduce energy use and carbon emissions. The mainstream perspective views energy as a subsector of capital, and therefore, energy resources can be substituted equally by either different energy resources or by other forms of capital. Under this economic perspective, energy is not a primary input influencing economic growth. In contrast, ecological economists view energy as a main input affecting economic growth. As such, ecological economists suggest that limits to substitution exist between other energy resources and other forms of capital. Therefore, mainstream and ecological economists have different ideas of how energy efficiency policies may affect economic growth.

By claiming that energy is not a main factor affecting economic growth, the mainstream perspective believes energy can be decoupled from economic growth, and thus, energy efficiency policies can lower energy use, without impacting economic growth. In contrast, by stating that energy is a main factor affecting economic growth, the ecological perspective believes energy cannot be completely decoupled from

economic growth, and therefore, energy efficiency policies cannot lower energy use without affecting economic growth. However, ecological economists state that the potential impact on economic growth may not entirely negate energy efficiency actions.

While ecological economists believe that energy use and economic growth are very much intertwined, ecological economists also highlight that energy resources differ in quality. As mentioned in Chapter 4, when weighted by average price, energy resources appear to differ in their ability to affect productivity or total GDP. As such, energy quality becomes an important variable affecting economic growth.   Historical evidence suggests that as countries develop and per capita incomes rise, countries exhibit a similar pattern as they shift their primary energy inputs overtime. Specifically, evidence indicates that countries transition from lower to higher quality energy resources as economies develop. Therefore, this chapter also explores the policy implications related to energy transition patterns during economic development.

To examine the policy implications of energy efficiency and climate policy, section two examines the mainstream economic perspective on the relationship between energy and economic growth, and the policy implications for energy efficiency. Section three examines the ecological critique of the mainstream perspective, and the policy implications resulting from the ecological perspective. Section four discusses the energy transition of developing countries, and the role of energy efficiency policy during this transition. Section five discusses different energy efficiency policy options proposed by international organizations and adopted by countries around the world. Finally, section

six discusses future research opportunities surrounding the policy implications of energy efficiency and its role in climate policy.

5.2   Mainstream Economics Perspective

Mainstream economists rely on economic models that operate in a closed system solely focused on capital and labor for production, and firms and consumers for exchange (Ockwell, 2008). In the closed system model, energy and natural resources are not directly included as primary inputs. Rather, energy and natural resources are viewed as intermediary inputs to capital and labor. [26] As an example, energy is considered an intermediate input, similar to a raw material, which is used up completely during the production process of capital (Stern and Cleveland, 2004). As a result, energy and natural resources play a relatively minor role in economic growth and act as an intermediate input within mainstream economic growth models.

As a result, mainstream economic growth models do not view energy and natural resources as main drivers of economic growth. Rather, mainstream economic growth theories focus on the relationship between capital accumulation and output. Solow's basic model of economic growth assumes that a hypothetical economy produces output through manufactured capital, which depreciates overtime.[27] As capital depreciates, it is replaced using savings from the population. However, the theory concludes that diminishing returns to capital will eventually place the economy in a stationary state. To perpetuate

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[26] Natural resources sometimes are included within extensions of mainstream economic models. For example, the broader circular flow model includes both the source and sink of natural resources. The broader circular flow model also includes the interaction of the water cycle, carbon cycle, nitrogen cycle, and organic cycle, and the flow of pollution from firms to households.

[27] Labor is assumed to be constant.

economic growth, Solow's growth model relies on exogenous technological progress to counter diminishing returns to capital (Stern, 2011; Stern and Cleveland, 2004). More recent mainstream models of economic growth view technology as endogenous. In this model, economic growth continues into perpetuity because diminishing returns to capital are offset by technological progress, thereby exhibiting increasing returns.

In regards to finite natural capital, mainstream economic growth models assume that natural capital can be equally substituted by man-made capital to perpetuate economic growth (Ockwell, 2008). Therefore, mainstream growth models believe that the barriers of overcoming nonrenewable resource depletion are institutional rather than ecological. For example, government and market structures must assure that man-made capital replaces natural capital at an appropriate rate that would not impede continued economic growth (Stern, 2011). This assumption of substitution allows for continued economic growth, while accounting for the existence of nonrenewable resources.

Under this perspective, energy efficiency is viewed as a technological advancement that could effectively reduce the amount of energy needed per unit of GDP (Sorrell and Ockwell, 2010). Therefore, energy efficiency functions as a successful technological solution to control increasing energy demand and associated carbon emissions. Simply, the substitution of man-made capital and technological change can effectively eliminate ecological limitations to economic growth. Because energy is not directly tied to economic growth, the mainstream perspective believes decoupling of energy and economic growth is feasible and is already occurring. As such, mainstream economists advocate for the widespread deployment and development of energy efficient

68

technologies to lower energy use and carbon emissions. In sum, this perspective views energy efficiency policies as an effective climate policy tool that does not interfere with economic growth.

5.3 Ecological Economics Perspective

In contrast to the mainstream perspective, ecological economists believe that energy is a main driver of economic growth. The ecological perspective is based on the laws of nature, and specifically, the laws of thermodynamics. For example, the second law of thermodynamics states that energy is required for any transformation of materials or matter (Stern, 2003). This corresponds to economic growth by indicating that all economic activity is derived from capital and labor's use of energy (Ockwell, 2008). Under this perspective, both capital and labor require energy to be produced and to function, respectively. Thus, capital and labor are intermediate inputs to economic growth, while energy is considered the primary input (Sorrell and Ockwell, 2010; Stern, 2011). For this reason, ecological economists view energy and economic growth as a coupled interaction.

As natural resources become depleted, mainstream economists believe the economy will manufacture additional man-made capital to substitute as an equivalent production input to natural energy resources. However, ecological economists note that additional energy resources will be required in this manufacturing process and point to this contradiction as an example of the ecological limits to substitution between man-made capital and finite natural resources. Stern (2011) states, "Producing more of the 'substitute' for energy—manufactured capital—requires more of the things that it is

supposed to substitute for" (p. 33). Moreover, ecological economists believe that man-made capital cannot equivalently substitute for natural resources. As an example, ecological economists are not convinced that man-made alternatives exist to substitute for certain natural resource systems, such as the climate and weather system, clean water supplies, and clean air supplies (Ockwell, 2008). In sum, ecological economists believe that mainstream economic growth models undervalue the role of energy in economic growth and that energy and economic growth are much more intertwined than what mainstream economists believe.

Because ecological economists view energy as a main driver of economic growth, this viewpoint suggests that energy use cannot be lowered without simultaneously affecting economic growth. Due to the global economy's reliance on fossil fuels, energy emissions cannot significantly decline without affecting economic growth until the economy shifts to low-carbon energy resources. As such, Ockwell (2008) advocates that policy efforts should focus on decarbonizing energy resources. This does not negate the role of energy efficiency as an effective climate policy tool because energy efficiency technologies can help aid in the transition to decarbonize the economy. However, Sorrell and Ockwell (2010) emphasize that the rebound effect, which could stimulate increased energy consumption, should be considered and included within climate policy models. To eliminate large rebound effects, Ockwell suggests promoting energy efficient technologies that target dedicated purposes, such as thermal insulation.

5.4   Energy Quality and the Energy Transition of Developing Countries

Ecological economists also believe that energy resources differ in quality. This section discusses the importance of energy quality and the historical trends related to the energy transition as countries switch from lower quality to higher quality primary energy inputs.   This transition may create detrimental impacts to the global climate as the trends suggest that developing countries may increase their reliance on fossil fuels rather than low-carbon energy resources. This section also discusses the role of energy efficiency within the energy transition of developing countries.

Ecological economists suggest that gains in economic growth within the last century were partly a result of a greater reliance on high-quality energy resources (Sorrell and Ockwell, 2010). Through an econometric analysis, Burke (2013) found that countries' energy mix shifts from lower quality energy resources to higher quality energy resources as countries develop and GDP per capita increases; this theory is called the "energy ladder". Under the energy ladder theory, low income, developing countries utilize lower quality energy resources, such as biomass and hydroelectricity, because these sources are readily available within the countries' borders or in close proximity. As countries continue to develop, countries begin to rely on fossil fuels such as coal, oil, and natural gas. As per capita income continues to rise further, countries begin to increase their reliance on nuclear and renewable energy resources, which are considered among the highest quality energy resources. As an example, Figure 5.1 on the following page depicts this transition occurring within the United States from 1850 to 2008. In the early stages of development, the United States relied largely on wood (biomass) as a primary

71

energy input, as the theory would suggest. As development progressed and per capita

incomes increased, the United States transitioned from wood to coal, then from coal to

oil. While the primary energy input continues to be oil, the United States increasingly is

relying on higher quality energy resources, such as natural gas, nuclear, and renewable

resources.

Figure 5.1: U.S. Primary Energy Inputs 1850- 2008
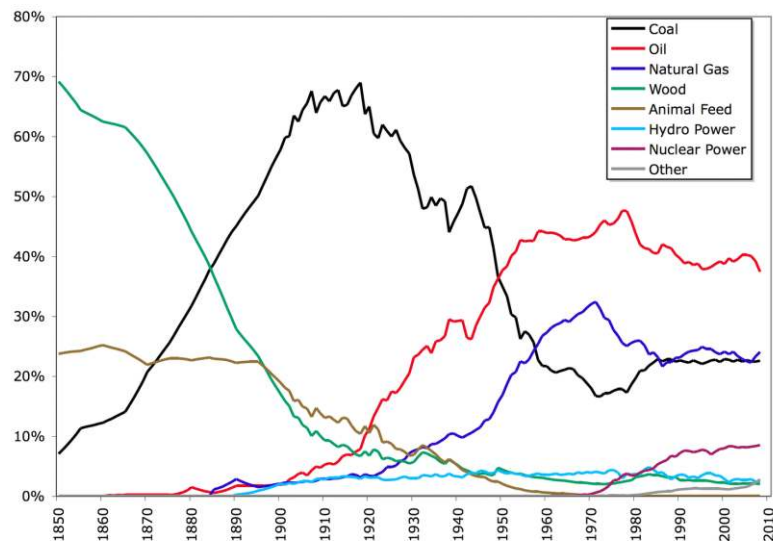
To further illustrate the energy ladder transition, Burke (2013) compiled the percent share

of primary energy use by source in 2010 for 138 countries using World Bank income

classifications.[28] The results are displayed in Figure 5.2 on the next page and

demonstrate the current relevance of this theory among low-, middle-, and high-income

countries. In this data set, low-income countries rely on biomass as their primary energy

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[28] The World Bank classifies income groups based on gross national income (GNI) per capita. Using 2012 dollars, the classifications are low-income ($1,035 or less), middle income ($1,036 - $12,615), and high income ($12,616 or more). Low- and middle-income countries are commonly classified as developing countries by the World Bank.

resource, while middle-income countries rely on oil, and high-income countries still rely on oil, but exhibit a greater reliance on nuclear and renewable energy resources.

Figure 5.2: Percentage Share of Primary Energy
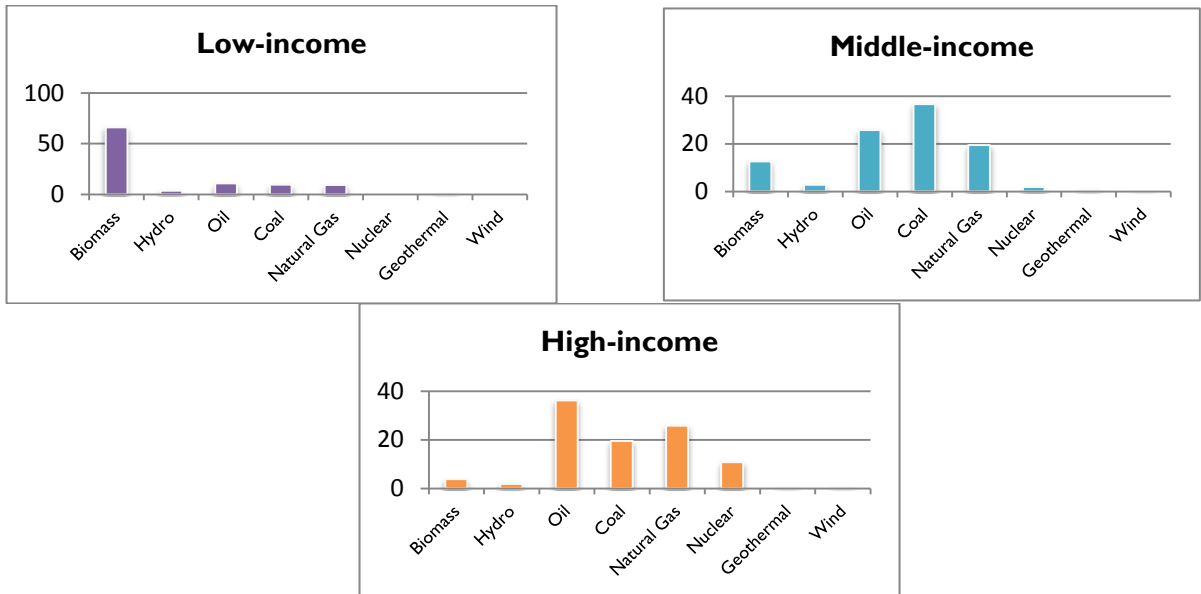
Source: Data compiled from Burke, 2013

The energy ladder theory creates important policy implications for future energy use trends and associated greenhouse gas emissions. As developing countries continue to develop and experience rising per-capita income levels, trends suggest that developing countries will begin to rely on a greater percentage of fossil fuels as their primary energy resource. If this prediction becomes true, the world would realize a significant increase to greenhouse gas emissions. As a result, Burke (2013) states that international policy efforts must encourage developing countries to skip the fossil fuel transition and leapfrog to high-quality, low-carbon energy resources, such as nuclear and renewable resources. In addition to carbon pricing or renewable energy subsidies, energy efficiency policies could aid in this effort. Burke suggests that developed countries must help developing

countries during this transition by facilitating the adoption of energy efficient

technologies. From a climate policy perspective, as per-capita income rises in developing

countries, it will be imperative that energy efficient technologies are distributed to

developing populations.[29]

5.5   Energy Efficiency Policies

The International Energy Agency (IEA) believes that energy efficiency policies

should play a large role in future climate policy actions. In a 2013 report, the IEA states

that regardless of the political challenges, limiting the global temperature increase to two

degrees Celsius can still be achieved using current technologies, specifically relying on

energy efficiency technologies. The report also urges that changes must be made within

the energy sector because the sector accounts for approximately two-thirds of global

greenhouse gas emissions. The report suggests four policy priorities to achieve the two

degree Celsius goal. The three policy measures other than improving energy efficiency

include limiting inefficient coal use in power generation, reducing upstream methane

emissions, and phasing out fossil fuel subsides. Of the four policy priorities, increasing

energy efficiency accounts for 49 percent of the energy and emissions savings. Eighty

percent of energy-efficiency related energy and emissions savings were attributed to

China, the United States, European Union, India and Russia. Figure 5.3 on the next page

depicts the IEA's estimated energy saving potential related to energy efficiency by

region, identifying a significant potential for energy efficiency gains in developing

countries, such as India and China.

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[29]While this thesis paper primarily focuses on the policy implications of energy efficiency related to developed countries, this thesis paper does acknowledge that increasing the energy efficiency of developing countries will be critical in order to achieve global climate stabilization.

Figure 5.3: Energy Efficiency Emissions Savings Potential by Region
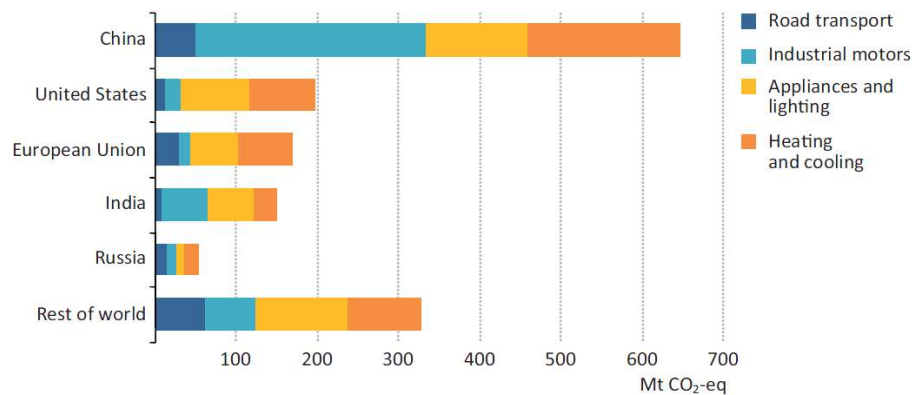
The IEA divided the energy efficiency savings into four broad categories: (1) road transportation; (2) industrial motors; (3) appliances and lighting; and (4) heating and cooling. The specific policies within these categories are summarized in Table 5.1. The policy options exclude the early retirement of existing capital stock and apply only to new equipment. For example, this analysis depicts the 'road transportation' category as having the lowest energy reduction potential. The report notes that this is due to a longer lag time for the policies to be effective due to slower vehicle turnover rates. In addition to having a lower impact due to the slower replacement cycle of vehicles, the IEA notes that energy efficiency gains within the transportation sector have a lower impact compared to other energy efficiency actions because many developed countries, such as the United States, have already implemented strict fuel-efficiency regulations.

Table 5.1: International Energy Agency- Energy Efficiency Policy Recommendations

CATEGORY	POLICY
Road transportation	Fuel-economy standards
	Fuel-economy labeling
Industrial Motors	Adoption of more efficient pumping systems
	Adoption of more efficient methods to compress air
	Adoption of more efficient mechanical handling and processing systems
Appliance and Lighting	Residential efficiency upgrades
	Commercial efficiency upgrades
Heating and Cooling Systems	Minimum energy performance standards for new equipment
	Technology switching with greater use of heat recovery
	Increased automation and control systems

Source: IEA, 2013

Important policy implications arise from the IEA analysis. First, the IEA analysis

suggests that developing countries could realize significant benefits by upgrading their

industrial equipment to more energy efficiency products. China also has vast potential to

reduce heating and cooling emissions; this is most directly due to increased demand for

air conditioning as quality-of-living standards continue to increase in China. Second, the

analysis recommends that energy efficient lighting and appliance upgrades should be

emphasized for both developed and developing countries. The IEA notes that lighting

and appliances account for 37 percent of electricity demand in developed countries and

26 percent in developing countries. Also, lighting and appliances have a shorter lifespan

relative to other capital goods and thus, can be replaced with more efficient alternatives at

a faster rate. Evidence indicates that this should be an important area of focus due to the

large proportion of overall electricity demand associated with lighting and appliance use and the future expectation of increasing demand for lighting and appliance use from developing countries. Other studies, however, suggest that developing countries are more susceptible to a rebound effect resulting from these actions (Stern, 2011). For example, Roy (2000) studied the rebound effect in India, and the results indicated that a large rebound effect existed due to highly elastic demand for energy services, such as household lighting. Roy states that the rebound effect might lessen after the pent up demand and supply bottlenecks are removed. While the IEA report does not directly address the potential rebound effect, the report does acknowledge that energy efficiency policies may increase household spending and consumption. However, the IEA states that increases in consumption by households related to energy efficiency will be counterbalanced by a reduction in energy consumption by firms if subsidies for fossil fuels were eliminated.[30]

The United Nations Foundation also released a report urging G8 countries to increase the rate of energy efficiency improvements to 2.5 percent from 2012 to 2030, claiming that energy efficiency is the most efficient method to achieve sustainable development and avoid catastrophic climate change.[31] The report also recommends that the G8 countries should aid the +5 countries (Brazil, China, India, Mexico, and South Africa) in a coordinated effort to increase energy efficiency across the G8+5 countries.

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[30] Removing fossil fuel subsidies was one of the four key policy priorities recommended in the report. The report analyzed the net economic effect of all its policy recommendations. Therefore, the report indicates that energy efficiency, alone, would stimulate a small increase in consumption and spending in households, but the report did not indicate that this rebound effect would negate energy efficiency policy actions.

[31] The G8 countries include Canada, France, Germany, Italy, Japan, Russia, the United Kingdom, and the United States.

The 13 countries addressed in the report contribute a combined total of 70 percent of

global greenhouse gas emissions, and therefore, the report concludes a combined effort to

increase energy efficiency in these countries could significantly reduce global emissions.

Table 5.2 lists the energy efficiency policies recommended by this international report.

Table 5.2: United Nations Foundation- Energy Efficiency Policy Recommendations

CATEGORY	POLICY
Buildings and Equipment Efficiency	Stricter building codes and appliance standards
	Encourage the installation of advanced lighting
Industrial Efficiency	Encourage the adoption of advanced motors
	Negotiate individualized efficiency improvement targets by sector
Transportation Efficiency	Establish coordinated fuel standards
	Encourage and develop mass transit
Energy Supply Efficiency	Restructure utility rates to decouple profits from energy use
	Increase adoption of combined heating, cooling, and power installations
	Increase efficiency in generation and transmission infrastructure
	Reduce natural gas flaring
Energy Efficiency in Developing and Transitioning Economies	G8 countries should provide technical assistance
	Foster an export market of energy efficient technologies to reduce the trade of second-hand, inefficient equipment
	Encourage international finance institutions to guarantee loans for energy efficiency investments

Source: United Nations Foundation, 2007

The United Nations Foundation report explicitly states that due to empirical evidence,

decoupling energy and economic growth is feasible, and thus, supports the mainstream

perspective that energy efficiency policies can be an effective climate policy tool.

Beginning at the G8 summit in 2006, the IEA released 25 energy efficiency policy recommendations across seven priority areas (cross-sectoral activity, buildings, appliances, lighting, transport, industry, and energy utilities). Progress evaluations have been conducted in 2009 and 2011 to measure the rate of adoption of the energy efficiency recommendations. The evaluation indicated that energy efficiency policies have received broad support amongst IEA member countries. Between all IEA member countries, 70 percent of the recommendations are either fully implemented, substantially implemented, or are in the process of being implemented (Pasquier & Saussay, 2012). Figure 5.4 shows the progress by each IEA member country and demonstrates that energy efficiency policies have received broad support.

Figure 5.4: Country Comparison of Energy Efficiency Policy Implementation
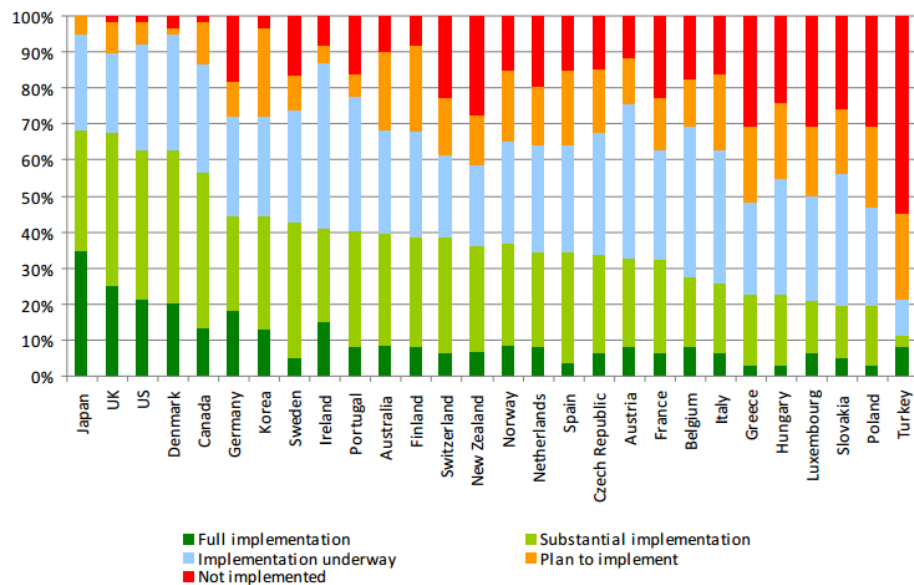
Source: Pasquier & Saussay, 2012, p. 122 (Figure 37)

5.6 Conclusion

While energy efficiency appears a world priority, current empirical evidence is inconclusive regarding whether the mainstream perspective or the ecological perspective

is correct in its viewpoint of the relationship between energy use and economic growth. Dobnik (2011) surveyed the current empirical evidence on the energy consumption-growth nexus and summarized the conclusions of 22 panel data studies on developing and developed countries. The results varied widely, mostly due to different econometric techniques and data sets. Studies concluded causality from energy use to economic growth and vice versa. However, other studies concluded no causality between energy use and economic growth. Therefore, further empirical research is needed.

Evidence is equally inconclusive regarding the magnitude of the rebound effect for different energy efficiency policies and policy settings (i.e. developed versus developing countries). In a comprehensive analysis of the rebound effect, Sorrell (2007) determined that the rebound effect varies widely based on different technologies, sectors and income groups. However, Sorrell emphasizes that current evidence indicates that energy efficiency can lead to lower energy use and carbon emissions and does not consistently result in economy-wide increases in energy use. The lack of empirical research regarding the rebound effect and energy efficiency policies spurred a new, collaborative project between economists at UC Berkeley and MIT. The project, named E2e, began in January 2013 and seeks to evaluate energy efficiency policies and programs to determine their effectiveness and how human behavior can affect energy efficiency decisions (E2e, 2014). Specifically, the program aims to address three unanswered questions:

1. Are consumers and businesses bypassing profitable opportunities to reduce their energy consumption?

2. What are the most effective ways to encourage individuals and businesses to invest in energy efficiency?

3. Are current energy-efficiency programs providing the most savings? (Energy Manager Today, 2013).

Currently, energy efficiency policies are gaining widespread approval by world political leaders, including leaders in the United States.   Research projects, such as the work being conducted by E2e, can guide future energy efficiency policy and build empirical evidence to continue to address what role energy efficiency plays within climate policy.

CHAPTER SIX: THE FUTURE OF ENERGY EFFICIENCY

Global climate change creates a worldwide challenge requiring a coordinated international policy response. However, political pressures and disagreements between developed and developing countries have obstructed past climate negotiations and have stalled the adoption of binding, international carbon emission reduction targets. In addition to stalled climate negotiations, large-scale carbon emitters, such as the United States and China, have failed to enact comprehensive climate policies within their own borders. Climate scientists and economists, alike, have warned that climate inaction is a dangerous threat to current and future generations. The possibility of cataclysmic climate change and the enormous costs of inaction create sizeable risks if climate action continues to be delayed. Despite slow-moving international climate negotiations and comprehensive climate policies, many countries have turned to energy efficiency as a politically feasible tool to lower energy use and carbon emissions. As the largest source of carbon emissions, the energy sector is an obvious target for climate policy efforts.

This thesis has investigated the role of energy efficiency as an international climate policy tool. Economists debate the effectiveness of energy efficiency policies due differing perspectives regarding the relationship between energy use and economic growth. Because of this fundamental disagreement, economists often provide different conclusions as to whether energy efficiency routinely leads to either a reduction in energy use or leads to an economy-wide increase in energy use. Dobnik (2011) summarized the

different conclusions into four hypotheses regarding the relationship between energy use and economic growth:

1. *Energy Dependent Hypothesis*: Energy consumption is a critical component to economic growth. A decrease in energy use will create adverse impacts to economic growth.

2. *Conservation Hypothesis*: Energy consumption is not a critical component to economic growth. A decrease in energy use will not substantially affect economic growth.

3. *Feedback Hypothesis:* Energy use and economic growth affect each other simultaneously; causality is bi-directional. A decrease in energy use may create a rebound effect on economic growth, offsetting a portion of energy reduction gains.

4. *Neutrality Hypothesis:* Energy use and economic growth are not related. Reducing energy use will not affect on economic growth.

Each hypothesis results in different policy implications for the role of energy efficiency in climate policy. Many countries, such as the United States, are concerned about the possible affect of energy conservation could have on economic growth. Arguably, this concern has prevented large-scale climate policy action, such as the United States' failure to sign the Kyoto Protocol and failure to enact a carbon tax or cap and trade program. However, three out of the four hypotheses would suggest that energy efficiency policies or energy conservation, in general, would successfully lead to lower energy consumption without substantially affecting economic growth.

Many economists agree that energy efficiency policies can act as a bridge fuel to aid in the transition toward low-carbon resources. Simply, the penetration of renewable energy resources as primary energy inputs is progressing too slowly. While BP's 2014 Annual Energy Outlook projects that the global energy supply is slowly transitioning away from fossil fuels, the report also projects that renewable energy resources will only represent seven percent of the total global energy share in 2035. Therefore, energy efficiency policies can act as an essential complement to strategies targeted toward the adoption of renewable energy resources. Even when accounting for the rebound effect, many studies indicate that energy efficiency remains a highly cost-effective energy resource in the near future (Sorrell, 2007; Laitner, 2009).

While the rebound effect is often determined to be less than unity, the size of the rebound effect varies based on multiple factors such different energy efficiency technologies, income groups, or energy sectors (Sorrell, 2007). Therefore, the area in which efficiency gains are made is an important indicator in predicting the size of the rebound effect. For example, home energy insulation may be much less susceptible to a rebound effect. A consumer will not continue to heat or cool his home beyond a certain comfort threshold. Thus, in this scenario, the direct rebound effect has a bounded limit. These energy efficiency gains are referred to as 'dedicated' energy efficiency upgrades, and the rebound effect is often small.

However, the rebound effect can be larger for other types of energy efficiency upgrades, referred to as 'general purpose technologies'. These types of technology upgrades can provide multiple uses or benefits and can create positive feedback loops

resulting in increased energy use (Sorrell and Ockwell, 2010). An example of this type of energy efficiency gain was the creation of a more efficient process to make steel, as discussed in Chapter 3. In regards to 'general purpose' efficiency improvements, negating the rebound effect is crucially dependent on policies that increase energy prices. Increased energy prices coupled with efficiency gains can lead to greater energy reduction gains as higher energy prices remove the incentives to use more energy through either direct or indirect rebound effects. Sorrell (2007) emphasizes that increased energy prices are essential in order to ensure that the price for an energy service remains constant as energy efficiency improvements lower the marginal cost of an energy service. Therefore, energy efficiency policies need to be coupled with increased energy prices, possibly through a carbon tax, in order to reach a socially efficient outcome.

Plumer (2014) also summarized the importance of the debate regarding the relationship between energy use and economic growth by listing three critical components to the future growth of carbon emissions:

1. The growth rate of the global economy;
2. The energy intensity of the global economy; and;
3. The carbon intensity of the global energy supplies.

The relationship between the three variables listed above is interdependent. Energy efficiency policies target component number two (the energy intensity of the global economy). However, energy efficiency may also affect the growth rate of the global economy, which is why energy efficiency becomes subject to debate and further research.

However, global climate stabilization will not occur unless component number three (the carbon intensity of global energy supplies) is targeted.

While energy efficiency acts as a critical component to global climate policy it cannot act as a stand-alone climate policy to achieve climate stabilization. More action is needed, and the global economy must transition toward low-carbon energy resources. Thus, the benefits of energy efficiency are limited and other policies need to be introduced. To decrease the carbon intensity of the global energy supply, the following three policies must occur in addition to the promotion of energy efficiency in order to achieve global climate stabilization:

1. Energy prices must be increased to internalize negative externalities associated with greenhouse gas emissions and to mitigate the rebound effect;

2. Fossil fuel subsidies must be eliminated to phase out the use of these energy resources and promote the use of renewable and low-carbon energy resources; and

3. Developed countries must share energy efficient technology and resources to developing countries in order to encourage sustainable development.

While certain aspects of energy efficiency remain inconclusive, such as the presence of an energy efficiency gap and the magnitude of the rebound effect, Allcott and Greenstone (2012) state, "Policymakers must make policy, even in absence of ironclad evidence" (p. 22). While mainstream economic theory would suggest that a carbon tax or cap and trade program are the most economically efficient climate policy interventions, Allcott and Greenstone believe that energy efficiency policies still can act

as an effective climate policy tool due to the political gridlock associated with carbon taxes and cap and trade programs, especially in the United States. Essentially, energy efficiency policies are a better alternative than climate policy inaction. As the global climate problem continues to escalate, energy efficiency policies offer an immediate and politically feasible policy tool to encourage the adoption of more comprehensive climate policies in the future.

BIBLIOGRAPHY

Ackerman, F. (2007). Economics for a warming world. *Post-autistic Economics Review, 44, p 2-18.*

Alliance to Save Energy (ASE). (2013). The history of energy efficiency. Retrieved from: http://www.ase.org/sites/ase.org/files/resources/Media%20browser/ee_commission_history_report_2-1-13.pdf.

Alliance to Save Energy (ASE). (2014). Recommendations. Retrieved from: https://www.ase.org/policy/energy2030/recommendations.

American Council for an Energy-Efficient Economy (ACEEE). (2013). Energy efficiency resources standards (EERS). Retrieved from: http://www.aceee.org/topics/eers.

Arimura, T., Li, S., Newell, R., & Palmer, K. (2012). Cost-effectiveness of electricity energy efficiency programs. *The Energy Journal, 33*(2), 63-99.

Banuri, T. (2009). Climate change and sustainable development. A United Nations Sustainable Development Journal: *Natural Resources Forum*, 33(4), 257-258.

Barker, T. & Foxon, T. (2007). The macro-economic rebound effect and the UK economy. *Energy Policy, 35*(10).

Behrens, C. & Glover, C. (2011). U.S. energy: Overview and key statistics. *U.S. Congressional Research Service.* (7-5700-R40187).

Bin, S., & Dowlatabadi, H. (2005). Consumer lifestyle approach to US energy use and the related CO2 emissions. *Energy Policy* 33 (2): 197-208.

Bodansky, D. (2010). The Copenhagen climate change conference: A post-mortem. *American Journal of International Law, Vol. 104.*

Borenstein, S. (2009). To what electricity price do consumers respond? Residential demand elasticity under increasing-block pricing. *University of California, Berkeley.*

BP. (2014). BP energy outlook 2035. Retrieved from: http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf.

Burke, P. (2013). The national-level energy ladder and its carbon implications. *Environment and Development Economics, 18*(4), 484-503.

Chertow, M. (2001). The IPAT equation and its variants. *Journal of Industrial Ecology, 4*(4), 13-29.

Cooley, H., Donnelly, K., & Ajami, N. (2013). Energizing water in California: Applying energy efficiency strategies to water. *Pacific Institute.*

Council on Foreign Relations. (2013). *The global climate change regime*. Retrieved Jan, 2014. Available at: http://www.cfr.org/climate-change/global-climate-change-regime/p21831#.

Database of State Incentives for Renewables and Efficiency (DSIRE). 2012. Public benefit funds. Retrieved from: http://www.dsireusa.org/solar/solarpolicyguide/?id=22.

Dietz, S., Hepburn, C. & Stern, N. 2008. "Economics, Ethics and Climate Change." *Ethics and Climate Change (December 2007)*. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1090572.

Dobnik, F. (2011). Energy consumption and economic growth revisited: Structural breaks and cross-section dependence. Ruhr Economic Papers

E2e. (2014). About us. Retrieved from: http://e2e.haas.berkeley.edu/about.html. Retrieved on March 12, 2014.

Easterling, W., Aggarwal, P., Batima, P., Brander, K., Erda, L., Howden, S., Kirilenko, A., Morton, J., Soussana, J., Schmidhuber, J., & Tubiello, F. (2007). Food, Fiber, and Forest Products. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability . Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom.

Ebinger, C. & Banks, J. (2013). The electricity revolution. *The Brookings Institute.*

Eichhammer, W., Fleiter, T., Schlomann, B., Faberi, S., Fioretto, M., Piccioni, N., Lechtenböhmer, S., Schüring, A., Resch, G. (2009): Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries. *Fraunhofer-Institute for Systems Innovation Research.*

Energy Information Administration (EIA). (2009). Emissions of greenhouse gases in the U.S. Retrieved from: http://www.eia.gov/environment/emissions/ghg_report/ghg_carbon.cfm.

Energy Information Administration (EIA). (2012a). International Energy Statistics database. Retrieved from:

http://www.eia.gov/oiaf/aeo/tablebrowser/#release=IEO2013&subject=0-IEO2013&table=1-IEO2013&region=0-0&cases=Reference-d041117

Energy Information Administration (EIA). (2012b). Annual energy review. Retrieved from: http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0813

Energy Information Administration (EIA). (2013a). Frequently asked questions: How much energy does a person use in a year? Retrieved from: http://www.eia.gov/tools/faqs/faq.cfm?id=85&t=1

Energy Information Administration (EIA). (2013b). What are the major sources and users of energy in the United States?: Energy in Brief. Retrieved from: http://www.eia.gov/energy_in_brief/article/major_energy_sources_and_users.cfm

Energy Information Administration (EIA). (2013c).State energy data system (SEDS): 1960-2011. Retrieved from: http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US#Consumption.

Energy Information Administration (EIA). (2014). Annual energy outlook 2014 early release overview. Retrieved on February 15, 2014.

Energy Manager Today Staff. (2013). UC Berkeley and MIT launch energy efficiency research project. *Energy Manager Today.*

Environmental Protection Agency (EPA). (2013). Overview of greenhouse gases: Carbon dioxide emissions. Available at: http://www.epa.gov/climatechange/ghgemissions/gases/co2.html.

Eto, J., Kito, S., Shown, L., & Sonnenblick, R. (2000). Where did the money go? The cost and performance of the largest commercial sector DSM programs. *The Energy Journal 21* (2): 23-49.

European Commission. (2013a). The EU emissions trading system (EU ETS). Available at: http://ec.europa.eu/clima/policies/ets/.

European Commission. (2013b). International carbon market. Available at: http://ec.europa.eu/clima/policies/ets/linking/index_en.htm.

Foster, J., Clark, B., & York, R. (2010). Capitalism and the curse of energy efficiency: The return of the jevons paradox. *Monthly Review, 62*(6), 1.

Foster, J. (2011). Capitalism and degrowth: An impossibility theorem. *Monthly Review 62*(08).

Friedrich, K., Eldridge, M., York, D., Witte, P., & Kushler, M. (2009). Saving energy cost-effectively: A national review of the cost of energy saved through utility-sector energy efficiency programs. *American Council for an Energy Efficient Economy.* Report no. U092.

Gillingham, K., Newell, R., & Palmer, K. (2004). Retrospective examination of demand-side energy efficiency policies. *Resources for the Future.*

Gillingham, K., Newell, R., & Palmer, K. (2009). Energy efficiency economics and policy. *Annual Review of Resource Economics, 1*(1), 597-619.

Gold, R., Nadel, S., Laitner, J., & DeLaski, A. (2011). Appliance and equipment efficiency standards: A moneymaker and job creator. *American Council for an Energy-Efficiency Economy.* Research Report ASAP-8/ACEEE-A111.

Golove, W & Eto, J. (1996). Market barriers to energy efficiency: A critical reappraisal of the rationale for public policies to promote energy efficiency. Lawrence Berkeley National Laboratory (LBNL).

Greening, L., Greene, D., & Difiglio, C. (2000). Energy efficiency and consumption — the rebound effect — a survey. *Energy Policy, 28*(6), 389-401.

Grubb, M. (1990). *Energy policies and the greenhouse effect*. Dartmouth Publishing Company, Royal Institute of International Affairs.

Hamilton, J. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy, 91(2),* 228-248.

Hansen, J., Sato, M. Kharecha, P., Beerling, D., Masson-Delmotte, V., Pagani, M., Raymo, M., Royer, D. & Zachos, J.. (2008). Target atmospheric CO2: Where should humanity aim?. *Open Atmos. Sci., J.* 2: 217.

Hansen, J. (2009). Carbon tax & 100% dividend vs. tax & trade. *Testimony Submitted to the Committee on Ways and Means, US House of Representative* 25.

Harris, J., & Roach, B. 2009. *The Economics of Global Climate Change*. Global Development And Environment Institute Tufts University.

Harvey, F. (2013). As the Warsaw talks end, the hard work is just beginning. *The Guardian.* Retrieved from: http://www.theguardian.com/environment/2013/nov/25/warsaw-climate-talks-end-cop19-2015.

Heinberg, R. (2011). *The end of growth: Adapting to our new economic reality*. Gabriola, B.C: New Society Publishers.

Holmes, I. & Mohanty, R. (2012). The macroeconomic benefits of energy efficiency: The case for public action. *E3G.*

Horowitz, M. (2004). Electricity intensity in the commercial sector: Market and public program effects. *The Energy Journal, 25*(2), 115-137.

Howarth, R., & Andersson, B. (1993). Market barriers to energy efficiency. *Energy Economics, 15*(4), 262-272.

Hovi, J., Skodvin, T., & Aakre, S. (2013). Can climate change negotiations succeed? *Politics and Governance,* 1(2), 138-150.

International Energy Agency (IEA). (2007). Mind the gap. Available at: http://www.iea.org/publications/freepublications/publication/mind_the_gap.pdf°

International Energy Agency (IEA). (2013). Topic: Energy insecurity. Available at: http://www.iea.org/topics/energysecurity/.

International Energy Agency (IEA). (2013). Redrawing the energy-climate map. World Energy Outlook Special Report.

Jackson, T. (2009). *Prosperity without growth: Economics for a finite planet.* London: Routledge.

Jaffe, A. & Stavins, R. (1994). Energy-Efficiency Investments and Public Policy. *The Energy Journal 15* (2): 43-65.

Jevons, W. (1865). *The coal question: An inquiry concerning the progress of the nation, and the probable exhaustion of our coal-mines*. London: The Macmillan Company.

King, D., Ebrahim, Z., & Inderwildi, O. (2014). Macroeconomic impacts of oil price volatility: Mitigation and resilience. *Frontiers in Energy, 8*(1), 9-24.

Laitner, J., Nadal, S., Elliott, N., Sachs, H., & Khan, A. (2012). The long-term energy efficiency potential: What the evidence suggests. *American Council for an Energy-Efficiency Economy.* Research Report E121.

Leggett, J. (2011). Climate change: Conceptual approaches and policy tools. *U.S. Congressional Research Service* (7-5700-R41973).

Linares, P., & Labandeira, X. (2010). Energy efficiency: Economics and policy. *Journal of Economic Surveys, 24*(3), 573-592.

Lomborg, B. (2007). Perspective on climate change. *Joint Hearing of the Subcommittee on Energy and Air Quality and the Subcommittee of Energy and Environment of the House Committee on Science and Technology, March* 21.

Lovins, A. (1976). Energy strategy: The road not taken? *Foreign Affairs, 55*(1), 65-96.

Madlener, R., & Alcott, B. (2009). Energy rebound and economic growth: A review of the main issues and research needs. *Energy, 34*(3), 370-376.

McKinsey and Co. (2009). Unlocking energy efficiency in the United States economy.

National Action Plan for Energy Efficiency (2009). Energy efficiency as a low-cost resource for achieving carbon emissions reductions. *Prepared by William Prindle, ICF International, Inc.*

National Resource Defense Council (NRDC). (2014). Mayors from 10 major cities unite to cut climate pollution from buildings. [Press Release]. Retrieved from: http://www.nrdc.org/media/2014/140129a.asp.

Nordhaus, W. (2007). A review of the 'Stern Review on the Economics of Climate Change'. *Journal of Economic Literature*: 686–702.

Ockwell, D. (2008). Energy and economic growth: Grounding our understanding in physical reality. *Energy Policy,36*(12), 4600-4604.

Oikonomou, V., Becchis, F., Steg, L., & Russolillo, D. (2009). Energy saving and energy efficiency concepts for policy making. *Energy Policy, 37*(11), 4787-4796.

Pacala, S., & Socolow, R. (2004). Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science (New York, N.Y.), 305*(5686), 968-972.

Pasquier, S. & Saussay, A. (2012). Progress implementing the IEA 25 energy efficiency policy recommendations: 2011 evaluation. *International Energy Agency.*

Pimentel, D., Jackson, A., Lee, M., Eaton, A., Pleasant, A., Barron, J., & Schiavoni, C. (2004). US energy conservation and efficiency: Benefits and costs. *Environment, Development and Sustainability, 6*(3), 279-305.

Plumer, B. (2013). Europe's cap and trade program is in trouble. Can it be fixed? *The Washington Post.*

Plumer, B. (2014). Can we severe the link between energy and economic growth? *The Washington Post: Wonkblog.*

Rhodium Group. (2013). American energy productivity: The economic, environmental, and security benefits of unlocking energy efficiency. *Prepared on behalf of Alliance to Save Energy.*

Ridgwell, A & Schmidt, D. (2010). Past constraints on the vulnerability of marine calcifiers to massive carbon dioxide release. *Nature Geoscience, 3*, 196-200.

Rockström, J., W. Steffen, K. Noone, A.A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, and H. J. Schellnhuber. (2009). A safe operating space for humanity." *Nature 461*(7263), 472–475.

Ross, M. (2013). How the 1973 oil shock saved the planet. *Foreign Affairs.*

Roy, J. (2000). The rebound effect: Some empirical evidence from india. *Energy Policy, 28*(6), 433-438.

Ryan, L. & Campbell, N. (2012). Spreading the net: The multiple benefits of energy efficiency improvements. *International Energy Agency.*

Sachs, J. (2008). Economics for a Crowded Planet. New York: The Penguin Press.

Saunders, H. (1992). The khazzoom-brookes postulate and neoclassical growth. *The Energy Journal, 13*(4), 131-148.

Schiller, S., Prindle, B., Cowart, R., & Rosenfield, A. (2008). Energy efficiency and climate mitigation policy. *American Council for an Energy-Efficient Economy.*

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., Tignor, M., & Miller, H. (2007). IPCC: Summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Sorrell, S. (2007). The rebound effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency. UK Energy Research Centre.

Sorrell, S. (2009). Jevons' paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy, 37*(4), 1456-1469.

Sorrell, S. & Ockwell, D. (2010). Can we decouple energy consumption from economic growth? *Sussex Energy Group.* Policy Briefing Number 7.

Stern, N. (2006). Stern review: Executive summary. *HM Treasury: London*.

Stern, N. (2009). Lord Stern on global warming: It's even worse than I thought. *The Independent.*

Stern, D & Cleveland, C. (2004) Energy and economic growth. Rensselaer Working Papers in Economics 0410.

Stern, D. (2010). Energy quality. *Ecological Economics, 69*(7), 1471-1478.

Stern, D. (2011). The role of energy in economic growth. *Annals of the New York Academy of Sciences, 1219*(1), 26-51.

Stocker, T., Qin, D., Plattner, G., Tignor, M., Allen, S., Boschung, J., Nauels, A., Xia, Y., Bex, J., & Midgley, P. (eds.). (2013). Summary for policymakers. In: Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Stuggins, G., Sharabaroff, A. Semikolenova, Y. (2013). Energy efficiency: Lessons learned from success stories. *The World Bank.*

The Economist. (2008). Energy efficiency: The elusive negawatt. May 8th print edition. Retrieved from: http://www.economist.com/node/11326549.

The Global Carbon Project. (2013). Global carbon budget: 2013. Retrieved from: http://www.globalcarbonproject.org/carbonbudget/13/files/GCP_budget_2013.pdf

The Library of Congress. (2009). Bill summary and status: H.R. 2454. Available at: http://thomas.loc.gov/cgi-bin/bdquery/z?d111:H.R.2454.

The Nature Conservancy. (2011). Climate change impacts: Higher temperatures.

The White House, Executive Office of the President. (2013). The president's climate action plan

The White House, Office of Press Secretary. (2013). The President's plan for a strong middle class and a strong American [Press Release].

The World Bank. (2014). World bank open data: World Development Indicators. Retrieved from: http://data.worldbank.org/?display=default on February 10, 2013.

Tonn, B., & Peretz, J. H. (2007). State-level benefits of energy efficiency. *Energy Policy, 35*(7), 3665-3674.

United Nations Environmental Programme. (2013). The 2013 emissions gap report. Available at: http://www.unep.org/publications/ebooks/emissionsgapreport2013.

United Nations Foundation. (2007). Realizing the potential of energy efficiency: Targets, policies, and measures for G8 countries. Expert Report.

U.S. Global Change Research Program (USGCRP). (2009). Global climate change impacts in the United States: Second national climate assessment. Available at: http://www.globalchange.gov/resources/reports.

Van Den Bergh, J. (2011). Energy conservation more effective with rebound policy. *Environmental and Resource Economics, 48*(1), 43-58.

Warner, K., Afifi, T., Henry, K., Rawe, T., Smith, C., &de Sherbinin, A. (2012). Where the rain falls: Climate change, food and livelihood security, and migration. *Global Policy Report of the Where the Rain Falls Project.* Bonn: UNU and CARE.

Wilbanks, T., Lankao, P.,, Boa, M., Berkhout, F., Cairncross, S., Ceron, J., Kapshe, M., Muir-Wood, R., & Zapata-Marti, R.. (2007). Industry settlement and society. Climate change 2007: Impacts, adaptation, and vulnerability. *Contribution of Working Group II to the* Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK: 357-390.

World Wildlife Fund (WWF). (2012). The living planet report 2012: Biodiversity, biocapacity, and better choices. Available at: http://awsassets.panda.org/downloads/1_lpr_2012_online_full_size_single_pages _final_120516.pdf

Zhou, N., Levine, M., & Price, L. (2010). Overview of current energy-efficiency policies in China. *Energy Policy, 38*(11), 6439-6452.