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ENERGY VISION UPDATE 2010

Towards a More Energy Efficient World

World Economic Forum
in partnership with
IHS Cambridge Energy Research Associates

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Message from the Energy Community Leader 2009: Towards a More Efficient World

By José Sergio Gabrielli de Azevedo, Chief Executive Officer, Petrobras, Brazil

I welcome the opportunity, on behalf of the Energy Community of the World Economic Forum, to introduce the *Energy Vision 2010* because of the importance of energy efficiency in all parts of today's world – and its even greater importance for tomorrow. For developing and developed nations, for countries that import energy and for those that export energy – and for the entire world community – energy efficiency is front and centre.

The long-term prospect of increasing energy demand is very challenging. It can contribute to high production costs and complex geopolitical issues, thus reinforcing the trend of rising prices and volatility. On the other hand, rising demand creates incentives for the development of new and promising alternative technologies. Indeed, the persistent quest for access to energy sources and energy security shapes national policies. Demand for alternative energy is growing at a fast pace, although from a small base, and the pursuit of a low carbon economy is likely to escalate further as a result of increasing social pressure.

In the years ahead we will pave the road towards a more energy efficient world, with the objectives of sustainable growth and long-term benefits, including energy security. A lasting lesson from the recent economic crisis is that business as usual is not sustainable. It is time to change paradigms. Energy efficiency is central to the new paradigm.

The potential of energy conservation is unquestionable. The wise use of resources is among the most valuable initiatives we can take to face our challenges. Within this context, public policies and regulation are crucial, as the price system takes into account only part of the energy production costs, and may disregard environmental externalities and market inefficiencies. Price incentives and business opportunities, together with suitable and transparent rules, are required for successful public policies. Public policy is also essential to accelerate the adoption of advanced efficiency standards for household and industrial appliances and equipment, and to promote innovative financing schemes for energy efficiency.

Technology plays a critical role in enabling energy efficiency. On the energy supply side, the use of increasingly efficient procedures, technology and equipment is evident. On the demand side, the search for higher efficiency is particularly evident in the automotive industry, through incentives to incorporate hybrid and electric vehicles in the market. New engines, new vehicles, new modes of transportation, new structures of urban planning and better utilization of logistical networks – and new attitudes – all these will further increase transportation efficiency.

New equipment and new forms of production organization contribute to the gains from energy efficiency. Similarly, the link between energy and mobility requires a new concept of urban life, new building standards, efficient mass transportation and better organization of the economic space.

The energy landscape of the world will change with renewables in response to environmental challenges. However, alternative sources of energy will be marginal additions to primary energy supply in the medium run. There is no obvious scenario for 2030 where oil, natural gas and coal do not predominate. Even if new sources of supply grow in an intense way, the size of the existing inventory of vehicle fleets, energy systems, housing and industrial processes implies gradual and slow progress.

Notwithstanding the gradual reduction of oil's share of the global energy mix, the use of oil will increase in absolute terms over the next years. The absolute number of barrels will increase, even though the relative share may decline. It is thus necessary to focus not only on the consumption of fossil fuels, but also on the quality of such consumption.

Challenges associated with energy production and consumption prompt the human mind to be creative. At the core of current international negotiations to fight climate change, the world energy system stands out, as it is responsible for 75% of the total greenhouse gas emissions. Its effective contribution to a sustainable future implies substantial conservation policies and efficiency gains in concert with development and use of new energy technologies. Sustainability requires society to adopt new economic and sociocultural norms. Cooperative programmes are needed to identify and implement structural changes. Apparent limitations may become opportunities to shape a better future for generations to come.

All these issues are what make energy efficiency so important a topic. But what are the routes to a more energy efficient world? And how will we get there? These are the questions we explore in this *Energy Vision.* We do so in the report that follows and the deeply informed Perspectives that are integral to our energy vision. From the research and writing of this report, we have learned a great deal that we are pleased to share with you. I certainly want to express the appreciation of the Energy Community to those who have created this report and directed the overall project and to all who, in contributing their Perspectives, share their experiences and insights, all of which are so timely and so relevant.

Towards a More Energy Efficient World

Contents

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Towards a More Energy Efficient World

EXECUTIVE SUMMARY

Energy efficiency has moved to the top of the global political and business agenda. Both governments and industry are turning to energy efficiency as a critically important "energy source" in the quest to meet the world's growing energy demands while also addressing climate change and energy security concerns and supporting economic growth. Energy efficiency was one of the main themes at the Copenhagen climate conference and one on which there was widespread agreement. Of all the energy options, it can provide the biggest "amount" of energy in the near and medium term while contributing to reductions in greenhouse gas emissions. It meets major objectives of both developed and developing countries, whether importers or exporters of energy.

The long-term trend of rapid economic growth in the developing world gives additional urgency to energy efficiency. A major surge in world energy consumption is at hand. Emerging market nations and the traditional industrial countries both recognize that increased emphasis on energy efficiency is a requirement for accommodating the scale of this economic growth. Energy efficiency is essential for the world's energy strategies, yet it is often misunderstood or underappreciated. This Energy Vision seeks to provide a framework and perspective for harnessing this highly prospective energy source.

To begin with "energy efficiency" is really shorthand for increasing energy efficiency beyond the status quo. Energy efficiency means getting the same benefit while using less energy – reducing the energy input required by a process without changing its output, either in quality or quantity. It may actually provide an improved benefit. Efficiency means that consumers use less energy while not sacrificing their lifestyles. However, encouraging efficiency requires a thoughtful discussion among policy-makers and business leaders and a broader understanding among publics. We hope to contribute to the discussion with this report.

Companies and individuals tend to invest in assets and products they can see, feel and touch. Governments tend to support programmes that generate jobs and create technologies that can be exported. Energy efficiency does not necessarily meet these criteria – at least not directly. Energy efficiency is a process or a way of thinking or an approach that leads to new technologies, new jobs, new revenues and even new export markets. But these are not the immediate drivers. How can energy efficiency be converted from an intangible attribute to a visible and central factor for decision-making across the energy value chain? How can we close what is described as the "efficiency gap" – the difference between available cost-effective efficiency options and those that are actually implemented?

Drivers and Barriers to Energy Efficiency

Four key factors influence efficiency decisions: consumer behaviour, competition for and availability of capital, energy price and price volatility and technological innovation.

- *Consumer behaviour* is central to understanding the efficiency gap. To implement efficiency opportunities, energy consumers require knowledge about those opportunities as well as the motivation and ability to implement them. However, consumers do not always have the information they need to make the best energy efficiency decisions, and the analysis is often difficult. Consumer preference for the status quo and familiar technologies can sometimes tilt them against energy efficient choices.
- What we call the *investment grade* test is important for sustainable investment in energy efficiency. *Competition for and availability of capital* is a key factor in energy efficiency decisions. A household may not have the capital available to purchase a more energy efficient product, even though it would save on operating costs in the future. For corporations, efficiency investments must have a high enough rate of return to compete with other potential uses for capital – they must be "investment grade". This question of choice and trade-offs in efficiency investments compared to other allocations of capital is often overlooked.
- Variation in *energy prices* and the *unpredictability of future prices* make the returns from energy efficiency investments uncertain. Government policies can reduce the uncertainty but also risk unintended consequences. Market pricing or higher taxes on energy, for example, can help promote energy efficiency. Subsidies that shield consumers from energy prices may meet some social objectives

and protect consumers from volatility. But they discourage energy efficiency investments and reduce or remove the incentive for consumes to be "energy thoughtful" in their daily decisions.

- *Innovation* is crucial to improving energy efficiency. The ongoing revolution in lighting technology – from incandescent to compact fluorescent bulbs to LEDs – is a clear example. Although breakthrough technologies capture the headlines, continuous improvement in existing technologies also plays a significant role. For example, the average refrigerator in the United States today uses three-quarters less energy than in 1975, despite being 20% larger.

Fast growing economies have the opportunity to build greater efficiency into their infrastructure. The Chinese government's recent decision to commit to lower energy intensity targets illustrates the understanding that energy efficiency improvements can be made much more effectively at the front end. India plans to establish efficiency targets for industrial processes by the end of 2010. These decisions also demonstrate the important role that governments can play in setting the framework for energy efficiency investments.

Despite the central role that improved energy efficiency must play in the future, barriers to efficiency investment exist. Three of the most common are asset life and capital turnover, split incentives and disaggregated investments.

- *Asset life* is a significant issue in energy efficiency. After investments are made, they are typically "locked-in" for the life of the product. The useful life of computer equipment is approximately three years, a cell phone even less. However, cars are generally on the road for 10 years or more and many power plants operating today are more than 50 years old. Through regular maintenance, facilities often become more efficient, but retrofits tend to be more expensive and less effective than building in efficiency in the first place.

- *Split incentives,* also known as principal-agent problems, arise when a second party makes efficiency decisions on a consumer's behalf. A classic example is a home builder who focuses on cosmetic touches to sell a home while skimping on efficiency investments that are hard for the buyer to evaluate – or may even be invisible to the buyer – including windows, heating and cooling systems and insulation. Builders do not have the incentive to spend available capital on energy efficiency unless they are confident that they can recover the capital and make a profit.

- The problem of *disaggregated investments* occurs in both industry and households. Many efficiency opportunities do not involve one large investment with a substantial return. Instead, they consist of large numbers of small actions that add up to significant energy savings. Steam leaks in industrial facilities are a classic example. Each leak is likely to be incidental, but a programme to eliminate all steam leaks can add up to major savings.

Energy Efficiency across Sectors

Opportunities for energy efficiency savings occur in every energy consuming sector – industrial, building, household and transportation.

- Industrial firms aggressively pursue energy efficiency as a way to improve profitability. For companies in energy-intensive industries, energy is a significant operating cost. Long-lived assets and disaggregated efficiency opportunities are recurring themes in the industrial sector. Many companies set specific energy efficiency goals and embed them into the performance objectives of managers.

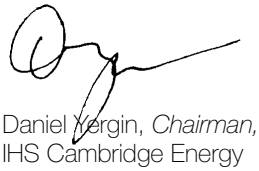
- Buildings represent 40% of energy use in the European Union and the United States and one-third of the world's primary energy. Because buildings can last 50 to 100 years or more, the rate of capital turnover is working against efficiency in the building sector. Although the disaggregated nature of the building sector as well as split incentives can work against energy efficiency improvements, certification programmes offer promising opportunities for both new and retrofit building.

- For households, energy may or may not be a significant cost and energy efficiency is not "front of mind". As a result, energy efficiency standards and labels are often used to guide consumers towards higher efficiency products. More than 50 countries around the world have energy efficiency standards or labelling programmes. Technologies like the "smart grid" or "intelligent buildings" that automate efficiency can help overcome behavioural barriers. Programmes that help low-income consumers pay for efficiency investments can overcome lack of access to capital.

Towards a More Energy Efficient World

- The transportation sector represents another major opportunity for reducing energy use through efficiency improvements and through changing transport policy to focus on movement of people and goods, not simply movement of vehicles. Commercial transport providers, such as airlines and freight haulers, have strong incentives to invest in energy efficiency because fuel is a large part of their variable costs. On the other hand, transportation efficiency is not nearly so central or constant in the decisions of many individuals. They tend to focus on convenience, comfort, cost and status when they choose an automobile or other modes of transport if fuel prices are relatively low. Governments establish vehicle efficiency standards to nudge consumers towards more efficient vehicles. However, changing the way individuals think about transportation is a much larger efficiency opportunity, avoiding unnecessary trips and shifting transport to more efficient modes.

The new emphasis on increasing efficiency – and the forces driving it – has energized a growing business sector that delivers energy efficiency in the form of both products and services. Companies focused on efficiency have existed since the 1970s, but the sector is now growing rapidly in a diversified way into a much larger sector, applying a wide range of technologies and building on new business models. Supporting and facilitating the effort toward greater efficiency are new communication and information technologies that were not available even a decade ago. The expansion of this sector will help to provide a foundation for increasing efficiency in the future and develop the distinctive "infrastructure" of energy efficiency.



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Towards a More Energy Efficient World

CHAPTER 1: THE QUEST TO DO MORE WITH LESS

Introduction

In a way that has never happened before, energy efficiency has moved to the top of the agenda around the world. Governments across the globe have made it a priority for energy and economic policies. Although energy efficiency has always been important for energy-intensive firms, it is gaining new traction across the entire private sector. As José Sergio Gabrielli de Azevedo points out in his perspective *Towards a More Efficient World,* "The potential of energy conservation is unquestionable. The wise use of resources is among the most valuable initiatives we can take to face our challenges."

The reasons governments are placing this new emphasis on energy efficiency are many. They regard it as the quickest means to substantially reduce greenhouse gas (GHG) emissions and more generally improve the environment. They also see it as a way to ensure energy security – to protect their economies against sharp energy price increases, shortages and disruptions. Energy-exporting countries see it as a way to preserve more supplies for world markets. For developing countries, it is a way to reduce pressure on their balance of payments.

For industry, the primary drivers are costs and energy price volatility, a quest for reliability and an understanding that improving energy efficiency is a major tool for meeting mandates to reduce GHG emissions. For consumers more broadly, cost is often a primary concern. Steven Chu, in his perspective, *Energy Efficiency: Achieving the Potential,* points out that "Energy efficiency can save both energy and money."

One other factor is giving a worldwide boost to energy efficiency. With the success of globalization and rapidly growing emerging market nations, it is clear that a major surge in world energy consumption, and thus the call on energy resources, is at hand. Both emerging market nations and established industrial nations recognize that energy efficiency is a requirement for sustaining this economic growth without putting unsustainable burdens on the world's energy supplies and the system that delivers them.

This report is organized into seven chapters:

- The first chapter introduces the concept of energy efficiency and describes past and present initiatives to encourage efficiency.
- The second chapter describes the barriers to and drivers for energy efficiency investments.
- The third through sixth chapters show how these drivers and barriers can play out, with examples from four sectors: industry, buildings, households and transportation. The available resources, motivation and level of knowledge about efficiency differ across these groups.
- The seventh chapter raises questions for policy-makers and businesses about how to encourage cost-effective efficiency investments.

Efficiency: An Answer to Multiple Questions

Global population is expected to grow from 6.6 billion today to more than 8 billion in the next 25 years. With rising incomes, people will want access to energy services, including heating and cooling, electricity and mobility. Providing these services to the world's growing population is challenging enough, but doing so while reducing GHG emissions and increasing the security of energy supply multiplies that challenge.

Improving energy efficiency is a powerful strategy for energy supply, climate change mitigation and energy security. Although becoming more energy efficient is less tangible than exploring deep in the ocean for oil and gas, building power plants or designing new forms of renewable energy, increasing the efficiency of energy use addresses concerns about reliable, low-carbon energy as surely as any of these other investments. In fact, using less energy to complete the same task reduces GHG emissions and is often the least expensive way to do so. With respect to energy security, efficiency can be implemented locally and regionally and can be easily accomplished by rich and poor countries alike. Moreover, greater efficiency in their own operations is a major objective of energy companies themselves. Energy efficiency is sometimes described as the "fifth fuel", in addition to oil and gas, coal, nuclear and renewables. "Energy efficiency will be the single most important source of energy available to the world's economies in the years to come," writes Rex Tillerson in his perspective, *Energy Efficiency – Unleashing the Power of*

Towards a More Energy Efficient World

Ingenuity. In contrast to fuels, opportunities for efficiency are ubiquitous, embedded in nearly every use of energy. Rising and volatile energy prices, supply pressure, population growth, energy security and climate change – energy efficiency helps to address all of these problems.

However, energy efficiency is not a thing, but a process and an approach. It is embodied in new equipment, new buildings and new consumer goods – and in the investment decisions that generate them. It can also be seen as a way of thinking, a way of performing tasks and functions in new ways. Energy efficiency is not simply a matter of technology. The roots of efficiency are often buried in the processes that govern passenger and freight transport, housing, commercial buildings and industries.

Energy efficiency may be ubiquitous, but it is also invisible. You can't see it. That is what creates the unique challenge in realizing its potential. Individuals and corporations tend to invest in assets they can touch or see. They may value more efficient products, services and assets, but the attribute of energy efficiency may be a secondary consideration. Buildings, automobiles and appliances serve their own purposes – efficiency is not the need they are designed to meet.

The objective of this Energy Vision report is to provide a framework for understanding energy efficiency – its attributes and its potential, but also the challenges and obstacles to its realization. How can it be converted from an intangible attribute to a visible and central factor for decision-making across the energy value chain? The report examines what is fuelling the current drive for energy efficiency as well as the barriers that will need to be overcome to achieve greater efficiency. It also observes that, while the record indicates that a good deal has been accomplished in energy efficiency over the last few decades – more than many recognize – tools exist today that can carry it to a new level.

Energy Efficiency: How Did We Get Here?

The conversation begins by defining what energy efficiency is – and what it is not. From an engineering perspective, efficiency is the ratio of outputs to inputs in any process. However, discussions of energy efficiency have come to mean *increasing* energy efficiency, and we will use that convention here.

Reducing energy use is clearly part of the equation, but not the entire answer. Energy efficiency means getting the same benefit while using less energy – reducing the energy input required by a process without changing its output, either in quality or quantity. Efficiency means increasing the productivity of each unit of energy used. Sacrifice is not the point – efficiency should be economically and socially non-destructive.

Before the first oil price shock in 1973, energy efficiency was not a public policy issue in most places. Until the early 1970s, prices for oil, gas and coal were relatively low and stable (see Figure 1). However, the oil crises of the 1970s made explicit what had been previously taken for granted – the critical role of energy in the world economy. The push for energy savings led to a series of new policies, laws and mandates to increase vehicle, building and appliance efficiency – particularly in the United States, Europe and Japan. Japan, acutely conscious of its limited resources, put a high emphasis on efficiency. France set up a separate agency to promote energy efficiency. The United States introduced automobile fuel efficiency standards and began to implement standards for appliances.

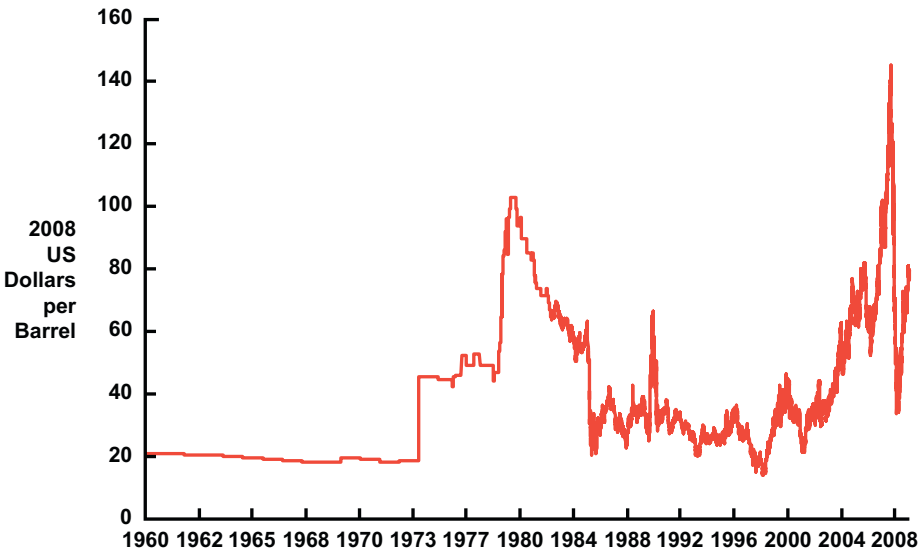
Generally in these years, "energy conservation" became the more familiar phrase. For some, it took on a connotation of "sacrifice" and doing with less, rather than becoming more efficient in how we perform tasks, use equipment and construct buildings. That negative aura created a drag that lasted for many years. As energy prices declined and supplies became more abundant, the attention to efficiency declined, along with its place on the agenda.

Yet, its impact was far more significant than many recognized. The United States and Japan are twice as energy efficient today as they were in the 1970s, as measured by energy use per unit of gross domestic product (GDP). Yet, one could also see in the data that the trend towards greater efficiency that had been stimulated in the 1970s was slowing down in the 1990s, in an era of relatively low energy prices.

But with the beginning of this decade, interest in efficiency began to grow again. Two major factors brought about the change. One was skyrocketing energy prices and the other growing understanding of the potential for man-made climate change.

Figure 1

Ringing the Bell for Energy Efficiency: Crude Oil Prices, 1960–2009



Sources: IHS CERA, Platts, US Energy Information Administration, US Bureau of Labor Statistics.
Note: Price for West Texas Intermediate crude oil. Nominal prices have been deflated using the Consumer Price Index-Urban from the US Bureau of Labor Statistics.
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The industrial sector has always undertaken continuous process improvements in an effort to reduce operating costs and increase margins. In addition, each new building, refinery, airplane or power plant tends to be more energy efficient that the one it replaces, in large part because industry has always valued reducing operating costs. However, when energy prices are low, the focus of manufacturers has been on adding new features to consumer products rather than improving their efficiency.

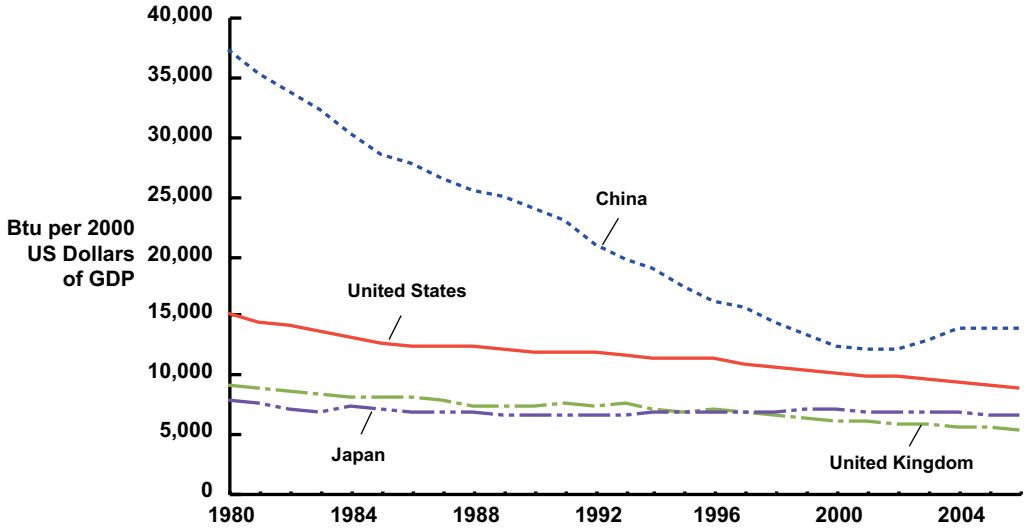
How Far Have We Come?

Energy intensity is defined as the amount of energy used to generate a unit of GDP. Energy intensity has been declining around the world. The United States uses one-third more energy today that it did at the time of the 1973 oil crisis, but the economy is more than two-and-one-half times larger in real terms. Thus, the amount of energy needed to produce a dollar of GDP has declined by nearly half. If the energy intensity of the United States was the same today as in 1972, it would be using approximately 213 exajoules of energy per year (202 quadrillion British thermal units [Btu]), twice as much energy as it uses today, and an amount roughly equal to the energy use of Europe, China, India and Japan combined. A similar decline in energy intensity occurred in other parts of the world, as shown in Figure 2.

Although greater efficiency played a role in the energy intensity decline, structural changes in developed economies also contributed. Many developed economies have become more service oriented as energy-intensive manufacturing has shifted across borders and across seas to developing economies. However, estimates for the United States show that

Figure 2

Energy Intensity of Selected Countries, 1980–2006



Source: IHS CERA.
Data Source: US Department of Energy, Energy Information Administration, *International Energy Annual 2006*, December 2008.
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energy efficiency is responsible for one-half to two-thirds of the decrease in energy intensity.[1] This is a subject that calls for further research.

Governments Emphasize Efficiency as Never Before

Today, in response to volatility in energy prices and growing concerns about GHG emissions, energy efficiency is once again at the top of the world's agenda. The Copenhagen conference on climate change emphasized that energy efficiency has the greatest potential for near-term GHG reductions. Current efforts focus not on the notion of sacrifice but rather on the idea of doing more with less.

Governments are working to build the "soft infrastructure" – policies and programs – that support energy efficiency development. Additionally, many governments are looking to energy efficiency investments as a way to create jobs and promote growth in their economies as the "Great Recession" comes to an end. Figure 3 shows ExxonMobil's estimate of the potential effect of efficiency on global energy demand – a reduction of 316 exajoules (300 quadrillion Btu) in 2030.

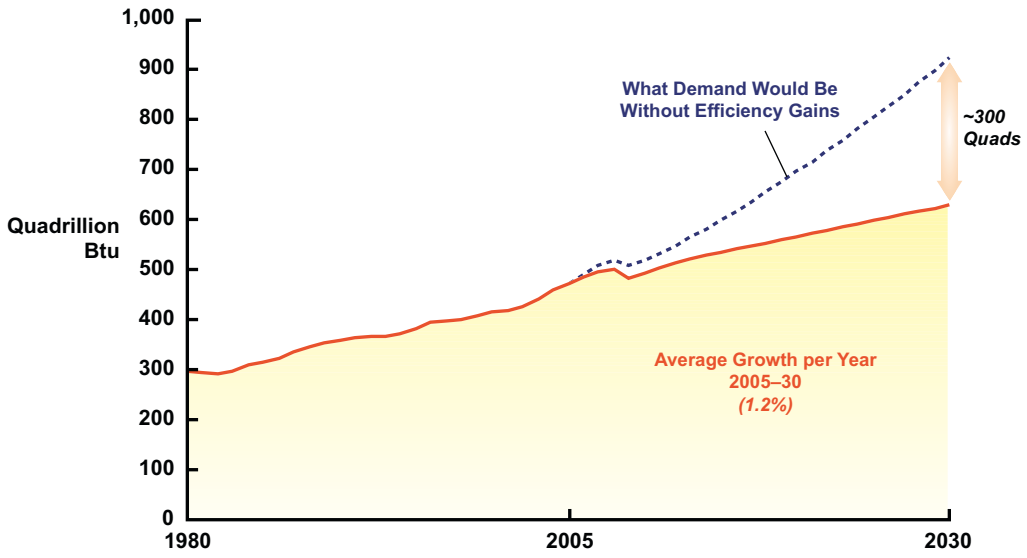
In 2006 the European Union set an aggressive target for energy efficiency – a 20% reduction in primary energy use from a business-as-usual path by 2020. However, the goal is proving challenging to reach, and the EU is set to reach only an 11% reduction by the 2020 deadline.[2] The European Commission is working on an updated Action Plan for Energy Efficiency to make up the

1. Scott Murtishaw and Lee Schipper, "Disaggregated Analysis of US Energy Consumption in the 1990s: Evidence of the Effects of the Internet and Rapid Economic Growth". *Energy Policy* 29 (2001): pp 1335-56.

2. European Commission, Evaluation and Revision of the Action Plan for Energy Efficiency, August 2009.

Figure 3

Potential Impact of Efficiency on Global Energy Demand



Source: ExxonMobil.
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shortfall. The plan targets areas with the most potential, including energy efficiency in buildings and small businesses and access to and better use of financing.

In the United States, the Obama Administration is focusing on energy efficiency investments as an engine of economic growth. "One of the fastest, easiest and cheapest ways to make our economy stronger and cleaner is to make our economy more energy efficient," said President Barack Obama. The US economic stimulus plan includes investments in building and lighting efficiency research, building retrofits and increasing efficiency standards. Additionally, in October 2009 the administration ordered the federal government, the largest consumer of energy in the country, to create energy efficiency and GHG emissions goals.

China set an aggressive energy efficiency target in 2006. The Eleventh Five Year Plan calls for a reduction in the energy intensity of China's economy, measured as units of energy used per unit of GDP, of 20% in the five-year period from 2006 through 2010. As Li Junfeng describes in his perspective *Energy Conservation and Energy Efficiency in China,* "The government considers this target as a significant aspect of China's overall economic and societal development planning." Concerns about energy security, rapid growth in energy demand in recent years and pollution drove this policy. Reaching this goal requires a reversal in the recent trend of Chinese energy efficiency. From 1980 through 2000, the energy intensity of the Chinese economy declined steadily – China's GDP more than quadrupled, yet energy consumption only doubled. However, from 2001 through 2005 the trend reversed and energy use grew faster than GDP, as energy-intensive industries such as steel and cement grew.[3] There is now a very strong emphasis on reducing the energy intensity of China's economy. Li points out, "As China progresses along the path of greater energy conservation and efficiency, there

3. Jiang Lin, Nan Zhou, Mark Levine, and David Fridley, "Taking out one billion tons of CO_2: the magic of China's 11th five year plan?" Lawrence Berkeley National Laboratory, June 2007.

is a need not only for further innovation in technology and mechanisms, but also for adjusting the industrial mix and the way the economy develops."

Russia is also focusing on energy efficiency. In the past, abundant supplies of domestic energy made efficiency a lower priority for Russians. However, the global economic downturn helped to expose weakness in the Russian economy. As Arkady Dvorkovich describes in his perspective *Raising Russia's Energy Efficiency – From Vision to Action,* "Too low energy efficiency and too high dependence on natural resources exports … make the Russian economy vulnerable in the age of globalization." President Dmitry Medvedev set a goal of reducing the energy intensity of the Russian economy by 40% by 2020. "We need to change the mindset shaped by decades of seemingly limitless available energy," states Dvorkovich, emphasizing the level of change needed and the opportunity available.

Japan has been a role model to the world in energy efficiency. Japan's stance on efficiency stems from a sense of resource scarcity and thrifty cultural values. In response to the energy crises of the 1970s, the Japanese government pushed forward with a wide range of government initiatives, including the Law Concerning the Rational Use of Energy (Energy Conservation Act) in 1979. Masayuki Naoshima's perspective *Japan's Energy Conservation Policies: A Model for the Future* describes Japan's efficiency programmes. "The Energy Conservation Act, which has a 30-year history, requires energy management in wide-ranging fields, including the industrial, residential and transportation sectors.

"Backed by such programmes and other efforts," he adds, "the development of innovative energy conservation technologies has been accelerated, significantly contributing to the promotion of energy conservation and the creation of new demand and employment."

Bridging the Efficiency Gap

Although the wise use of all resources, including energy, is a logical objective for all societies, the reality is that sensible energy efficiency investments are not always made. The *efficiency gap* is a term used to describe the difference between the entire pool of cost-effective efficiency investments and the subset of these investments that actually gets done. The extent of the efficiency gap and why it occurs have been a matter of debate for decades. Rather than quantifying available efficiency opportunities or the efficiency gap itself, this report aims to describe factors that businesses and individuals consider when making energy efficiency decisions.

Perspectives on the Quest for Energy Efficiency

The chapter concludes with the perspectives of five individuals who discuss the quest for energy efficiency in various parts of the world.

- **Steven Chu,** United States Secretary of Energy
- **Arkady Dvorkovich,** Aide and Economic Advisor to the President of the Russian Federation, Russia
- **Li Junfeng,** Deputy Director-General, Energy Research Institute, National Development and Reform Commission, China
- **Masayuki Naoshima,** Minister of Economy, Trade and Industry, Japan
- **Rex Tillerson,** Chief Executive Officer and Chairman, Exxon Mobil Corporation, USA

Energy Efficiency: Achieving the Potential

By Steven Chu, United States Secretary of Energy

For the next few decades, energy efficiency is one of the lowest cost options for reducing US carbon emissions. Many studies have concluded that energy efficiency can save both energy and money. For example, a recent McKinsey report calculated the potential savings assuming a 7% discount rate, no price on carbon and using only "net present value positive" investments. It found the potential to reduce consumer demand by about 23% by 2020 and reduce GHG emissions by 1.1 gigatons each year – at a net *savings* of US$ 680 billion.

Likewise, the National Academies found in 2009 that accelerated deployment of cost-effective technologies in buildings could reduce energy use by 25-30% in 2030. The report stated: "Many building efficiency technologies represent attractive investment opportunities with a payback period of two to three years."

Some economists, however, don't believe these analyses; they say there aren't 20-dollar bills lying around waiting to be picked up. If the savings were real, they argue, why didn't the free market vacuum them up? The sceptics are asking a fair question: why do potential energy efficiency savings often go unrealized?

I asked our team at the Department of Energy to review the literature on savings from home energy retrofits. We are pursuing energy efficiency in many areas – from toughening and expanding appliance standards to investing in smart grid – but improving the efficiency of buildings, which account for 40% of US energy use, is truly low-hanging fruit.

In this review, we looked only at studies that compared energy bills before and after improvements and excluded studies that relied on *estimates* of future savings. We found that retrofit programmes that were the most successful in achieving savings targeted the least efficient houses and concentrated on the most fundamental work: air-tight ducts, windows and doors, insulation and caulking. When efficiency improvements were both properly chosen and properly executed, the projected savings of energy and money were indeed achieved. In science, we would call the successful programmes an "existence proof" that efficiency investments save money. Too often, however, the savings went unrealized, due to a number of reasons, including poor efficiency investment decisions and shoddy workmanship.

There are other reasons why energy savings aren't fully captured. Market failures include inertia, inconvenience, ignorance, lack of financing and "principal agent" problems (e.g., landlords don't install energy efficient refrigerators because tenants pay the energy bills). To persuade the sceptics and spark the investments in efficiency we need, the Department of Energy is now focused on overcoming these market failures.

First, the Department is working to develop a strong home retrofit industry. We are creating a state-of-the-art tool that home inspectors can use on a handheld device to assess energy savings potential and identify the most effective investments to drive down energy costs. We're also investing in training programmes to upgrade the skills of the current workforce and attract the next generation. The Department is also focused on measuring results – to both provide quality assurance to homeowners and promote improvement. For example, we're pursuing new technologies such as infrared viewers that will show if insulation and caulking were done properly. Post-work inspections are a necessary antidote and deterrent to poor workmanship.

To address inconvenience and to reduce costs, we're launching an innovative effort called "Retrofit Ramp-Up" that will streamline home retrofits by reaching whole neighbourhoods at a time. If we can audit and retrofit a significant fraction of the homes on any given residential block, the cost, convenience and confidence of retrofit work will be vastly improved. Another goal of this programme is to make energy efficiency a social norm.

To help pay for investments, we're working with the Department of Housing and Urban Development to encourage new financing tools. For example, homeowners might pay back energy improvement loans via an assessment on their property tax bill. Out-of-pocket expenses are eliminated and energy savings will exceed the increase in property tax. Both the savings and the loan payments would stay with the house if the owners decide to sell.

Another opportunity comes when a property changes hands. Banks require a structural inspection and a termite inspection; they should also ask for the last year's worth of utility bills, which speaks directly to the home's affordability. If improvements are needed, the costs could be seamlessly tacked onto the mortgage.

The greatest gains can be realized in new construction. By developing building design software with embedded energy analysis and building operating systems that constantly tune up a building for optimal efficiency while maintaining comfort, extremely cost-effective buildings with energy savings of 60-80% are possible.

Regardless of what the sceptics may think, there are indeed 20-dollar bills lying on the ground all around us. We only need the will – and the ways – to pick them up.

Raising Russia's Energy Efficiency – From Vision to Action

By Arkady Dvorkovich, Aide and Economic Advisor to the President of the Russian Federation, Russia

The global financial crisis, like an outgoing sea tide, exposed many deficiencies lying under the surface of the Russian economy. These deficiencies have been there for many decades – known but ignored – complicating sailing by economic actors. But they did not threaten navigation, thanks to the high sea level of the global economy.

No more. Impeded by domestic limitations that suddenly gained in importance, the Russian economy suffered from the global economic crisis more than its competitors. Out of the complex mix of factors, I would single out two interrelated domestic reasons for the Russian economy's difficulties – too low energy efficiency and too high dependence on natural resource exports. These two factors make the Russian economy vulnerable in the age of globalization. The end of the anaesthesia from high levels of energy demand hurts.

Russia's future critically depends on how soon and how successfully it gets rid of the economic obstacles preventing it from competing on an equal footing with other economies. Multi-dimensional competition and effective regulation are the keys to overcoming the downturn and positioning for the newly emerging world economy. Of course, this recognition is not new. However, the crisis jolted our economy so much that there is now practically a national consensus that Russia must undertake concerted efforts to become more energy efficient.

We used to think that our rich endowment of energy resources protected us from worrying about energy efficiency. In the current environment we lag behind our partner-competitors in many areas. We need to change the mindset shaped by decades of seemingly limitless available energy.

It would be wrong to say that nothing has been accomplished. The energy intensity of the Russian GDP dropped by one-third between 2000 and 2008. At the same time, electricity intensity decreased by 30%. These look like decent results. However, these results were reached through extensive measures. The easy changes have been made and the next level of energy efficiency improvements will require going deeper to identify where the gains can be realized.

Today, we aim for an energy efficient model of economic development. In practice this means that to be globally competitive, we must at least catch up with most advanced countries with regard to energy intensity. President Medvedev set the goal of increasing the energy efficiency of the Russian economy by 40% by 2020. This goal considers energy efficiency as an inclusive and interactive notion. It implies improving the efficiency of energy production, transmission, transformation and use in all areas. Gas- and coal-fired generation facilities must be renovated; new power stations must be constructed using the latest technological advances. Just as important for us, increasing energy efficiency meets other related challenges, primarily reducing GHG emissions.

However, the real challenge lies in converting concepts and legal provisions into action. In this regard, a special presidential commission has been established to promote five priority areas that are the key drivers for modernizing the Russian economy. These priorities include researching, developing and implementing the newest technologies in the medicine, information technology and nuclear energy sectors; developing space and telecommunications systems and radically increasing energy efficiency. This Commission on Modernization has already approved specific projects in all of these areas and has drawn up timetables for their implementation, which is already underway.

In the sphere of energy efficiency we envisage moving quickly and simultaneously in several directions:

- Introducing energy use smart metering for households on a wide scale within five years
- Gradually expanding the use of energy saving lighting devices, including banning circulation of incandescent lamps by 2011
- Launching city block energy efficiency projects, as well as more focused projects, including for schools and hospitals, within three years
- Modernizing and retrofitting utility networks
- Introducing new energy payment schemes and energy service contracts

Innovation in the energy sector will eventually make the difference, ranging from superconductivity technology for long distance energy transmission to advanced safer nuclear energy and much wider use of renewable energy sources.

Isolated breakthroughs cannot change the whole picture unless they become a rule. In addition, a nation's level of energy efficiency cannot be sustainably improved unless the notion of efficiency becomes a real factor in a country's development, a required condition for its sustainable growth. We have a solid legal basis for Russia's rapid advance in this direction. A milestone occurred when the State Duma recently adopted the "Law on Energy Saving and Increasing Energy Efficiency". It has all of the major components for being a success, and of course we are prepared to adjust it as we gain experience.

All these and other contemplated measures prove that Russia is becoming more energy responsible, in cooperation with other major nations and relevant organizations. Raising energy efficiency will not only help the Russian economy become more competitive. It will also expand Russia's contribution to ensuring global energy security and meeting other related common challenges.

Energy Conservation and Energy Efficiency in China

By Li Junfeng, Deputy Director-General, Energy Research Institute, National Development and Reform Commission, China

As long ago as the early 1980s, the Chinese government announced energy strategies that strived to balance conservation and development. The government has always regarded conserving energy and improving efficiency as fundamental national policies and has taken energy conservation very seriously. Earlier this decade, the Chinese government set a strategic objective to build "a resource-conserving and environmentally friendly society" and emphasized this objective in the country's overall industrialization and modernization strategy.

Many laws, regulations and planning documents support the government's conservation and efficiency efforts. Passed in 1998 and amended in 2007, the *Energy Conservation Law* lays a solid legal foundation for conservation-related policies. The 2007 Climate Change Action Plan represents another step forward in the nation's sustainable energy development by identifying the development of renewable energy and the improvement of energy efficiency as crucial measures to combat climate change. In 2008, several rules and regulations were issued to set specific building requirements related to conservation, including the *Energy Conservation Ordinance for Civil Construction* and the *Energy Conservation Ordinance for Public Institutions.* In addition, the Chinese government announced 22 compulsory national standards for selected high energy-intensity products as well as 19 compulsory national efficiency standards for end-user appliances.

Energy conservation and energy efficiency are not makeshift half measures in China, but rather crucial, long-term fundamental policies that support the country's sustainable development and help tackle global climate change.

Specific Policy Mechanisms Govern Energy Efficiency

To ensure the effective implementation of energy conservation and efficiency improvement, the Chinese government established a Leading Group on Energy Conservation and Emissions Reduction, headed by Premier Wen Jiabao. Most provincial, municipal and county governments as well as large enterprises established similar entities within their organizations.

The central government also created energy conservation and emissions reduction targets for all regions as well as the top 1,000 energy consuming enterprises; it also issued a plan to monitor statistics and assess implementation for each region and the key enterprises. The provinces established similar systems to evaluate progress.

To ensure that energy conservation objectives are reached, the government commenced a programme to retire inefficient productive capacity in industries, focusing specifically on the electric power, iron and steel, aluminium and cement sectors.

The Chinese government launched key energy conservation projects, promoted energy-saving construction (i.e., energy-saving light bulbs), started a programme to benchmark energy efficiency of key energy-intensive industries and identified three key areas for focused encouragement of energy conservation and efficiency: industry, construction and transportation. In addition, China's government launched the *Top-1,000 Enterprises Energy Efficiency Programme* and put forward energy-use auditing of key enterprises, which includes the drawing up of energy conservation plans and the reporting of energy consumption.

To promote energy conservation and efficiency, China's central government increased the taxable amount for coal, oil and natural gas; implemented policies that encourage the use of energy-saving technology; carried out price and tax reform for finished-oil (refined) products; and implemented many other economic measures that promote energy conservation. Furthermore, the establishment and refinement of energy conservation laws and regulations provides the legal support for China's push towards greater energy conservation and efficiency.

China's Efforts Have Already Shown Significant Results…

The effectiveness of relevant policies and the organization, mechanisms and legal framework surrounding them have enabled China to continuously implement conservation and efficiency measures and achieve notable results. From 1980 to 2000, China's GDP more than quadrupled; yet, energy consumption only doubled. In the 11th Five Year Plan, the Chinese government introduced a binding target of reducing GDP energy intensity by around 20%. The government considers this target as a significant aspect of China's overall economic and societal development planning. Within the last three years, China's GDP energy intensity has decreased annually: -1.79% in 2006 (the first decline since 2003), -4.04% in 2007 and -4.59% in 2008. In other words, during the first three years of China's 11th Five Year Plan, the country's GDP energy intensity declined 10.1%, already completing half of the designated target.

…But There Is Still a Long Road Ahead

China has already achieved great progress with energy conservation and efficiency; however, the conflicting forces of energy supply and economic development are still a significant issue. As China progresses along the path of greater energy conservation and efficiency, there is a need not only for further innovation in technology and mechanisms, but also for adjusting the industrial mix and the way the economy develops. Furthermore, there must be a change in lifestyle thinking that pushes towards a path of low carbon development. On 26 November 2009, the Chinese government announced that by 2020 China's carbon emissions per unit of GDP will decrease 40-45% from 2005 levels. This is a binding target now integrated in China's mid- and long-term planning of its economic and societal development. Along with this integration, China will establish relevant data collection, supervision and evaluation methods to ensure this carbon intensity target is achieved.

Japan's Energy Conservation Policies: A Model for the Future

By Masayuki Naoshima, Minister of Economy, Trade and Industry, Japan

We currently face an urgent need for international policy coordination to overcome the financial crisis and tackle other issues, including global warming and unstable resource prices. All of these require concentrating the wisdom of all mankind, working across government and industry borders.

Japan will play a leading role in these efforts. Japan's own circumstances have concentrated its mind. Lacking energy resources, Japan has made energy conservation one of its central pillars for ensuring a stable energy supply. Twice in the past, Japan has overcome severe oil crises and, in response, has endeavoured to create innovative, energy efficient technologies. In the past 30 years, during which the country's GDP has almost doubled, Japan has improved its energy efficiency levels by nearly 40% and has succeeded in striking a sound balance between the environment and the economy.

Japan's primary energy consumption per unit of GDP is the lowest in the world among industrial countries. Furthermore, Japan has made contributions as the world's most advanced country in terms of energy conservation by providing assistance to developing countries, mainly in Asia.

Energy conservation needs to be facilitated by a framework of laws and policies, and the Japanese government has promoted energy conservation with such a framework. The Act on the Rational Use of Energy (Energy Conservation Act) aims to enhance energy management and improve the energy conservation performance of equipment and buildings. The government provides support in terms of budgets, taxation and national programmes through such means as providing assistance for the introduction of energy-saving equipment. The Voluntary Action Plan on Environment, in which 108 types of industries participate, has also played an important role in promoting the energy conservation movement in Japan.

The Energy Conservation Act, which has a 30-year history, requires energy management in wide-ranging fields, including the industrial, residential and transportation sectors. From a worldwide perspective, legislation that imposes energy conservation regulations on the industrial sector is quite rare.

Because nearly 90% of energy consumption in the industrial sector is subject to regulation under the Energy Conservation Act, the sector has actively made efforts to promote energy conservation. As a result, energy consumption has remained almost the same for nearly 30 years. In the meantime, energy consumption in other business sectors has increased significantly in recent years. The Act's revision in 2007 further strengthened energy conservation measures by expanding the regulation's coverage.

The Top Runner Programme, based on the Energy Conservation Act, has had far-reaching effect on both energy and on strengthening industrial competitiveness. This programme aims to raise fuel efficiency standards for automobiles and energy conservation standards for electric appliances above that of the most energy efficient product in the current market within the target fiscal year. Through this programme, average fuel efficiency for Japanese automobiles improved by 28% in the 12 years from 1995 to 2007.

Backed by such programmes and other efforts, the development of innovative energy conservation technologies has been accelerated, significantly contributing to the promotion of energy conservation and the creation of new demand and employment. One such innovation, hybrid vehicles, is having worldwide impact. Hybrid vehicles were developed by Japanese automakers ahead of other manufacturers and are dramatically improving fuel efficiency. Moreover, hybrid vehicles are highly valued both in domestic and foreign markets.

Japan's experience with energy conservation over several decades has led to a very positive change in attitudes. In the past, companies and individuals have regarded energy conservation as a restrictive factor that forces "savings". Now that perception has changed. Companies and individuals that regard energy conservation as a "strength" that contributes to productivity enhancement will be successful.

The Japanese government will further support such companies and individuals to promote energy conservation in all areas as one of the components of addressing global warming. At the same time, it will also contribute to resolving global warming issues and contributing to energy security by transmitting the superior energy conservation technologies that Japan has developed over the years to the international community.

Energy Efficiency – Unleashing the Power of Ingenuity

By Rex Tillerson, Chief Executive Officer and Chairman, Exxon Mobil Corporation, USA

Unlocking new sources of energy requires ingenuity and innovation. In the years ahead, the world will face tremendous growth in energy needs, as citizens of the developing world strive to grow their economies and improve their quality of life. By supporting innovative thinking and new technologies, we can expand energy supplies to meet these needs and increase the contributions from the most underestimated energy source of all – energy efficiency.

By 2030, energy demand is expected to increase by about 33% over 2005. Meeting this enormous global need will require the world to develop all economic sources of energy – including oil, natural gas, nuclear power, wind power and more. Advances in technology can help expand our energy supplies. But over time, one energy source is set to grow more than any other. That "source" is the energy efficiency gains flowing from new ideas and innovations.

In recent decades, energy efficiency has proven to be a powerful component of the global energy mix. Take the United States, for example. Since 1970, more efficient use of energy has helped to meet more than half of its growing energy demand. Looking ahead, in 2030, the amount of energy saved globally through efficiency gains is projected to be 300 quadrillion Btu – or about twice the amount of the actual energy supply increase we expect from *all* other sources.

Energy efficiency will therefore be the single most important source of energy available to the world's economies in the years to come. In addition, it will also play an important role in helping reduce GHG emissions.

Yet, we must remember that efficiency gains from innovation are not automatic. Energy efficiency's full potential can only be achieved with the combination of long-term investment; sound and stable policies from government; and the widespread use of energy-saving technologies and practices by consumers.

Like all our energy challenges, the key to increasing energy efficiency is technology. And the key to developing and deploying that new technology is disciplined investment.

ExxonMobil is one of many companies showing that commitment and discipline. Since 2004 alone, we have invested more than US$ 1.5 billion in activities to reduce GHG emissions and improve energy efficiency, and we have plans to spend at least a half-billion dollars more on additional energy efficiency initiatives over the next few years. ExxonMobil has also committed to improving energy efficiency in our refineries 1% per year over 10 years – and we are on target to meet that goal.

We have become an industry leader in cogeneration, a technology that enables us to produce electricity to power our operations while also capturing heat to make steam to transform raw materials into consumer products. This process provides a more efficient power source than purchasing from a local utility – in some cases up to 50% more efficient. We now have interests in about 100 cogeneration facilities in more than 30 locations worldwide. These projects can produce more than 4.5 gigawatts (GW) of electricity, enough to supply the needs of approximately 2 million US homes. With new facilities under construction, we expect to increase our cogeneration capacity to more than 5 GW by 2011.

Our scientists and engineers are also working to advance other energy-saving technologies in the short and medium terms, and we are pursuing even more transformative technologies over the long term. For instance, we are investing in research and development of technologies that increase vehicle fuel economy – through lighter plastics, improved tyre inner liners and more advanced synthetic motor oils. We have pioneered innovative separator films for lithium-ion batteries, which could enable their more widespread use in hybrid and electric vehicles. And we are advancing an on-board hydrogen reformer system for potential limited application in industrial vehicles. This technology could lead to an 80% improvement in fuel economy.

These are just a few of the solutions that ExxonMobil is pursuing. The energy industry and the entire private sector are pursuing many more. To ensure this work continues and that new innovations are found and deployed, government has a role to play.

Government leaders can encourage the long-term planning and investments required to develop new technologies by upholding sound, stable energy policies. Government must also promote free markets and trade, which help scientists, engineers and innovators work across borders, share ideas and speed the delivery and adoption of new technologies.

Finally, consumers have a role to play in increasing energy efficiency. By investing in and practicing efficient energy use in the home and on the road, every citizen can help develop this valuable source of energy.

No single source can meet the world's growing needs for energy. And no single sector or nation alone can provide the energy needed to grow the global economy while reducing emissions and strengthening energy security. But by working together to develop new sources of energy – including, most importantly, the unexpected source, energy efficiency – we can meet these shared challenges and achieve a brighter future.

CHAPTER 2: "INVESTMENT-GRADE" – DRIVERS AND BARRIERS TO ENERGY EFFICIENCY

Increasing energy efficiency is crucial to meeting the world's future needs. Efficiency can allow the provision of energy services to more people at lower cost, with lower GHG emissions. But how can efficiency opportunities bridge the gap and move from potential to reality?

Rather than suggesting that energy efficiency investments are free, which they are not, we would like to introduce the concept – and the importance – of "investment-grade" efficiency. This chapter focuses on the factors businesses and consumers consider when making efficiency decisions and barriers that stand in the way of efficiency investments. It argues that efficiency investments are still investments, and thus investors, whether businesses or consumers, face trade-offs. Finally, as described by Kateri Callahan in her perspective *Building the Infrastructure for Energy Efficiency,* "soft infrastructure" like public policy, education and financing tools is crucial to increasing efficiency.

Factors that Influence Efficiency Decisions

Four key factors influence efficiency decisions: consumer behaviour, competition for and availability of capital, energy price and price volatility, and technological innovation. Each is discussed below.

Consumer Behaviour Is Central to Understanding Efficiency

Energy consumer behaviour is crucial to overcoming the efficiency gap. Consumers require knowledge about efficiency opportunities as well as the motivation and ability to implement them. Although structural barriers to energy efficiency exist, understanding behaviour is a key starting point.

Estimates of the efficiency gap often assume perfect information – that consumers know which energy efficiency investments are available and cost-effective for them. However, consumers don't have perfect information about efficiency options. This is particularly true in households and in businesses where energy is not a major cost. Decisions about energy efficiency involve analysis of potential energy savings and future energy prices. Understanding the difference in initial cost is easy for consumers, but understanding the potential future savings is much more difficult.

Energy efficiency labels are one way to inform consumers about the efficiency attributes of products in a way that minimizes effort for the consumer. A government-affiliated label is particularly effective, because it is standardized and becomes familiar. Many countries require efficiency labels on a variety of products, including cars and trucks, appliances, heating and cooling equipment and industrial equipment such as electric motors.

Consumer preference for the status quo and familiar technologies can sometimes bias them against energy efficient options. Consumers take time to adopt new technologies. Additionally, some consumers do not find energy efficient options to be as appealing as the technology they are used to. For example, some consumers dislike compact fluorescent light bulbs because of their colour, shape, mercury content or difficulty of disposal. As technology continues to advance, manufacturers will find ways to make efficient products that better meet the needs of consumers. Improving compact fluorescent technology means that today's lights have more pleasing light colour and less flicker and hum than past models – a direct response to customer demands.

Competition for and Availability of Capital – The Central Framework for Investment

The competition for limited capital provides a framework for understanding energy efficiency decisions. Businesses and individuals do not have unlimited funds and energy efficiency investments compete for money with other needs and wants. Lawrence J. Makovich describes competition for capital in his perspective *Energy Efficiency – An Investment Perspective* "Energy efficiency investments require capital. To make financial sense, the savings from the investment must cover the cost of capital and provide a return on the investment. However, capital is a scarce resource, meaning that that consumers can do some but not all of the investments available to them that promise a positive return."

Knowing that an energy efficiency investment will pay for itself over time is not sufficient to make the investment decision. Efficiency must be "investment grade" – it must have a high enough rate of return to compete with other potential uses for capital. Homeowners may

Compact Fluorescent Light Bulbs – 75% less electricity

know that they can save on heating bills by replacing older windows or adding insulation. But that knowledge does not facilitate making the investment if homeowners cannot pay the up-front costs or have other, more pressing needs.

The competition for capital is one of the main considerations for industrial and commercial efficiency investments, particularly for large, capital-intensive projects. Even operating changes may require an investment in retraining personnel. Thinking of energy efficiency as an investment demonstrates that not all technically feasible efficiency efforts make sense. Competition for capital explains a portion of the efficiency gap – some efficiency projects with a positive rate of return are out-competed by other investments with a higher return.

For small business and households in particular, availability of capital is an important issue. A homeowner may need to borrow money to install a new, higher efficiency boiler or new windows or insulation. Financing is less available to low-income borrowers or those with poor credit, even if the efficiency investment itself would have a high rate of return. Most types of credit do not take into account the savings in energy costs that result from an efficiency investment, improving the borrower's cash flow – and thus reducing the risk to the lender. Kateri Callahan describes a remedy for the lack of capital availability. "Property Assessed Clean Energy (PACE) bonds are an elegant approach to overcoming this barrier. Municipalities float PACE bonds to allow owners to finance renewable energy or energy efficiency improvements at attractive rates through their tax bills, thereby allowing the 'mortgage' to roll over upon sale of the property."

Towards a More Energy Efficient World

Energy Price and Price Volatility – The Most Important Driver

Why would individuals or corporations try to improve their energy efficiency? The single most important driver is the price of energy. Although energy efficiency investments can pay dividends in terms of comfort, process reliability or other factors, reduced energy cost is the primary economic payback for efficiency investments.

Unfortunately, variation in energy prices and the unpredictability of future prices make the returns from energy efficiency investments uncertain. As Makovich describes in his perspective, "The promise of payback from an efficiency investment is just that – a promise and not a guarantee." Policies that increase energy prices with certainty, such as taxes, can increase the incentive for energy efficiency investment. However, they are often politically unpopular. Conversely, subsidies that shield consumers from increases in energy prices can discourage energy efficiency investment, even though they decrease volatility as well.

In many developing countries, energy subsidies are a contentious and often very difficult matter. On one hand, subsidies are seen as an ingredient for social stability and a stimulus to economic growth. They impose a cost of their own, however, by suppressing price signals and stimulating consumption. Untargeted subsidy payments are unnecessary for households that can afford market energy prices. Countries with subsidized energy prices can enter a destructive cycle. Low energy prices provide little or no incentive for consumers to use energy efficiently, resulting in increasing energy demand. More demand requires developing more energy resources, but the subsidized rates don't provide enough money to invest. Energy shortages and drain on government resources can result.

Singapore provides an example of helping low-income households pay for energy without introducing distorting subsidies. As S. Iswaran describes in his perspective *Singapore: An Energy Efficient Nation,* "The starting point is to price energy properly and avoid subsidies – this incentivizes energy efficiency and discourages over-consumption. For example, all consumers in Singapore see the full cost of electricity in their bills. Lower-income families receive a 'Utilities Save' rebate to help lighten their burden. But this is extended as a separate credit, instead of an across-the-board subsidy on the price of electricity."

As countries seek to promote energy efficiency, the issue of subsidies becomes especially significant. In September 2009, leaders at the G20 meeting agreed to phase out subsidies for fossil fuels over time. Subsidizing energy efficiency investments for low-income consumers can be a substitute for subsidized energy prices. This policy can reduce the future need for energy subsidies and greater energy supply, providing benefits for society as a whole.

Particularly for long-lived assets, consumers have no idea what energy prices will be over the asset's life. Determining which efficiency options are investment grade for long-lived assets is challenging. The process is frequently affected by the tendency to assume that energy prices in the future will look much like today's prices.

Consumers respond to price signals when making efficiency decisions. For example, higher taxes on gasoline as compared to diesel fuel have encouraged European consumers to buy more efficient diesel cars. In response, diesel car sales in Europe have grown from 28% to 52% of new car sales over the last decade.[1] Conversely, low gasoline prices in the United States in the 1990s encouraged a surge in the popularity of SUVs. These large, low-fuel-efficiency vehicles made up as much as 55% of US vehicle sales in 2004. However, when US gasoline rose significantly, SUV sales dropped and the fuel economy of new car purchases started rising.

Energy prices generally do not include all of the externalities associated with the production of energy, including GHG emissions, pollution and energy security concerns. When externalities are not included in prices, some argue that underinvestment in efficiency results. Including the cost of externalities in energy prices results, they argue, is a more accurate calculation of the return on efficiency investment for society as a whole. As Singapore's S. Iswaran describes, "Ideally, energy prices should take into account not just today's fuel prices,

1. US Department of Energy, Energy Information Administration, *Light Duty Diesel Vehicles: Efficiency and Emissions Attributes and Market Issues,* February 2009.

but also externalities such as the social cost of carbon emissions. Hence, we apply a shadow price for oil and carbon in our cost-benefit analysis to better inform government policies and decision-making."

One purpose of Europe's transportation fuel taxes and emissions trading system is to include externalities in energy price, thus promoting greater energy efficiency investment. However, linking any reduction in demand to the policies is difficult because of other variables that can influence energy demand. In both the United States and Europe, for example, GHG emissions declined in 2008. Policy initiatives may have played a role, but they were overwhelmed by the impact of the Great Recession on energy demand.

Technological Innovation – Enabling New Approaches to Energy Efficiency

Innovation is crucial to improving energy efficiency. The ongoing revolution in lighting technology provides an example of transformational innovation in action. Compact fluorescent bulbs use as little as 25% of the electricity of a similar incandescent bulb, in part because they waste much less energy in the form of heat. They also last 6 to 15 times as long.[2] Compact fluorescent bulbs now make up approximately 80% of sales in Japan, 50% in Germany, 20% in the United States and 14% in China.[3] Solid-state lighting – light produced by light-emitting diodes (LEDs) – is the next transformational step. LEDs are a type of semiconductor that generates light when a current is passed through. LED lights use less energy than fluorescent, contain no mercury, are easier to dim and come in a range of colours. LEDs are not yet economic in many applications, but costs are declining rapidly. The US Department of Energy estimates that prices for integral LED lamps will decline by two orders of magnitude by 2025, from approximately € 130 to € 1.30 per thousand lumens (US$ 200 to US$ 2). Technology is also improving to produce "warmer", more aesthetically pleasing light, allowing LEDs to be used in more applications.[4]

Breakthrough innovations are also occurring on the supply side of energy efficiency. Many electric power utilities have worked hard to increase the efficiency of generation. Still, substantial quantities of electricity are lost between the generating plant and the final customer. John Krenicki, in his perspective *Take Advantage of Scale,* describes emerging technologies that can increase the efficiency of the transmission and distribution processes. "The technology exists to minimize these losses, and government and utilities should consider such investments within broader energy efficiency initiatives."

However, innovation does not refer only to breakthrough technologies. Continuous improvements – "tinkering" – with existing products can make a great difference in energy use, leading to innovative surprises over time. Refrigerators provide a good example. The average refrigerator sold in the United States today uses three-quarters less energy than the 1975 average – even though it is 20% larger and costs 60% less in inflation-adjusted terms.[5] Factors that have improved refrigerator efficiency include greater insulation; heavier doors that form a tighter seal; more efficient fans, motors and compressors; and "smarter" controls that adapt to varying conditions. However, consumers have taken back some of this efficiency improvement. The number of US households with two or more refrigerators has increased, and the secondary refrigerators are typically older and less efficient than the primary models.

Barriers to Efficiency Investment

The four factors discussed above – consumer behaviour, competition for and availability of capital, energy price and price volatility and technological innovation – may align in a way to promote energy efficiency investments.

2. United States Department of Energy, http://www.energysavers.gov/your_home/lighting_daylighting/index.cfm/mytopic=12050
3. McKeown, Alice, "Strong Growth in Compact Fluorescent Bulbs Reduces Electricity Demand", *Vital Signs,* WorldWatch Institute, October 2008.
4. US Department of Energy, Energy Efficiency and Renewable Energy, Building Technologies Program, *LED Basics,* November 2009.
5. Joe Loper, Selin Devranoglu, Steve Capanna and Mark Gilbert, "Energy Efficiency Potential in American Buildings", Working document of the National Petroleum Council Global Oil and Gas Study, 18 July 2007; Steven Chu, Plenary Address, United States Energy Information Administration Conference, 7 April 2009.

Towards a More Energy Efficient World

However, several barriers still need to be addressed to ensure that energy efficiency investments become embedded in day-to-day decisions. The three most common – and troubling – are asset life and capital turnover, split incentives and disaggregated investments. Each is discussed below.

Asset Life and Capital Turnover – Long-lived Assets Pose a Challenge

Asset life is a significant issue in energy efficiency. After investments are made, they are typically "locked in" for the life of the product. The useful life of computer equipment is approximately three years, and cars are generally on the road for 10 years or more. However, the useful lives of buildings, power plants and industrial facilities are measured in decades. Many hydroelectric power plants operating today are more than 80 years old. Although coal power plants were originally designed for a life of 30 years, many plants operating today are more than 50 years old. Even some nuclear power plants in the United States have been granted a 20-year extension to their initial 40-year operating licence.

Through regular maintenance, many facilities become more efficient. Homeowners can also make efficiency improvements to existing assets, such as adding insulation or installing new windows. However, retrofits – in homes, refineries, manufacturing operations and power plants – tend to be expensive and not as effective as building in greater efficiency in the first place.

Some attributes cannot be changed – a large vehicle or house will not get smaller. Assets can be retired before the end of their useful life, but this comes at a cost. For example, consumers in the United States who owned large SUVs found that the value of their vehicles dropped substantially when gasoline prices rose in the summer of 2008. Those who wanted to switch to a more efficient vehicle found it difficult since their current vehicles were worth less than expected.

Split Incentives – Spending Someone Else's Money

Split incentives, also known as principal-agent problems, arise when a second party makes efficiency decisions on a consumer's behalf. In a sense, someone else is making decisions about spending the energy consumer's money. For example, builders often choose the heating and air conditioning systems, appliances and windows in new buildings. However, the eventual tenant or owner of these buildings pays the energy bills after the building is finished. Thus, the incentives for the builder are not aligned with those of the owner or tenant. The builder wants to construct the building at least cost and may not make all of the energy efficiency investments that the occupant might want.

Building codes that include efficiency standards and green building certifications help to reduce the agency problem in new buildings. Efficiency certification standards include the United Kingdom Building Research Establishment Environmental Assessment Method (BREEAM) in Europe, Leadership in Energy and Environmental Design (LEED) in the United States, and the Green Building Council of Australia's Green Star. Additionally, providing more information about efficiency during the sale or lease of both new and existing buildings allows consumers to make informed choices. It also enables builders or landlords a greater opportunity to recoup their energy efficiency investments.

Private homes are particularly prone to split incentives. Private homes are often built "on spec", meaning that construction on the homes begins, and sometimes ends, before the builder has a buyer. Incentives in this situation are for the builder to economize on insulation and other energy efficiency attributes that are hard for the homebuyer to see and evaluate. Often homebuyers do not know what to ask about or look for with respect to energy efficiency, or it is not clear whether efficiency should affect their buy decision.

Another form of split incentives can occur within businesses. Capital and operating budgets are often handled separately in the accounting and budgeting process. Projects that require upfront capital may be rejected in the capital budget, even if they provide investment-grade returns to the operating budget.

Disaggregated Investments – Small Changes Can Make a Big Difference

Many energy efficiency opportunities do not involve one large investment with a substantial return. Instead, they consist of a large number of small actions that add up to significant energy savings. Insulating individual

homes, fixing steam leaks in industrial processes and ensuring proper tyre pressure to increase automobile fuel efficiency are examples of disaggregated opportunities. Cost-effectively implementing these diffuse opportunities is a challenge because of the transaction costs involved.

Energy efficiency standards are one way to get around the problem of transaction costs. Standards work well for investments that are common to a large group of consumers. For example, many consumers purchase automobiles, appliances and home insulation. If a government entity sets efficiency standards for these investments, consumers do not have to spend a lot of time analysing the energy efficiency of each product. Standards don't optimize efficiency at every house or business, but they do allow efficiency improvements in these settings with minimal effort from the consumer. They also set a "floor" for efficiency, removing the most inefficient products from the market.

Standards can also help reduce split incentive problems. For example, when purchasing a new house, certain energy efficiency features are visible, such as windows and appliances, but others are not, such as insulation. Building codes can ensure that builders don't skimp on efficiency features that buyers can't see.

Conclusions

What motivates an individual, corporation or government to take action to use energy more efficiently? The most important driver is normally the cost of energy. Individuals, corporations and governments are all motivated by ways to save energy costs, and efficiency investments have historically ebbed and flowed with the price of energy. However, the equation is not that simple. Energy efficiency investments can be derailed by lack of capital or lack of information; the difficulty of adding up small, incremental fixes or the disconnect between the party who makes the initial investment and the party who pays the ongoing operating costs.

As Peter Voser describes in his perspective *Making the Most of an Energy Efficiency Revolution,* "Energy efficiency has rightfully been put on the top of the to-do list of most energy-policy proposals...To move the energy system in the right direction, the technologies that make our machines and buildings consume less energy must be accompanied by regulations that ensure a lasting positive impact."

None of these challenges is insurmountable. Turning good ideas into innovative technologies and encouraging their penetration throughout society can be done. Governments are leading the way, in some instances, by setting energy efficiency standards. Corporations are also leading the way by creating products and services that focus on energy efficiency. But more needs to be done. In the next chapter, we look at specific studies of what has been done in the four major energy consuming sectors, setting the stage for a more energy efficient future.

Perspectives on the Drivers and Barriers to Energy Efficiency

The chapter concludes with the perspectives of five individuals who describe the drivers and barriers to greater energy efficiency.

- **Kateri Callahan,** President, Alliance to Save Energy, USA
- **S. Iswaran,** Senior Minister of State, Ministry of Trade and Industry and Ministry of Education, Singapore
- **John Krenicki,** Vice-Chairman, GE and President and Chief Executive Officer, GE Energy, USA
- **Lawrence J. Makovich,** Vice-President and Senior Advisor, IHS CERA, USA
- **Peter Voser,** Chief Executive Officer, Royal Dutch Shell, The Netherlands

Building the Infrastructure for Energy Efficiency

By Kateri Callahan, President, Alliance to Save Energy, USA

As the saying goes, “good things are hard to come by.” Energy efficiency is the cheapest, quickest, cleanest, most abundant and most readily available resource. All these make it an attractive solution for meeting the world’s energy imperatives – growing global demand, security and reducing GHG emissions. Unfortunately, there is a need for better understanding of how to mine this resource’s full potential. Effectively deploying efficiency remains elusive and complex, requiring the build-up of a significant and unconventional infrastructure.

Energy efficiency's attributes are proven and compelling. It’s cheap: utilizing efficiency to meet electric needs typically has costs less than one-half of those for installed coal or nuclear capacity and nearly 5 times less than solar. It's fast: energy efficiency can be “up and running” in less than 2 years as opposed to 8 and 12 years to bring on coal and nuclear capacity. It's clean: it’s the only resource available today that has no environmental footprint. It's abundant: study after study indicates that cost-effective energy efficiency is the "fuel" with the greatest potential for meeting the world's growing energy demands. Finally, it's here and it’s ready: unlike other clean energy resources, energy efficiency is available today virtually everywhere, unhindered by climate, difficult access to transmission lines or need for further research and development.

Nevertheless, tapping into energy efficiency is challenging and requires a significant, if unconventional, infrastructure. While other fuels need “hard” infrastructure like pipe and transmission lines, energy efficiency requires “soft” elements like public policy support, education and awareness and innovative financing tools. Further, for efficiency to compete fully with conventional fuels, the cost of energy must be high enough – and visible enough – to make savings and investments valuable.

Effective public policy is critical. Unlike other energy sources, efficiency typically comes in “small doses.” Case in point: replacing inefficient incandescent light bulbs in homes around the world will collectively yield tremendous savings, yet it requires the mobilization of millions of people. The savings from improvements in lighting are being fully realized only through the phase-out of inefficient light bulbs by legal fiat. New US lighting standards, when fully implemented, are expected to save $13 billion annually and avoid emissions equivalent to those from 60 mid-size power plants.

Education and awareness help aggregate small actions into meaningful energy savings. To make appropriate purchase decisions (based on life-cycle costs instead of shelf price), consumers and businesses must have information on the energy use and costs associated with a product, service or building. Until recently, such information was largely unavailable, but the situation is changing. For instance, the US government's voluntary labelling programme, *Energy Star,* is helping highly efficient products penetrate the marketplace. Last year, the one-millionth Energy Star home was constructed, which must be at least 15% more efficient than required by law.

Energy efficiency isn't free, and finding ways to finance upgrades to existing buildings, factories and homes represents a stubborn barrier. While some improvements have a relatively short payback period, “deep retrofits” – which save the most energy – need more time. In the United States, the average turnover rate for homes is about seven years, but the hold period for commercial real estate is often substantially shorter, giving investors less confidence that they will recover investments in efficiency before selling the property. Property Assessed Clean Energy (PACE) bonds are an elegant approach to overcoming this barrier. Municipalities float PACE bonds to allow owners to finance renewable energy or energy efficiency improvements at attractive rates through their tax bills, thereby allowing the “mortgage” to roll over upon sale of the property.

Finally, prices matter. If energy costs exert little impact on budgets, there is little motivation to lower them. Where and when energy prices are impactful, consumer behaviour shifts in favour of aggressive efficiency. Electricity consumption has remained relatively flat in states like New York and California where prices are high, while the US average has grown roughly 60 percent in three decades. And importantly, the monthly bills paid by residents of these states – despite higher per unit costs – are roughly equal to those of residents in states where electricity rates are much lower. The stark shift in the United States toward smaller, more fuel efficient vehicles only occurred when the price of gasoline surged last year.

As an energy efficiency advocate, I wish it were different; but energy efficiency is no more a panacea for the world's energy challenges than any other resource. Deploying energy efficiency requires the worldwide investment of capital as well as development of a wide-scale support infrastructure – though an infrastructure different from that associated with other energy sources.

Energy efficiency's potential is greater than any other resource. All roads to a clean and sustainable global energy future are paved with energy efficiency. We need to be realistic about the challenges and barriers. Yet, clearly this “good thing” is well worth the effort.

Singapore: An Energy Efficient Nation

By S. Iswaran, Senior Minister of State, Ministry of Trade and Industry and Ministry of Education, Singapore

Energy efficiency has gained renewed importance worldwide as a key strategy in tackling the challenges of energy and climate change. Energy efficiency improvements, found in almost every sector of the economy, offer tremendous opportunities to reduce energy consumption and carbon emissions while achieving savings and increasing productivity. Energy efficiency represents a vast, low-cost energy resource for all countries. That is also the challenge.

The concept of resource efficiency is not new to Singapore. As a small island state, we have always had to make the most of our limited indigenous resources. These resource constraints are felt even more acutely in terms of energy. Singapore is completely dependent on imports of oil and gas for our energy needs. We liberalized our electricity market in 2001 to promote effective competition and thus efficiency, prompting a fuel switch by power companies from oil to gas. However, we do not have viable sources of renewable energy to reduce our dependence on fossil fuels. This is why energy efficiency features prominently in our portfolio of energy solutions.

Our approach towards energy efficiency is based on sound economic principles. The starting point is to price energy properly and avoid subsidies – this incentivizes energy efficiency and discourages over-consumption. For example, all consumers in Singapore see the full cost of electricity in their bills. Lower-income families receive a "Utilities Save" rebate to help lighten their burden. But this is extended as a separate credit, instead of an across-the-board subsidy on the price of electricity.

Ideally, energy prices should take into account not just today's fuel prices, but also externalities such as the social cost of carbon emissions. Hence, we apply a shadow price for oil and carbon in our cost-benefit analysis to better inform government policies and decision-making. Through the consistent application of market forces and price signals, we ensure that households and businesses have the right incentives to economize on the use of energy.

At the same time, we recognize that there are limitations to a pure market-based approach. Energy efficiency improvements typically require considerable upfront investments. Even if these investments pay for themselves over time, they may not always be undertaken due to market distortions and failures, such as poor information, limited access to capital and split incentives between tenants and landlords. These barriers persist at multiple levels and have to be overcome through a combination of policy tools, including targeted financial incentives and regulatory codes and standards.

Our efforts so far have brought about a 15% improvement in energy efficiency between 1990 and 2005, but there is still more we can and will do. To drive our energy efficiency efforts at the national level, we have mapped out the *Sustainable Singapore Blueprint,* which aims to raise Singapore's energy efficiency by 35% from 2005 levels by 2030. It covers a wide range of measures to mitigate carbon emissions and improve energy use, such as:

- More information on energy use, costs and benchmarks, including mandatory energy labelling and minimum performance standards
- More public transport facilities to support the projected growth in traffic, with better infrastructure to encourage cleaner forms of commuting like cycling
- More efficient buildings and greener public housing estates where the vast majority of Singaporeans reside

While these measures make economic sense, they are not cost-free and require considerable adjustments for many individuals. Hence, we take a pragmatic approach in implementation, finding the most cost-effective solutions, and pacing out measures appropriately. Within the government, we have set up a multi-agency vehicle called the Energy Efficiency Programme Office to coordinate these implementation activities across the power generation, industry, transport, buildings and household sectors.

Another critical aspect of our national strategy for energy efficiency is the fostering of innovation in the development and deployment of new energy technologies. Smart grid technologies enable consumers to manage their energy needs and make better decisions about energy use. Electric vehicles are far more efficient than internal combustion engines and can serve as energy storage systems to feed power back into the grid during peak periods, thereby enabling the power system to operate more efficiently. We are embarking on pilot projects for both smart grids and electric vehicles, with a view towards possible large-scale deployment when these technologies are developed and proven.

Technology is an important enabler. But the key to unlocking the full potential of energy efficiency lies in individual attitudes and mindsets. The government can take the lead in raising awareness and initiating change, but others must step up to the plate too. Companies must make use of more efficient processes and systems. Families have to embrace new habits – and rediscover traditional values – to conserve energy and reduce waste.

The pursuit of energy efficiency demands long-term commitment and effort. Singapore has every intention to excel as an energy efficient nation. We will do our part to drive efficiency improvements across the whole economy and contribute to the global effort in reducing emissions.

Take Advantage of Scale

By John Krenicki, Vice-Chairman, GE and President and Chief Executive Officer, GE Energy, USA

How does the world meet its rising demand for energy, yet, at the same time, reduce its carbon footprint? Energy efficiency, largely recognized as demand-side management, seems an obvious answer. Demand-side strategies are part of the equation for sure. Energy efficient appliances, homes and buildings will contribute to the solution. But we must not overlook the significant opportunities that exist on the supply side of the equation.

Energy is a large-scale business. Since scale and efficiency can work hand in hand, the supply-side opportunities both are abundant and can be readily implemented. This is particularly true in the case of electric power generation, manufacturing, heavy industry and mining operations – sectors where decision-making is concentrated and gains can be made more quickly and effectively when supported by the proper incentives. Incremental improvements, when multiplied across the scale of the energy sector, can result in huge gains in energy efficiency and carbon reductions. Here are a few of my favourite opportunities.

Let's start with the foundation of electricity supply – the grid. Substantial quantities of electricity are lost in the transmission and distribution of power from generation sources to load sources. For example, in the United States, line losses approach 6% of total generation; in India, these losses can reach 25% of generation. The technology exists to minimize these line losses, and governments and utilities should consider such investments within broader energy efficiency initiatives. On the distribution side, utilities can invest in technology that optimizes reactive power flows and system voltage. One such solution, Integrated Volt/VAR Control (IVVC), offers utilities the ability to reduce voltage by as much as 4%. In the United States alone, a 4% reduction in voltage could save 28 billion kilowatt-hours per year – the equivalent of 16 million tons of CO_2 – by 2030. On the transmission side, similar reductions in line losses are made possible through investment in Flexible AC Transmission Systems (FACTS). IVVC and FACTS are but two examples of the advanced technologies that comprise a smart grid. Indeed, a useful way to think about the smart grid is a fusion of information technology with the transmission system to improve efficiency and productivity.

Combined heat and power (CHP), also known as cogeneration, offers another highly efficient supply-side opportunity. By using more effectively the heat generated in producing electricity, these plants can achieve overall efficiencies of 70% or more at the point of use. Cogeneration can be applied to a variety of energy needs, from district heating to water desalination to industrial processes. One recent example is the new cogeneration plant at Coca-Cola Hellenic's Ploieti bottling facility near Bucharest, Romania. The new CHP plants will supply electricity as well as hot and chilled water to the bottling facilities. While these particular plants are fuelled by natural gas, CHP can also operate on renewable fuels such as biogas from local farms. Each of the bottling plants will be able to eliminate up to 40% of their annual CO_2 emissions.

Gas flaring reduction is not typically discussed as an energy efficiency strategy, but it represents a tremendous opportunity. The gas flared annually is equivalent to 25% of the United States' or 30% of the European Union's gas consumption, and adds about 400 mt of CO_2 in annual emissions. Examples exist of companies reversing this trend. The gas producer Monolit in Russia is finding new ways to use previously flared gas at a Western Siberian production facility. At the facility, the waste gas will be separated into liquefied natural gas and other "transportable" products (including propane, butane and ethane) for the chemical industry. By utilizing the gas from nearby drilling fields at Shapinskoe for on-site power generation, the Russian producer will avoid the need to transport diesel fuel over long distances, thus delivering significant environmental benefits. Utilization of otherwise flared gas for on-site power generation will help save up to about 536,000 tons of CO_2 equivalent per year.

Finally, government policy is inextricable part of addressing the energy challenge. Efficiency and scale should be considered here as well. In order to achieve the technology investments and supply chain competitiveness that are required to answer the energy challenge, we need government policy that supports the free trade of green technology. Protectionism and green industrial policy, implemented through tariffs, domestic content provisions and other trade barriers imposed on green technology increase costs and are impediments to efficiencies in the market and economies of scale. Agreement among governments on the free trade of green technology would offer a significant boost to energy efficiency.

Energy Efficiency – An Investment Perspective

By Lawrence J. Makovich, Vice-President and Senior Advisor, IHS CERA, USA

Increasing energy efficiency is highly desirable. But it is not free. It requires trade-offs like any other investment, and as a result has a cost. This has been obvious for decades to energy-intensive businesses, which have to calculate costs and benefits and make investment choices.

But in recent years, there has come to be a view that energy efficiency is, in one way or another, free. If this view predominates, widespread disappointment will likely result. An energy efficiency strategy can have far-reaching impact, but to succeed it must be grounded in economic reality. Some have argued that efficiency gains can reduce global GHG emissions by as much as one-half, with savings that more than pay for the costs. These expectations sound too good to be true.

Many people believe that massive efficiency gains are available at little or no cost by closing the "efficiency gap" – the difference between available cost-effective efficiency investments and the efficiency investments that households and businesses choose to do. It is easy to conclude that the marketplace must be failing if consumers do not make efficiency investments that promise to pay for themselves. Consequently, closing the efficiency gap looks easy.

The efficiency gap is not new, and closing it has never been easy. Time and effort spent trying to fix energy market imperfections have produced mixed results. On the one hand, consumers have responded to incentives and better information by shifting their investment decisions towards more energy efficient options. On the other hand, despite impressive gains, the efficiency gap looks as big today as it did 30 years ago.

It may be time to question the hypothesis that market failures cause the efficiency gap. Maybe the efficiency gap has been hard to close because markets are working rather than failing. Let's start with the premise that energy and capital markets work, even though they are not perfect. From this perspective, typical consumers are not uninformed, irrational or wasteful but instead do their best to put energy to good use.

Whenever energy is put to good use, energy efficiency happens. But there is no reason to expect consumers to maximize energy efficiency. For example, when consumers need to purchase an appliance, they find lots of makes and models that differ in numerous ways – including energy efficiency. All else being equal, the upfront cost of a more efficient appliance is often greater than that of a less efficient appliance. Thus, increasing efficiency involves a trade-off.

An energy efficiency investment is often described as having a negative net cost because the discounted value of expected energy savings exceeds the upfront cost. A more conventional way to describe this is as an investment with an expected positive return. Restating energy efficiency in conventional investment language makes something immediately clear – the promise of a positive payback is a necessary but not a sufficient reason to make an investment. Two other factors are just as important – capital and risk.

Energy efficiency investments require capital. To make financial sense, the savings from the investment must recover the upfront capital cost and provide a return on the investment. However, capital is a scarce resource, meaning that that consumers can do some but not all of the investments available to them that promise a positive return.

There seems to be a simple solution for consumers who do not have enough savings to afford an efficiency investment – just borrow the capital and pay it back with the energy savings. This is where the second factor – risk – comes into play. Even if the expected rate of return on an efficiency investment exceeds the cost of borrowing more capital, it still is not sufficient to make the investment happen.

The promise of payback from an efficiency investment is just that – a promise and not a guarantee. When consumers decide to spend more of their cash or borrowed funds on efficiency, they are making a bet on the value of the energy they expect to save in the future. This is not a sure bet, because predicting energy prices is difficult. People differ in their expectations, tolerance for risk and ability to take on additional debt. So, even if the odds favour the consumer, we nevertheless expect some people to make the bet on efficiency and others not to do so.

From an investment perspective, efficiency investments must compete with other investments with an upfront cost, an expected return and an associated level of risk. When investors allocate scarce capital to the options that they think have the best risk-adjusted returns, then shifting investments towards more efficiency requires them to give up other investments that they value more.

Evaluating efficiency costs from an investment perspective helps rather than hurts the case for efficiency in addressing the climate change challenge. A realistic efficiency cost assessment is essential to properly weigh the cost of efficiency against other alternatives in determining the cost-minimizing mix of GHG emission abatement options.

Making the Most of an Energy Efficiency Revolution

By Peter Voser, Chief Executive Officer, Royal Dutch Shell, The Netherlands

Energy efficiency has rightfully been put on the top of the to-do list of most energy-policy proposals. After all, we stimulate economic productivity when we use less energy for each unit of the goods or services that we provide or consume. What's more, because the great majority of the world's energy is generated by burning fossil fuels, efficiency improvements can also lead to lower carbon dioxide (CO_2) emissions. And many of those improvements can be done now, with off-the-shelf technology.

But before we get too far with an efficiency-led revolution of the energy system, we should first consider a few lessons from history. Past energy-efficiency enhancements have often resulted in improvements in comfort and convenience that actually led to greater energy use, rather than less. To move the energy system in the right direction, the technologies that make our machines and buildings consume less energy must be accompanied by regulations that ensure a lasting positive impact.

The automotive industry illustrates how big efficiency gains can be lost if we aren't careful. Since the 1970s, fuel injection, microprocessors and other technical advances contributed to improved engine efficiency. But they did not result in better fuel economy for the average vehicle. Why not? The efficiency gains were instead used to add power for quicker acceleration and higher maximum speeds – or merely to move heavier vehicles, such as the pickup trucks and SUVs that became so popular for personal transportation in the United States and, increasingly, in Europe and other parts of the world. The net effect is that, between 1980 and 2005, there was only modest improvement in the average fuel economy of new cars in Europe and virtually none in the United States.

Our habit of losing the savings from our efficiency gains extends beyond motor vehicles. We tend to travel to destinations that we previously considered too distant to visit, warm spaces that were previously left unheated, cool spaces that were previously left hot and illuminate areas that were previously left dark. And this temptation to do more travelling, heating, cooling and illuminating will become increasingly powerful in developing nations. In these countries, billions of people yearn for their first taste of the household amenities that energy savings and growing wealth may finally bring into their reach.

So how do we capture the carbon-reducing benefits of energy-efficiency gains without depriving the majority of the households of the world from better livelihoods? We need regulations in key areas, such as motor transport and building construction, to achieve lower CO_2 emissions – even as energy efficiency rises.

Japan offers a shining example of what is possible when clear government policies shape business practices. For a host of products ranging from cars to space heaters and air conditioners, the Japanese government holds up the most efficient model on the market as the standard for the industry to match. The programme, called Top Runner, could account for up to 25% of Japan's energy-savings target by 2010, according to a study supported by the European Commission.

The United States' new, tighter fuel-economy rules as well as the European Union's recent legislation for passenger-car emission standards also point us in the right direction. We can already see that consumers are choosing more efficient cars. Perhaps for the first time, car owners, vehicle manufacturers, oil companies and policy-makers have come together to moderate both energy demand and CO_2 emissions.

The next critical step for policy-makers should be to set a price on CO_2 emissions for industry. Making that the cornerstone of a well-designed and harmonized global climate policy framework would help lock in the environmentally friendly gains of increased energy efficiency. Indeed, it would be an important enabler of a gradual global transition to a more sustainable energy system.

Shell favours a framework built around a cap-and-trade system for CO_2 that applies to major sectors of the economy. The cap sets a certifiable environmental outcome, while the capability to trade emission credits provides the commercial incentive for companies to look for the lowest-cost reduction measures – which are also likely to be the most energy efficient.

Through such national and international efforts, consumers can continue to enjoy the energy they need to power and sustain their lives, while helping society capture lasting environmental benefits from the emerging energy efficiency revolution. That is the lesson of history when it comes to energy efficiency.

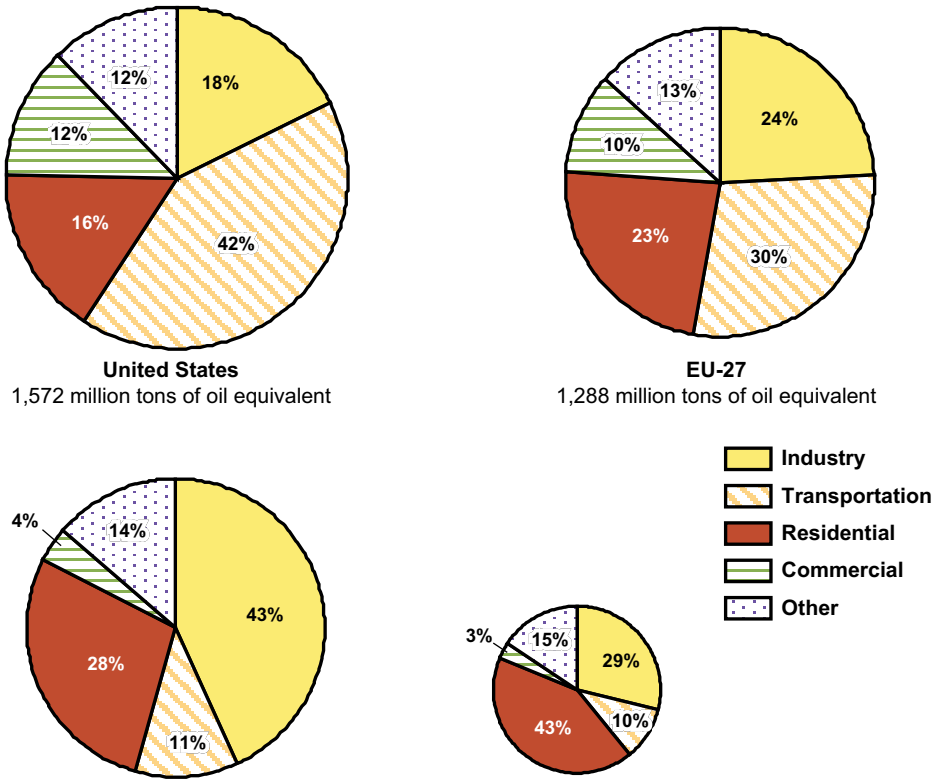
Different Sectors, Different Challenges

Understanding where energy is used helps to focus energy efficiency efforts. As shown in Figure 4, different sectors dominate in different parts of the world. In China, the industrial sector is the largest user of energy; in India the residential sector dominates and in the United States transportation uses the most energy. The European Union has an evenly distributed energy use profile.

The drivers and incentives for efficiency investments described in chapter 2 play out in different ways across sectors and types of consumers. Businesses often have significant financial incentive to invest in efficiency and may want to differentiate themselves in the marketplace by advertising their efficiency. Individuals choose products for many reasons, and energy efficiency is often not high on their wish list. Individuals may also have tight budget constraints that prevent up-front investments in efficiency or, on the other hand, may want visible efficiency improvements to be "eco-chic". The next four chapters use practical examples to demonstrate efficiency decisions in the industrial, building, household and transportation sectors.

Figure 4

2006 Primary Energy Use by Sector



Source: IHS CERA.
Data source: International Energy Agency.
91207-2

CHAPTER 3: INDUSTRY – PAYING DIVIDENDS

For companies in energy-intensive industries, energy is a significant operating cost. These companies have the resources and the incentive to monitor energy use and evaluate programmes to increase efficiency. The primary decision factors are competition for capital and potential return on efficiency investments given fluctuating energy prices.

Long-lived assets are a central theme in industrial efficiency. Efficiency gains often occur when capital stock turns over. The speed at which this occurs depends on the industry, the degree of efficiency increase and the payback period for new equipment. Retiring equipment before the end of its useful life can be prohibitively expensive, even if the new equipment would be more efficient.

Disaggregated efficiency opportunities are also common. In addition to investments in capital stock, energy efficiency opportunities often exist in better monitoring and maintenance of existing equipment – better operating practices. Additionally, small steps repeated at all of a large company's facilities can add up to significant energy savings. Recognizing and implementing these opportunities is challenging but can provide significant payback.

Integrating Efficiency into Business Goals

Many companies are turning to process improvements that pay dividends to their bottom line. John Krenicki describes one of these technologies, cogeneration, in his perspective. Cogeneration, also known as combined heat and power, uses the heat generated during electricity production for other purposes. "Cogeneration can be applied to a variety of energy needs, from district heating to water desalination to industrial processes," he explains. "By using more effectively the heat generated in producing electricity, these plants can achieve overall efficiencies of 70% or more at the point of use."

Incorporating energy efficiency into management goals can also pay dividends in energy-intensive industries. The experience of Dow Chemical provides an example. As Andrew Liveris describes in his perspective *The Positive Benefits of Energy Efficiency and Conservation,* "Since 1990, Dow has reduced our energy intensity by 38% saving 1,600 trillion Btu of energy. This savings is equivalent to the energy needed to power all the residential buildings in California for one year." Efficiency has been a significant money-saver for Dow. "For an initial investment of US$ 1 billion, we have delivered US$ 8.6 billion in savings to Dow's bottom line." Dow is continuing its drive for efficiency, setting a goal of a 25% reduction in energy intensity from 2005 to 2015.

There is an increasing focus on energy conservation itself as a business. Efficiency is a sector of interest to established companies, but the emphasis on efficiency is also spawning a growing number of new companies. "The energy efficiency business first emerged in the 1970s and has made an important contribution to reducing intensity," observes James Rosenfield. "But the last few years have witnessed a new and much larger wave of innovative companies that are applying a wide variety of technologies and new business models to deliver energy efficiency, whether in the form of services or products."[1]

These companies work across a wide canvas. Advances in information technology and communication provide opportunities for efficiency that did not exist a decade or two ago. Examples include combining smart sensors, Web-based software and control technologies to automate energy efficiency, such as in demand-control ventilation systems that adjust in real time to building occupancy and air quality. Another example is the rise of demand response companies that aggregate facilities into a network operating system – remotely lowering energy consumption at times of peak power. Other businesses provide hardware and Web-based software to track, analyse and diagnose poorly performing industrial equipment, allowing plant managers to improve industrial efficiency while increasing their up-time. New companies are also harnessing technologies that have emerged from advances in material sciences, such as LED lighting. Two of the most prominent areas for these "efficiency deliverers" are in making buildings more "intelligent" and in creating the different segments of what will become the smart grid.

1. James Rosenfield, "Energy Innovative Business," presentation at the Harvard Business School, 17 October 2009.

Steam leaks add up

Energy Efficiency in the Energy Industry

One tends to think of energy efficiency as applying to end-users of energy. However, the energy industry itself is energy intensive. Investments in efficiency in the energy industry pay dividends through lower costs, increased competitiveness and reduced GHG emissions.

ExxonMobil demonstrates the potential of energy efficiency in downstream energy production. It has committed to improving the energy efficiency of its refineries 1% per year over 10 years and is on target to meet this goal so far. Cogeneration is a central strategy for ExxonMobil. As Rex Tillerson describes, "We have become an industry leader in cogeneration, a technology that enables us to produce electricity to power our operations while also capturing heat to make steam to transform raw materials into consumer products. This process provides a more efficient power source than purchasing from a local utility – in some cases up to 50% more efficient."

Tokyo Electric Power Company (TEPCO) has made efficiency a top priority for electricity generation. "TEPCO is committed to the efficient use of fossil fuels and to achieving the world's highest level of thermal efficiency in electricity production," Masataka Shimizu describes in his perspective *Smart Use of Energy as a Society.* To meet this goal, TEPCO focuses on technology, including high efficiency combined-cycle gas turbines for power generation, and operational excellence, including high-quality facility maintenance, to maintain efficiency over time.

Ageing Oil Fields – A Need for Energy Efficiency in Energy-Producing Countries

Aging oil fields provide one example of the benefits of efficiency in energy production. Oil production requires energy – more and more energy as the oil field ages. At the end of a light oil field's life, the energy used to recover the oil can reach 10% to 15% of the energy in the oil produced. More complex fields require even more energy as they mature. Sour oil and gas fields can use as much as 20% of the energy produced, and heavy oil fields using thermal recovery techniques can use 35% of the energy contained in the produced oil.

The energy intensity of an oil field increases over time for two primary reasons. First, the natural pressure in the oil reservoir declines as oil is produced, meaning that it takes more energy to bring oil to the surface as time passes. Second, water production generally increases over time. The energy used to bring oil to the surface brings water along as well. As the percentage of water increases, so does the amount of energy required per barrel of oil produced. Additionally, produced water often requires energy-intensive equipment to separate the oil and treat the water before disposal.

Oil fields that have produced more than half of their initial reserves account for a quarter of today's world oil supply. This proportion could rise to one-third or more by 2020. Increasing the efficiency of energy use in mature oil fields while maximizing production and containing costs is a challenge.

The most important factor in increasing the efficiency of mature oil fields is putting a value on associated natural gas. In many of the world's largest oil-producing countries, natural gas produced along with oil is ascribed no monetary value. The availability of natural gas at no cost has led to the use of inefficient equipment and wasteful operating practices. Competitive market pricing policies for associated gas would create incentives to invest in energy efficiency. For example, replacing open-cycle power systems, often used in oil-producing countries, with combined-cycle systems can result in a 40% reduction in the energy intensity of each barrel of oil produced. Operational decisions could change if the value of the energy used, usually natural gas, is taken into account. For example, an oil well producing a large percentage of water would likely be taken out of production earlier in its life if the cost of the natural gas used in water treatment were taken into account.*

*Source: Markwell, Paul, *Mature Oil Fields: An Energy Intensity Dilemma,* IHS CERA Decision Brief, September 2009.

Perspectives on Understanding Energy Efficiency in the Industrial Sector

The chapter concludes with the perspectives of two individuals who have shared examples of energy efficiency improvements in the industrial sector.

- **Andrew Liveris,** Chief Executive Officer and Chairman, The Dow Chemical Company, USA
- **Masataka Shimizu,** President, Tokyo Electric Power Company, Japan

The Positive Benefits of Energy Efficiency and Conservation

By Andrew Liveris, Chief Executive Officer and Chairman, The Dow Chemical Company, USA

Over the past decades, three dramatic factors have changed the way the world thinks about energy. The first factor is economic, especially the volatile price of oil and natural gas. The second factor is geopolitical, especially the way political instability in some of the world's most significant oil producing regions has brought attention to the issue of energy security around the globe. And the third factor is the growing concern about climate change and the increasing consensus that the world's dependence on oil and other hydrocarbons is compromising the long-term health of the planet.

Taken together, these factors represent one of the greatest global challenges of our time: how to fuel economic growth while also addressing climate change and the consequences of our dependence on fossil fuels. To meet this challenge head on, the nations of the world will need to rely on a plan full of energy options.

Yes, we need more supply and we need to support increased development of oil and natural gas fields. And, yes, we need to support alternative and renewable energy solutions: nuclear, solar, wind and biofuels all need the support of our governments.

But the simplest, most accessible and cheapest option is increasing energy efficiency and conservation. It is not only the cleanest option; it is also the easiest to implement and the quickest way to extend our energy supplies while also slashing carbon emissions.

According to a 2007 UN Foundation Report, a modest 2.5% per year improvement in the energy efficiency of the G8 nations would create tremendous gains. The world could avoid US$ 3 trillion worth of new power generation, eliminating the need for the energy equivalent of 2,000 coal-fired power plants, and reduce CO_2 concentrations – in other words, a serious and cost-effective down payment on stabilization. Perhaps most importantly, this approach would free up much-needed investment capital for the development of new energy sources.

I know energy efficiency works because I've seen it in action at my own company. As one of the world's largest industrial consumers of energy, the Dow Chemical Company is living proof of how efficiency gains can provide real and sustainable benefits.

We use energy, primarily natural gas and natural gas derivatives, both as a fuel source and as feedstock material to make a wide array of products. For our global operations, Dow uses the energy equivalent of 850,000 barrels of oil every day. This amount is roughly equivalent to the oil consumption of the Netherlands or Australia.

In order to reduce our own energy consumption and carbon footprint, Dow has been a pioneer in energy efficiency and has been recognized for its leadership. Since 1990, Dow has reduced our energy intensity by 38%, saving 1,600 trillion Btu of energy. This savings is equivalent to the energy needed to power all the residential buildings in California for one year.

During that same time, we have reduced our absolute GHG emissions by 20% – well beyond Kyoto targets. This has prevented 86 mt of CO_2 from entering our atmosphere – a clear demonstration of the power of energy efficiency in reducing GHG emissions.

How much did these energy and CO_2 reduction cost us? You may be surprised to know that, for an initial investment of US$ 1 billion, we have delivered US$ 8.6 billion in savings to Dow's bottom line. For Dow, energy efficiency has represented a relatively low-cost solution to the challenge posed by the significant issues of energy security, volatile energy prices and rising GHG emissions.

If the world expects to make a serious attempt at addressing its energy needs while also addressing climate change, we need this same kind of approach on a global scale. And we need to start with the areas that are most energy intensive: buildings, the power sector, industrial operations and transportation.

A global commitment to maximize energy efficiency would represent a tremendous down payment on the transition to a robust low carbon economy. Policy-makers around the globe should draw on Dow's experience and expertise to advocate for targets, timetables and standards that will help the world community break the bonds that tie economic growth to rising GHG emissions.

As the UN Foundation report noted, "only energy efficiency can generate nearly immediate results with existing technology and proven policies and do so while generating strong financial returns ..."

As the nations of the world follow up on Copenhagen and chart the path to a low carbon future, they must embrace energy efficiency as their first choice. It is the common platform upon which to launch a secure and sustainable energy future.

Smart Use of Energy as a Society

By Masataka Shimizu, President, Tokyo Electric Power Company, Japan

Energy efficiency improvement should be regarded as one of the major tools for tackling climate change, in addition to nuclear power and renewable energy. Public-private collaboration is necessary to facilitate increased energy efficiency on both the supply and demand sides. These are principles that guide Tokyo Electric Power Company (TEPCO) throughout our business, and the value of these principles is already clearly demonstrated.

On the energy supply side, TEPCO is committed to the efficient use of fossil fuels and to achieving the world's highest level of thermal efficiency in electricity production. Thermal efficiency improvement in coal-fired power stations is critical, since coal will continue to play a key role in global energy supply. TEPCO has joined the Asia Pacific Partnership (APP) and shared its know-how with APP member countries, including China and India, to improve the thermal efficiency of their coal-fired power stations and contribute to capacity building. In its own operations, TEPCO has introduced state-of-the-art gas turbine combined-cycle power units with 59% thermal efficiency and plans to implement the next generation of technology with 61% thermal efficiency in 2016. Compared to conventional steam power generation, the second generation technology could reduce CO_2 emissions by 30%.

Operational excellence is also central to supply-side energy efficiency. TEPCO optimizes the operation and maintenance of its facilities through development of professional human resources and expertise, as well as through close communication and cooperation with manufacturers. As a result, we have been able to operate our plants at efficiency levels very near their original design for many years. TEPCO has also achieved the lowest transmission loss rate in the world (4.9% last year) by building a compact and efficient transmission and distribution system. The system uses information and communication technology to monitor demand and power flow, allowing optimization of transformer operation.

On the demand side, Japan has implemented the Top Runner Programme to facilitate the development of energy efficient equipment. The plan applies to 21 products, such as cars, refrigerators, air conditioners and televisions. This scheme has been successfully managed to decrease the competitiveness of energy inefficient technologies, which as a result will be gradually phased out of the market. As of 2004, the energy efficiency of air conditioners has improved by approximately 55% and refrigerators by approximately 68%.

TEPCO is committed to advocating environmental protection and energy efficiency at the user end. TEPCO has developed energy efficient technology such as Eco-Cute (a heat pump hot water supply unit) and a quick charger for electric vehicles jointly with manufacturers. We promote such technology through public exhibitions and the media. We have also taken a solution-oriented approach to encourage our industrial customers to reduce their energy consumption as well as CO_2 emissions. Key tools for efficiency include heat pumps, all-electric kitchens, induction heating technologies and heat storage technologies. For example, some factories achieved substantial reduction of energy use and CO_2 emissions by replacing oil-fuelled boilers with efficient heat pumps. TEPCO has also implemented joint promotions with housing manufacturers, stressing the merits of all-electric homes and heat pumps.

We understand that various countries and companies have undertaken these kinds of activities on both the supply and demand sides, though the levels and impacts vary. However, we suggest a more innovative approach to energy efficiency improvement that involves a wide variety of experts such as policy-makers, consumers, academics, financiers, technology specialists and more. Energy efficiency improvement involves three steps: improvement of equipment parts such as car engines, motors and light bulbs; improvement of assembled products such as the car itself, air-conditioning systems and refrigerators; and improvement of city planning, including an optimized traffic system to avoid congestion. Facilitation of this "Smart Use of Energy as a Society" approach requires close linkage of stakeholders across sectors, such as represented in the World Economic Forum.

Furthermore, electricity has a unique profile in that it can be used across sectors and can be generated by non-fossil fuel resources that do not emit CO_2. "Smart Use of Electricity" has huge potential to reduce primary energy use globally. For instance, applying energy efficient electrical appliances such as electric vehicles and heat pumps for heating rooms and boiling water can significantly reduce primary energy use in businesses and homes, thereby lowering CO_2 emissions. According to a study by Euro-electric, to reduce CO_2 emissions by 30% by the year 2030 compared to 1990 levels, using more electricity in a smart way will be more cost effective and will reduce import dependence on oil and gas more than any other option. International Energy Agency (IEA) statistics say that the global share of electricity in final energy consumption is around 17%, and I believe there is still more room for electricity to play its unique role.

There is no doubt that electricity is indispensable to a future low-carbon society, and I believe that the "Smart Use of Energy as a Society" and the "Smart Use of Electricity" will become important in the near future.

CHAPTER 4: BUILDINGS – THE CHALLENGE OF LONGEVITY

The potential for efficiency improvement in buildings is large but not easily captured. Buildings represent 40% of energy use in the European Union and the United States and one-third of the world's primary energy.[1] Buildings can last 50 to 100 years or more. Thus, the rate of capital turnover is working against efficiency in the building sector. Building codes target new buildings and major renovations – an important step, but one that affects only a small portion of the building stock. Policies that encourage energy efficiency upgrades in existing buildings will have a much faster and larger impact. The Intergovernmental Panel on Climate Change found that the building sector could cost-effectively reduce its CO_2 emissions by 29% by 2020, the largest reduction among all sectors studied.[2]

The disaggregated nature of the building industry is a challenge to designing and constructing energy-efficient buildings. Split incentives are also an issue in many cases, when design and construction companies are not incentivized to include energy-efficient features that would be cost effective for the eventual buyer or tenant.

Overcoming Barriers to New Building Efficiency

Buildings consume a large portion of primary energy in developed economies, and energy used in buildings in emerging economies is likely to grow rapidly. Therefore, buildings are an obvious place to look for energy efficiency improvements. However, the building sector is fragmented and very conservative, making realization of efficiency potential difficult, even in new construction. As Leon Glicksman describes in his perspective, *Energy Efficiency in the Building Sector,* "Numerous architects, developers and construction companies design and construct buildings. It is difficult for these players to have the expertise to properly evaluate and integrate the range of current technologies; nor do they have the resources to investigate promising new systems."

However, Glicksman emphasizes that integrated design is the closest thing to a "silver bullet" in the building sector. Integrated design views the building as a system, where each component works together to achieve greater efficiency. Architects, developers, engineers and energy consultants working in concert from design through construction can optimize efficiency in the building system. Steven Chu points out that, "By developing building design software with embedded energy analysis and building operating systems that constantly tune up a building for optimal efficiency while maintaining comfort, extremely cost-effective buildings with energy savings of 60-80% are possible." The United States Green Building Council states that, "Prescriptive, independent measures will no longer suffice. Leaps forward in building performance require design that fully integrates envelope, lighting, HVAC [heating, ventilation and air-conditioning] and water systems, and integrates energy efficiency with renewable energy applications."[3]

How can the building sector overcome its fragmented nature to focus on efficiency? Better monitoring of the real-life impact of efficiency investments is a good start. According to the old engineering adage, what gets measured is what gets done. Glicksman describes in his perspective how this adage applies to the building sector. Clear monitoring results can dispel doubts about energy efficiency, point out which technologies deliver and which fall short, and educate building professionals about new technologies. Efficiency monitoring can also contribute to establishment of stronger building codes and standards. Finally, education programmes can push promising technologies from pilot phase to reality and teach leaders in all parts of the construction industry how to work together to achieve efficiency gains.

Improving Energy Efficiency in Existing Buildings

Since buildings are such long-lived assets, improving the energy efficiency of existing buildings has the potential to have a large near-term impact on energy

1. EU Action Plan; Joe Loper, Selin Devranoglu, Steve Capanna and Mark Gilbert, "Energy Efficiency Potential in American Buildings", Working document of the National Petroleum Council, 18 July 2007; United States National Science and Technology Council, *Federal Research and Development Agenda for Net-Zero, High-Performance Green Buildings,* October 2008.
2. Levine, M., D. et al., 2007: Residential and Commercial Buildings. In *Climate Change 2007: Mitigation.* Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York.
3. United States Green Building Council Research Committee, *A National Green Building Research Agenda,* Revised February 2008.

Towards a More Energy Efficient World

Kroon Hall at Yale University, a showcase of green building technology*

demand. Improvements can consist of retrofits and of improvements in the operations and maintenance of existing assets. In addition to standards for new construction, energy efficiency standards and certifications are also in place to encourage renovation and operations and maintenance improvements in existing buildings. For example, the US Environmental Protection Agency and Department of Energy administer the Energy Star programme, which awards certification to buildings in the top 25% of energy efficiency. Standards and certification programmes can help to mend split incentives. Efficiency-certified buildings, both new and existing, allow consumers to identify energy-efficient properties and builders to recoup their investment in efficiency.

The US Green Building Council's Leadership in Energy and Environmental Design (LEED) recently introduced a programme to certify existing buildings. Energy efficiency efforts that contribute to LEED certification include benchmarking the energy use of the entire building and individual systems against similar structures; establishing a maintenance schedule to keep equipment functioning efficiently; installing automated control systems for heating, cooling, ventilation and lighting; and measuring the performance of energy efficiency actions.[4] The three-building headquarters of Adobe Systems in San Jose, California, was certified LEED platinum, the highest level, in 2006. Over the five-year period after retrofits began in 2001, Adobe reduced its electricity and natural gas use by 35% and 41%, respectively, with a rate of return on efficiency investments of 115%. The project included upgrading and adding motion sensors to lighting, installing variable-speed drives on large fans and chillers, and upgrading building control systems.[5]

4. United States Green Building Council, *LEED for Existing Buildings: Operations and Maintenance,* September 2008.
5. Adobe Systems Press Releases, "Adobe Wins Platinum Certification Awarded by US Green Building Council", 3 July 2006, and "Adobe Headquarters Awarded Highest Honors from US Green Building Council," 5 December 2006.

*Source: Robert Benson Photography.

Perspectives on Understanding Energy Efficiency in the Building Sector

The chapter concludes with a perspective on improving energy efficiency in the building sector.

- **Leon R. Glicksman,** Professor of Building Technology and Mechanical Engineering, Massachusetts Institute of Technology, USA

London City Hall – uses a quarter of the energy of a typical office building

Source:StraH

Energy Efficiency in the Building Sector

By Leon R. Glicksman, Professor of Building Science and Mechanical Engineering, Massachusetts Institute of Technology, USA

Buildings are an area where energy efficiency can make a big impact. In the developed world, buildings are the largest end-use sector of energy. For example, in the United States, about 40% of all primary energy is used in residential and commercial buildings, far larger than the energy use of the transportation sector. In some European countries, such as the United Kingdom, buildings use almost 50% of primary energy.

Numerous studies have shown that efficiency measures in buildings are a far more cost-effective method for CO_2 reduction than many advanced energy supply options. Although in the last few years increasing attention has been focused on efficiency, the actions to date fall far short of the potential gains. Although numerous professional societies and regulatory bodies have laid out ambitious goals for future buildings, including so-called zero net energy buildings, widespread acceptance by commercial developers is lagging. A number of measures must be put into place to allow us to meet present and future goals.

The fragmented nature of the building industry is a major roadblock to energy efficiency. Building components come from a wide variety of suppliers that specialize in particular components such as windows, insulation, HVAC systems, controls and lighting. In contrast to the aircraft and automobile industries, where a few very large technically skilled enterprises integrate the design and manufacture of the final product, numerous architects, developers and construction companies design and construct buildings. It is difficult for these players to have the expertise to properly evaluate and integrate the range of current technologies; nor do they have the resources to investigate promising future systems.

Further challenges arise because promising design solutions are dependent on climate as well as building use. An example is a selection of roof systems. Proponents have heralded the energy efficiencies of green roofs as well as cool roofs, the latter highly reflective surfaces that reduce solar gains. A recent study comparing conventional roof systems to green and cool roofs showed that in a hot dry climate, such as the US Southwest, both new technologies result in substantial energy savings. In other parts of the United States conventional roof insulation has a much larger impact on energy efficiency.

Example buildings have shown that proper integration at the design and construction stage will result in substantial energy savings for a very modest increase in initial costs. In considering new building designs that approach zero energy performance it is important to trade off energy efficiency measures with the use of renewable energy sources on site. At a community level this should include large-scale energy systems such as cogeneration. Retrofits of existing buildings can also benefit from an integrated approach that identifies the measures that have the largest impact and are most cost effective.

Commercial developers have been reluctant to embrace energy efficiency for a number of reasons. One is the perception that such designs are too expensive and do not meet projected energy savings. A comprehensive public programme of monitoring building performance will help to dispel such doubts. New European rules requiring energy evaluation of new buildings or buildings being sold will make the energy costs a quantifiable factor in commercial property evaluation. Monitoring results will also serve to provide lessons learned about new design concepts that will help educate professionals. In some cases, such monitoring may also point out design concepts that fall short, such as the recent controversy in the United States concerning the effectiveness of LEED-rated buildings. Monitoring information is essential to establishment of future building metrics that then become a part of new codes and standards.

Adoption of stricter codes and standards for new buildings and for retrofits has already led to improvements in appliance efficiency and overall building performance. However, measures that establish economic viability will go a long way towards convincing a very conservative industry to lead rather than follow. In some parts of the developing world, enforcement of building codes is lacking. Even if the initial design meets required codes, the final product falls far short. In many instances incentives can be put in place, such as acceleration of government approval for green buildings. Further measures must be considered to reverse some of the existing disincentives, such as the disconnect between the building developer who pays for building construction and the tenant who pays for energy use.

A number of promising technologies for building efficiency have not received adequate attention or support. These include using daylight to reduce or eliminate lighting energy, nanotechnology to produce very thin insulation panels for retrofits of building envelopes, software to enhance integrated design by architects and developers who do not have specialized technological expertise and advanced diagnostic and control techniques to optimize commercial building operations. Support of this research will also have the added benefit of enhancing educational opportunities for the next generation of leaders in the building efficiency field. That will take time. Currently, there is a dearth of knowledgeable professionals.

CHAPTER 5: HOUSEHOLDS – INCREASING THE MIND SHARE

Businesses compete with each other to provide the best product at the lowest price, and minimizing energy cost through efficiency is part of the competition. On the other hand, homeowners do not face the same competitive pressures with respect to their energy bill. Energy competes with other needs and wants for consumers' limited income, but households do not compete with each other on the basis of who has the lowest energy bill. For households, energy is often not a significant cost and energy efficiency is not "front of mind."

Knowledge and behavioural issues are key hurdles to household energy efficiency. Opportunities in households are generally diffuse – small changes in numerous systems that, in aggregate, could amount to significant energy savings. Consumers often do not have the time, motivation and funds to research and implement energy efficiency options.

Efficiency Standards and Labels

Energy efficiency standards and labels enable efficiency improvements in products present in most homes, including appliances, heating and air conditioning, and lighting. Efficiency standards remove the least efficient products from the marketplace, while labels empower consumers to make an informed choice about the efficiency of the products they buy. Standards and labels reduce the time and hassle that consumers invest in efficiency decisions. They also allow widespread efficiency improvements by changing the practices of a manageable number of manufacturers, rather than those of the entire consuming public. More than 50 countries around the world have energy efficiency standards or labelling programmes – see Figure 5 for examples of labels from around the world.[1]

Multiple types of efficiency labels are in use, sometimes on the same product. Comparison labels describe the energy use or approximate operations cost of a product and compare the product to others in its class. Endorsement labels indicate products that achieve a specified efficiency standard, generally much higher than average. The European Group for Efficient Appliances and the US Energy Star labels are two examples.

Government standards can also push innovation farther and faster than it otherwise might go. Governments must keep standards up to date for optimal effectiveness. This can be particularly challenging with rapidly changing technology. As Masayuki Naoshima describes, Japan's Top Runner Programme is an example of a standards system designed to result in continuous improvement. The programme periodically updates the efficiency standard for a product to the level achieved by the most efficient product on the market. Therefore, when the new standard comes into force, all products are as efficient as the most efficient product offered just a few years ago. The programme began in April 1999 and has grown from 9 to 21 products, including heating and air-conditioning systems, appliances and office equipment.

Energy efficiency standards and labels are not just common in developed countries. China's standards programme began in the mid-1980s, and since then standards have been strengthened and expanded to cover additional products. China has established efficiency standards for 25 individual products in five categories: household appliances, lighting, commercial equipment, industrial equipment and vehicles. Energy efficiency labels are required on a total of 56 products. Efficiency labels and standards are particularly crucial in the Chinese market, since sales of many appliances, including clothes washers, televisions and refrigerators, are skyrocketing.

In contrast to China's programme, India's energy efficiency labelling programme is just getting started. India created the Bureau of Energy Efficiency in 2001 and launched its National Energy Labelling programme in 2006. Refrigerators, fluorescent lamps, air conditioners and distribution transformers must have efficiency labels, and more categories will be added over time. India's efficiency label was adopted based on the results of a market research study that measured how consumers reacted to the label and how well they understood its content.

Incentivizing Utilities to Promote Efficiency

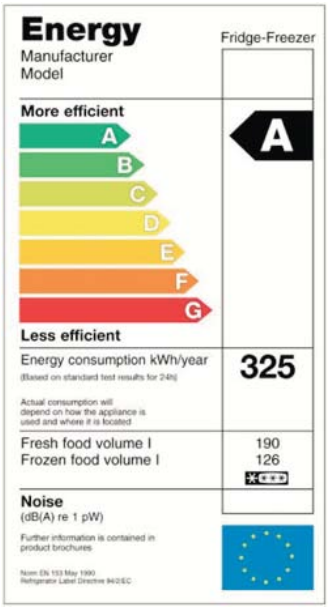
A significant barrier to increasing household energy efficiency is that electric utilities generally do not have an incentive to sell less of their services. In a traditional

1. Weil, Stephen and James E. McMahon, *Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting,* Second Edition, Collaborative Labeling and Appliance Standards Program, Washington DC, February 2005.

Figure 5

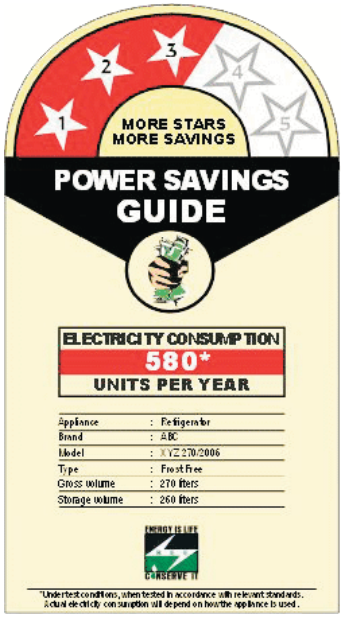
Product Energy Efficiency Labels

United States



European Union

China



India

91207-3

rate system, a utility earns more revenue as it sells more electricity. Therefore if a utility encourages its customers to save energy, it decreases its earnings.

A policy known as decoupling is one way to break the link between sales volume and revenue. Decoupling can work in various ways, but the main aim is to put a floor under revenues; if sales fall below the threshold a slight rate increase takes affect that brings revenue back to that level. This allows a utility to pursue energy efficiency measures without harming its profitability or ability to meet fixed costs. It also incentivizes utilities to use efficiency programmes to reduce demand instead of building new generation capacity when efficiency programmes are the more economical choice. California has been a leader in decoupling, first introducing it in 1982.[2] Several other US states have recently introduced decoupling or are running pilot programmes.

Setting efficiency goals for utilities is another element to encourage their sponsorship of efficiency measures. In 2009 three Australian states – New South Wales, Victoria and South Australia – started energy savings certificate programmes aimed at promoting energy efficiency and concurrently reducing GHG emissions. These programmes require utilities to collect a specified number of certificates by providing their customers with efficiency products and services, such as home audits, energy efficient appliances and other home improvements. In New South Wales and Victoria the certificates are tradable, meaning that retailers that earn excess certificates can sell them to those that have not achieved enough energy savings. In South Australia the certificates are not tradable, but excess certificates can be saved and applied towards subsequent years' targets.

Technology to Enable Efficiency

Behaviour is an important hurdle for household energy efficiency. People often do not want to take time out of their busy lives to reduce their energy use, such as turning down thermostats at night and when leaving for the day or unplugging appliances that use energy in stand-by mode.

Technology that automates energy efficiency can break through the behavioural barrier. A simple and common technology for household efficiency is a programmable thermostat. Such devices allow consumers to programme their heating and air-conditioning systems to correspond to their needs and to not think about turning systems off when they leave each day. Smart grid technology provides an additional example of automated efficiency. As Peter Corsell describes its potential in his perspective *Smart Grid Is the Internet of Electricity,* "Smart grid technology can enable businesses and consumers to gain visibility into their energy use. For example, consumers can create an online energy profile that automatically manages energy according to their personal consumption preferences, such as turning off an electric water heater when a facility or home is unoccupied. The technology gives consumers the ability to easily lower their electricity bills and carbon footprint by controlling their electricity use from their computers or mobile devices."

Additionally, providing real-time information about energy use can help a consumer to use energy more efficiently. For example, the Toyota Prius gives drivers continuous feedback about fuel consumption. Drivers often respond by trying to drive using as little fuel as possible. Feedback allows them to learn what driving behaviours result in lower fuel use. In contrast, homeowners receive their electricity bill once a month. The feedback comes up to 30 days after they have made a decision that affects their energy use, making it difficult to know which decisions had the most impact on energy use. Many smart grid proposals would provide more immediate feedback to homeowners. Smart grid combined with prices that vary over time would allow consumers to change their behaviour by turning off lights or operating high electricity-use equipment during off-peak hours, when prices are lower.

Providing Efficiency Assistance to Households

Lack of available capital can be a significant barrier to efficiency investment in households. Low-income households are a particularly suitable environment for investment – they are most likely to live in energy-inefficient housing and least able to afford improvements. Even if an efficiency investment has the potential to

2. The state discontinued decoupling for several years after a restructuring of the electricity industry. It was reintroduced in 2002.

pay off manifold, consumers will not invest if they cannot afford the up-front cost. Programmes that help consumers pay for efficiency investment can help bridge this gap. However, many government programmes focus on tax credits for efficiency investment. These programmes do encourage investment, but they are least effective for those who need them most, since low-income residents pay little to no income tax.

Programmes that provide direct assistance to low-income customers for efficiency improvements provide better results. A recent study found that successful efficiency programmes for low-income customers generally have the following characteristics:[3]

- Partnerships among utilities, community service agencies, private businesses and other stakeholders can create an effective delivery structure.
- Customer education is an integral part of the service provided. Programmes help customers to understand the technology installed in their homes and the behavioural changes they could make to further decrease their energy bill.
- Integrated approaches that consider the entire home and all fuels are most successful. Such an approach considers the interaction among various efficiency measures and results in the most cost-effective investments.
- Programmes participate in ongoing evaluations to assess and improve performance.

Steven Chu describes steps that the US Department of Energy is taking to encourage home energy retrofits. The Department is focused on creating tools for home inspectors to use and training them to identify the most cost-effective investments. Monitoring results is a crucial step to providing quality assurance and promoting improvement. An effort called "Retrofit Ramp-Up" is an innovative way to encourage energy efficiency retrofits in entire neighbourhoods. "If we can audit and retrofit a significant fraction of the homes on any given residential block, the cost, convenience and confidence of retrofit work will be vastly improved. Another goal of this programme is to make energy efficiency a social norm," notes Chu.

San Francisco Mayor Gavin Newsom provides an example of a successful investment programme in his perspective *Energy Efficiency: From Crisis to Creativity.* One focus of the city's PowerSavers programme was the southeast portion of San Francisco, "an area that has historically suffered a disproportionate burden of pollution and other environmental blight." The programme offered free energy audits and coordinated lighting retrofit installation. Newsom also describes the San Francisco Sustainable Financing Program, "the country's largest local property tax-based loan programme focused on greening local buildings. It will loan money to San Francisco residents and businesses to install renewable energy systems and make energy efficiency upgrades to their buildings."

3. Kushler, Martin, Dan York, Patti Witte, *Meeting Essential Needs: The Results of a National Search for Exemplary Utility-Funded Low-Income Energy Efficiency Programs, American Council for an Energy Efficient Economy,* September 2005.

San Francisco – home of the Energy Watch program

Perspectives on Understanding Energy Efficiency in the Household Sector

The chapter concludes with perspectives of two individuals who provide examples of energy efficiency improvements in households.

- **Peter Corsell,** Chief Executive Officer, GridPoint, USA
- **Gavin Newsom,** Mayor of the City of San Francisco, USA

Smart Grid Is the Internet of Electricity

By Peter Corsell, Chief Executive Officer, GridPoint, USA

Just as the Internet enabled a dramatic improvement in the efficiency of commerce and communication, the "smart grid" will enable the electric grid to efficiently produce and deliver the ideal amount of power exactly when and where it is needed. At the same time, it will enable consumers to become more efficient. Today, the existing grid does not possess the intelligence to determine or execute at this level of efficiency. Instead, it must blindly distribute huge amounts of power even when a small amount of power is needed. This "all-you-can-eat buffet" approach is not sustainable in the 21st century economy with its growing demand for energy.

Achieving efficiency does not mean we will have to sacrifice actual energy services in our daily lives. It means we will have a system that automatically conserves power and delivers only the electricity we need, when we need it. Additionally, efficiency is achieved by optimizing the balance of traditional and clean power sources at any point in time to meet both economic and environmental goals. A true smart grid requires technology that scales to accommodate future energy needs, increases operational efficiency and establishes a mutually beneficial relationship among utilities, consumers and the environment. Smart grid technology can provide utilities and their customers with an intelligent, self-optimizing network that enables the efficient production, delivery and consumption of the cleanest and most economical power available at any point in time.

Smart grid technology delivers something very important to businesses and consumers – visibility into their energy use. For example, consumers can create an online energy profile that automatically manages energy according to their personal consumption preferences, such as turning off an electric water heater when a facility or home is unoccupied. The technology gives consumers the ability to easily lower their electricity bills and carbon footprint by controlling their electricity use from their computers or mobile devices.

Smart grid technology also opens the door for utilities and their customers to establish two-way communication, which at scale helps utilities efficiently manage peak demand periods. For example, utilities can avoid turning on a less fuel-efficient peaking power plant by adjusting select customers' thermostats by a few degrees. Customers who have opted in to the utility programme via their online profile can receive a reduction in their bill in exchange for their participation.

These examples barely scratch the surface of the efficiencies utilities can gain with the smart grid. Smart grid software provides utilities with a network operating system to integrate and optimize various new technologies, including smart meters, batteries, solar panels and plug-in electric vehicles. The result is a "virtual power plant" that provides utilities with a source of clean power to draw upon any time demand is high. Utilities gain a whole new level of visibility and control of our increasingly complex power system and can meet growing demand without having to build new power plants, while at the same time incorporating more renewable energy into the grid.

To illustrate the pressing need and benefits of a smart grid, consider a single emerging technology: plug-in electric vehicles. Nissan and General Motors are among several automakers that will release plug-in vehicles beginning this year. A study by the US Oak Ridge National Laboratory concluded that 160 new power plants would be required if everyone plugged in such a hybrid in the early evening, when demand is already high. With smart grid technology, utilities could stagger charging times and offer consumers lower rates for off-peak electricity. This capability, dubbed "smart charging", would virtually eliminate the need for new power plants to meet this need, according to the study. When wind or solar power is available, this technology can increase the rate of charging to expand the use of renewable energy.

Smart charging is now getting charged up. GridPoint is providing smart charging software to support the largest deployment of electric vehicles in the United States, a project backed by federal stimulus funding and involving up to 5,000 Nissan LEAF vehicles. It is among several projects we are working on that will determine how real-time grid conditions and driver needs can be balanced to intelligently charge plug-in vehicles.

Ultimately, the smart grid will dramatically transform the way we generate, consume and think about energy – because it will make each one of us a more relevant point on the grid. We will be empowered to optimize energy use in our own homes and businesses, and we will understand our role in a new energy ecosystem. The result will be a highly efficient, reliable grid that benefits our communities, our economy and the environment.

Energy Efficiency – From Crisis to Creativity

By Gavin Newsom, Mayor of the City of San Francisco, USA

It's been said that crisis breeds opportunity. In San Francisco, the energy-related crises of the past decade, including climate change, have presented us with the opportunity, and an imperative, to be creative. And we've responded by developing innovative solutions that reduce energy use and emissions, save money, create jobs and protect human health in a city of 800,000 people that is the heart of California's Bay Area.

Spurred by California's energy crisis in 2001, the city's Department of the Environment received state funds to develop the Power Savers Program, which offered direct incentives and technical assistance to more than 4,000 hard-to-reach owners of small businesses such as grocery stores, retail and restaurants. The programme offered free energy audits and coordinated lighting retrofit installation, as well as buydowns of the cost of lighting retrofits. Participating businesses saved more than US$ 3.5 million on their electricity bills.

Buoyed by the success of the Power Savers Program, the City then sought funds to address another of its challenges: with only a single transmission line, San Francisco needed to cut its power load, especially during peak hours. So from 2003 to 2005, the Department of the Environment and Pacific Gas & Electric (PG&E) jointly administered the Peak Energy Program, funded by ratepayer dollars. On the residential side, the programme focused on multi-family buildings and single-family homes of lower-income, elderly or disabled residents in the city's southeast, an area that has historically suffered a disproportionate burden of pollution and other environmental blight.

On the commercial side, the Peak Energy Program provided rebates to small and medium-size businesses to install energy efficient lighting and equipment, as well as technical assistance and performance-based incentives. By the conclusion of the Power Savers and Peak Energy Programs, electricity use was down by 18 megawatts, enough to power 18,000 homes.

Now we are in the fourth year of our energy efficiency work under the current programme, San Francisco Energy Watch, also administered in partnership with PG&E. This programme expands on the successes of prior programmes by offering a higher level of expert technical assistance and incentives on more types of energy efficient equipment and newer technologies.

San Francisco Energy Watch has saved businesses and residents more than US$ 8 million in utility bills annually – more than 21,000 tons of GHG reduction. By the end of this year, our combined programmes will deliver annual energy savings surpassing US$ 22 million for San Francisco residents and businesses. We will have reduced our carbon dioxide emissions by nearly 60,000 tons – the same as taking 12,000 automobiles off the road, forever. In terms of energy conservation, we will have saved enough energy to power 22,000 San Francisco residences.

While the Department of the Environment has focused on the private sector, the San Francisco Public Utilities Commission has saved millions of kilowatt-hours of electricity and natural gas by installing energy-efficient lighting, motors and controllers, new chillers and updated HVAC systems in city clinics, hospitals, police stations and other facilities. In fact, City Hall is part of a larger Civic Center Sustainable Resource District, with plans to retrofit heating, cooling and lighting energy efficiency, as well as to install a 100 kilowatt solar photovoltaic system on the roof. When completed, these energy improvements will save the equivalent of the energy use of approximately 200 San Francisco homes.

The City Hall project is an example of putting into practice lessons from our previous programmes, and of the obstacles we still need to overcome. We've adopted a strategy of Zero Net Energy Buildings, which integrates efficiency retrofits with renewable and cogeneration capacity, delivered in a planned, comprehensive manner to get deeper savings. It is one thing to implement such a strategy with new construction, but with the beautiful and aging building stock we have in San Francisco, much of our focus will be on how to implement this strategy in our existing buildings.

Another facet of our creativity has been establishing innovative financing sources and mechanisms to help San Franciscans pay for the efficiency they're investing in. We're the recipient of more than US$ 7 million in stimulus package money for energy that will be added to our current efforts by the end of 2009. And our new San Francisco Sustainable Financing Program is the country's largest local property tax-based loan programme focused on greening local buildings. It will loan money to San Francisco residents and businesses to install renewable energy systems and make energy efficiency upgrades to their buildings.

Our energy efficiency programmes have reduced San Francisco's environmental footprint, created real change in our neighbourhoods and improved our quality of life. This should give us confidence in the creativity that the crises of the future will inspire.

CHAPTER 6: TRANSPORTATION – EFFICIENCY ON WHEELS

The transportation sector is divided into groups that have very different drivers for efficiency. Commercial transport providers, such as airlines and freight haulers, have strong incentives to invest in energy efficiency. Fuel is a large part of their variable costs, and they compete on providing services at lowest cost. The drivers for commercial transportation efficiency are very similar to those found in energy-intensive industrial businesses.

On the other hand, transportation efficiency is not nearly so central to the decisions of individuals. Convenience, comfort, cost and status are often the most important considerations when consumers purchase vehicles or choose other modes of transport. Cars, in particular, have come to be a reflection on the style and status of the owner. Although rising fuel prices and the worldwide recession have recently – if temporarily – decreased demand for personal vehicles in the developed world, they remain an object of desire throughout the developing world, where demand is soaring.

Commercial Transportation – Growing Efficiency in Airlines

Incentives for energy efficiency are very strong in the competitive airline industry. As oil prices have risen since 2003, fuel prices have made up a growing percentage of airline operating costs. The global airline industry's fuel bill grew by € 21 billion (US$ 31 billion), or 23% from 2007 to 2008. In 2008 fuel costs made up 31% of airline operating expenses, compared to 14% in 2003.[1]

Air traffic tripled between 1980 and 2005, but jet fuel consumption grew by only one-and-one-half times. Thus, the world's aircraft fleet doubled its efficiency between 1980 and 2005. These efficiency gains stem from advancing aircraft technology and operational improvements.

Approximately one-third of the efficiency improvement results from advancing aircraft design technology. Aerospace engineers have achieved fuel efficiency gains through ongoing adoption of new technologies and materials. Airplane technology is improving so rapidly that the economic life of aircraft has declined, as operating costs lead to retirement of older, less efficient aircraft.

Operational efficiencies make up the remainder of the fuel economy improvement. Increasing passenger occupancy rates on commercial flights account for one-third of the efficiency improvement achieved since 1980.[2] Operational improvements can occur throughout the flight cycle. On the ground, changes include using ground power rather than the plane's auxiliary power unit during gate operations, taxiing on only one engine and using tugs to reposition planes when possible. In the air, optimization of speed, flight path and altitude reduces fuel consumption and makes air traffic bottlenecks less likely.

Air traffic control systems and practices have a substantial impact on aircraft fuel use. In the United States, an analogue control system using ground beacons and radar has been in use since the 1950s. This system requires greater distances between planes and sometimes longer flight paths than would be possible with a digital automated technology. Air traffic control in Europe has the additional problem of being fragmented, with 38 different air traffic control services across the continent. These services have little obligation to cooperate and generally operate different systems, making cooperation more difficult. In both the United States and Europe, fuel savings of approximately 6-8% are possible with better air traffic control systems and practices.[3]

Personal Transportation – Maximizing Vehicles or Mobility?

Traffic-choked highways and long rush hour delays are the reality in many areas around the world. Bruno Marzloff, a sociologist specializing in mobility and the founder of Groupe Chronos, points out that, "The incredible freedom [the automobile] provides has turned out to be counterproductive. The mass production of the automobile created a terrible saturation, a congestion

1. International Air Transport Association, Fact Sheet-Fuel, http://www.iata.org/pressroom/facts_figures/fact_sheets/fuel.htm, September 2009.

2. Abadie, Olivier, *Jet Fuel: How High a Flyer? Demand, Supply, and the Endless Quest for Efficiency.* IHS CERA Private Report, April 2007.

3. Air Traffic Organization Strategy and Performance Business Unit, US Federal Aviation Agency and European Organisation for the Safety of Air Navigation, EUROCONTROL, *US/Europe Comparison of ATM-related Operational Performance,* October 2009.

Bangkok, Thailand – does gridlock threaten economic growth?

that transformed the automobile into an 'auto-immobile'. Before the car crisis, there was a mobility crisis, a lifestyle crisis and a territorial crisis."[4]

As Lee Schipper points out in his perspective *Changing the Paradigm of Transportation Efficiency,* "The barriers to a step change in transportation energy efficiency are not technology, but rather urban development policies, lifestyles and behaviour." Improving efficiency in personal transportation is a question not only of vehicle efficiency, but also of system efficiency. Policies that consider the overall question of mobility rather than the efficiency of individual vehicles stand to provide greater efficiency benefits.

The developing world, in particular, is at a crossroads. Following the car-dependent path of the United States is a recipe for permanent gridlock in rapidly growing cities, dramatically reducing the productivity of entire cities and countries. Traffic and pollution are growing as car ownership skyrockets in the large cities of Asia. However, car ownership is a means of mobility and a symbol of advancement to which people around the world aspire.

How can the world move from today's system to the more efficient system of tomorrow? In his perspective, Schipper describes a three-step framework:

- Avoid unnecessary trips.
- Shift to more efficient and less CO_2 intensive forms of transport.
- Improve transportation technology and operational efficiency.

Land use is a crucial issue that affects consumers' decisions about what trips to take using what mode of transport. Transport systems are affected in many places by land use policies that are driven by real estate decisions; various subsidies to land and housing

4. Mentzel, Laure, "Image Breakdown?" *Energies,* No. 16, Autumn 2009.

Source: Lee Schipper

Mexico City Bus Rapid Transit – "convince people with convenience"

development; restrictive zoning regulations that separate jobs, services and homes and policies that tend to concentrate transport investment on roads. As a result, personal vehicles are used for 95% of land travel in the United States and about 85% in Europe. This travel pattern uses two or three times more energy per person than could be achieved in an area that integrates transportation and land use planning.

Curitiba, a city of approximately 1.8 million people in southern Brazil, provides an example of using integrated urban planning to provide efficient transportation and avoid unnecessary car trips. The city limited vehicle traffic in its central downtown area and established bus routes using dedicated lanes along existing roadways. This system was much less expensive than building rail transit. Zoning in the city encourages walking and use of public transit. Curitiba residents have one of the highest rates of car ownership in Brazil, but gasoline use per person is one-third lower than comparable Brazilian cities, demonstrating the impact of integrating transit and land use.

Congestion pricing in inner cities provides another example of avoiding unnecessary trips. Stockholm has charged drivers to enter the inner city area since 2007. The policy has resulted in a 20% reduction in traffic in and out of the Stockholm inner city and a 30-50% decrease in travelling times. The public has also changed to more efficient modes of travel as a result of congestion pricing. Since 2007 clean cars (hybrids and those running on biofuels or biogas) have increased from 3% to 15% of cars entering the centre city, and public transit ridership has increased 7%.[5] Singapore has a similar congestion pricing system, in concert with an extensive public transit system and a very high tax on car ownership.

Mexico City provides an example of shifting transport modes to improve the efficiency of transportation while also making it more convenient. In 2005, the city implemented a bus rapid transit system on the

5. Gunnar Söderholm, Director, Stockholm Environment and Health Administration, 2 December 2009.

Insurgentes artery that runs in dedicated lanes, avoiding traffic and attracting new riders. This line saves 18 million litres (4.8 million gallons) of diesel fuel per year, one-third from the replacement of small buses with larger ones, one-third from reduction in travel time for all vehicles and one-third from riders switching from cars to the bus. The bus line serves more than 300,000 people per day and saves each rider about 10 minutes in travel time. Martha Delgado, Mexico City's environment minister, described the effect this way: "You convince people with convenience. It's not a matter just of conscience. If you're stuck in traffic and you're not an environmentalist, you want to get on the Metrobus."[6]

Many initiatives are underway worldwide to improve the fuel efficiency of vehicles. The United States and China both recently increased their vehicle efficiency standards, and Europe moved from a voluntary to a mandatory standard. In his perspective, Peter Voser points out a potential pitfall to increasing fuel efficiency standards. "The automotive industry illustrates how big efficiency gains can be lost if we aren't careful. Since the 1970s, fuel injection, microprocessors and other technical advances contributed to improved engine efficiency. But they did not result in better fuel economy for the average vehicle. Why not? The efficiency gains were instead used to add power for quicker acceleration and higher maximum speeds – or merely to move heavier vehicles." Vehicle efficiency standards will provide their greatest benefit if applied along with other measures to avoid trips and shift transport to more efficient modes.

Perspectives on Understanding Energy Efficiency in the Transportation Sector

The chapter concludes with a perspective that suggests options for efficiency in the transport sector.

- **Lee Schipper,** Project Scientist, Global Metropolitan Studies, University of California at Berkeley and Senior Engineer, Precourt Energy Efficiency Center, Stanford University, USA

6. Friedman, Lisa, "Mexico City's Cleanup Pitch – It's Not Climate, It's Convenience", *ClimateWire,* 23 November 2009.

Changing the Paradigm of Transportation Efficiency

By Lee Schipper, Senior Engineer, Precourt Energy Efficiency Center, Stanford University, and Project Scientist, Global Metropolitan Studies, University of California at Berkeley, USA

Distance can be measured not only in miles and kilometres, but also in terms of what has been accomplished. That is certainly true in transportation.

The transport sector has made real strides in reducing fuel use and CO_2 emissions in the last 35 years. In developed countries cars use 20-30% less fuel per kilometre (km) than they did in the early 1970s; air travel uses 50-60% less energy per passenger-km, and trucking 10-25% less fuel per tonne-km. More improvement is on the way as tighter vehicle fuel efficiency standards go into effect in the United States, Europe and some developing countries; as major aircraft and truck producers bring out even more fuel efficient equipment; and as all vehicles are loaded better.

The problem is that increasing energy security and decreasing the CO_2 emissions from transport require bigger savings, sooner. How will this happen?

Technology is part of the answer, provided that vehicle manufacturers, consumers and transport companies face realistic fuel prices. Car manufacturers and users need continual pushing from fuel economy standards. Consumers, manufacturers and governments also have to agree on how car ownership and use is taxed, to prevent both continuation of the past upward spiral of weight and power and to make sure vehicle users face the real costs of driving, parking, congestion and accidents. Only then can technology deliver real energy savings.

Focusing only on cars' technologies will result in important but limited savings. Unfortunately, barriers to a step change in transportation energy efficiency are not really those of technology, but rather those related to urban development policies, lifestyles and behaviour. Decisions rest with politicians and individuals, not just equipment manufacturers. Trends towards larger cars, greater car ownership and more driving negate some of the gains from increased vehicle efficiency.

Transport and development policy strongly favour and subsidize car-oriented development worldwide. A three-step framework describes the change between today's transportation system and tomorrow's more efficient system.

Avoid automobile-focussed development in development patterns and land uses of cities. Coordinate schools, healthcare, recreation and services' locations with jobs and housing. Today, much of North America is helter-skelter, which is what most of the developing world is copying.

Shift to more efficient and less CO_2-intensive modes of transport. Focus planning on non-car travel, rather than just giving lip service to "mass transit". This is supported by policies that make all transport modes and individual drivers face the real costs of moving, and give real priority to collective transport through exclusive lanes for buses and improved pedestrian and cycle access to transit, homes and jobs. High speed rail corridors that really pull passengers from cars or airplanes are another good example.

Improve transportation technology and operational efficiency. As noted above, technology does have a strong role to play, but only as a complement to avoiding problems in the first place or shifting away from them. Lower levels of traffic also reduce the economic losses that occur as a result of vehicles stuck in traffic or in the air over airports.

Reducing fuel use and CO_2 emissions are a co-benefit of the first two changes, not their primary focus. That focus should be better access to cleaner, quieter and safer transport, and more human cities that are not simply built around roads and highways.

The public and private sectors both must act. The public sector can transform transport pricing to reflect the real costs of building and maintaining transportation systems. Fuel and carbon taxes must reflect government's concerns about energy security and climate change. Carbon taxes are particularly important to separate real low-carbon fuels from impostors. Government can also rebalance infrastructure investments away from the domination of cars and trucks, reducing snarled traffic. High-speed rail in Japan and France succeeded in part because the competition (air travel, road fuels and toll roads) were expensive. The many hidden tax subsidies for urban sprawl must end.

In the private sector, the automobile industry must recognize that, for most of the world, the role of the car should be cut back. Transport providers (bus, rail, air and trucking companies) have to be prepared to work with the public sector in a different mode. The private sector must support pricing reforms, including policies that help reduce miles driven, such as selling insurance by how far a car is driven.

Individuals have to change their aspirations away from big cars and car-dominated lives. This begins with those in countries with the biggest cars, both to set examples and to have the largest impact on global oil use.

Global transport and fuel authorities agree that the potential exists to more than double the efficiency of cars, trucks and aircraft over the next 30 to 40 years. But that is not enough when facing a more than sixfold increase in transport activity in cars, trucks and airplanes. Maybe it is equally important to avoid the increasing traffic jams on the ground and the air in the first place.

CHAPTER 7: QUESTIONS FOR THE FUTURE

This report demonstrates the importance of energy efficiency as a major "energy source". It explores the opportunities in different sectors and provides a framework for understanding the obstacles and challenges. At the heart of the discussion is the recognition of how essential energy efficiency is to sustainably meet the requirements of a growing world economy and the challenges of climate change, energy security and economic vitality.

But, as we emphasize throughout this Energy Vision report, efficiency is not a "thing." It is a process – a way of thinking about making better use of energy sources, rather than just using more energy. This way of thinking needs to be embedded into energy investment decisions in all four major energy-consuming sectors. Yet, the perspective from each sector is different. As a result, the potential solutions, barriers to investment and government policies all need to adapt to these differing realities. Achieving a more energy-efficient system involves many dimensions – some very material, some requiring intensified innovation and some behavioural.

Focusing on energy efficiency is not a new concept. The energy intensities of the United States and Japan are today roughly half what they were in the early 1970s. Other economies have experienced similar changes. This reduction in energy intensity is a result of improved energy efficiency and of the changing make-up of many economies. However, ever-improving technology means that there is more potential for efficiency improvement in the future. An ongoing debate exists as to how to bring about future efficiency, based on the nature of the "efficiency gap." Is it a result primarily of market failures and barriers or of markets working and people making investment choices? The answer is a balance between the two. Insights from the four primary energy using sectors – industry, buildings, households and transportation – shed light on this fundamental question.

Insights from the Four Sectors

Industrial firms – particularly in energy-intensive industries – actively pursue energy efficiency to manage costs and improve profitability. They approach efficiency with an investment mindset. "Investment-grade" efficiency projects must be competitive with other uses of capital – energy savings must cover the upfront cost of the investment and also provide a competitive return.

Capital spent on energy efficiency investments must be allocated along with other uses of capital – there is not a vast untapped pool of money waiting to be invested in efficiency. At the same time, best practices show that organization and focus are critical factors in capturing the energy efficiency potential and that there are opportunities for continual improvement.

In the building sector, providing incentives for energy efficiency is more complex due to two concepts that can be barriers to investment. The first is disaggregation. This refers to small changes that appear to be of little significance individually in terms of investment but can add up to large savings. Leaks around doors and windows are one example. Each leak is incidental, but fixing all leaks can add up in terms of both energy savings and comfort. The second concept is split incentives, in which a second party makes efficiency decisions on a consumer's behalf. Builders of office buildings may spend their limited funds on amenities rather than features that could reduce the future tenants' energy bills. In addition to government building standards, new voluntary certification programmes are designed to overcome some of the barriers to investment. When a building certification programme makes energy efficiency features evident, consumers can make more informed choices and builders can better recoup their efficiency investments.

The third major energy-consuming sector is households. Calculating the costs and benefits and determining which efficiency projects are investment grade is difficult for households. The lag time between energy use and the energy bill raises challenges. For example, most households get an aggregated electricity bill once a month. Homeowners generally are not clear about which actions contributed the most to their energy bill and they receive the bill too late to make behavioural changes to lower their energy use. Technologies such as the "smart grid" or "intelligent buildings" that automate efficiency can help overcome behavioural barriers. Additionally, many governments mandate energy efficiency standards and labels, allowing consumers to integrate efficiency into their purchase decisions with little effort. Programmes that help consumers pay for efficiency investment, such as tax credits or direct grants, can overcome a lack of access to capital.

Towards a More Energy Efficient World

Transportation is the fourth major energy-consuming sector. This sector, which has received a great deal of attention, is a blend of commercial transport providers, such as airlines and freight haulers, and household vehicles. Like the industrial sector, the providers of commercial transport have a clear financial incentive to reduce energy costs through improved energy efficiency. However, efficiency is often not a decision factor in personal transport, particularly when fuel prices are low. The automotive industry is pursuing a wide range of energy efficient concepts, from lighter weight materials to changes in the internal combustion engine. However, changes in the vehicles themselves, whether brought about by efficiency standards or fuel prices, can only go so far, particularly in developing countries where cities are growing rapidly and traffic is in a state of near-constant gridlock. A systemic approach to transportation efficiency considers mobility of people and goods rather than just the efficiency of individual vehicles. This approach, combined with more efficient vehicles, would reduce growth in fuel demand much more than improving vehicle efficiency alone.

Implications for Policy

Consideration of the four sectors clarifies the roles that policy can play in encouraging efficiency. Efficiency at any cost is not the goal. However, policy does have the power to remedy some economic inefficiencies and information deficits and to create the "soft infrastructure" needed to promote energy efficiency.

One crucial way for government to encourage efficiency across the entire economy is through the price of energy. Governments have the ability to include the cost of externalities in energy prices, and doing so is a powerful encouragement for efficiency. Calculating the cost of externalities can be challenging, however, and increasing energy prices is politically unpopular. Conversely, subsidizing energy prices lessens the drive for efficiency. Removing generalized, untargeted energy subsidies and targeting low-income people and helping them invest in energy efficiency can reap benefits for an entire economy. Another way of targeting efficiency is through tax credits or other fiscal incentives.

Governments can encourage technology solutions to make efficiency cheaper or easier, through spending on research and development of new technology or directly toward helping consumers buy efficient products. Governments also have the ability to use planning tools to encourage energy efficient development. This is evident in the transportation sector, where decisions about urban planning and land use can have a vast impact on the overall efficiency of transportation. Also, as is becoming more common, governments can also mandate more efficient technologies and provide benchmarks, comparative frameworks and rankings.

The best policy intervention is not necessarily the one that results in the greatest efficiency increase. When considering policy options, governments must compare the cost of a new program to the efficiency lost by maintaining the status quo. For example, the transaction cost for making many small efficiency improvements across homes and businesses may be very high. Determining the cost-efficient level at each location would likely cost more than the energy that would be saved. In this case, product standards and rankings are a good policy intervention, since they can improve average efficiency levels without resulting in high information-gathering costs for consumers. Standards would not be the most energy-efficient solution to this problem, but they would likely be the best balance between efficiency and cost.

Implications for the Private Sector

The private sector has a major role to play in implementing efficiency. Even in industries where energy is a significant cost, additional management focus and development of an energy efficiency mindset throughout a company can bring about significant savings. This translates into organization, priorities, operating standards and incentives. Some entire industries are working together on efficiency initiatives. For example, the cement industry has partnered with the World Business Council for Sustainable Development and the International Energy Agency to produce a roadmap to improve the industry's energy efficiency and reduce its GHG emissions.

Integration of new technology is another crucial role for the private sector. Advances in information technology and communication provide opportunities for efficiency that did not exist a decade or two ago. For example, smart grid technologies can provide efficiency and management benefits to utilities as well as helping

consumers better understand their energy use and make better efficiency decisions. Businesses that introduce appealing products with energy efficiency benefits are likely to benefit from consumer demand.

Individuals have their own decisive role to play in making energy efficiency a part of their lives. Small behaviours, such as turning out lights when leaving a room, can make a big difference in energy use when played out globally. This change could occur through technology, such as motion sensors that shut lights off when a room is unoccupied, or through education, such as making it a social norm and a habit to turn off lights. Both of these methods deliver benefits, but the effectiveness of each depends on the situation.

Additionally, companies whose business is efficiency are a growing presence in the marketplace. Such companies provide energy efficiency products and services to buildings and industry. For example, new technology allows automation of energy efficiency, allowing businesses and buildings to save energy with little change to their operating practices.

Questions for the Future

One of the basic characteristics of human society is how, again and again over centuries, challenges have been overcome through technological advancement, behavioural change, visionary leadership and practical adaptation. The world will overcome the 21st century's energy challenges in the same way, by investing in technology and promoting education so that people can integrate efficiency into their lives.

Looking ahead, both business leaders and policy-makers have come together in the new consensus that energy efficiency must be a significant component of the solution to meeting growing demands of energy while addressing concerns about GHG emissions. The overarching objective is to ensure that the attributes of energy efficiency – disaggregated and sometimes not visible – are captured across the energy value chain. This objective sets a series of key questions for the future. Some of them are:

- What is the relative role among prices and market forces, mandates and regulation, and information and education that will encourage greater energy efficiency in creative, constructive ways? What is the best and most feasible balance of these forces for achieving national and global efficiency improvements?
- How can businesses and governments share best practices and learn from the experiences of others in encouraging and implementing energy efficiency?
- How can businesses and individuals fashion energy efficiency decisions that take into account the "investment grade" test? How can this concept be mainstreamed and integrated into fundamental business decisions?
- What are the strategies that will promote efficiency for businesses, both for those that are energy intensive and those that are not?
- What strategies are most effective at encouraging energy efficiency in households? How can the costs and barriers to household efficiency be minimized?
- How do energy efficiency programmes that work in emerging economies differ from those in developed countries? Can emerging economies take advantage of the opportunity to "leap-frog" and build more efficient infrastructure?
- How can knowledge about effective efficiency programmes be shared globally? How can local leaders learn which efficiency policies fit their circumstances?
- How can consumers and policy-makers encourage the diffuse and conservative building industry to embrace efficiency?
- What are the emerging and new technologies – and new business models – that will promote efficiency, and how can they be developed and diffused?
- How can industry and governments assure that continuing research and development supports efficiency?

The World Economic Forum and IHS CERA will be exploring this critical set of questions in the months ahead.

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