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Thematic & Trading Research

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Research Flash for London Accord

Investment Ideas
Energy efficiency: The global case for efficiency gains

Private Banking

Executive summary

We expect the current energy supply/demand imbalance to worsen in the future: In the 21st century, population growth, rising GDP per capita, urbanization, and industrialization in emerging markets (EMs) are likely to further boost demand for energy. However, supplies of traditional energy, mostly oil, are limited, creating a need for new solutions. In the emerging markets in particular, rapid growth of energy demand towards Western standards is pushing up our energy needs. Furthermore, global warming and global environmental concerns limit the growth of fossil fuel use (oil and coal).

With over USD 20 trn of investments in energy supply infrastructure expected by 2030, we believe that the world will be able to come up with energy-efficient solutions to meet the energy supply and security challenges. This will be achieved by implementing state–of-the-art and next generation energy technologies.

The long-term answer to this new energy paradigm is the development of new energy sources and technologies. Changing production processes in industries and individual habits takes time and will require considerable investment but it is the only viable solution in the long term. An interim solution requiring less sweeping change would be to dramatically increase energy efficiency by making only slight alterations to individuals and corporations' daily lifestyles, but still having a significant impact on energy consumption. This solution is all the more viable as globalization has increased competition in major industries. Reducing the percentage of energy costs in relation to total sales has become a key means of remaining competitive and lessening the impact of higher raw material costs on profit.

The trend of improving energy efficiency is not new. Efficiency has already improved vastly in the past few decades. However, high energy prices, increased industrial competition in the wake of globalization, and increased popular awareness about energy issues have triggered a massive increase in R&D to improve energy efficiency. Consequently, we expect a major acceleration in energy efficiency in the coming years, with an impact on many sectors from lighting and power producers to building materials. Several new products are expected to come onto the market in the next few years that can significantly change industries and daily lifestyles. For example, United Technologies' new jet

Highlights

- Urbanization, population growth and globalization will significantly increase energy demand. Sustained high energy prices and increased societal awareness of global warming issues are the driving forces that will help to create the necessary solutions to meet this challenge.
- Substitution with alternative energy is the long-term solution. However, in the short to medium term, lower energy use for similar output levels, i.e. increasing energy efficiency, appears to be the best bridge between existing habits and the new energy environment.
- With over USD 20 trn of investments in energy supply infrastructure expected by 2030, we think the world has plenty of room to cope with the energy efficiency, supply and security challenges by implementing next generation and state-of-the-art energy technologies.
- For EMs, convergence to Western standards of living translates into higher energy consumption per capita, which is not sustainable without endangering world resources. Therefore, we expect BRIC countries to achieve significant energy efficiency increases, in some cases over 30% by 2020.

engine (currently under development and expected to be launched after 2010) could reduce emissions and kerosene consumption by half.

In this report we detail the major industrial improvements we expect. We also highlight the impact of new technology on energy efficiency in many sectors. We detail our long-term expectations for alternative energy use, which we believe will further significantly improve energy efficiency. Finally, we study the reaction of public authorities and detail the energy efficiency targets and tools announced in several countries.

Outline of the report

The present report is structured as follows:

Executive summary

1. Sustained energy prices justify investment in energy efficiency
2. Global warming and government targets to reduce carbon emissions make the case for higher energy efficiency
3. Energy efficiency, history of achievements and catalysts for acceleration in the future
4. Energy efficiency outlook per country: EU-25, special topic on UK, USA, and BRICs
5. Energy efficiency outlook by sector and new energy technologies expected to further increase energy efficiency.

1. Sustained energy prices justify investment in energy efficiency

The world's primary energy consumption is highly dependant on oil and gas resources. Their share of gross energy consumption in 2004 was over 55%, as shown in Figures 1 and 4. We assert that the supply and demand balance in oil and gas remains key to energy efficiency development.

1.1 Supply in oil markets is declining

The world's proven oil reserves could sustain current production levels for around 42 years, according to the IEA. We share this view in light of the current rapidly depleting existing wells and lack of major discoveries in the past 30 years.

1.2 Demand is rapidly rising

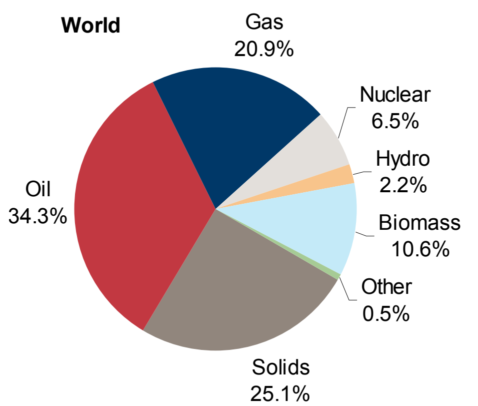
As highlighted in Figure 2, global population and energy demand are growing in tandem. The population is expected to grow at a CAGR of nearly 1%, leading to a population of 8.32 billion in 2030, according to the UN's medium population estimates. According to the International Energy Agency (IEA), energy use is expected to grow in tandem with population at an annualized rate of 1.8%, resulting in a demand of 701.6 quadrillion Btu in 2030. A significant portion of this growth is expected to come from EMs as these countries are experiencing population growth, rapid economic development, and GDP growth. Emerging markets are particularly important since they are entering a more oil intensive growth phase fueled by trends in globalization, industrialization, urbanization, and rapid economic growth. This abrupt and continuing increase in demand from emerging markets is not reversible. In particular for BRIC countries, urbanization and the alleviation of poverty both mean increasing per capita energy use as people earn higher incomes and expect higher standards of living.

Therefore, we expect oil prices to remain at sustained levels. Figure 3 shows the trend in oil prices beginning in 1960, based on the US dollar in 2006. The highest oil prices to date were found during the 1970s and oil prices are rising to record values again today.

We estimate that the current fever in oil prices is different to the 1970s and is more durable. In the 1970s, oil prices were driven by the political cuts in supply (OPEC 1973, Iran 1979). However, the recession induced by oil prices also cut

Figure 1

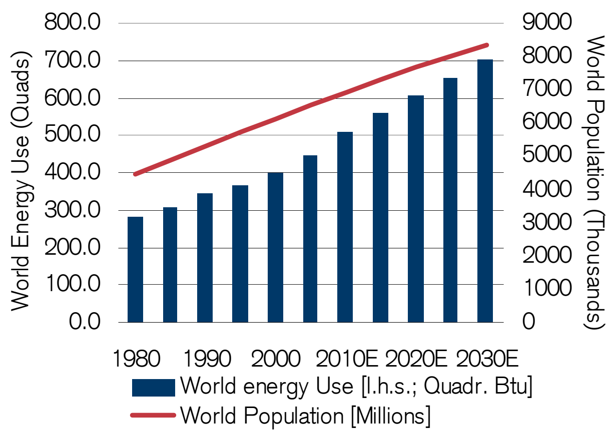
Share of world fuel use, based on gross inland (primary) energy consumption, by fuel type in 2004



Source: Eurostat, OECD, Credit Suisse

Figure 2

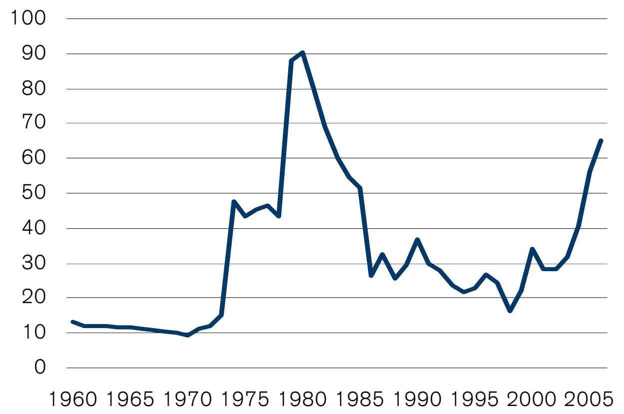
Population and energy use growth to 2030



Source: EIA, UN POPIN, Credit Suisse

Figure 3

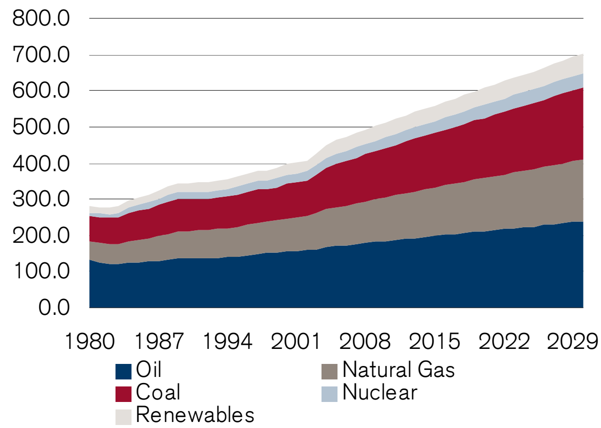
Historical crude oil prices (in 2006 USD/bbl)



Source: BP Statistical Review 2007, Credit Suisse

Figure 4

World fuel use by type from 1980-2030 [in Quadr. Btu]



Source: EIA, Credit Suisse

demand, while supply was restored after several months, creating a massive drop in oil prices in the early 1980s. In the last few years, the price of crude oil has increased again but, this time, it is being driven by the rapid growth in demand. Therefore we expect the supply/demand imbalance to increase.

As long as the long-term trend of emerging market growth that started in 2002 does not abate, oil demand will keep rising and prices will remain at sustained levels.

As a result, long-term investment in new energy sources and energy efficiency is justified, supported by the expectation of sustained high oil prices.

Intrinsic improvements in technology are also driving improvements in energy efficiency. A clear example of this is the push for smaller, faster, cheaper electronics, for instance, coming from Moore's law and from nanotechnology innovations. Smaller electronic devices and transistors use less power. Portable electronics with low power consumption are in high demand and we expect this trend to continue, and the energy savings benefits that come as a result should also benefit sectors outside of technology.

2. Global warming and government targets to reduce carbon emissions make the case for higher energy efficiency

A second key driver for energy efficiency stems from mandates to reduce carbon emissions. Greenhouse gas emissions have now been linked to climate change. The devastation caused by the various natural disasters in the recent past, including Hurricane Katrina and the Asian tsunami, has brought this issue to the forefront. Natural disasters have been particularly devastating in recent years and have further fuelled people's fears about the health of the planet and our ability to preserve it for future generations. The Kyoto Protocol, enacted in February 2005, set ambitious targets for the reduction of greenhouse gas emissions between 2008 and 2012. This is likely to benefit suppliers of lower-emission technologies including renewable fuels, clean coal technologies and makers of carbon capture equipment and technologies. The Stern Review suggests that up to 55% of the reduction in carbon emissions could come from carbon capture technology. The review further asserts that higher costs for carbon emissions are expected to drive the development of technologies that reduce them.

One of the most critical elements in reducing carbon emissions is the advancement of alternative energy technologies. Figure 4 shows the EIA estimates of fuel types and their relative importance by 2030. Although oil use is expected to grow, it is clear that coal, nuclear, and natural gas based energy sources are going to increase their share as well. Renewables will also increase in importance, partially fuelled by government mandates, and we see this trend as a key driver of efficiency innovation. However, it will not eliminate oil use, which is expected to remain by far the leading source of energy to 2030. So the targets enacted to combat global warming will unlikely offer a solution to high oil prices in the medium term, making the case for energy efficiency. The main factor impeding the replacement of fossil fuel technologies with alternative energy technologies including solar, wind, biofuels, etc. is **cost competitiveness** with existing energy infrastructure. This is spurring technological research and development (R&D) as the race is on to achieve efficiencies that make these cost competitive. The EU goal is to generate 20% of electricity production from renewable sources by 2020. These types of government mandates will push economies of scale and R&D such that technical innovation will improve the efficiency of alternative energy.

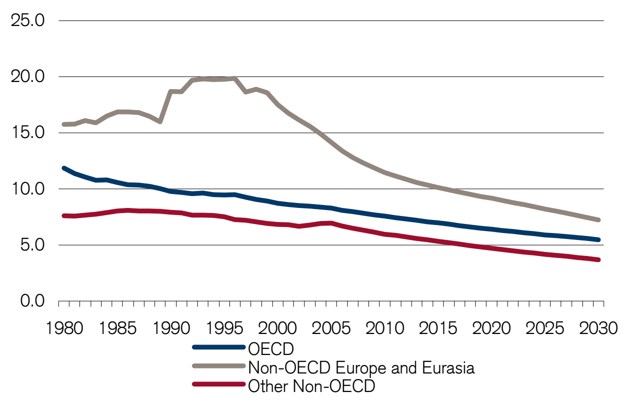
3. Energy efficiency, history of achievements and catalysts for acceleration

An important indicator measuring the dependence of the economy on energy is energy or oil intensity (Figure 5). Since the 1990s, the major regions in the world have seen a decrease in their oil intensity, meaning that there is less energy required to produce a similar level of GDP. It shows that economies can keep growing despite the higher energy costs. The first major boost for energy efficiency stemmed from the oil crisis of the 1970s, which triggered a reaction by several countries and industries. For instance in the USA, energy intensity started to significantly drop, from 12 Thousand Btu per unit GDP (per 1 USD in 2000) in 1990 down to 9.4 Thousand BTU per unit GDP (per 1 USD in 2000). Interestingly, the intervention of innovation and R&D justified by oil prices was not cut off when oil prices moved significantly lower in the 1980s, and oil intensity kept declining in the 1990s. While a large share of this decline per unit of GDP is linked to a lower industry share of GDP and higher service component of total US GDP, industrial and transportation energy intensities kept declining, in an effort from corporations to reduce energy costs as a percent of total sales and widen profit margins.

Non-OECD Europe (i.e. former Eastern Europe and FSU states) highlights a different pattern: a sudden jump is observed at the start of the 1990s and energy intensity reached its highest level in 1995, as shown in Figures 5 to 8. This is likely due to the lack of official statistics before the early 1990s, while low efficiency Soviet-style industries together with a massive collapse of former Communist countries' GDP following the end of the Cold War significantly boosted their average energy intensity. Massive investments and replacement of old plants as of 1995, plus economic recovery, enabled those countries to rapidly converge to OECD levels of energy intensity.

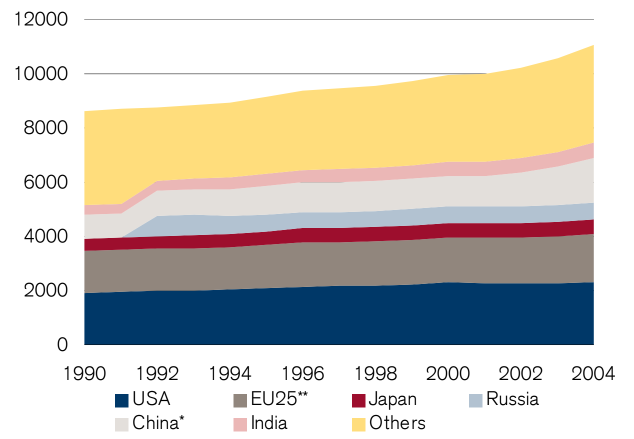
Figure 8 highlights the energy intensity of selected countries. Interestingly, while energy efficiency has improved in

Figure 5:
Oil intensity [Thousand Btu per 1 USD in 2000 of GDP]



Source: EIA, Credit Suisse

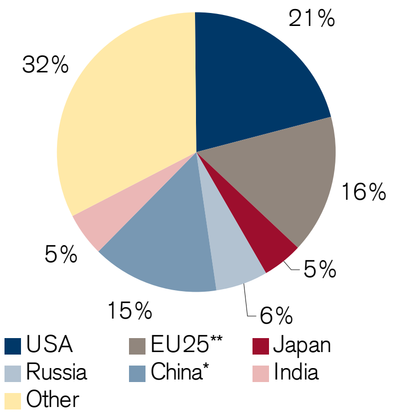
Figure 6:
Breakdown of world gross inland primary energy consumption [in Mtoe]



Source: Eurostat, Credit Suisse

Figure 7

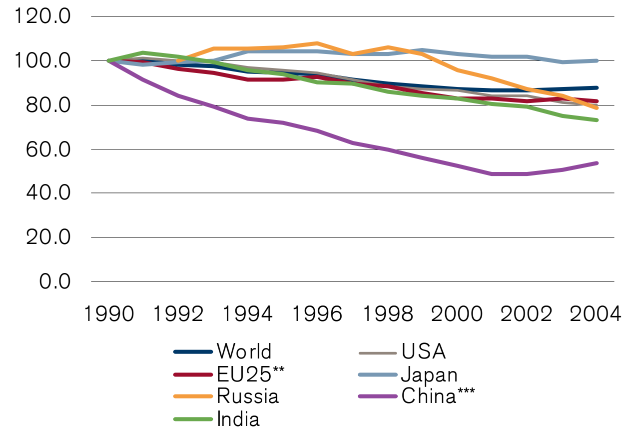
Breakdown of world gross inland (primary) energy consumption



Source: Eurostat, Credit Suisse

Figure 8

Energy intensity indicators in OECD regions relative to the starting value of 100 [in toe /MEuro 2000]



Source: Eurostat, Credit Suisse

all of these countries except for Japan, China has achieved the best increase in efficiency. This is due to the booming construction of new plants with better energy consumption patterns. However, this increase in energy efficiency is more than offset by rising industrial production, so despite China's major achievements in improving efficiency, its share of global pollution has risen significantly, as shown in Figure 9. The same applies to India.

Looking at the numbers in greater detail, between 1990-2004, the energy intensity, see Figures 7 and 8, defined as gross inland (primary) energy consumption to GDP [in toe/MEuro in 2000 in the EU scale or in Thousand Btu/ 1 USD in 2000 in US scale], decreased the most in China, 4.1% annually, or over 46% in total, due, among other factors, to increased use of modern energy technologies in the power generation sector as new power plants were built. This was followed by India with a 2.1% annual decrease or 27% in total.

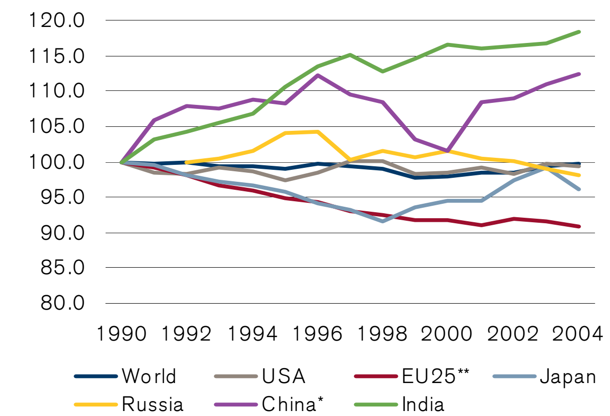
In the US and EU-25, the annual decreases were 1.5% and 1.3%, respectively, driven by various factors and developments such as:

- gradual implementation of modern energy technologies in the power generation sector, e.g. of new combined cycle gas turbines (**CCGT**)
- and/or replacement of older coal- and oil-fired power plants with next generation gas-fired plants offering superior thermal efficiency
- continuous introduction of more efficient energy technology and processes in the industry sector
- gradual implementation of more energy efficient household appliances in the household sector

Interestingly, by analyzing the carbon intensity, defined as CO_2 emission to unit of gross inland energy consumption [in 1 tonne of CO_2 / toe in EU-scale or 1 tonne of CO_2 / Billion Btu in US-scale], Figure 9 shows that the highest increase of carbon intensity between 1990-2004 was seen in India with 1.1% p.a. followed by China with 0.8%. This is mainly due to the high proportion and/or ongoing construction of coal-fired power plants. Figure 10 confirms the high proportion of solid

Figure 9

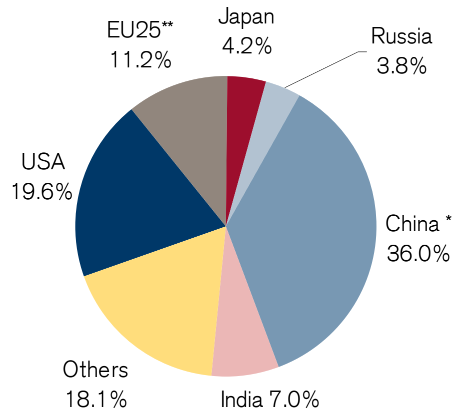
Carbon intensity indicators in OECD regions relative to the start value at 100 [measured in t of CO2 / toe]



Source: Eurostat, Credit Suisse

Figure 10

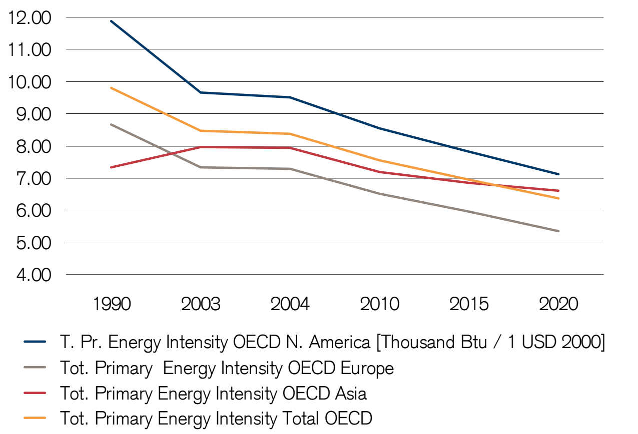
Breakdown of world gross coal primary energy consumption (2004)



Source: Eurostat, OECD, Credit Suisse (* includes Hong Kong, ** Source: Eurostat)

Figure 11

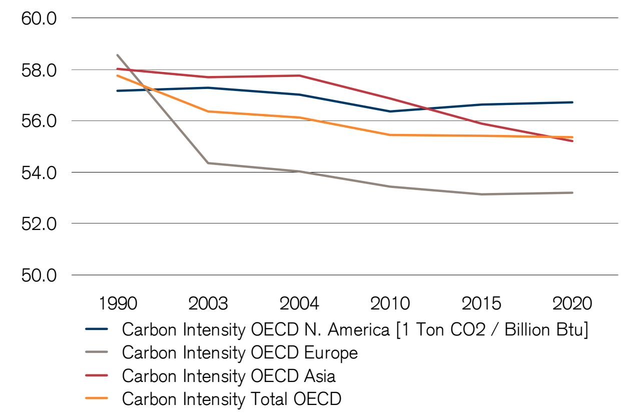
Energy intensity indicators in OECD regions [Thousand Btu / 1 USD 2000]



Source: EIA, OECD, Credit Suisse

Figure 12

Carbon intensity indicators in OECD regions [1 t of CO_2 / Billion Btu]



Source: EIA, OECD, Credit Suisse

(coal)-based energy consumption, especially in China with a 36% market share worldwide.

3.1 Energy savings potential worldwide

On the back of the key drivers described in chapters 1 and 2, there is strong institutional support for renewable energy and energy efficiency (RE+EE) going forward. For example, the World Bank Group targeted 20% annual growth in RE+EE projects worldwide in Bonn Commitments 2004. The EBRD launched a Sustainable Energy Initiative with investments amounting to EUR 1.5 bn over 3 years. All of these institutional measures are expected to significantly increase energy efficiency and energy saving levels. The EU provides another example of policy supporting RE+EE. It endorsed the following key legislative measures including energy-linked policy targets by 2020:

- Reduction in Greenhouse Gas (hereafter: GHG) emissions by 20% or more compared to 1990 levels
- Renewable energy market share of 20% in the global energy portfolio
- Biofuels content of 10% in total gasoline and diesel fuel volumes
- Energy efficiency gains are expected to save 20% of total EU Energy consumption, measured against the year IEA forecasts for 2020.

A more detailed analysis of selected countries is presented in the following chapters.

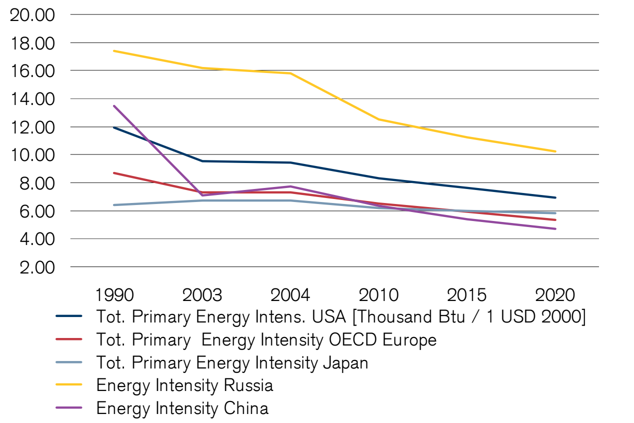
At the global level an analysis of energy intensity and carbon intensity indicators (Figures 11 and 12) shows substantial potential for energy savings and lower consumption by 2020. Energy intensity in the OECD region is expected to decrease from 8.38 to 6.38 Thousand Btu/1 USD 2000. This represents a total reduction of 23.9% or a 1.7% annual decrease between 2004 and 2020. The biggest fall is expected to come from OECD Europe and North America with 1.9% and 1.8% annual decreases, respectively. In North America, the decrease would be from 9.50 to 7.12 Thousand Btu/1 USD 2000, or -25% in total, and in OECD Europe a decrease from 7.29 to 5.35 Thousand Btu/1 USD 2000 is expected, or more than 26% savings in total. This is on the back of the implementation of the legislative measures and directives described above and discussed in more detail in the following chapters.

Significant energy intensity decreases are also expected from developing countries, such as the BRICs (Brazil, Russia, India and China), particularly from Russia, India, and China. In the IEA reference scenario, global primary energy demand is expected to increase 53% between 2004 and 2030, with 70% of this increase coming from developing countries. As shown in Figure 13, Russia is the most energy intensive country with nearly 15.8 Thousand Btu/1 USD in 2000, primarily due to high consumption by the highly energy–intensive industry sector, combined with use of outdated and energy inefficient coal and oil-fired power plants and energy technologies.

We note that global investments to build energy supply infrastructure are expected to total more than USD 20 trillion (in 2005 USD) between 2005-2030 in the IEA reference scenario. From this, nearly USD 11.3 trn is expected to be invested in power supply infrastructure. The OECD region is expected to invest over USD 4.24 trn while the developing countries should spend over USD 6.4 trn over the same period for power supply infrastructure. This analysis of investment patterns (Figure 15) indicates that the highest proportion of investments in power-supply infrastructure will be in developing countries, especially BRIC countries. This fact offers BRIC countries, particularly China, Russia and India, plenty of room to cope with energy efficiency issues by 2030, in our view. We expect these investments will be green-field investments, using new, state-of-the-art energy-efficient supply technologies and infrastructure. In Figure 16, we show the

Figure 13

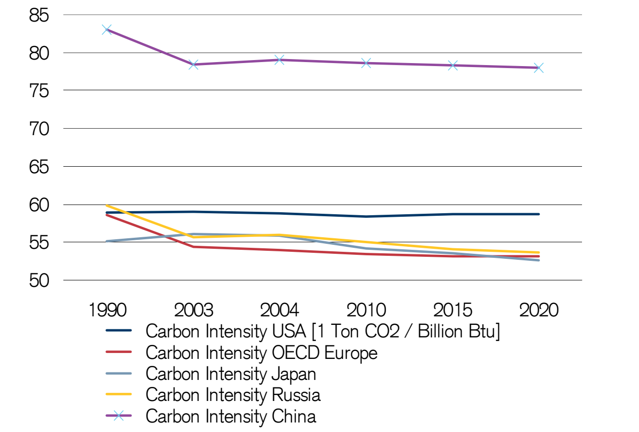
Energy intensity indicators in selected countries [Thousand Btu / 1 USD 2000]



Source: EIA, OECD, Credit Suisse

Figure 14

Carbon intensity indicators in selected countries [1 t of CO2 / Billion Btu]



Source: EIA, OECD, Credit Suisse

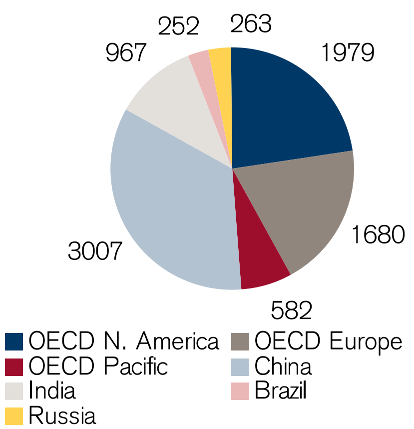
total energy supply investment, which includes investments for transmission and delivery systems and other infrastructure complementary to energy generation. More detailed insights including quantitative assessment of energy efficiencies will be described in the following chapters.

The analysis of final energy consumption patterns of developing countries at the sector level generally shows a relatively high proportion of energy consumption by the industrial sector, often due to use of old and inefficient industrial and manufacturing technologies. In addition, as they are rapidly growing and developing new infrastructure, they have the opportunity to choose energy efficient alternatives to older technologies. Therefore, the potential for high energy savings and energy efficiency can be realized by the developing countries. For example, in Russia, energy intensity is expected to decrease by 2.7% per annum between 2004-2020. This can be attributed to the expected structural shift in economic activity from the highly energy-intensive industrial sector to the less energy-intensive services sector. In China, energy intensity is expected to decrease 3% annually in the 2004-2020 period. This decrease is likely to be fueled by a switch to and the construction of more efficient coal-fired, gas-fired and nuclear power plants, more efficient energy use in the industrial sector, and other measures described in more detail in the following chapters.

Finally, the analysis of carbon intensity, see Figure 14, used as a broad indicator for the potential decrease in carbon emission per unit of total primary energy consumption and measured in 1 ton of CO_2/1 Billion Btu, shows that the greatest total decrease is expected in OECD Asia, Russia and India with 4.4%, 4.1% and 5%, respectively, in the 2004-2020 period due to the expected gradual implementation of less carbon emission-intensive technology, e.g. renewable energy sources, worldwide and other factors.

Figure 15

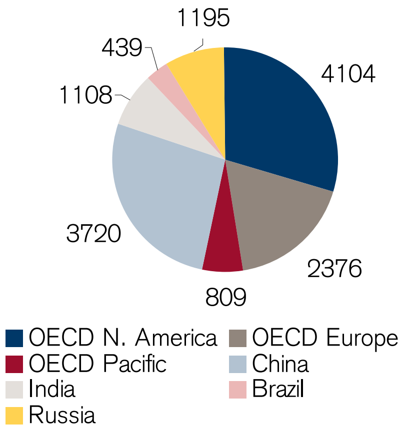
Power supply investments in the IEA Reference Scenario 2005-30 in USD bn at 2005 market prices



Source: IEA

Figure 16

Total energy supply investments in the IEA Reference Scenario 2005-30 in USD bn at 2005 market prices



Source: IEA

4. Methodology aspects

In the previous chapters, we analyzed **the primary energy intensity** (efficiency) trends that relate to **energy consumption and GDP (toe/Euro at 2000 price in EU-space or Btu/USD at 2000 price in US-space)** and that indicate the overall energy productivity or measure energy efficiency from an economic viewpoint. **The final energy intensity trends** linked to the energy productivity of final consumers excl. the power sector also need to be analyzed in order to capture trends at the sector level. The difference between primary and final (delivered) energy intensity trends depends primarily on two factors:

- Changes in the efficiency of energy transformations and distribution in power sector
- Rate of change of electricity consumption, e.g. high electricity consumption growth increases transformation losses from thermal systems
- Industrial and economic activities, which are often adjusted to reflect the same (energy) value-added.

In addition, to make a direct comparison of energy efficiency indicators between countries, some adjustments are needed, especially:

- Adjustment of general price levels at purchasing power parities (PPP), national currencies are converted into Euro or USD at PPP
- In order to analyze main structural features at the sector level, a decomposition of energy use components is necessary.

In more detail, monitoring changes in the energy intensity of a country's economy is not always sufficient to draw conclusions regarding energy efficiency because energy consumption has multiple components. These are aggregate activity, sectoral structure, and energy intensity. Sectoral structure can have a great impact on the energy intensity. For example, in the early stages of development a country might have an emphasis on heavy industry including cement and iron and steel. As the economy becomes more service oriented, the mix between sectors can shift, dramatically decreasing the energy consumption of the country. In order to understand the concept of energy measurement at the sub-sectoral level, we outline below the main features of methodology for decomposition of final energy use components, as used by IEA. The decomposition of energy use into sectors is done using:

$$E = A \cdot \sum_r \left(S^r \cdot I^r\right)$$

E is the total energy use in a sector
A is the overall sectoral activity
r is for subsectors or end uses within a sector
S^r is the share of a subsector within sector 'r'
I^r is the energy intensity of each subsector 'r'

The activity effect is calculated by letting aggregate activity vary and holding energy intensities and structure constant:

$$E_t^A = \frac{A_t \cdot \sum_r \left(S_0^r \cdot I_0^r\right)}{E_0}$$

This activity can represent energy value-added in industry, population in households, etc. The structure effect is calculated using the same formula but this time assuming constant activity and intensity, while letting structure vary. The intensity effect is calculated at constant activity and structure, letting intensity develop.

The impacts of energy efficiency measures can thus be determined by examining the intensity component, which is stripped away from the activity and sectoral components. Finally, the energy savings are calculated using:

$$SAVINGS_t^I = HEU_t^I - E_t$$

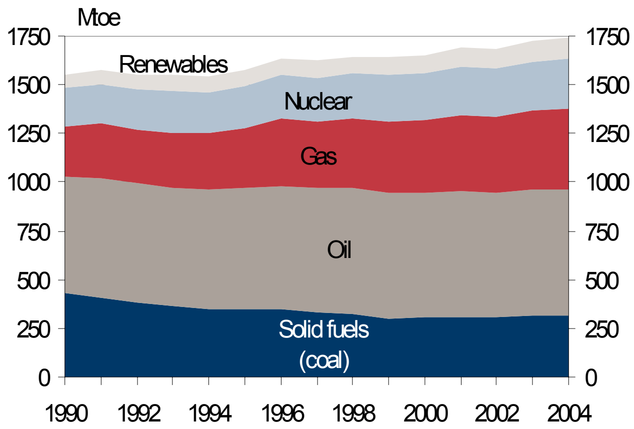
where HEU is the hypothetical energy use that would have occurred if energy intensities had remained constant in each sector.

$$HEU_t^I = \frac{E_t}{E_t^I}$$

Finally, in the following chapters the European Union's PRIMES data are used for interpretation of the main sectoral trends.

Figure 17

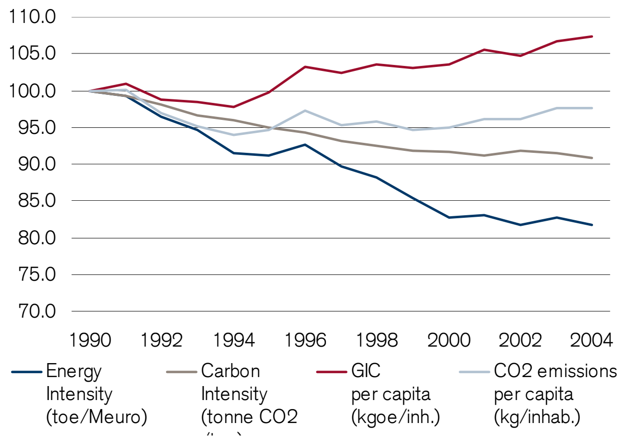
EU-25 Gross inland primary energy consumption since 1990 [Mtoe]



Source: Eurostat, Credit Suisse

Figure 18

EU-25 Energy and carbon intensity indicators development since 1990



Source: EU, Credit Suisse

5. European Union (EU) energy efficiency profile and outlook

This section gives an overview of the role energy efficiency plays in the EU's plans to reduce CO_2 emissions and enhance energy security and energy competitiveness. We outline its energy efficiency scenario, and all changes in energy demand are listed with respect to the baseline scenario, which assumes 2.3% annual GDP growth to 2020. The efficiency scenario assumes that the existing policies will be implemented and enforced. In our view, new policies are highly likely, and will provide further support for efficiency linked programs and companies.

5.1 Europe among the world leaders

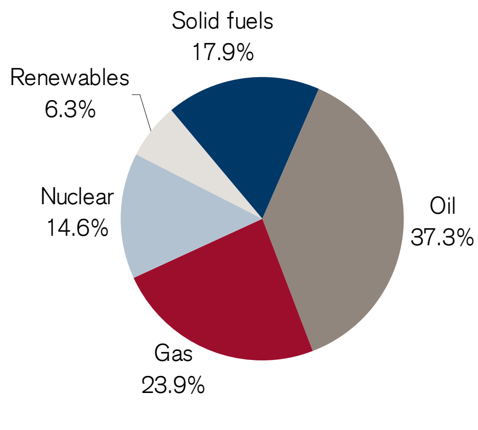
Europe is one of the most advanced countries as far as energy efficiency (intensity) and carbon intensity measurements are concerned, as shown in Figures 17-18.

This is also due to a well balanced fuel mix. Figure 10 indicates a smaller coal-based primary energy consumption share of 11.2%, well behind China with 36% market share and USA with 19.6% market share. As shown in Figure 17 and 19 the coal-based energy consumption has steadily decreased since the 1990's to a 17.9% share in 2004.

With its 2004 energy intensity level at 7.29 Thousand Btu/1 USD in 2000 (hereafter: Th. Btu/USD), OECD Europe is ranked 3rd behind Japan, exhibiting an impressive 6.72 Th. Btu/USD and Mexico (6.5 Th. Btu/USD). It is well ahead of the USA with 9.41 Th. Btu/USD, OECD Asia (7.94 Th. Btu/USD), China (7.72 Th. Btu/USD), and Russia (15.78 Th. Btu/USD), as shown in Figures 11 and 13. We note that the primary energy intensity indicator does not indicate all structural efficiencies due to e.g. size and type of industrial manufacturing base, climatic conditions, etc. A country with a low energy intensity relative to other countries does not necessarily demonstrate superior energy efficiency. This can also be attributed to the level of energy supply infrastructure

Figure 19

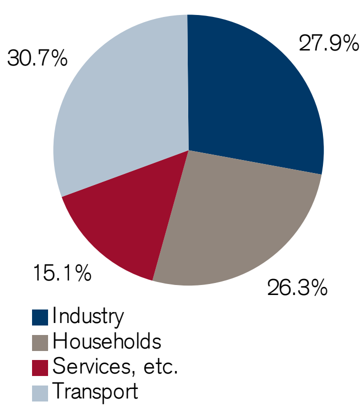
EU-25 Gross inland primary energy consumption share by fuel type (2004-05)



Source: Eurostat, Credit Suisse

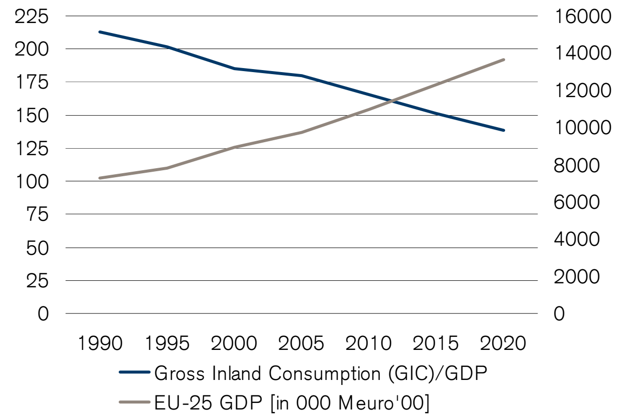
Figure 20

EU-25 Final energy consumption share by sector (2004-05)



Source: EU, Eurostat

Figure 21
EU-25 GDP [in 1000 MEuro at 2000 prices] and gross inland primary energy intensity indicator [in toe/MEuro at 2000] development between 1990-2020



Source: EU (PRIMES), Credit Suisse

development, or the economic structure of the country. Nevertheless, the evolution of energy intensity may show trends indicating the technical and system efficiency of power generators or energy technologies, for example.

The EU's energy efficiency efforts since 1990 have paid off. As shown in Figure 18, the primary energy intensity indicator decreased from 220 toe/MEuro in 2000 (hereafter toe/MEuro) in 1990 to less than 180 toe/MEuro in 2004. This corresponds to a 1.3% annual decrease or -18.3% in total between 1990 and 2004 despite the increase in primary energy consumption per capita (GIC/capita) from 3.5 toe per capita to 3.8 toe per capita over the same period.

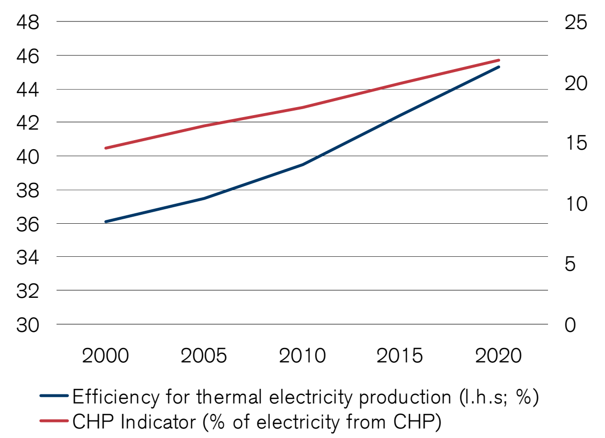
5.2 Main drivers of energy efficiency, legislative measures and assessment of EU-25 energy efficiency landscape by 2020

The main drivers of energy efficiency can be identified as **market forces** and **government policies**. Market forces begin with energy prices and competition and are very powerful and steady incentives for taking energy efficiency action. High oil prices are an excellent example as described previously. Fortunately, modern economies are expected to continue the trend of reducing their dependence on oil and implementing more energy efficient measures observable since the 1990's and the EU-25 is leading in this field. Europe ranks among the world's leaders with regard to energy efficiency and carbon intensity, as already described previously, second only to Japan (shown in Figures 13 and 14). The total primary renewable energy consumption share of nearly 8% in OECD Europe is 2nd worldwide after Brazil with over 34% renewable energy consumption. Moreover, Figures 17 and 18 show the development of the gross inland energy consumption by fuel type and of the main energy and carbon intensity indicators since 1990. The energy intensity decreased from 220 toe/MEuro in 1990 down to less than 180 toe/MEuro in 2004, resulting in a 1.3% annual decrease, or 18.3% in total. The carbon intensity decreased 0.6% p.a. or 9.1% in total (Figure 18).

As markets are imperfect, government measures are needed in order to address all market imperfections and other issues, in our view. Therefore, the EU-25 enacted various legislative measures in March 2007 in order to assure the continuity towards more clean energy and a more energy efficient European energy space. Key to this plan is the aim to derive 12% of energy use from renewable energy sources in 2010 and 20% in 2020 along with a 20% reduction in greenhouse gas (GHG) emissions. On the demand side, the EU anticipates that by using cost-effective existing technologies, overall energy use could be decreased by 20% (see also section 3).

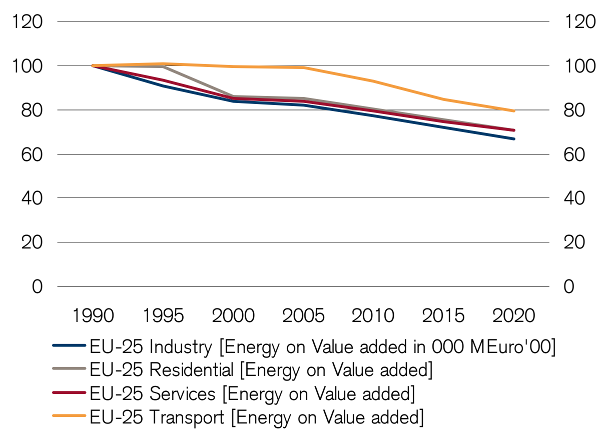
The objectives of the various measures suggested by the EU are to decrease energy intensity by 1.73% annually between 2005 and 2020, or 23% in total, in the reference (baseline) scenario, assuming 2.3% annual GDP growth, primarily due to the above reasons and as shown in Figure 21.

Figure 22
EU-25 Efficiency for thermal electricity production and CHP indicator development in 2000-2020 period



Source: EU (PRIMES), Credit Suisse

Figure 23
EU-25 Energy intensity indicators on sector level [Energy on value added in 000 MEuro'00 at PPP]



Source: EU (PRIMES), Credit Suisse

Table 1: EU final energy saving potential by sector to 2020

Sector	Energy Consumption 2005 (Mtoe)	Energy Consumption (Mtoe) 2020 (business as usual)	Energy Savings Potential 2020 (Mtoe)	Full Energy Saving Potential 2020 (%)
Households (residential)	280	338	91	27%
Commercial Buildings (tertiary)	157	211	63	30%
Transport	332	405	105	26%
Manufacturing Industry	297	382	95	25%

Source: EU

The total EU energy use in 2020 would be equivalent to the value in 2000 despite the 2.3% annual increase in GDP over that period. The result manifests itself in changes in the fuel mix, with demand for coal and nuclear decreasing the most.

As shown in Figure 19, the EU's energy consumption is dominated by the residential, industrial, and transportation sectors. By adding new combined cycle gas turbine **(CCGT)** and combined heat and power **(CHP)** power generation systems (also called cogeneration systems), the thermal efficiency is expected to increase from the current 36% to 45% or more as highlighted in Figure 22. The share of CHP systems used to generate power is expected to increase from over 16% in 2005 to nearly 22% in 2020 on the back of government measures and incentives. All energy efficiency measures, as described in more detail in the following sections, are expected to translate into a decrease in all energy intensity indicators at the sector level, as shown in Figure 23. The largest energy intensity decrease is expected from the transportation sector with nearly 20% (-1.5% p.a.), followed by the industry sector with nearly 19% saved between 2005 and 2020.

In the **transportation** sector, the government is pushing for energy efficiency through measures such as developing more fuel efficient and cleaner cars, ensuring optimal tire pressure, and improving the efficiency of urban, maritime and aviation transport systems. In addition, **modal shares** are another indicator for the energy and social cost efficiency of the transport system. The rail and inland water transport modes with over 30 and around 25 ktonne-km/toe of energy input unit, respectively, are 5 to 6 times more efficient than road transport with around 5 ktonne-km/to (Source: EU).

In **industry**, significant energy savings can be achieved by introducing modern and more energy efficient manufacturing technologies, and optimizing industrial processes.

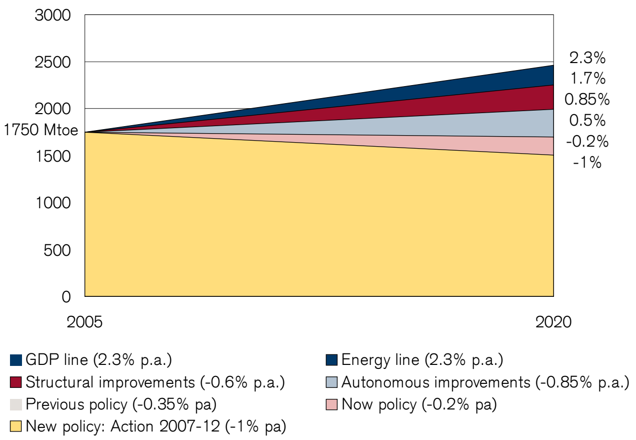
In the **residential sector**, new lighting technologies like compact fluorescent lamps **(CFL)**, new building insulation systems (windows, roofs...), reducing stand-by power losses, use of energy efficient household appliances e.g. with the **Energy Star** label, are expected to contribute to significant energy savings. All in all, Table 1 shows the European Union's expectations for over 20% energy savings by 2020, based on several European directives, Directive 2006/32/EC among others. Figure 24 shows schematically various policy-linked and structurally–based contributions to the targeted 20% energy savings by 2020. In Figure 24:

- the top line represents schematically the assumed annual GDP growth of 2.3% by 2020 with elasticity assumed to be 1 with the energy demand.
- the 0.6% annual savings in energy demand growth by 2020 are expected to be realized with **structural** changes by implementation of more energy-efficient industrial and manufacturing processes
- the additional 0.85% annual savings in energy demand by 2020 are expected to be realized with **autonomous** improvements, such as normal replacement of technology stocks by new more energy-efficient technologies,

so energy consumption growth of 1.45% p.a. may be saved by 2020. Moreover, with previous Community legislation, the

Figure 24

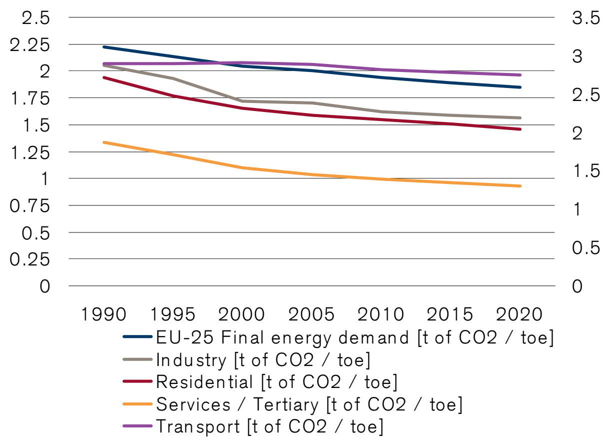
EU-25 Annual improvements in energy intensity indicators by 2020



Source: EU

Figure 25

EU-25 Carbon intensity indicators on sector level [in t of CO_2/toe]



Source: EU (PRIMES), Credit Suisse

impact of efficiency was estimated to save 0.35% p.a. of energy demand and a new policy named "Action Plan for Energy Efficiency: Realizing the Potential" [COM 2006] was created. An additional 1.2% per annum of energy demand may be saved by 2020 by e.g. implementing novel power and energy technologies (CCGT, advanced combined cycle (ACC), CHP, CFL etc.). All in all, 3.3% energy intensity savings p.a. by 2020 can be realized. The average annual increase in energy demand would be 0.5% with assumed 2.3% annual GDP growth.

Finally, as shown in Figure 25 the carbon intensity is expected to decrease from 2 t CO_2/toe in 2005 down to 1.85 t CO_2/toe in 2010 or -7.5% in total. This is mainly driven by strong decreases in the services and industry sectors.

5.3 Emissions trading and carbon capture are the core elements of the EU strategy for energy efficiency

Across all sectors the key measure of the EU is to use the European Union Emissions Trading Scheme (EU-ETS) to deliver a market price for carbon emissions that encourages the end emitters to make cost-effective changes. According to the World Bank, in 2006 carbon markets were valued at USD 30 bn, tripling from the value in 2005. Of these, USD 25 bn were traded under the EU-ETS. This together with the renewable energy targets for 2020 will support several sectors, including companies providing higher energy efficiency products and the renewable energy sectors such as wind, solar, and biofuels.

The Stern Review suggests that up to 55% of the reduction in carbon emissions could come from carbon capture technology, so it is part of the EU's aims as well. It further states that the markets for low carbon energy products are likely to be worth at least USD 500 bn per year. In the following section we give a general overview of the impact of EU policies on the transport, industry, residential, and services sectors.

As a result, the EU-25 carbon intensity indicators show in Figure 25 that with rigorous implementation of legislative measures linked to CO_2 emissions per unit of energy, a total decrease of more than -10% in services sector, followed by industry and residential sectors with -8.2% and -8.1%, respectively, may be achieved in the 2005-2020 period.

5.4 The services, industrial, and residential sectors dominate efficiency improvements on the demand side

In addition to the previous paragraphs, in the transport sector, the energy efficiency scenario projects a 2.1% reduction in energy use by 2010, rising to 9.3% in 2020. Expected transport measures include new vehicle technologies and superior labeling to make it easier for consumers to make energy efficient choices. Consumer-level incentives and education are the main instruments for pushing energy efficiency in this sector. Extending the EU-ETS to the aviation sector is also highlighted as a necessary step.

In industry, energy demand is expected to decrease by 0.6% in 2010, rising to 3.1% in 2020. These figures are relatively low because the sector is assumed to change very gradually as the scenario assumes steady changes to energy related activity. Energy audits in industry are planned to ensure regulations are followed. In our view, new regulations and the EU-ETS will likely change the industry sector, particularly if the cost of carbon emissions is to increase.

The services and residential sectors are responsible for the bulk of the reduction in energy use. The residential sector is expected to reduce its energy demand by 3.1% by 2010 and by 17.4% in 2020. The services segment sees a 6.7% reduction in energy use in 2010 and a 21.6% reduction in 2020. Thermally efficient building designs, supported by building codes and regulations, are one aspect of the savings. Labeling electric appliances is important for informing the public about energy choices. Heating, cooking, cooling, lighting, and appliances are all important factors for energy efficiency.

Electric appliances are expected to see the most dramatic decrease in energy demand as a direct result of efficiency labeling and promotion of rational energy saving choices.

5.5 What is happening on the supply side in the meantime?

Cogeneration plants (CHP), particularly generating steam and electricity, are a key part of the efficiency improvements on the supply side. Other aspects of the scenario depend primarily on changing the fuel mix to reduce carbon emissions. The key figure comes from the fall in demand for electricity, which accounts for 37% of the final reduction in energy demand seen in 2030. Natural gas consumption also changes and its share increases to 23.8% by 2030. Changes in the transport sector are largely responsible for the decrease in demand for oil in the medium term, resulting in a 2.4% decrease in its share of total energy demand.

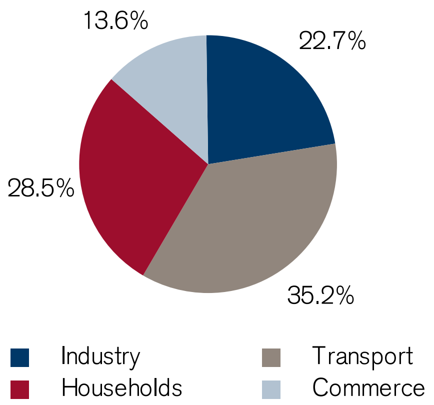
6. EU Special Topic: UK Energy Efficiency Action Plan 2007

This year the UK released its energy efficiency action plan designed to respond to the long term challenges of tackling climate change and ensuring secure, clean and affordable sources of energy in the future. The plan reaches across the household sector, non-household sector, public sector, and transport sector. The transport and household sectors have the highest final energy consumption with a share of 35.2% and 28.5%, respectively, as illustrated in Figure 26. Therefore, all energy efficiency measures introduced for these two sectors will significantly contribute to the country's energy savings.

The UK energy production and primary energy consumption relies strongly on oil and gas, as shown in Figures 27 and 28. In particular, oil-based energy production, e.g. in power sector and oil-based household heating systems, is less energy efficient than gas-based energy production. Nevertheless, the primary energy intensity decreased by nearly 1.7% p.a. or over 22% in total from 171.9 toe/MEuro down to 133 toe/MEuro between 1990 and 2005. The UK's high reliance on oil and gas indicates substantial fuel efficiency potential, e.g. by promoting efficient fuel switching or the implementation of CCGT and/or CHP systems in the power generation sector. Therefore, the UK still has considerable energy saving potential with regard to energy production and consumption going forward to 2020, as highlighted in Figure 27 for power generation and in Figure 28 for final energy consumption. In the power sector, thermal efficiency is expected to increase from over 42% to close to 50% and the CHP indicator, shown in Figure 29, from over 12% to 17% in 2005-2020. On the final energy consumption side, the transportation sector is expected to yield the greatest improvement in energy efficiency with savings of 28% (2.2% p.a.), followed by the services and residential sectors sector, both with 23% (1.7% p.a.) in total for the 2005-2020 period. Finally, the industrial energy intensity decrease is expected be 14% (1% p.a.) between 2005-2020. A summary of these data is found in Figures 30 and 31.

Figure 26

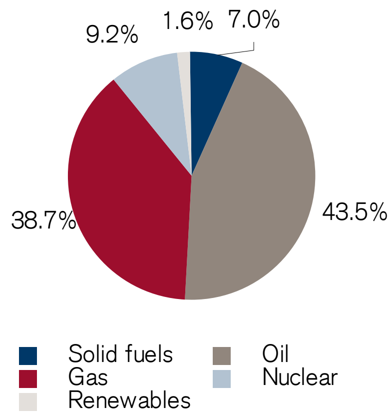
UK final energy consumption share by sector (2004-05)



Source: Eurostat, Credit Suisse

Figure 27

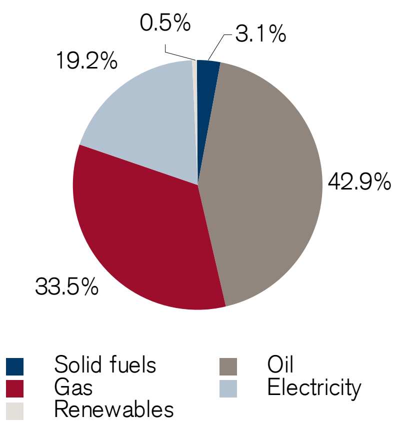
UK energy production share by fuel type (2004-05)



Source: Eurostat, Credit Suisse

Figure 28

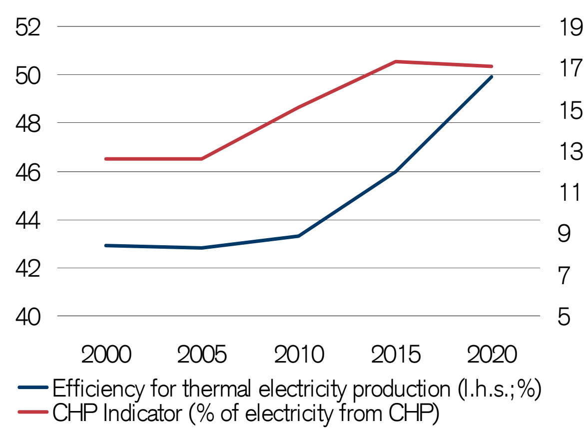
UK final energy consumption share by fuel type (2004-05)



Source: Eurostat, Credit Suisse

Figure 29

UK efficiency for thermal electricity production and CHP indicator development in 2000-2020 period



Source: EU (PRIMES), Credit Suisse

6.1 Household sector

The household sector is expected to account for savings of 142.1 TWh of energy and 9.3 million tons of carbon (MtC) by 2016 as shown in Table 2. The energy demand in this sector is expected to grow an average of 2.5% per year. Energy efficiency improvements are expected to offset this growth from 2010 onwards and from then on energy demand is expected to decrease 1.8% per year. To reach this goal, the UK government plans to implement several measures including energy performance standards for new housing developments through regulations. The aim here is to produce zero carbon homes by 2016.

Buildings account for 45% of total emissions, with housing reaching 27%. Efficiency improvements have already occurred such that houses built before 2002 are said to be 40% less energy efficient than houses built in 2007. The plan is aiming for zero carbon homes in 2016 and contains interim goals for 2010 (further 25% improvement in efficiency compared with today) and 2013 (44% improvement over today). This is a key driver for change and more efficient construction-related materials. Support for these targets will come from additional government incentives. For example, zero carbon homes that cost up to GBP 500,000 will pay no stamp duty, while the stamp duty on zero carbon homes selling for more than this will be reduced by GBP 15,000. Implementation of these codes is expected to spur the use of low or zero carbon energy generation, such as solar water heating or wind turbines. Other technologies, including low carbon biomass heaters, ground-source, water-source, and air-source heat pumps should also benefit. The UK government's microgeneration strategy reported a study that microgeneration can provide between 30 and 40% of current energy demand in the UK. The VAT rate has been reduced to 5% on the installation of these energy sources.

For existing homes, the mandates set minimum requirements for landlords, and protection for households that spend more than 10% of combined income on fuel. Products in the home including appliances and electronics are going to see new standards and labeling procedures. Other tax incentives are in place and further legislative policies are expected to push up the energy efficiency standards of existing homes. The reduced 5% VAT has been applied to several energy savings materials installed by a professional, including insulation, heating control and other energy related technologies.

Another key target is for all homes to have smart metering capability, allowing consumers and energy suppliers to reduce costs and offer incentives to change usage patterns during peak hours.

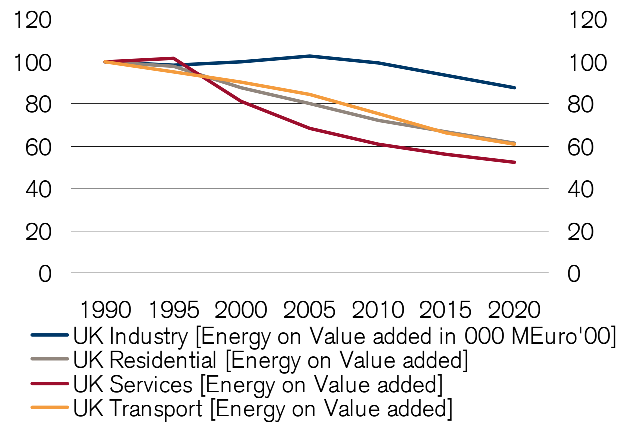
6.2 Public and commercial sector

These sectors, which are aggregated in official UK documents and represent companies in the service sector plus public administrations, account for about 33% of emissions in the UK and are expected to see savings of 71.5 TWh and 5.4 MtC by 2016 as highlighted in Table 2. The EU Emissions Trading Scheme (EU-ETS) scheme coupled with a Climate Change Levy and Climate Change Agreements are to act as incentives to prompt change in energy intensive industry. Energy efficiency advice will be provided for large firms with energy bills over GBP 1 million per year and site surveys provided for organizations paying more then GBP 50,000 per annum. The key focus in this sector is on mandates and carbon trading, with a special effort to make information regarding energy efficiency methods easily available to organizations.

The public sector in the UK is called on to act as a role model in reforming its business around carbon footprint. For example, the National Health Service is planning to achieve a 15% reduction in primary energy consumption by 2010. They have strict mandates for reducing emissions all the way to carbon neutrality for certain government buildings as early as 2012. The government has also pledged to support further investment in research and development, including

Figure 30

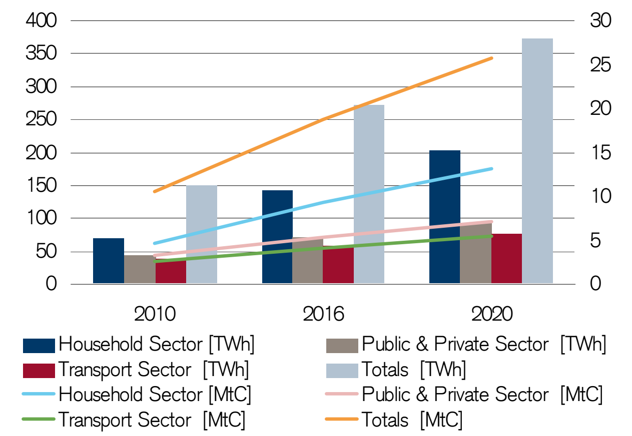
UK energy intensity indicators on sector level [Energy on value added in 000 MEuro'00 at PPP]



Source: EU (PRIMES), Credit Suisse

Figure 31

UK energy and carbon saving targets by 2020



Source: UK (DEFRA)

investments in small businesses developing low carbon technologies.

6.3 Transport sector

Enhancements in transport energy efficiency are expected to save 59.1 TWh of energy and 4.1 MtC by 2016 as shown in Table 2. In this sector, the government plans to make aviation industry part of the EU-ETS framework. The government is pushing the private sector by increasing the vehicle excise duty on inefficient vehicles and reforming other car related tax programs.

An additional measure is to increase funding of specific programs to encourage research and development of low carbon emissions transportation technologies. Furthermore, the plan calls for aviation and large-scale ground transport to be included in the EU-ETS. Several other mandates regarding minimum efficiency standards for new vehicles are expected to come in the future.

The UK government also intends to invest more in public transportation systems. This involves improving the capacity of rail systems and improving bus-use among end users. Schools are also given mandates to create better transportation systems or programs for students.

The plan proposes increasing several government standards to reduce the UK contribution to global emissions by 60% to 2050 compared to the 1990 level, with a 26-32% reduction targeted by 2020.

In summary, Table 2 and Figures 30 and 31 show the UK energy and carbon savings targets by 2020. The household and public / private sectors have the highest saving potential with an annual decrease of 11.4% and 7.9%, respectively, by 2020.

Table 2: UK Energy Savings Targets by 2020

UK Energy Savings Targets	2010		2016		2020	
	TWh	MtC	TWh	MtC	TWh	MtC
	2010	2010	2016	2016	2020	2020
Household Sector	68.7	4.7	142.1	9.3	202.7	13.1
Public and Private Sector	43.4	3.3	71.5	5.4	93.1	7.1
Transport Sector	37.8	2.6	59.1	4.1	76.7	5.5
Totals	149.9	10.6	272.7	18.8	372.5	25.7

Source: UK (DEPRA), Credit Suisse

7. US federal efficiency programs profile and outlook for 2020-30

The USA is the world's largest primary energy consumer with over 2.3 Gtoe energy consumption, as shown in Figure 7 in terms of market share. The USA has the highest oil-based energy consumption in the world (see Figure 32) with a 25% share and the 2nd highest ranking in coal-based energy consumption with a 19.6% share (see Figure 10). Moreover, oil and gas-based final energy consumption have a combined share of more than 77% (see Figure 33). Figure 34 illustrates that nearly 38% of final energy is consumed by the transportation sector. These energy consumption patterns indicate broad use of relatively energy-intensive technologies and processes in the power, transportation, and industrial sectors in comparison with the EU-25 and Japan. As a result, the USA with 284 toe/MEuro primary energy intensity level (see Figure 35) is well behind Japan with 141 toe/MEuro and the EU-25 with 180 toe/MEuro.

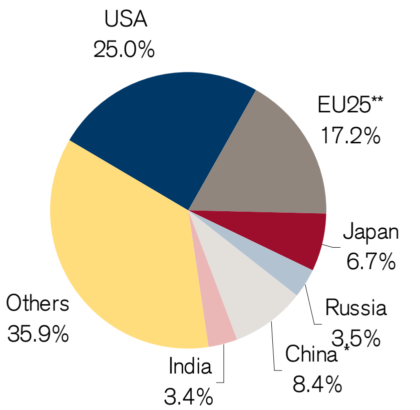
Another interpretation of this analysis indicates significant energy saving and efficiency potential in:

- the industrial sector, e.g. optimization of fuel switching, building more efficient motors, etc.
- the power sector by replacing old oil-fired power plants with modern CCGT turbines and/or CHP generation systems
- the transport sector through replacement of fuel inefficient vehicles with new, more efficient models, e.g. hybrid cars
- the residential sector replacing energy inefficient household appliances with new ones bearing the Energy Star label

as will be described in more detail in the following section.

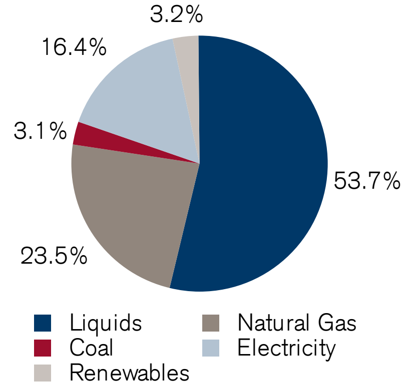
To generate significant energy savings and efficiency increases on a forward-looking basis, the federal energy efficiency and renewable energy (EERE) programs are structured to make economical sense for consumers and the overarching theme is to enhance energy security. They project that more than USD 630 bn dollars can be saved by

Figure 32
Breakdown of world gross oil energy consumption (2004)



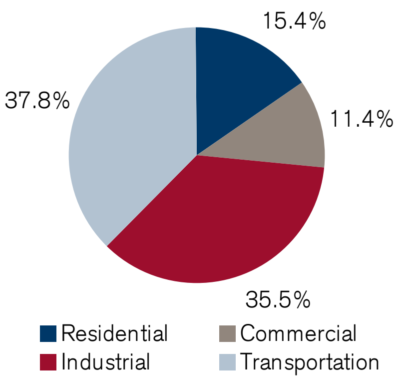
Source: Eurostat, EIA, Credit Suisse

Figure 33
US final energy consumption share by fuel type; liquids represents oil (2004-05)



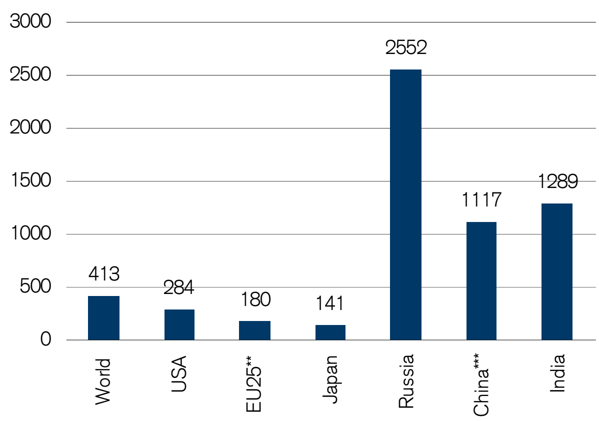
Source: EIA, OECD, Credit Suisse

Figure 34
US final energy consumption share by fuel type (2004-05)



Source: EIA, OECD, Credit Suisse

Figure 35
Gross inland (primary) energy consumption by major countries in toe/MEuro at 2000 market prices (2004)



Source: Eurostat, OECD, Credit Suisse consumers, while reducing carbon emissions by two billion tons and reducing oil imports by 6 bn barrels between 2008 and 2030. The EERE programs expect to decrease the energy intensity of the economy (beyond the existing trend in reduction) by 8% in 2030. Consumer savings to 2030 have a net present value (NPV) of about USD 700 bn, and NPV of savings to the electric power sector is USD 170 bn. Efficiency is also expected to decrease oil intensity by 10% in 2030.

In the electricity generation sector the changes are largely in fuel mix, with the share of steam coal decreasing, and renewables largely picking up its share. The measures essentially double the output related to renewable fuels in 2030. The US Department of Energy asserts that their efficiency portfolio doubles the share of renewable energy in electricity generation, from 300 to 600 bn kWh per year, by 2030, compared with their baseline scenario. This will particularly benefit the wind and solar sectors.

The transportation sector is highly sensitive to energy pricing. In the government's "business-as-usual" scenario new vehicle technology replaces one-third of standard gasoline engines. The strongest growth is expected to come from hybrid, hydrogen fuel cell powered vehicles, and pneumatic hybrid electrical vehicle. R&D in this sector is to focus on hybrid and electric, advanced combustion, and materials technologies for improved fuel efficiency. Specific aims include over 50% efficiency improvement across platforms by 2010.

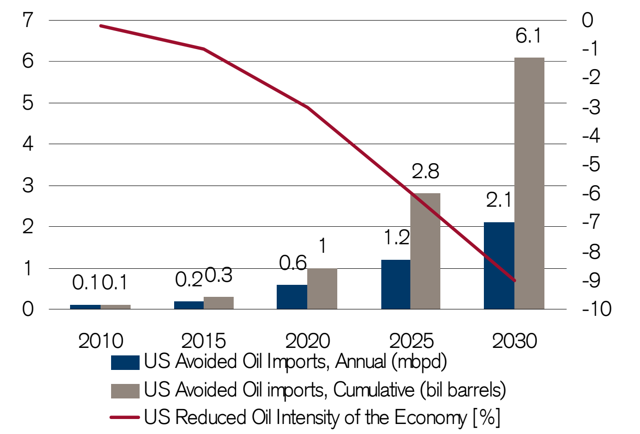
The building sector aims to develop net-zero energy buildings by 2025 through the Building Technologies Program (BTP). This will largely be achieved through reforms in regulations and technologies for heating and cooling, lighting, and the use of micro-generation. The program is designed to fund R&D towards these goals. In particular, solar energy efficiency improvements are a key element of the program, which are expected to reduce the grid-connected price for solar PV systems to USD 0.08 – USD 0.10 per kWh in 2015 from their benchmark 2005 price range of USD 0.23 – USD 0.32 per kWh.

For industry, the Industrial Technologies Program is responsible for working with industry to improve energy efficiency and reduce environmental impact. The agency acts as an information source providing knowledge and services down to the product level to help companies make efficient choices. There is also a plant evaluation service to determine cost effective changes that improve the energy efficiency of overall operations. The program also includes R&D programs dedicated to new technologies for high energy intensity processes such as boilers, drying, catalysis, and natural gas replacements. Other programs are for fuel and feedstock flexibility and interagency manufacturing. Cumulative carbon emissions savings to 2030 are expected to add up to 600 MMTCE (million metric tons of carbon equivalent) and the net present value of savings is USD 97 bn due to lower energy consumption.

In conclusion, the USA is expected to decrease the primary energy intensity levels from 9.41 Th. Btu/USD in 2004 down to 6.92 Th. Btu/USD in 2020, or 26.4% in total (-1.9% p.a.), as shown in Figure 14. This would mean that they would approach the Japanese and OECD European levels by that time. This would imply significant economic savings and environmental benefits, as illustrated in Figures 36 and 37. The annual economic benefits to consumers are estimated to be around USD 43 bn by 2020 and USD 110 bn by 2030. The avoided GHG emissions are expected to be 165 MMTCE/year (million metric tons of carbon equivalent/year) by 2020 and 447 MMTCE/year by 2030, respectively. In addition, as shown in Figure 36, by 2020 0.6 million barrels per day (mbpd) of oil imports would be avoided, increasing to 2.1 mbpd by 2030.

Figure 36

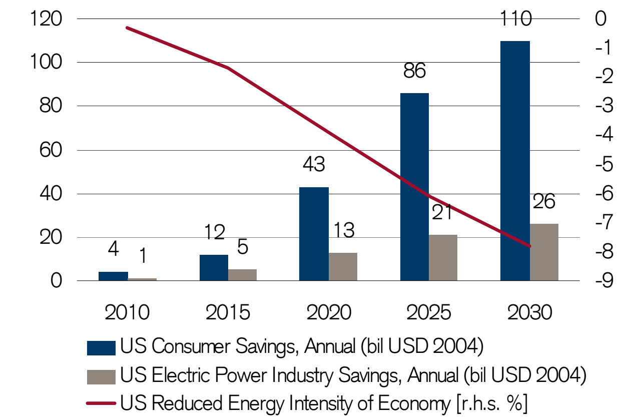
US avoided oil imports (mbpd) and reduced oil intensity of the economy (%, LHS)



Source: US. DoEERE, EIA, Credit Suisse

Figure 37

US energy intensity indicators consumption (GIC) / GDP [in 000 Euro2000 at PPP]



Source: US. DoEERE, EIA, Credit Suisse

8. Energy efficiency analysis and outlook for 2010-20 in BRIC countries

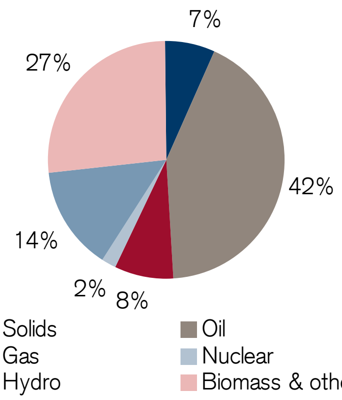
In this chapter, the energy efficiency and potential economic and environmental benefits in Brazil, Russia, India and China (BRIC countries) will be analyzed. Since 1990, China and India have displayed impressive economic growth with China growing 8.8% p.a. and India 5% p.a. during the 1990-2004 period, well above the global economic growth rate of 3% p.a., implying strong growth in energy use as well. The OECD expects strong economic growth in the 2004-20 period in these four developing countries, especially in China and India, with strong implications for energy production and consumption patterns worldwide. As shown in Figure 35, there is a large gap between the main developed countries and BRIC countries from an energy efficiency perspective due to numerous reasons, as will be described in the following sections.

8.1 Brazil

Since 1980, Brazil's deliberate government policy has been to diversify energy sources, especially by reducing the oil-based energy consumption. The oil share decreased from over 50% in 1980 to a 42% share in 2004, which still represents an oil-based primary energy consumption of around 84 Mtoe, as shown in Figure 38. Brazil is the largest country in Latin America and its largest energy consumer, taking 40% of the region's share, with around 200 Mtoe energy use. At the sector level, the industrial sector is the biggest final energy consumer with a 48% share. This indicates that the greatest potential for efficiency and intensity improvements comes from the industrial sector relative to other sectors on a forward-looking basis, particularly in the cement, pulp and paper and aluminum industries, according to the IEA. In Brazil transport and industry are the key energy consumers, as shown in Figure 39.

Figure 38

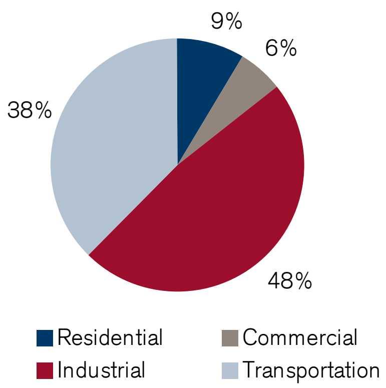
Brazil's primary energy consumption by fuel type (2004)



Source: IEA, Credit Suisse

Figure 39

Brazil's primary energy consumption by sector (2004)



Source: IEA, Credit Suisse

Assuming the IEA reference scenario GDP growth rate of 3.3% annually from 2004 – 2015, primary energy demand is expected to grow at a 2.6% CAGR to 264.8 Mtoe in 2015. In the alternative policy scenario, the CAGR in energy demand can be decreased to 2.1% over the same period. Brazil's situation is unique among the BRICs as it is the world's second largest producer and largest exporter of ethanol derived from sugarcane, and is aggressively expanding its production of biofuels.

The country is resource rich and plans to build considerable hydropower, as shown in Figure 41. In their reference scenario the IEA estimates that 66 GW of capacity will be added between 2004 and 2030. In addition, coal use is relatively low, they don't need to import oil, and natural gas use is low, but growing. Carbon intensity is quite low for Brazil, at 550 t CO_2 per Million 2004 USD GDP (source: UNEP), however, deforestation is the largest source of emissions (79.7%) in the country.

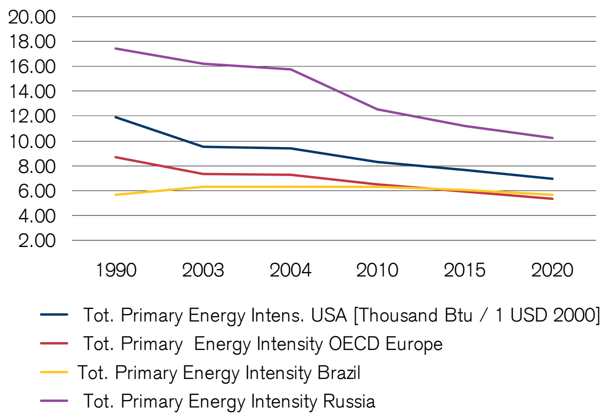
8.1.1 Brazil's energy efficiency potential

Government policies have already been pushing energy efficiency in Brazil for more than 25 years in both the residential and industrial sectors. These programs were motivated by the drive to reduce oil derivative imports, then later by the challenges associated with expanding capacity fast enough to meet rising demand. An additional key factor was the energy crisis in 2001 when hydroelectric power was disrupted by a lack of rainfall (90% of electricity generation is from hydroelectric sources). This event triggered a sudden reduction in energy use by about 20%, with almost no notice, through the use of energy rationing.

PROCEL, one of the Brazilian energy efficiency initiatives for the electric sector, is run with Electrobras, and in mid-2004 they estimated that BRL 2.7 bn could be saved per annum from energy efficiency initiatives (source: UN). Other government initiatives include programs for public buildings,

Figure 40

Brazil's energy intensity indicator in comparison with USA, OECD Europe and Russia [Thousand Btu / 1 USD 2000]



Source: EIA, OECD, Credit Suisse

water and sewage treatment, energy management, labeling for domestic and commercial appliances, buildings, industry, and education. Budgets for the programs range from BRL 2-6 mn. The energy efficiency sector is established and growing, as the government and banks set up funding routes specifically for efficiency mandates.

There is significant potential for improving energy efficiency in the energy generation industry. Cogeneration is already in use, but can be increased further. According to the UNEP, 15.3% of energy is lost in electricity distribution and there are transformation losses associated with oil and gas (8.9% of gross supply), and in bioenergy (about 50%). As the share of biofuels increases in the energy supply, the energy intensity is likely to increase because of the aforementioned inefficiencies, but the use of hydropower can mitigate this, as its use pushes down the apparent energy intensity.

All in all, the energy efficiency in Brazil is expected to improve at a moderate pace, in comparison to Russia (see Figure 43), India and China, due to the expected slower implementation of novel energy-efficient technologies in industry and moderate energy efficiency increases in the residential and commercial (services) sectors. As a result, the final energy intensity is expected to decrease by a moderate 0.9% p.a., or 13% in total over the 2004-2020 period. The total primary energy intensity indicator shows a moderate decrease of nearly 10% in 2004-2020, as shown in Figure 40.

The development of the renewable energy industry has been a critical component. Brazil grows 20% of the world's sugar. Its climate and land lend themselves well to sugar cane agriculture. As such, the ethanol sector and the rapid uptake of flex-fuel vehicles by the Brazilian population have helped decrease the dependence on fossil fuels. In addition, energy generated by the use of sugarcane residues (bagasse) is used to power biofuel production plants. Brazil is currently considered the most profitable and efficient source of ethanol, but trade barriers such as import tariffs in the USA are key factors preventing export increases.

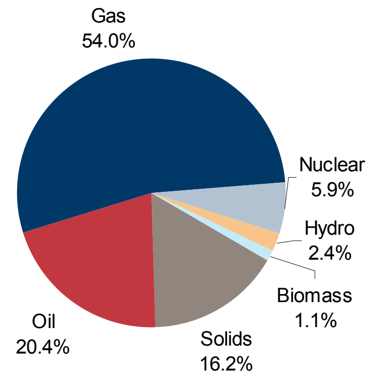
In many senses, Brazil's energy efficiency experience is a good model for nations developing rapidly, but its rich resources make it somewhat more tractable. Changes in policy and a review of energy efficiency programs are likely to spur further development in this area.

8.2 Russia

Russia is strongly relying on its own oil and gas reserves. As expected, nearly 2/3 of gross (primary) energy inland and final consumption comes from gas and oil, as highlighted in Figure 41 and 42. Looking at the final energy consumption pattern at the sector level in Figure 43, 72% of final energy consumption is realized in the industrial sector. As Russia owns very large reserves of natural resources in oil, gas, and metals like aluminum, nickel etc, the industrial sectors linked to natural resources and industrial and manufacturing processes are highly energy-intensive ones. Moreover, the very old and often highly inefficient energy, power, and industrial technologies from the ex-Soviet Union's time make Russia the most energy-intensive country in the world, as highlighted in Figure 35. Nevertheless, the high intensity level (In 2004: 2552 toe/MEuro 2000) offers tremendous potential for energy savings.

Figure 41

Russia's primary energy consumption share by fuel type (2004)



Source: EIA, OECD, Credit Suisse

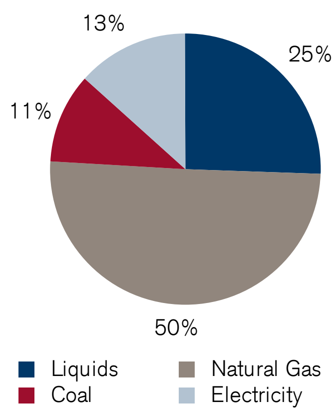
As shown in Figure 8, Russia started decreasing its energy intensity in 2000. Implementation of various organizational and technological measures towards more efficient use of energy by 2020 is showing progress to date. Russia's energy intensity decreased from 3092 toe/MEuro in 2000 down to 2552 toe/MEuro in 2004, or 17.5% in total, which seems to be a beginning towards more energy-efficient country. Russia's action plan (Source: Energy Ministry of Russia, 2001) foresees that estimated energy savings will offset more than half of the energy growth by 2020. The estimated investments of USD 7-17 bn by 2010 and an additional USD 25-50 bn between 2010-2020 are expected to modernize the country's energy supply linked infrastructure and implement novel energy-efficient technologies in the industrial and power sectors by 2020. As a result, primary and final energy intensity indicators are expected to fall by 35% or 2.7% p.a. and 39% or 3.1% p.a., respectively, by 2020, as shown in Figure 40. This figure also shows how large the gap between Russia and developed countries like USA and OECD Europe is, outlining the country's energy saving potential.

8.2.1 Deeper insight into "Energy Strategy to 2020"

Russia is the world's third largest energy consumer and with its GDP growing fast, its energy consumption growth trend is expected to continue. A key difference between Russia and the other BRIC countries is that Russia is the world's largest exporter of primary energy and is self-sufficient in meeting all of its own energy requirements. APEC estimates that its GDP will grow at an annual rate of 3.8% to 2030, while its final energy demand will grow at a rate of 1% per annum. In 2003, the Russian government released its Energy Strategy to 2020, which outlined long term energy policy. While the report proposes further development and modernization of the oil and gas sectors in the country, it also emphasized the importance of energy efficiency through economic restructuring and demand side measures. In this

Figure 42

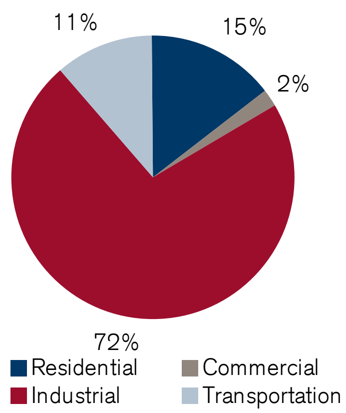
Russia's final (delivered) energy consumption share by fuel type (2004)



Source: EIA, OECD, Credit Suisse

Figure 43

Russia's final (delivered) energy consumption share on sector level (2004)



Source: EIA, OECD, Credit Suisse

section, we outline the major sectors in Russia and their energy efficiency targets and measures.

At the G8 summit in 2006 Russia stated that priority measures in the energy sector itself could contribute significantly to energy efficiency. These include reducing gas flares, collecting methane from coal mining, landfills, and agriculture, improving energy infrastructure, and raising the efficiency levels for processing hydrocarbons. In addition, improving electricity and heat supply generation systems, replacement of gas-fired power plants with combined-cycle gas turbine technology, clean coal and other measures are also expected to boost the overall efficiency. In our view, Russia is likely to significantly improve its energy efficiency despite its abundance of gas, nuclear, and coal sources.

8.2.2 Industry replacement cycles and a switch to natural gas are key for efficiency improvements

APEC expects energy demand from industry to grow by 1.6% annually to 2030 and the energy intensity is expected to decrease at an annual rate of 2.4% over the same period. Energy efficiency will play a key role. Replacement cycles for equipment are critical, as most infrastructure is obsolete. Deregulation of energy prices is likely to fuel both the replacement cycle and the drive to build energy efficient new operations. Also in industry, a change in fuel mix is expected, as further operations will require on-site heating. Industry is expected to command 51% of final energy demand in 2030 and of this, natural gas will have the biggest share at 34%, which is expected to improve the overall energy efficiency of the sector.

8.2.3 Specific measures in Russia point to transport and residential heating being key efficiency areas

Economic growth is expected to increase passenger travel and freight traffic as incomes rise. APEC estimates that vehicle ownership will increase from 14.8% in 2002 to 45% in 2030.

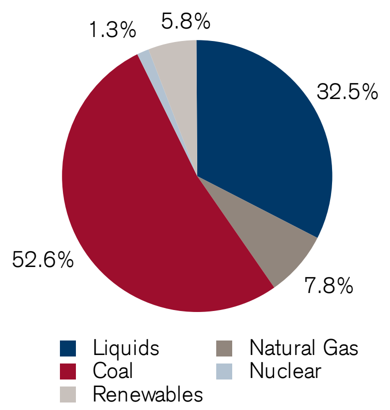
In the residential and commercial sector, the efficiency of heat generation is low and improving efficiency here is the main way of mitigating energy demand. The Russian government also plans to improve the efficiency of heat generation and insulation of buildings. In addition, a move towards more efficient natural gas, electricity and petroleum-based heaters and boilers is expected. As a result of these actions and the expected decline in population, demand in the residential sector is expected to grow at 0.1% per annum, and heat energy demand is expected to decline at 0.6% per annum to 2030. In the commercial sector heat demand will also be the key driver in pushing down the average growth rate to 0.3% annually despite increased electricity use.

8.3 India's Challenge

India is currently the world's 5th largest energy consumer and is set to become the third largest by 2030, according to the IEA. In addition, India is the 4th largest coal-based primary energy consumer with 7% world market share (see Figure 10). The coal-based primary energy sources account for over 52% of total energy consumption (see Figure 45) and only 25% of final (delivered) energy consumption. This indicates relatively high losses along the energy transformation and distribution (hereafter: T&D) chain. As shown in Figure 15 and 16 the investments in the power sector are estimated to account for USD 967 bn (in USD at 2005) of the more than USD 1.1 trn in total investments by 2030. This investment will be to cover the strong need for power supply infrastructure in all sectors. We believe this gives India plenty of room to cope with energy efficiency issues as most of the energy supply infrastructure is expected to be built with new, more energy-efficient technologies. The industrial sector is by far the largest final energy consumer with a 62% share, likely due to inefficient use of energy in industrial processes and other factors. Due to the high energy intensity level, e.g. 1289 toe/MEuro in 2004 as shown in Figure 35, there is still plenty of scope to improve India's energy intensity (efficiency) by 2020 despite the 27% energy intensity decrease already achieved between 1990-2004 (shown in Figure 8).

Figure 44

India's total primary energy consumption share by fuel type (2004)



Source: EIA, OECD, Credit Suisse

The key drivers of the growth in energy use in India are urbanization and the associated improvements in quality of life (more appliances, cars, etc) and the development of industry. According to the Integrated Energy Policy (IEP) report from the government of India, India needs to sustain an 8-10% growth rate for the next 25 years to achieve its goal of eradicating poverty, and this will require a tripling or even quadrupling of its primary energy supply. Electricity generation alone will be 5-6 times the current level. Poverty being the central concern in India, there are several barriers in place towards energy efficiency. In addition, the bureaucratic structure has made it challenging to create clear, enforceable targets and past targets have often been missed. In the next section, we overview the energy landscape and efficiency related policies in India.

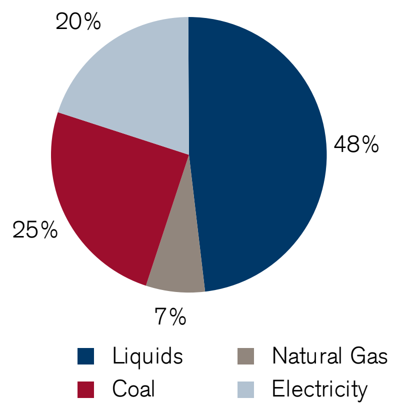
8.3.1 Energy growth and another coal crisis

Access to energy in India is uneven, and the IEA calculated that in 2005, 580 million people in rural communities and 126 million people in cities did not have access to electricity. This may be the reason behind the low electricity consumption per capita figures (553 kWh consumed per capita in India in 2003 compared with 1379 kWh per capita in China). In the most energy efficient scenario calculated by the Indian government, the per capita primary energy supply in 2031 is 1046 kgoe (note: 1 kgoe ≅ 40 Th. Btu) per year, which is far below the 2003 world average of 1688 kgoe, and therefore even the government assumes this estimate may be too low.

Coal is abundant in India but at this point, mining operations and power plants based on coal are highly

Figure 45

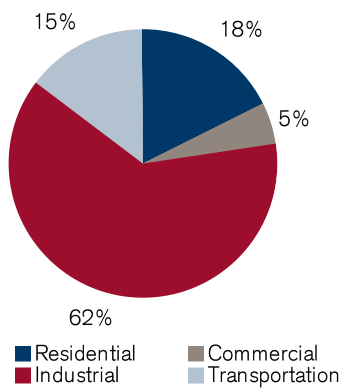
India's final (delivered) energy consumption share by fuel type (2004)



Source: EIA, OECD, Credit Suisse

Figure 46

India's final energy consumption share on sector level (2004)



Source: EIA, OECD, Credit Suisse

inefficient. In the most energy efficient scenario, coal accounts for 41% of the energy in India (rising to 54% for the least efficient scenario). This raises concerns about both coal-linked emissions and global coal markets. KPMG estimates that if the coal production increases at an annual rate of 5% the coal reserves in India will be exhausted in 40 years. They also say that allowing private investment in the coal sector will attract the USD 8-10 bn required to upgrade existing mines and open new ones. Markets for renewables, nuclear, and natural gas are expected to undergo considerable development in the next few years. India is planning to liberalize and allow private investment in several key sectors, most notably coal.

8.3.2 Energy efficiency measures

India's stance on energy savings is that saving a watt of power is better than buying another watt of power, because of the additional costs related to supplying the energy. Lowering the energy intensity of the economy is thus a key goal. At PPP, the energy intensity in 2006 was 0.16 kgoe per dollar of GDP, lower than China's 0.23 kgoe, and the 0.21 kgoe world average. The IEP calculated that energy efficiency improvements could reduce energy intensity by 20% compared with current levels using technologies alone. The Asian Development Bank (ADB) estimated that energy savings across all economic sectors in India could reach 9.2 GW and that the related investment potential is about USD 3.4 bn. Figure 46 shows the sectoral distribution of India's energy consumption, indicating clearly that the industrial sector is the key target for energy efficiency.

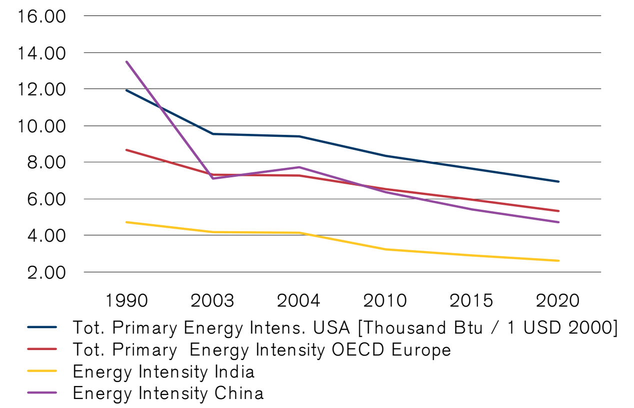
Key areas identified by the Indian government as inefficient were energy extraction, conversion, transportation, and consumption. Key sectors were mining, electricity generation, T&D, water pumping, industrial production, transport, buildings, and appliances. Examples of explicit targets are:

- Increasing the gross efficiency of coal power generation to 34% from 30.5%, and to an even higher 38-40% for new plants, bringing them in line with the standards of other countries.
- Promoting life cycle cost purchasing rather than minimum initial cost procurement in the public sector.
- Building urban mass transport systems, energy efficient vehicles, and increasing the use of freight trains
- Establishing benchmarks for energy consumption in high intensity industry
- Creating incentives for energy efficient appliances
- Increasing efficiency of coal mining by extracting coal bed methane before and during mining
- Increasing the use of renewables and nuclear energy, namely by creating incentives linked to energy generated
- Improving T&D infrastructure as financial losses amount to about USD 6 bn per year. This involves both reform of the political systems governing power, and also decreasing the losses due to theft, pilfering, and non-collection of funds owed. The networks in India are largely based on long networks of low voltage lines.
- Increasing hydroelectric power use to exploit India's resources.

In conclusion, due to the expected implementation of the above described measures, the gross energy intensity is expected to fall 37% in total or 2.8% annually between 2004 and 2020, as highlighted in Figure 50. Commercial intensity is expected to decrease by 20% in the 2006-2021 period by assuming 8% GDP growth rate (with electricity elasticity=0.95), as shown in Figure 48.

Figure 47

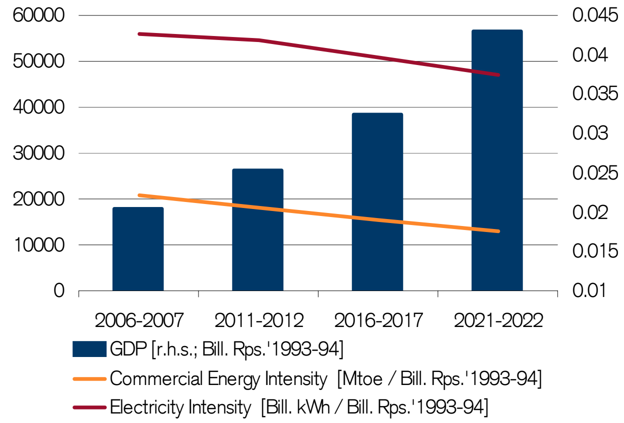
India's energy intensity indicator in comparison with major countries [Thousand Btu / 1 USD 2000]



Source: EIA, OECD, Credit Suisse

Figure 48

India's commercial energy intensity and electricity intensity by assuming 8% annual GDP growth (elasticity=1)



Source: Indian Government

8.4 China's perspective

8.4.1 The stage is set and a massive transition is ongoing

China has displayed impressive growth since the 1990's due to its huge basic infrastructure development activities. This trend is expected to continue to 2020 and beyond and it implies a strong demand for energy. China's GDP is expected to surpass the USA's by 2010 as it is expected to reach nearly USD 13,000 bn at 2000 market prices, according to the OECD. This implies 7.3% annual GDP growth to 2010.

China relies heavily on coal-based energy with 36% of worldwide market share (ranking 1st in the world) and with a 69% inland share, as illustrated in Figure 10 and 49 and 50. Industry consumes 73% of final energy, as shown in Figure 51. These data indicate that China has strong potential for energy savings and efficiency by implementing, for example, a more balanced energy generation portfolio using various energy sources, such as natural gas-based energy technologies and nuclear power in order to increase fuel efficiency and thermal efficiency for electricity generation. We will describe some examples of energy savings measures in the following section. Figure 51 indicates that huge investments are needed in the less developed residential and commerce (services) sectors in order to cover the energy needs of the Chinese population, especially outside the big cities.

As already cited in chapter 3, more than USD 3 trn (at 2005 market prices) is expected to be invested by 2030 to build energy-supply infrastructure. We believe that this gives China plenty of room to cope with energy efficiency issues, as much of the investments are expected to be used to build new energy supply infrastructure. The funds are also expected to be used to replace old infrastructure. New more energy-efficient technologies and power plants, e.g. CCGT, CHP, ACC, clean-coal technologies with higher thermal efficiencies, should also reduce the costs of pollution.

Table 3: World bank business as usual scenario for energy use in China, 2005 - 2050

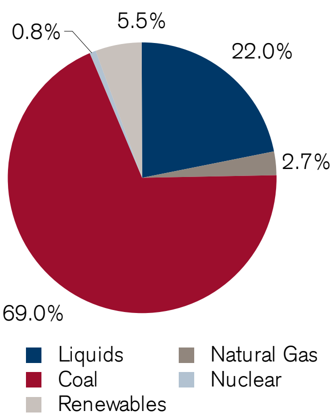
	2005	2020	2050
Total Final Consumption (Mtoe)	921.7	1683.2	2685.1
By Sector			
Industry and Services	58.5%	62.2%	54.6%
Transportation	10.2%	14.4%	20.8%
Residential	31.2%	23.5%	24.6%
Total Primary Energy Use (Mtoe)	1223.1	2483.5	4436.5
Coal	54.3%	58.9%	62.7%
Oil	23.1%	22.6%	20.5%
Natural gas	2.5%	3.5%	3.4%
Nuclear	0.5%	0.5%	2.4%
Hydro	3.7%	3.0%	3.1%
Renewables	15.9%	11.5%	7.9%

Source: World Bank

In the growth stages of an economy, the energy intensity generally increases until the later stages of development. However, this was not the case in China between 1980 and 2000. China has reached a point where increasing its energy intensity is inevitable if it is to meet its aggressive growth targets. Some of the key factors are the aggressive growth in energy intensive industries, particularly cement, and iron and steel, rapid infrastructure development, and the changing demographics. According to the UN, in 2005 40.4% of the Chinese population was living in urban areas, and by 2030, this figure is expected to be 60.3%. With urbanization and economic growth comes demand for energy related technologies including appliances, vehicles, lighting, etc. As mentioned previously, coal is by far the most abundantly used fuel in China and its share of total energy use is expected to grow to 2050 according to the World Bank (see Table 3), Therefore, China needs to address the coal problem with efficient and clean solutions like the aforementioned clean coal technology.

Figure 49

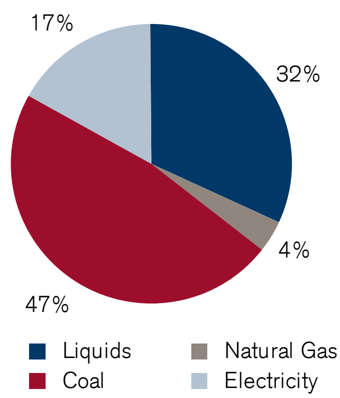
China's total primary energy consumption share by fuel type (2004)



Source: IEA, EIA, Credit Suisse

Figure 50

China's final (delivered) energy consumption share by fuel type (2004)



Source: IEA, EIA, Credit Suisse

8.4.2 Which policies should be adopted?

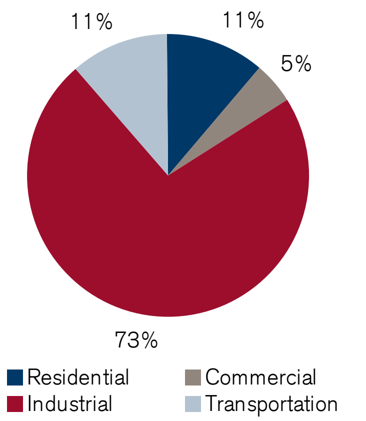
China's 11th five-year plan targets 7.5% GDP growth from 2005 to 2010 in tandem with a 20% reduction in energy intensity. The government also has targets for 2020 with calls for GDP to quadruple, while energy use should only double. According to a study by Lawrence Berkeley National Lab (LBNL), without aggressive policy measures to make sure that these standards are met, the goals will be missed (Table 3 assumes the 2020 targets are met), and will likely result in environmental and energy problems. Key suggestions by the group are:

- Removal of energy subsidies that hurt price drivers for market reform.
- Energy performance targets for industry with financial and non-financial incentives.
- More enforcement of codes for minimum efficiency standards.
- Development of public transportation systems to curb vehicle use.
- Encourage investment for adoption of energy efficient technologies and practices.

As part of China's 9th five year plan (1996 to 2000) the country identified 30,000 companies that were wasting resources and causing pollution, and acted accordingly to shut them down. In 2005 over 2600 companies in industries including cement, iron and steel were closed down for causing serious environmental pollution and violating industrial policies. It is clear therefore that China is serious about its environmental goals. In the following section we outline several of the potential energy savings in some key sectors.

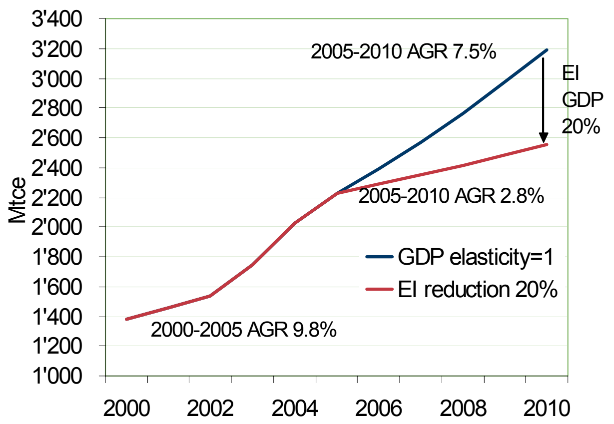
Figure 52 compares the energy consumption levels in China assuming it remains on its expected path (GDP grows at 7.5% p.a.), but does or does not achieve its energy efficiency goals (20% reduction by 2010.. In Figure 53 rather than holding the GDP elasticity constant, it is allowed to vary. The energy intensity (hereafter: EI) reduction curve shows the energy use attained if China achieves its targets, and LBNL asserts an even further development in their Baseline Policy

Figure 51
China's final energy consumption share on sector level (2004)



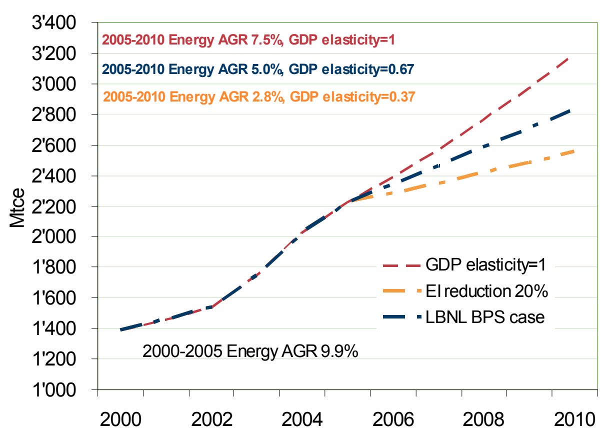
Source: EIA, OECD, Credit Suisse

Figure 52
China's energy efficiency potential by 2010: Part I



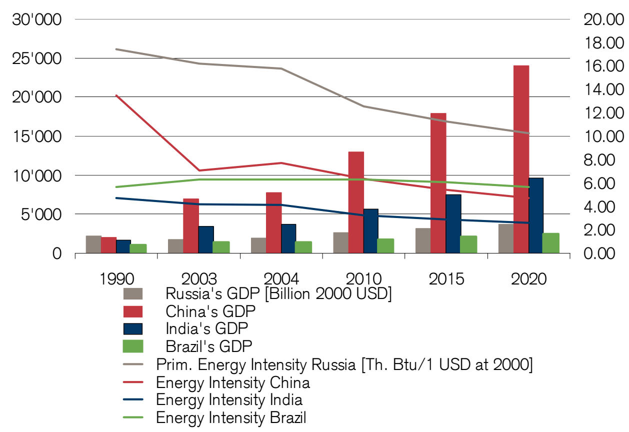
Source: J. Lin et al, LBNL

Figure 53
China's energy efficiency potential by 2010: Part II



Source: J. Lin et al, LBNL

Figure 54
GDP of BRIC countries [l.h.s.; Bill. 2000 USD] vs. Primary Energy Intensity Indicators [Thousand Btu / 1 USD at 2000]



Source: EIA, OECD, Credit Suisse

Scenario case, where they force the 2020 targets to be met in 2010. These scenarios illustrate the level of change required in China to achieve a reduction in energy intensity. China is focused on energy intensive sectors and as early as 2010 or even 2020, this is unlikely to change rapidly enough for the reduction to be structurally derived. The key will be energy efficiency improvements.

8.4.3 Sector specific energy saving potential

In the residential sector, the effect of energy efficiency can be extremely pronounced. According to LBNL, energy efficiency in major appliances (refrigerators, air conditioners, water heaters) can prevent 46 m tons of carbon emissions by 2030. Furthermore 3.07 Exa joules joule (10^{15}) (hereafter Ej) and USD 60 bn can be saved by 2030, as additional power plants will not need to be built, for energy savings related to these three appliances alone. An IEA study on standby power revealed that 1.5% of total national electricity consumption in 2020 could be saved by switching to energy efficient standby power in household appliances and thus 12 nuclear power plants would not need to be built. The savings are substantial, justifying the growth of the market for energy efficient technologies in the residential sector in China.

LBNL asserts that an aggressive savings policy for industry in China could lead to a 17% increase in efficiency in the cement sector and a 10% reduction in energy in the iron and steel industry. In this aggressive scenario, the 2020 targets are pushed to 2010 (Figure 53). In the same scenario, building energy consumption can be decreased 1.4% by 2010. In the electricity generation industry, a major opportunity for efficiency lies in the selection of generators. Small and less efficient generators can be replaced by larger ones.

8.4.4 BRIC country energy efficiency summary

Based on the present analysis we believe China presents the highest energy efficiency potential among BRIC countries and is well positioned on the global scale as well, as illustrated in Figure 54. As a result a 39% decrease in primary energy intensity from 7.7 Th. Btu/USD in 2004 down to 4.70 Th Btu/USD (as shown in Figure 57) may be achieved. We assume that the country will be implementing and enforcing the proposed measures described above.

On the other hand, we conclude that Brazil has the lowest energy savings potential with only a 9% decrease in primary energy intensity expected to 2020. This is primarily because of the country's rich natural resources, giving hydroelectric and bioenergy a large proportion of total energy consumption. This limits the potential for increased overall energy efficiency, for example, by fuel switching.

8. Traditional energy efficiency by sector, lighting and appliance technologies assessments

Figure 23 outlines the sectoral energy efficiency indicators by sector in the EU, showing more than 20% increase in energy efficiency for all sectors. Figure 55 shows the expected CO_2 savings (stemming primarily from energy savings) by type by 2030, as determined by the IEA. In this scenario, we can see that by 2030, major advances have to come from energy efficiency issues such as enhanced mileage, and the second biggest category is from the consumer end. 30% of reductions in CO_2 emissions are expected to come from lighting, air conditioning, appliances, and industrial motors. Looking at the graph it is likely that the demand side savings are among the biggest components. The plan calls for 65% of the reduction in CO_2 emissions to come from enhanced mileage and improved energy efficiency of lighting, air-conditioning, appliances, and industrial motors. Again nuclear and renewable fuels are called on as well as energy production efficiency to make up the remaining 35%.

8.1 Novel energy technologies are expected to further increase future energy efficiency

We expect technology to play a key role in increasing overall energy efficiency. Throughout this report the issue of replacement cycles has been mentioned, showing that modern technology has made advances that can improve energy use. In this section, we examine several energy technologies expected to play a big role in the future. This includes renewable energy technology, which is advancing rapidly, and improvements in efficiency are critical going forward as their share of total energy supply increases.

8.2 Zero energy buildings are driving improvements in several related technologies

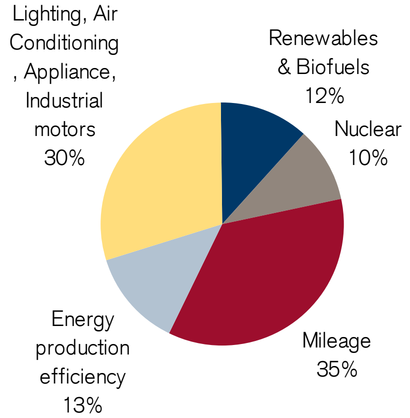
Zero energy buildings are mentioned in several parts of this report as many governments are setting targets for building these ultra energy-efficient buildings (see Figure 59 for a schematic illustration). Figure 56 shows the US residential consumption of electricity by end use. In the next sections we examine lighting, air conditioning, insulation and windows in more detail. The US DOE estimates that 10-25% of a residential heating bill can come from losses related to windows. Losses are related to heating from the sun in the summer and drafts and heat escaping in the winter. The use of **double or triple glazed windows** can reflect the heat wave energy and allow light to enter. In addition, future technologies including 'smart' or **electrochromic windows** that change their optical properties by applying different electric signals are being developed. According to the EWC (Efficient Windows Collaborative), savings from 27-39% of heating energy can be saved by changing to modern insulating windows available today for a home in Boston, MA. 6-32% savings in cooling energy can be achieved for a home in Phoenix, Arizona.

Insulation is another key technology for zero energy buildings. The US DOE estimates that 10% of heating and cooling expenses come from insulation related losses. EURIMA, the European Association of Insulation Manufacturers, asserts that roof and wall insulation can cut energy use in the EU by 20%, or 3.3 million barrels of oil equivalent per day. According to the IEA building insulation performance will soon be three times more effective than today's technology through the use of **vacuum panel technologies** among others.

Solar technologies have been advancing rapidly, but the development of low-cost technologies such as thin film and dye-sensitized solar cells, which can be manufactured in roll to roll processes, is critical. Zero energy buildings are correlated to the increase in efficiency of solar energy, so this technology is critical for meeting many of the future targets for energy savings. Innovation here that can boost the conversion efficiency of these cells is also necessary. The IEA estimates that in 2050, solar will still supply only 2% of the world's energy, but in our view non-incremental technological breakthroughs may significantly increase this share.

Figure 55

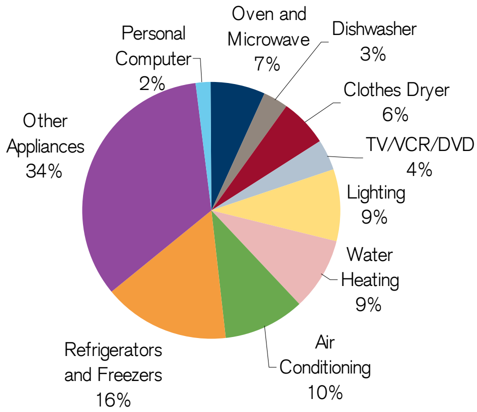
IEA Alternative Scenario: CO_2 savings by type, 2030



Source: IEA, Credit Suisse

Figure 56

US residential consumption of electricity by end use, 2001



Source: EIA, Credit Suisse

8.3 Lighting

As seen in Figure 56, lighting accounts for about 9% of total residential energy consumption in the US. The IEA estimates that about 19% of global demand for electricity comes from lighting, including industry and vehicle lighting. They further assert that CO_2 output from this lighting is equivalent to about 70% of the global emissions from passenger vehicles. According to the US ENERGY STAR program, if every American home replaced only one light bulb with an ENERGY STAR bulb, the savings would be enough energy to light more than 3 million homes for a year and would save USD 600 m in energy costs. Conventional incandescent bulbs are extremely inefficient because they work by passing electrical current through a filament to heat it and cause it to emit light. This results in a high portion of energy being lost as heat. Table 4 lists various lighting technologies and their efficacy (measured in lumens, or light output, per watt of energy input), their lifetime, and color temperature. Incandescent bulbs are clearly the least energy efficient, both in terms of efficacy and lifetime. The straight tube and CFL lighting technologies are two of the most energy efficient fluorescent-based technologies, as shown in Table 4.

The Australian government has a plan to phase out incandescent bulbs completely by 2010. Although other governments have not followed suit as aggressively, we believe that mandatory requirements are likely in the near future. The higher costs associated with fluorescent bulbs are offset by the cost savings in energy over the longer lifetime of the bulb. There are many companies that are developing these bulbs. Phillips is a leader in this technology and in February 2007 GE lighting announced that it has developed high efficiency incandescent bulbs capable of delivering the same energy efficiency benefits as fluorescent bulbs. The bulbs are targeted for the market in 2010.

Table 4: Lighting types compared

Lighting Type	Efficacy	Lifetime	Color Temperature
	(lumens/watt)	(hours)	(K)
Incandescent			
Standard "A" bulb	10–17	750–2500	2700–2800 (warm)
Tungsten halogen	12–22	2000–4000	2900–3200 (warm to neutral)
Reflector	12–19	2000–3000	2800 (warm)
Fluorescent			
Straight tube	30–110	7000–24,000	2700–6500 (warm to cold)
Compact fluorescent lamp (CFL)	50–70	10,000	2700–6500 (warm to cold)
Circline	40–50	12,000	
High-Intensity Discharge			
Mercury vapor	25–60	16,000–24,000	3200–7000 (warm to cold)
Metal halide	70–115	5000–20,000	3700 (cold)
High-pressure sodium	50–140	16,000–24,000	2100 (warm)
Low-Pressure Sodium	60–150	12,000–18,000	
LED			
High power white LED	50-70	50,000	

Source: US DOE, Nature Photonics, Credit Suisse

An alternative technology to the above is the development of LED lighting. Over the medium term, the energy efficiency delivered by this family of lighting may replace existing technologies completely. LEDs convert energy into light with excellent efficiency and boast even longer lifetimes than currently available lighting technologies (see Table 4). They are already produced in a variety of colors but the development of ultra bright white LEDs is important for their use in commercial and industrial lighting. The key challenge remains developing a cheap way to manufacture large quantities of ultra bright white LEDs to make them accessible for consumer markets. LEDs also offer an absence of toxic substances, like lead and mercury, in their manufacturing processes. The US SSL-LED Roadmap aims for an increase in LED efficacy to 150 lumens/watt and a lifetime of 100,000 h by 2012, which would make them better than any currently available light source.

We see companies manufacturing and developing high efficiency light bulbs as a distinct investment opportunity to take advantage of this energy efficiency theme. Examples of companies include Phillips and GE, as well as LED manufacturers such as Taiyo Nippon Sanso, Aixtron AG, and Emcore Corp.

8.4 Air conditioning

If the globe is warming, then demand for air conditioning is only going to increase. In Figure 56 we see that it accounts for about 10% of electricity demand from US households. The US DOE puts the figure at 5% of all the electricity produced in the United States, resulting in a cost of over USD 11 bn to homeowners and 100 million tons of CO_2 emissions per year. A key concern for these technologies is the replacement cycle. Modern systems are already 20-50% more efficient than legacy air conditioners according to the DOE. Government subsidies, incentives and regulations can help speed up the replacement cycle. In the US, the Energy Star program involves sales tax exemptions, credits, or rebates if consumers purchase participating appliances. There are also federal tax credits for home builders, consumers, appliance manufacturers, and commercial buildings that are made in an energy efficient way. Energy efficient air conditioner manufacturers are likely to benefit from the energy efficiency theme. LG, for example, has a new technology that uses 52% less energy than conventional air conditioning systems.

8.5 Standby switches and consumer monitoring equipment

In 2006 the Times of London reported that the UK government was investigating outlawing the use of standby switches on household electronics. They reported that the government's Energy Review had calculated that standby functions use 8% of all domestic energy. The UK Energy

Savings Trust further adds that leaving equipment on standby is responsible for 2% of total CO_2 emissions, or 3.1 million tons. Companies such as POWI and OIIM are focusing on products that address this energy savings challenge.

Another technology is for monitoring energy use and modulating it at peak hours. The PowerStream energy company in Toronto, Canada has begun a *peaksaver*™ program to reduce stress on the grid during the hot summer months. Under the program, consumers are being offered CAD 25 to allow the company to install a free thermostat with a CAD 250 value that allows the company to send a wireless signal to the air conditioner to reduce its power consumption during peak hours. This is only one example of a monitoring device that reduces energy consumption and decreases the stress-demand on the grid. Companies that manufacture these products and other energy management or power control devices will benefit from this trend, for example Schneider, whose technology can save 10-30% of power consumption through its products, and Emerson or Rockwell, which offer intelligent motor control products.

9. Industrial sector energy efficiency potential

The industrial sector, because of the amount of energy it uses, is heavily involved in energy efficiency. In Figure 57 the consumption of liquid fuels by end use sector is shown for three different oil price scenarios. Interesting to note is that, although the highest consumption is seen in the transport sector, it is also the most flexible with respect to oil prices, as people can choose to drive less (for example seek to use public transportation). In Figure 57, it can be seen that the industrial sector displays the most inelastic energy demand. We therefore assert that industrial demand for energy efficient technologies is the strongest, particularly when energy prices are increasing.

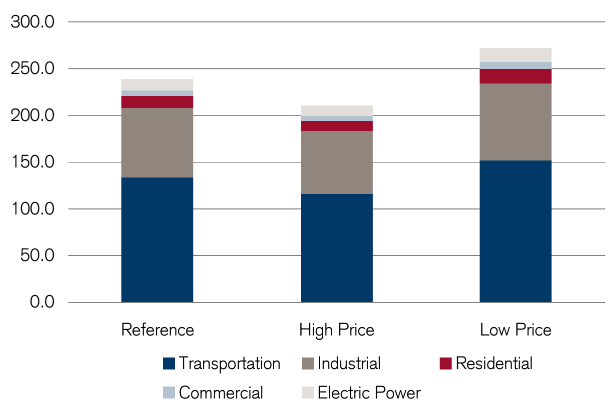
The IEA attributes a third of global energy consumption and 36% of CO_2 emissions to manufacturing industries. This is the most energy intensive sector and it is growing in tandem with the emerging markets that are developing their manufacturing economies. For example, China accountd for 80% of the industrial growth in the last 5 years. Energy efficiency is particularly important in this sector in view of the increasing price of oil, and especially as it starts to bear the cost of its carbon emissions through emissions trading schemes. Table 5 shows the potential energy savings in the industrial sector with respect to 2004 operations standards. The key finding is that energy efficiency measures could save 25 to 37 Ej or 1.5 times the current energy consumption of Japan. In addition, about 7-12% of global CO_2 emissions can be eliminated.

9.1 Efficiency trends are moving in the right direction, but emerging market developments are key

Overall, energy efficiency in industry has been improving such that plants built today are more efficient than older technologies. The replacement cycle is extremely slow, however, and the impetus to replace old materials is not strong as long as the cost of emitting carbon does not increase. In Eastern Europe this is the case. In other emerging markets such as China and India, where economic resources are limited and there is easy access to abundant coal, the energy efficiency is low. In these countries there is still an emphasis on small-scale operations and less efficient new developments. OECD countries, particularly the Asian countries such as Japan and Korea, have a high level of efficiency due to a variety of factors including available resources, average plant age, and environmental and energy related policy.

Figure 57

Three oil price scenarios and world liquids consumption by end use sector in Quadrillion Btu by 2030



Source: EIA

9.2 Sub-sector view

Chemicals and petrochemicals use about 30% of global industrial energy as shown in Figure 58. Being the largest energy consumers, they are not the largest carbon emitters due to the storage of carbon in manufactured products. This sector has limited efficiency savings potential because of the energy intensity of feedstock processing. According to the IEA energy savings potential is deemed to be 13-16% if plants are to use the best available technology today, including process efficiency, electrical systems and recycling. In this sector, more than 39% of energy use is for steam cracking. A 30% difference in energy efficiency has been observed for steam cracking between the best and the worst regions. This is a key

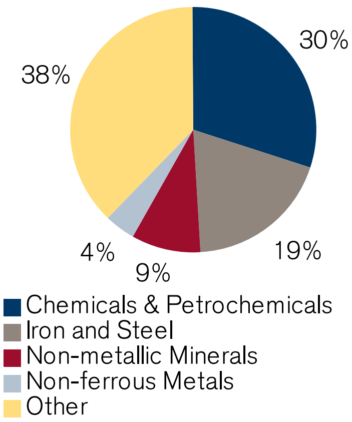
Table 5: Energy and carbon saving potential

	Low to high estimates of technical savings potential		
	EJ/yr	Mtoe/yr	Mt CO_2/yr
Sectoral Improvements			
Chemicals/Petrochemicals	5.0 - 6.5	120 - 155	370 - 470
Iron and steel	2.3 - 4.5	55 - 108	220 - 360
Cement	2.5 - 3.0	60 - 72	480 - 520
Pulp and paper	1.3 - 1.5	31 - 36	52 - 105
Aluminium	0.3 - 0.4	7 - 10	20 - 30
Other non-metallic metals minerals and non-ferrous	0.5 - 1.0	12 - 24	40 - 70
System/life cycle improvements			
Motor systems	6 – 8	143 - 191	340 - 750
Combined heat and power	2 – 3	48 - 72	110 - 170
Steam systems	1.5 - 2.5	36 - 60	110 - 180
Process integration	1 - 2.5	24 - 60	70 - 180
Increased recycling	1.5 - 2.5	36 - 60	80 - 210
Energy recovery	1.5 - 2.3	36 - 55	80 - 190
Total	25 – 37	600 - 900	1900 - 3200
Global improvement potential % of industrial energy use and CO_2 emissions	18 - 26%	18 - 26%	19 - 32%
Global improvement potential % of total energy use and CO_2 emissions	5.4 - 8.0%	5.4 - 8.0%	7.4 - 12.4%

Source: IEA, Credit Suisse

Figure 58

Percentage of final industrial energy use by sector



Source: IEA

opportunity for replacement or new developments in the space.

Iron and steel industries use 19% of total energy consumption in industry (see Figure 58) and generate 27% of CO_2 emissions. Key factors for the efficiency of a plant are the quality of the technology, plant size, raw materials, and the relative cost of energy. Plants in countries such as China, India, Ukraine, and the Russian Federation generally have a lower average efficiency than OECD countries and account for more than 50% of global CO_2 emissions in this sector. In countries where energy prices are high there are generally more systems that make use of waste heat from the iron and steel industry. The energy savings and potential is anticipated to be between 9 and 18% (source: IEA) and between 220 and 360 $MtCO_2$ per year (see Table 5). According to the IEA, about 35% of steel today is produced from recycled scrap while the rest is derived from pig iron. Incentives to increase the energy efficiency in the iron and steel sector are likely to benefit companies involved in recycling scrap, waste energy recovery, and that use steel byproducts including blast furnace and coke oven gas, and slag by-products.

The **non-metallic minerals** segment accounts for 9% of energy use (see Figure 58), and 27% of CO_2 emissions. 70-80% of the energy use in this segment is used for the cement industry. The energy efficiency of cement production varies widely across the globe because of its link to the age of resources. The savings potential for energy lies between 28-33% (source: IEA) and the reduction in CO_2 emissions between 480-520 $MtCO_2$ per year. China is the world's largest producer of cement, accounting for 46% of production. Although cement technology has been around for a long time, there is still a range of production efficiencies and the energy intensity involved in producing one ton ranges between 3.4 and 5.3 Gj. Again the key factor is the age of the production equipment and method. Key is to use the best available technologies and use more clinker feedstock replacements (traditional clinker feedstock releases significant CO_2 during the reaction, up to 50% of the total emissions, unaffected by energy efficiency).

Pulp, paper and printing industry accounted for 5.7% of total energy use in 2004 (source: IEA) and traditionally uses bioenergy for manufacturing, thereby meaning that its carbon intensity is already quite efficient. Best practices can yield energy reductions of 15-18% and a 50-105 $MtCO_2$ per year in emissions, but the replacement cycle is again an issue and capital costs for replacing existing equipment can be prohibitive.

Production of **aluminum and other non-ferrous metals** accounts for 3.5% of global electricity consumption (source: IEA) and the process is highly electricity intensive. Recycling aluminum, which takes 20 times less energy than making aluminum from primary sources, is a key way to continually drive down the energy intensity of this industry. From a plant operations perspective, the best practices lead to the figures in Table 5, highlighting energy savings of 6-8% (source: IEA) and CO_2 reductions of 20-30 $MtCO_2$ per year.

Table 6: Energy savings potential for selected commodities

		Apparent Consumption	Post-consumer flows	Total material available	Additional recycling potential	Primary energy savings potential
	Year	Mt/yr	Mt/yr	Mt/yr	Mt/yr	Ej/yr
Crude Steel	2005	1129	261	446	20 - 50	0.2 - 0.5
Aluminum	2004	44.1	7.3	13	6.7	0.9 - 1.2
Copper	2004	14.5	9	10.4	3	0.1
Plastics	2004	235	115	120	20 - 40	0.8 - 1.5
Paper	2004	354	254	274	50 - 75	0.5 - 0.8
Wood	2004	600	284	344	50	0.5 - 1
Glass	2004	100	77	87	23	0

Source: IEA, International Iron and Steel Institute, International Aluminum Institute, Credit Suisse

9.3 General process changes can have dramatic effects on energy intensity

Table 5 lists several system/life cycle improvements that can increase overall energy efficiency in industry.

In this sector, **more efficient electric motors** are our first point for discussion. They are responsible for approximately 60% of electricity use in manufacturing. The most efficient new motors are 20-25% more efficient than existing motors, so the key issue again is the replacement cycle and gaining market penetration. In the US and Canada, government incentives and legislation have pushed the use of these to a 70% rate, while in Europe, just 15% of motors are more efficient. Furthermore, the ACEEE (American Council for an Energy Efficient Economy) and NEMA (National Electrical Manufacturers Association) agreed in March 2007 to set a new energy efficiency standard for industrial electric motors.

The groups further recommended federal tax incentives for motor manufacturers and purchasers to accelerate the production and installation of the new class of motors. In Table 5, the IEA estimate is that 6-8 EJ per year and 340-750 $MtCO_2$ per year can be saved by optimizing motor use. This involves selection of a motor for a specific task to match the scale of performance, control strategies, using the highest efficiency motors available, improving maintenance practices, and using high efficiency transmission systems among other methods. Companies that can benefit from this trend include motor manufacturers such as ABB, Siemens, and Baldor.

Cogeneration, or combined heat and power, is another key technique to increase energy efficiency. It involves integrating generation systems for mechanical and thermal energy. This technique can also be used to mitigate CO_2 emissions. The cost effectiveness of installing these systems depends on local regulations regarding selling energy to the electric grid, and the relative pricing of natural gas and electricity, as the former is often a feedstock for cogeneration systems. Tokyo Electric Company and Alstom are leaders in the construction of CHP, ACC, and CCGT power generation systems.

Increased recycling is another major energy and carbon emission reducing method, particularly as recycling is generally less energy intensive than production from raw materials. In Table 5, recycling was seen to reduce energy consumption by 1.5 to 2.5 Ej per year and decrease carbon emissions by 80 to 210 $MtCO_2$ per year.

In Table 6, a breakdown by end industrial material is shown. Recycling steel is important as it is already the most widely recycled material and considerable energy is saved by doing so. According to the International Aluminum Association, recycling aluminum uses 5% of the energy required and releases only 5% of the carbon to make aluminum from primary sources.

9.4 Clean coal and carbon capture and storage technology are key factors for the future with reserves of coal so high

Clean coal and carbon capture and storage (CCS) technologies can significantly decrease emissions in the future, particularly in countries such as China, India, and the USA. In our view, coal, which is quite abundant in these 3 countries, will inevitably play a role in energy generation for years to come. As costs of carbon emission increase, these technologies will receive further investment and become more cost-efficient, particularly with regard to CCS, which is currently expensive.

Modern coal plants are already more efficient than old ones; new technologies include high-temperature pulverized coal and integrated coal-gasification combined cycle plants. In addition, harvesting methane emissions from coal mines is another way to boost the overall efficiency of coal use, and we expect to see this become commonplace. According to the IEA, clean coal technologies and CCS together can contribute 20-26% of CO_2 emissions savings compared to their baseline scenario. Hitachi Ltd. designed and developed a next generation coal fired turbine with over 48% thermal efficiency, one of the highest in the world.

9.5 Micro combined heat and power systems

Micro combined heat and power (CHP) systems produce both heat (water and ambient heating) and power. A sample system is shown in Figure 60 with a schematic of a zero energy home in Figure 59. According to the Micropower Council, use of a Micro CHP system can reduce emissions for a typical household by 25% while delivering the same comfort level. Technologies include reciprocating and Stirling engines. The two technologies differ primarily in fuel input and power capacity. The latter is the newer technology and we can likely expect performance improvements and cost reductions over time. The IEA estimates that these systems have a payback time of 4 – 14 years for commercial sector applications.

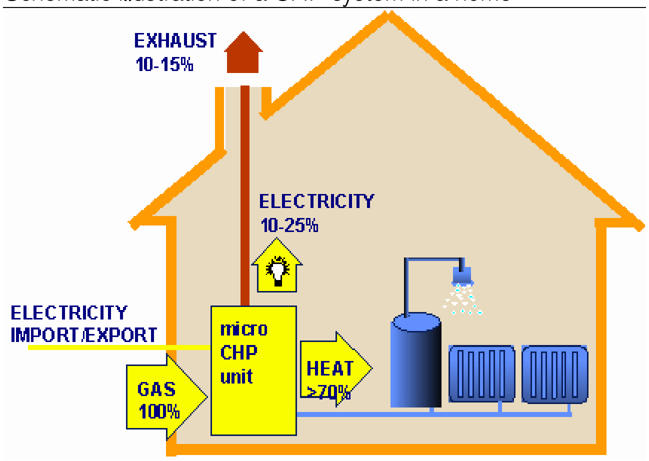
Figure 59

Schematic design for a zero carbon home

Source: discovery.com

Figure 60

Schematic illustration of a CHP system in a home



Source: microchap.info

9.6 Hydroelectric and wind power systems

Hydroelectric power is expected to grow significantly and systems such as those in Brazil that are designed to function in both low and high water conditions are particularly important as climate change may affect weather patterns in the future. Hydro is also important because it lowers the overall energy intensity of generation. Wind generation is also expected to expand its role in energy generation in the future as many countries have large generation capacity needs and areas suitable for this technology. Improvements in materials and blade design have already advanced the sector, but further improvements that additionally lower cost can lead to significant reductions in oil use and the more efficient use of natural resources, in our view.

10. Transportation

The transport sector is the largest consumer of energy, accounting for over 50% of energy use worldwide. Figure 6 shows that 35% of the reduction in carbon emissions by 2030 is to come from the transport sector. In this section we list some methods of improving efficiency in the transport sector and finish with an analysis of the growing ethanol fuel sector.

Increasing fuel efficiency of engines is clearly an important technique for energy savings and emissions reduction. President Bush announced the reform of the Corporate Average Fuel Economy standards for cars with the aim of reducing gasoline use by 5% or 8.5 bn gallons. There are also energy tax credits available for alternative fuel vehicles in place. In the UK higher road tax is being charged for larger and less efficient car engines. Similar programs are underway in other countries around the world. Solutions for reducing fuel consumption and increasing fuel efficiency are given below:

- Public transportation systems are one of the first methods that come to mind when considering energy efficiency. Companies that manufacture products and build infrastructure for public transportation systems are likely to benefit.
- Use of diesel engines. The EIA and UCS (union of concerned scientists) calculated fuel efficiency on the assumption that diesel fuel engines are 30-50% more efficient that gasoline engines. Market penetration in the US is only 3% compared with over 50% in Europe. The particulate emission problem has also been resolved.
- Another consumer-level product to improve efficiency in the transport sector is the hybrid car. These currently account for less than 0.5% of global sales but JD Power and Associates estimate this will increase to 4% in 2012.
- Development of better catalysts for clean burning and enhanced fuel efficiency. **Platinum based catalysts** are often used.
- Reducing the overall weight of vehicles using ultra lightweight composites. In this sector and in the area of catalysts, nanotechnology can make a key difference, as new materials and plastic composites are being developed with the goal of replacing metals without compromising strength or performance. Light weight materials can significantly increase the efficiency of fuel consumption in automobiles and aircraft.
- Jet engines can also be improved and the airline industry would benefit from this both in terms of fuel costs and in terms of reduced carbon emissions. The average jet engine is currently 15 years old so market penetration of new engines that already display a 20% improvement is low, and this presents a clear investment opportunity if legislation is imposed. Airlines are going to be included in the second round of the carbon emissions trading scheme, 2011 for domestic and 2012 for international, in Europe. Companies that make components and engines for aircraft are the key beneficiaries, including players like Rolls Royce.

Increasing the efficiency of motors and engines in transport has been largely the direction of progress. But two key themes emerge as the bottlenecks for non-incremental improvements in efficiency, these are weight and energy storage.

Lighter materials are critical for increasing the fuel efficiency of vehicles, aircraft, trains and other transport methods. Designing for aerodynamics and having materials that are both easier to manufacture and that weigh less are critical for the next step in fuel efficiency. At the same time, these lighter materials need to be just as safe and we therefore need innovation that yields this combination of strength and light weight. Innovations in nanotechnology and materials science are expected to solve this critical issue for transport.

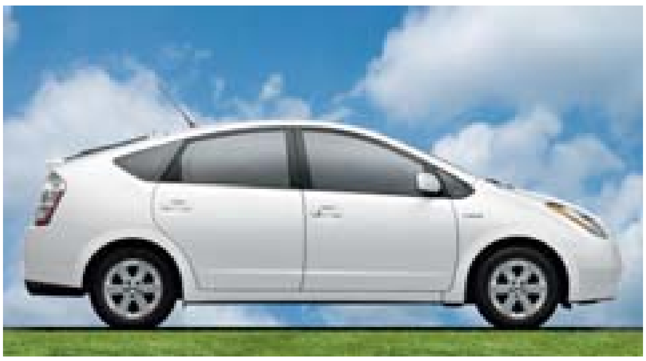
The second theme regards batteries and this theme extends beyond transportation. In a hybrid car, in addition to the battery being heavy, there are also the issues of needing greater storage capacity, a faster charge cycle, and a longer lifetime. Another example of the importance of batteries for energy efficiency is in wind power. Wind blows more strongly at night, when people use power less, so better battery technology can play a key role there. Because of its implications across energy applications and other sectors battery technology is considered to be a key hurdle.

10.1 Biofuel

Biofuel technologies have already been improving. In the section on Brazil, we referred to the process intensity involving the amount of input required to produce ethanol, and in both sugarcane and corn based ethanol, improving this process efficiency is important. In addition to the energy intensity of these processes, the CO_2 emissions from the overall production cycle, which includes deforestation, emissions from farm equipment, and the burning of fuel to run the plant, also need to be reduced if biofuels are to be a viable alternative to fossil fuels. The IEA estimates that sugarcane-based ethanol can reduce emissions by almost 90%, whereas grain-based ethanol's reduction potential is estimated by Farrell et al. at potentially 13%.

Figure 61

2007 Toyota Prius hybrid car



Source: Toyota

Second generation biofuels are currently in the R&D stage and involve deriving ethanol from cellulose, which has the additional advantage of not competing with food crops. Biodiesel is compatible with current engines and can reduce emissions by 40-60%. Costs are the key barrier as well as the conversion efficiency. We estimate that the alternative energies with the most promise are those that are self-supporting at an oil price of USD 50/bbl.

10.2 Vehicle technologies

Energy efficient vehicles, including hybrid and flex fuel vehicles, are expected to increase their market share as the costs of fuel, in societal and absolute terms, increases. To date, Toyota has sold more than 1.0 m hybrids and lists this as the single most important vehicle technology for its future. The EPA's most fuel efficient vehicle for 2008 is the Toyota Prius (Figure 61), with 48 miles per gallon (hereafter: mpg) in the city, and 45 on the highway. Costs of hybrid vehicles are considerably higher due to the battery technology involved. In the IEA's alternative policy scenario, mild or light hybrids would need to represent 60% and full hybrids 18% of new light-duty vehicle sales to achieve the predicted transport sector savings.

Flex fuel vehicles can run on either traditional gasoline, or on E85 (a blend with 85% ethanol, and 15% gasoline). In Brazil, these dominate the market due to the government's measures to promote ethanol use. In the future we can expect these and other vehicle technologies, namely **hydrogen fuel cells, diesel hybrids**, and even more efficient components to existing vehicles based on gasoline combustion engines to continue improving and gain market share.

Synfuel cars are another important innovation. Synfuels are fuels derived from natural gas or coal. They burn with less sulphur dioxide, aromatics, and carbon monoxide. Cars with synfuel compatible engines are as powerful as a diesel engine but weigh less. Overall, Synfuel vehicles offer the lighter weight of a gas engine, with the speed of a gas engine, and the power of diesel, all with a higher overall efficiency. This may also be a promising technology for a clean energy future.

10.3 Other transport technologies

As mentioned previously, automotive technologies are being developed and refined, but the transport sector comprises other energy users such as trains, aircraft, and ships. For trains, electrification is an important step, as electricity is usually cleaner and more efficient (depending on generation technique) than burning fossil fuels. In the US in particular, this is an issue as most of the trains there run on diesel. For airlines, modern engines are more efficient than the older ones, so the key technologies that can boost efficiency are the aforementioned materials with higher strength and lower weight, along with improved aerodynamic designs. The current environment with low interest rates and high energy prices is encouraging a speed-up of replacement cycles for old aircraft, which will bring energy efficiency improvements across the sector. In addition, talks of bringing the airline industry into the EU-ETS scheme can also push this ahead.

11. Conclusions

Energy efficiency is expected to accelerate in the next few years. The main catalysts here are sustained high oil prices and government policy, as well as the influence of societal awareness of global warming and energy independence issues. There are other catalysts that vary between developed markets and EMs:

Globalization is forcing companies in developed markets to become more competitive and cost efficient. Companies in several industries that are particularly dependent on energy will have to improve their margins, and thus their energy efficiency, if they want to survive.

In EM, rapid economic growth and convergence to Western standards of living translate into higher energy consumption per capita. However, world resources are limited and higher energy use per capita in EM would rapidly endanger world resources, thus leading to potential conflicts. Countries like China definitely need to significantly improve their energy efficiency at a faster pace than their economic growth in order to make their development sustainable in the long term. With more than USD 20 trn expected to be invested in energy supply infrastructure until 2030, we estimate that the world will be able to cope with the energy efficiency, supply and security challenges by implementing next generation and state-of-the-art energy technologies.

For those key reasons, we expect energy efficiency to improve significantly in the future. While this looks like an almost impossible task given current technology and consumption habits, we believe that the emergence of new technologies, like nano materials and nano batteries, fuel efficient vehicles, and combined heat and power systems can significantly lower energy consumption levels and enable much higher energy efficiency in many industries. In the 19th century, the economist Malthus warned that the world could not grow at an unbridled pace forever without endangering its resources, and since resource consumption in his eyes cannot be reduced, the world's economic growth was bound to stagnate at some point. Malthus's predictions have proven to be wrong for the last 150 years. We believe they will still be wrong in the coming 150 years, and energy efficiency is the key.

Abbreviations frequently used in reports					
Abb.	**Description**	**Abb.**	**Description**	**Abb.**	**Description**
CAGR	Compound annual growth rate	EPS	Earnings per share	P/B	Price-to-book value
CFO	Cash from operations	EV	Enterprise value	P/E	Price-earnings ratio
CFROI	Cash flow return on investment	FCF	Free cash flow	PEG	P/E ratio divided by growth in EPS
DCF	Discounted cash flow	FFO	Funds from operations	ROE	Return on equity
EBITDA	Earnings before interest, taxes, depreciation and amortization	IBD	Interest-bearing debt	ROIC	Return on invested capital

Disclosure appendix

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The analysts identified in this report hereby certify that views about the companies and their securities discussed in this report accurately reflect their personal views about all of the subject companies and securities. The analysts also certify that no part of their compensation was, is, or will be directly or indirectly related to the specific recommendation(s) or view(s) in this report.

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HOLD: variation between -10% and +10% in absolute share price
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AA: Obligor's capacity to meet its financial commitments is very strong
A: Obligor's capacity to meet its financial commitments is strong
BBB: Obligor's capacity to meet its financial commitments is adequate, but adverse economic/ operating/financial circumstances are more likely to lead to a weakened capacity to meet its obligations
BB: Obligations have speculative characteristics and are subject to substantial credit risk due to adverse economic / operating / financial circumstances resulting in inadequate debt-servicing capacity

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