ADVANTAGE ENERGY

Emerging Economies, Developing Countries and the Private-Public Sector Interface

INFORMATION PAPER

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Executive summary

In April 2011, the United Nations Foundation declared 2012 the **International Year of Sustainable Energy for All**. The declaration is intended to prompt actors in both the public and private sectors to direct action towards "extending modern energy services to the billions who still lack them."

Two aspects of this declaration warrant particular attention. The inclusion of energy in the development agenda acknowledges that it is essential to enabling economic growth, increasing productivity and improving overall health and welfare. The word "sustainable" emphasises the need to produce and consume energy in ways that contribute to global efforts to mitigate climate change and improve resource management. It also speaks to the need for countries and regions to recognise that a high level of energy security is required to ensure that modern energy services can support development goals.

Significant technology investment is required to meet these aims and this paper looks at these issues in a holistic fashion using an energy systems approach and highlighting the roles of the private sector. It considers that much of the technology deployed now will be used over prolonged periods; the actions taken in the short term must place heavy emphasis on avoiding technology lock-ins already known to be unsustainable. The move to sustainable energy access must begin quickly while potential investment needs to consider both today's best technologies and the potential of future opportunities.

It is estimated that 1.4 billion people – 20% of the global population – lack access to electricity and that a further 1 billion lack reliable access. Some 2.7 billion people – 40% of the global population – rely on traditional use of biomass for cooking (IEA, 2010a). Although these statistics are well known to many already engaged in the energy aspect of the development agenda, they serve as a relevant reminder of the scale of the challenge. It is also worth reiterating that lack of access to modern energy services is most prominent in emerging economies and developing countries, although issues of energy access and energy poverty[1] are evident throughout the world.

Additional support came in the UN Secretary-General's call for action to meet three interlinked global targets by 2030: achieving universal access to modern energy services, improving energy efficiency by 40% and produce 30% of the world's energy from renewable resources. These goals reflect the thematic clusters around which UN-Energy organises its efforts: Access to Energy, Energy Efficiency and Renewable Energy. These aims address the need for all actors to support efforts that enable emerging economies and developing countries to avoid outmoded energy technologies and ineffective policies, and to advance directly to modern sustainable energy systems.

[1] Energy access and energy poverty are at times used interchangeably (Bazilian, 2010) and consensus on the exact meaning of the terms has not yet been reached. The following definition of energy access will be used for the purposes of this report "access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses" (AGECC, 2010). Energy efficiency and renewable energy deployment are covered under the topic of energy access.

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Private sector engagement

Recent experience shows that with effective policies and adequate financing, the private sector in emerging economies and developing countries will seize the opportunity to deliver more sustainable energy options to growing consumer markets.

Small-scale entrepreneurs are increasing access to electricity in rural areas through sales and leasing of stand-alone solar systems and micro- and mini-grids. By adopting best-in-class technologies, some companies in developing areas are achieving higher heat energy efficiency rates in production processes than their competitors in developed countries. The market for solar water heating devices in China alone reached sales of USD 6.3 billion in 2008.

These examples demonstrate the power of private-public collaboration to transform energy production and consumption. This paper emphasises the private sector contribution, reflecting roles identified by the UN Global Compact (UNGC) that include core business activities but extend also to social investments and philanthropy, as well as advocacy and public policy engagement.[2] These roles provide opportunities for participants in the private sector to use its skills, experience and resources to support the many energy and development needs in emerging economies and developing countries.

The type of private sector organisation and its respective involvement will be influenced by the technologies being deployed. In the case of technologies with potentially large and diffuse markets (such as more efficient cookstoves or solar lighting), global corporations could support business development and supply chain management, while local businesses could be active in sales, deployment and education.

In certain technology areas, such as development of bus rapid transit (BRT) systems, public-private partnerships will be essential to ensure adequate financing and long-term operational strategies that include capacity building and education. Advocacy in policy development in areas including electricity market structures can ensure that customers have the ability to pay for electricity services when offered.

This report has two main objectives – to present the case for "access to energy" in the context of energy systems and to animate discussion on the role of the private sector in meeting the international community's goal to provide "sustainable energy access to all." This approach provides a platform for further discussion of partnerships and collective engagement that leverages the strengths of each contributing stakeholder, with the private sector playing a vital role in the area of technology deployment.

An energy systems approach

The topics of energy access and energy poverty are on the development agenda, but incorrect assumptions and misunderstandings still arise. Access to energy extends far beyond providing electricity or distributing cookstoves; it must encompass the full spectrum of energy sources and uses that form the overall system, incorporating targeted applications for specific purposes at all levels – from individual households to community needs to national infrastructures. In short, it

[2] www.unglobalcompact.org/docs/issues_doc/development/A_Global_Compact_for_Development.pdf.

requires a "systems approach" to developing energy systems (see the **Introduction** for a more detailed explanation).

In 2008, 91% of global energy demand was attributed to heat (47%), electricity (17%) and transport (27%). This paper treats each demand area as an energy subsystem, and explores how UN goals can be achieved within each (Table 1).

Table 1 Mapping of IEA subsystems to UN-Energy clusters

	Access to energy	Renewable energy	Energy efficiency
Heat	Modern heat	Renewable heat	Thermal efficiency
Electricity	Electrification	Generation	End-use technologies
Transport	Public transit and non-motorised modes	Biofuels	Vehicle fuel economy and electric vehicles

There are marked differences, particularly between emerging economies and developing countries, in current demand patterns and in the potential for the private sector players to capitalise on matching technologies to the needs of diverse end-users. One clear message that comes out in all energy subsystem inquiries is that countries and regions have varying needs that require targeted solutions.

Heat

At present, 47% of the worldwide final energy consumption is used for heat. This distribution of heat is highly dispersed and often decentralised, making it difficult to analyse. The inquiry can be advanced, however, through a regional comparison of residential and industrial uses of heat.

Mapping technology opportunities against the UN Energy clusters, several technologies are relevant to the residential sector. Access to modern heat can be provided by deploying more efficient cookstoves and liquid petroleum gas (LPG) or natural gas appliances to replace the inefficient, unsustainable and hazardous use of three-stone fires. In fact, one company in Sri Lanka has sold more than six million high-efficiency biomass cookstoves that substantially reduce indoor smoke. Thermal efficiency gains could be achieved through expanded use of high-efficiency appliances and improved building envelopes. Solar thermal energy and biogas are just two examples of renewables that can be applied at household or community levels.

To a large degree, temperature requirements will dictate which technologies can be applied in industrial sectors. In several sectors, efficiencies can be gained through co-generation (combined heat and power) and even through the integration of renewables such as co-firing of biomass with fossil fuels and industrial-scale solar thermal applications. Energy efficiency applications in industry (often using available technologies available in the global marketplace) can be inexpensive to deploy and offer attractive paybacks.

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Electricity

Electricity enables various end-use services – such as lighting, refrigeration and household appliances – that are difficult to provide using other forms of energy. Electricity demand currently represents 17% of worldwide final energy consumption. Its share is expected to increase significantly due to growth in general demand and increased use of electricity in heating and transport.

Multiple technologies – including those that capture renewable resources such as wind and solar – can rapidly increase provision of electricity services. Individual home solar installations and micro- or mini-grids can serve rural areas, especially when installed with electricity storage technology or in combination with fossil fuel generators. Construction, extension and reparation of national transmission and distribution (T&D) systems can reach more consumers in urban areas while strategically addressing rural applications.

From a sustainable business perspective, generators and system operators urgently need to reduce losses. The efficiency levels of large-scale generation facilities, which are often lower than those in OECD countries, can be improved through off-the-shelf technologies and improved operations and maintenance. Technical losses and theft in transmission and distribution systems can be greatly reduced through smart-grid technology deployment.

Broad deployment of renewables in both small-scale installations and large-scale networks will contribute to regional fuel security and global sustainability issues. Although the variability of supply of some renewable generation creates certain challenges in operation, solutions for these concerns are and can be addressed.

Local businesses in partnership with non-governmental organisations (NGOs) would be well suited in the deployment of efficient energy and cost competitive technologies like residential solar home installations. As electricity systems expand and increase in complexity, increased engagement of companies with experience in large-scale deployment and operation will be needed. The private sector rightly looks to governments to establish policies (such as alternative tariff structures) that address social equity considerations associated with universal access to electricity, as situations may arise in which the consumer's ability to pay is a challenge.

Transport

The transport sector represents 27% of final energy use on a global level, but regional patterns vary widely, as do levels of travel per capita. This report focuses on personal transport due to its great diversity at a regional level, rather than the more globally homogenous nature of freight transport. In addition, personal car ownership is expected to increase rapidly in many countries in the coming decades. As ownership rates in emerging economies and developing countries start to approach levels in OECD countries, a business-as-usual scenario would see them encounter significant increases in import fuel costs and environmental impacts.

A range of technologies and forms of mobility will be important to sustainable transport. Key solutions include public transit (such as light rail and bus rapid transit) and non-motorised transport (especially in regions that are unlikely to experience high car ownership levels), improved

vehicle fuel economy, adoption of electric and plug-in hybrid electric vehicles (EV/PHEVs), and wider use of biofuels.

As emerging economies and developing countries rapidly motorise, it is imperative that cars become much less energy intensive. The rapid rate at which EV/PHEVs are being developed in some countries affirms that strong policy commitments stimulate all elements of the automotive industry. China has become an early leader in both global development and national deployment and its efforts will help reduce costs and open opportunities for other countries. Development of two- or three-wheeled EVs/PHEVs for developing country markets could accelerate deployment, although care will need to be taken to ensure that this would not overtax the capacity of electricity grids.

Future efforts

Analysis of demand for heat, electricity and transport in emerging economies and developing countries highlights the diverse needs of each subsystem and demonstrates the overarching need for a systems approach to achieve sustainable energy access goals. This is most evident when considering a low-carbon future across all regions and sectors.

This short paper does not intend to provide a complete discussion of the issues associated with energy access and energy systems, but it hopes to advance the dialogue in literature and forums. Significant additional work is needed to carry forward a systems approach to energy access in emerging economies and developing countries, much of which will need to be targeted and conducted in relation to categories of use. Technology roadmaps specific to different regions – BRICS (Brazil, Russia, India, China and South Africa), the developing countries and the least-developed countries (LDCs) – could bring additional clarity to this discussion and generate the additional stakeholder engagement needed to provide sustainable energy access for all.

Following an Introduction that describes the energy systems approach, the next three sections of this report address the energy subsystems of heat, electricity and transport in more detail. Each energy subsystem will be explored according to its individual characteristics. The paper provides an overview of each subsystem, discusses the role of technology and key barriers, and concludes with an examination of the private-public interface required for deployment. The conclusion summarises key findings and suggests additional efforts needed to move towards more integrated energy systems in emerging economies and developing countries.

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Introduction

The term **energy system**, as used in this paper, refers to the totality of components that contribute to delivering energy services to end-users. To a large degree, the system comprises technologies that generate, distribute and convert energy. Yet the technological aspects of all energy systems – global, regional, national or local – reflect underlying factors such as the resources available, the stage of economic development, the political priorities of governing bodies and the opportunities for the private sector to realise a reasonable rate of return on their investment in providing energy services.

In general, an energy system can be organised in the following manner:

- **Energy sources** including fossil fuels, renewable energy and nuclear.
- **Distribution and conversion** including pipelines and shipping, electricity transmission and distribution networks.
- **Energy uses** such as transport, lighting, refrigeration, cooling, smelting and refining.[3]

This paper chooses to examine the overall energy system using a typology that breaks it into three energy subsystems: heat, electricity and transport.[4] Together, these three components accounted for 91% of global final energy consumption in 2008 (Figure 1).

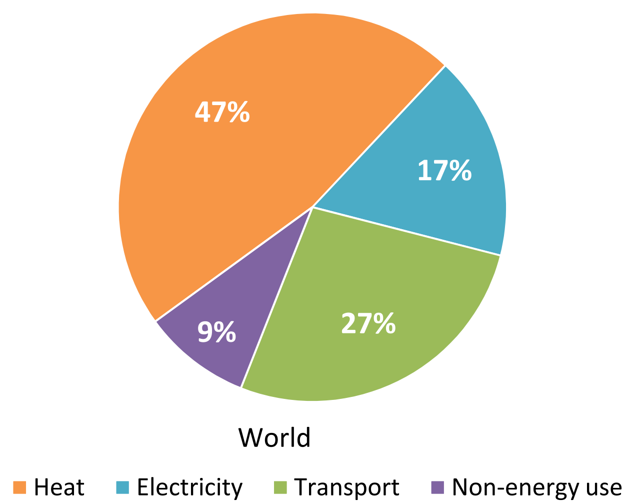
These three major energy subsystems provide a framework to discuss energy access that has not been prominently used in the global literature or the international dialogue on energy access as a whole. Heat, electricity and transport subsystems have different starting points, different infrastructure needs and different development pathways. Solving problems associated with household heating and cooking will, to a large extent, contrast greatly with approaches needed to improve the efficiency and reliability of existing electricity systems.

Better understanding of the differences between the various energy subsystems will help articulate both aspects of what needs to be done, and by whom. This will make it easier to organise stakeholders and develop solutions that can meet specific – and at times, diverging – needs within the overall energy system, noting that progress in all areas will need to be carried out in parallel. Involvement of the private sector will be vital in all situations. In some cases, small-scale local entrepreneurs and NGOs are best placed to take the leading role. In others, large companies need to engage in national or global scale deployment and operation of solutions. But governments must take a first step to provide a solid foundation for private sector action by establishing clear, consistent policies in the areas of economic development, energy security and environmental issues.

[3] Adapted from: Albert George, Kieran P. Donaghy, Rod Howe, Teresa Jordan and Jefferson W. Tester. "A Systems Research Approach to Regional Energy Transitions: The Case of Marcellus Shale Gas Development." Cornell University White Paper, http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/White%20Paper_9-22-10.pdf, 22 September 2010, Ithaca, NY

[4] Many other typologies exist, beyond those mentioned in this report. One notable energy type that is not addressed as an individual energy system is mechanical energy, which is noted by UNDP/WHO (2009). For the purposes of this paper, this is addressed in the section on electricity.

Figure 1 Global final energy consumption in 2008



Note: Non-energy use covers those fuels that are used as raw materials in the sectors and are not consumed as a fuel or transformed into another fuel. Non-energy use is shown separately in final consumption under the heading non-energy use. Electricity used in transport and heat is subtracted from transport and heat category and captured in the electricity category. Heat generated by auto producers for their own use will not be reported or registered, and therefore is not represented. Data on electricity use for heating in the industrial sector and other sectors are unavailable, and therefore have not been taken into account.

Source: Veerapen and Beerepoot, 2011.

It is hoped that presenting this perspective will increase discernment on the issues at hand, and lead to increased and more productive action. This exercise of mapping the energy system approach (also used by the UN in much of its technical work) to the UN-Energy clusters should help stakeholders refine their focus within energy subsystems while also capturing the benefits of more cross-cutting frameworks.

Further categorisation within an energy system context

Prior to implementation, technology and policy solutions considered for energy systems must recognise a country's specific resource, technological and community capacities, as well as the existing market structures. As the needs and abilities of emerging economies compared to developing countries can be significantly different, this paper makes a first categorisation based on stage of development.[5]

This paper categorises developed countries as members of the OECD, the major emerging economies as Brazil, Russia, India, China and South Africa (the BRICS countries) and developing

[5] It is understood that there exists a continuum from least developed countries to those qualified as developed countries.

countries as all other countries defined in the statistical listing by the United Nations (Figure 2).[6] Parts of the discussion will make reference to least-developed countries (LDCs)[7] but the needs of this group will not be addressed in detail. Several other regional categorisations will be used based on available data (countries that make up these groups are listed in the appendix).

Figure 2 Categorisation of the development status of countries

Differences between rural and urban needs are a second important distinction: it is estimated that 70% of the rural population lacks modern energy access, as opposed to 30% of the urban population. Solutions required in rural versus urban contexts can differ markedly due to factors such as population density and distance between energy supply and energy demand. Such factors can affect the development of sustainable business cases, deployment approaches and available local capacity for operations and maintenance.

Lastly, a division between residential and industrial sectors will be highlighted in the heat and electricity subsystem discussions, including a comparison of the diverse living conditions and types of industry.

Analysis according to the above categorisations has highlighted the unique characteristics of the heat, electricity and transport subsystems while also illustrating the similarities across all three. The paper identifies opportunities to apply common approaches to the overall issue of energy access while bringing to light areas in which varying targeted strategies will be needed.

[6] Although there is no established convention for the designation of "developed" and "developing" countries or areas in the United Nations system, the list found at this link provides an appropriate guide for this discussion: http://unstats.un.org/unsd/methods/m49/m49regin.htm.

[7] Least-developed countries (LDCs) under the UN statistics refer to a specific set of 48 countries of those categorised in the overall list of developing countries. This is not a formally adopted term, but is useful to illustrate the impact of differing needs of countries depending on the current level of overall development.

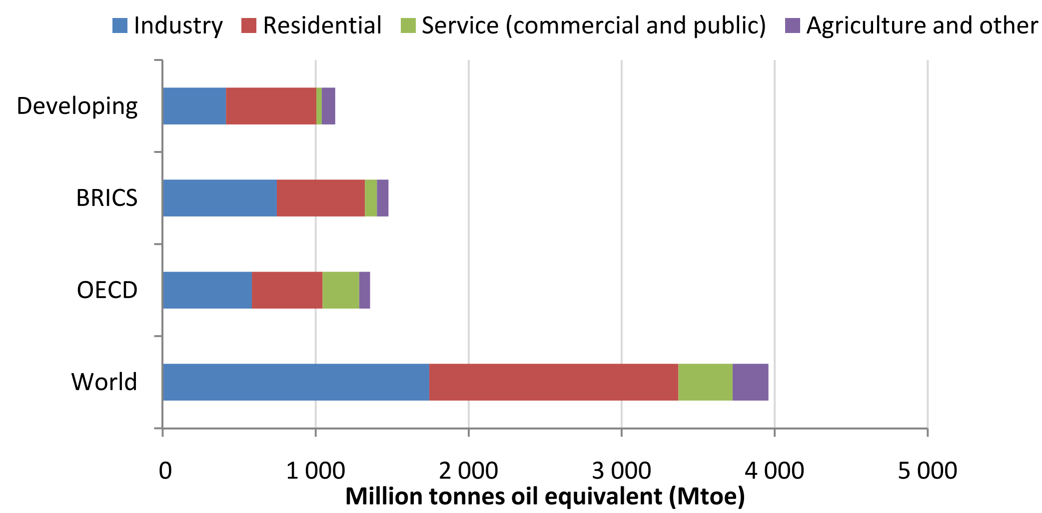
Heat

Context and current challenges

Thermal energy provides some of the most fundamental needs in society – domestic hot water, cooking and space heating in the building sector and process applications in the industrial sector. At present, 47% of worldwide final energy consumption is used for heat in this aggregated grouping, more than the combination of electricity and transport (Veerapen and Beerepoot, 2011). The market is dispersed and often decentralised, making it at once difficult to control and analyse. Trends do materialise, however, especially in the residential and industrial sectors.

Residential buildings mostly use heat for cooking and space and water heating. In 2008, the residential sector used 41% of global final energy for heat.[8] The share of residential heat out of total heat ranges from 34% to 39% in OECD and BRICS, up to 52% in developing countries (Figure 3).

Figure 3 Global final energy for heat consumption by sector and region in 2008



Note: Data for heat do not include that supplied by electrical energy estimated at roughly 2% of supply.
Source: IEA, 2009a.

The heat used in industrial processes is both environmentally and economically significant. The industrial sector tends to use heat in boilers, smelters or chemical transformations in the production of goods for trade. Industrial processes used 44% of the world's fuel for heat with BRIC countries using significantly more as a proportion of total and net heat demand than either developing or OECD countries.

[8] Cooling, although important in the case of efficiency, is powered by electricity in most cases and fits as a general appliance in the electricity section. Cooling is further more relevant to the electricity discussion due to its significant impact on peak loads for utilities especially in residential applications.

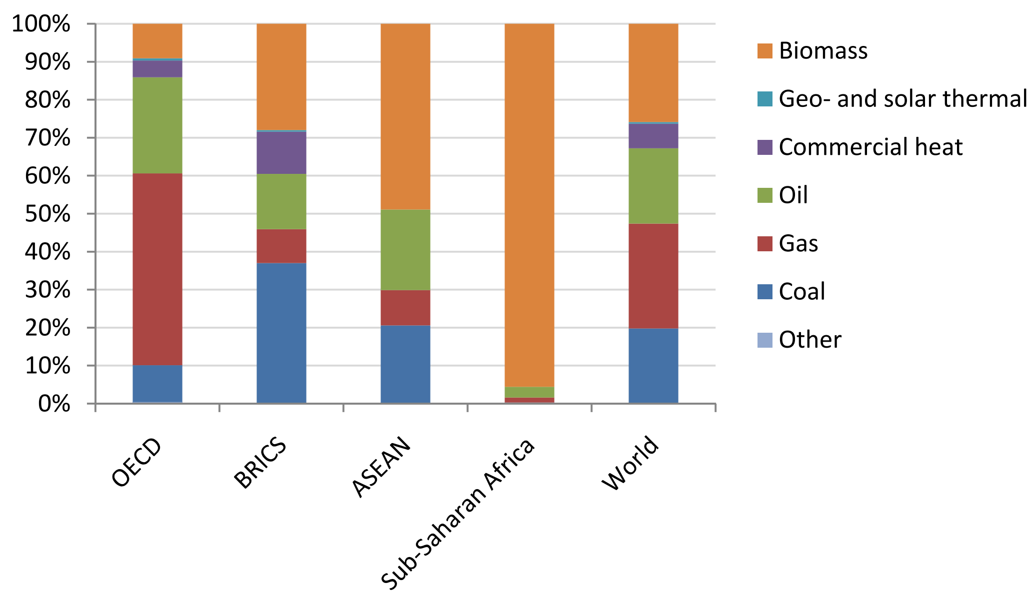
Although accounting for only 9% of global heat demand, the service sector can contribute to reducing emissions by incorporating energy efficiency into core business practices.[9] For example, the service and industrial sector in Thailand has made use of an Energy Efficiency Revolving Fund to implement efficiency renovations. (T'Serclaes, 2010).

Fuel supply

Globally, fossil fuels (including coal) make up two-thirds of all end-use fuel supply used for heat and therefore are still the most dominant fuels used in most countries (Figure 4). World end-use fuel supply captures fuels that are used for heat by customers. As an example, a commercial heating plant might use coal as a primary energy supply and will transform this into heat (steam) and provide this heat to customers through pipes. This output – commercial heat – is delivered to customers and as their fuel supply. In many cases, such as crude oil transformed into gasoline for transport, the category (oil) remains the same from primary to end-use fuels.

Fossil fuels usually require a vast import and distribution framework. From a global perspective, natural gas or LPG stoves are widely used. These appliances offer much higher efficiencies compared to indoor fireplaces or three-stone fires (chimneyless fireplaces made of three stones arranged vertically and used to support pots and pans). The cost of appliances is often considered very low, but in many developing countries, those costs may still be prohibitive. Also, emissions from fossil fuel use can have serious health and environmental effects, and if the fuel is not locally available, such use increases dependence on imports.

Figure 4 World end-use fuel supply for heat consumption (selected countries, 2008)



Source: IEA, 2009a.

[9] The service and agriculture sectors will not be discussed in detail in this report due to their small proportion of overall heat consumption in the developing and BRICS countries, but importance in the development agenda and growth in these sectors warrant future analysis.

The next significant portion of fuel is biomass[10] at 26%, or 1 056 million tonnes of oil equivalent (Mtoe), and varies by country as shown in Figure 4. The biomass category is composed of two subcategories, traditional and modern. Traditional biomass, such as twigs, firewood, dried leaves and crop residues, is burned at very low efficiencies of 8% to 10% in three-stone fires, or indoor fireplaces without chimneys (IEA, 2010a). Whereas modern biomass (made of preformed wood briquettes or pellets) is burned in advanced stoves with high efficiencies. Globally, traditional biomass is more prevalent than the modern form, accounting for 750 Mtoe of the total 1 056 Mtoe used on a global basis. In fact, 2.7 billion people, 40% of the population, make use of simple cookstoves using traditional biomass. It is estimated that the use of these stoves causes 1.45 million people to die of respiratory complications every year (IEA, UNDP, UNIDO, 2010). Burning wood with high moisture content also produces soot that has been found to have been deposited on Tibetan glaciers, increasing absorption of the sun's heat (Luoma, 2010). The issue is more comprehensively addressed in the Modern Heat Access section.

Commercial heat, solar thermal and geothermal sources provide for 7% of global heat supply. Commercial heat – where heat is sold and delivered through pipelines – was used widely in the former constituents of the Soviet Union and today provides for a large share (43%) of residential and service heat consumption in these countries (IEA, 2009a).

Heat demand

The IEA scenarios project that primary energy use will rise by 27% from current levels in the BLUE Map Scenario to 2050 or by 84% in the Baseline Scenario[11] to 2050. Based on the current portion of heat in total primary energy use, we can expect to see high levels of growth for heat demand in the future.

Heat demand across all sectors will grow, driven mostly by the high growth in BRICS and developing countries. BRICS and developing countries are projected to contribute more to greenhouse gas emissions than all OECD countries combined by 2050, with India and China contributing to almost 40% of the total. Reducing emissions must cover all end-use sectors: the heat systems of industrial, residential and service sectors. Many of these reductions will occur with energy efficiency programmes (such as heat recycling), switching to renewable fuel use and increasing access to modern fuel appliances.

Although issues in heat demand will vary by country, many are shared and can be discussed under the two main headings of residential and industrial sectors. Within each sector (residential and industrial) the most pertinent issues are then discussed to examine specific challenges in a more detailed manner.

[10] Biomass in this categorisation further includes combustible waste used for heating.

[11] The IEA's ETP BLUE Map Scenario sets out the least-cost path to reduce global energy-related CO_2 emissions to half their current levels by 2050. This scenario examines ways in which the introduction of existing and new low-carbon technologies could achieve this goal, while also bringing energy security benefits in terms of reduced dependence on oil and gas, and health benefits as air pollutant emissions are reduced. The BLUE Map scenario is consistent with a long-term global rise in temperatures of 2˚C to 3˚C, but only if the reduction in energy-related CO_2 emissions is combined with deep cuts in other greenhouse-gas emissions. The Baseline Scenario considers the business-as-usual case, not reducing emission levels to any predetermined goal by 2050. The BLUE Map and Baseline Scenarios are based on the same macroeconomic assumptions.

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Role of technologies and barriers for deployment

Many technologies exist to meet the world's heating needs. However, not every technology is suitable to each country or even every region within a country. There is no one-size-fits-all approach for every country though many options are available. Stakeholders must recognise a country's specific resource, technological and community capacities while implementing technology solutions. Most countries will need to employ an appropriate mix of the available heat technologies to make advances from their respective status of heat energy use.

Generally, the available technology solutions can be grouped into three broad categories: modern heat access, renewables for heat and thermal efficiency improvements. The three categories are then divided by approach in the industrial or residential sectors. Some examples in each category are presented in Table 2.

Industrial-scale heat projects differ in magnitude and approach over residential heat projects. Successful residential sector heat projects involve a wide array of stakeholders – significantly including local communities (Niez, 2010). Involving stakeholders is part of a holistic approach where, for example, a community's appetite for technology absorption could be elucidated. In addition, many technologies require customised solutions set in the geographic, political and societal context of a country.

Table 2 Example of heat technologies by application

	Modern heat access	Renewable heat	Thermal efficiency
Industry*	LPG, biogas, natural gas appliances	Solar thermal collectors, high-efficiency waste biomass fuel use	Coke oven gas recovery, power generation from blast furnace gas
Residential	Improved cookstoves†	Advanced biomass cookstoves,** biogas digesters, solar thermal collectors, geothermal heat	Improved building envelope and heating/cooling installations

*Fuel switching (increased use of electricity and natural gas) is expected to increase in the industrial sector but will largely be driven by conventional market dynamics and is beyond the scope of this paper.

**An advanced cookstove differs from an improved one since the advanced model has much higher operating efficiencies (over 75% versus about 25% for improved stoves) and uses preformed biomass fuel such as wood briquettes or pellets.

†Improved cookstoves have incremental though important benefits over traditional cookstoves such as chimneys to vent noxious pollutants outdoors.

Modern heat access

Modern heat access has been defined as the "percent of people that use electricity, liquid fuels or gaseous fuels as their primary fuel to satisfy their cooking needs … but exclude all traditional biomass (*e.g.*, firewood, charcoal, dung, and crop residues) and coal (including coal dust and

lignite)" (UN, 2009). It is important to note that renewable fuels such as biogas are included in this classification. In the absence of renewable heat support or a local economy for biogas, LPG or natural gas fuels are used because of low costs, high scalability and a wide array of stakeholders. Electricity is an especially important modern energy source and is discussed in its own section.

The overarching goal of modern heat access is captured by an effort to maintain and continuously improve the infrastructure already in place while extending it to reach more of the population. Challenges occur when there is little or no modern heating infrastructure in place. The problem of laying heat infrastructure goes beyond physical distribution and appliances. Financial and regulatory frameworks are needed for sustainable energy markets to take hold. Examples of such groundwork include proper import tariff management of fuel supplies or quality control for fuel bottles. Local capacity and buy-in are also necessary for modern heat access projects to be sustainable. Local capacity is vital for training workers in the installation, use and maintenance of gas lines, and for home connection valves. Buy-in from communities is necessary since it is widely accepted that communities cannot be "given" heat installations if they are to be sustainable. Instead, the customers must be convinced of their benefits over present technologies (World Bank, 2010a).

Residential

The challenge of providing modern residential heat access can be seen in two timeframes: universal access to modern fuels in the long term and access to improved cookstoves to quickly improve conditions in the short term. The physical infrastructure required for modern fuel use (such as natural gas or biogas lines to customers) and distribution or supply chain frameworks (such as countrywide LPG bottle distribution and refill services) will require time and resources to establish. Improved cookstoves, alternatively, improve the efficiency and safety of existing stoves with chimneys but still anchor the user to reliance on traditional biomass. This points to the need for a longer-term view towards modern heat access or constructing a modern biomass supply infrastructure, while at the same time deploying transitional technology.

Making use of modern fuel appliances will be part of many countries' long-term heat energy efforts. Modern fuel appliances such as LPG and biogas stoves can be used at much higher efficiencies (at least 80%) compared to traditional biomass stoves unlocking many benefits. Modern fuel use can minimise indoor and outdoor air pollution as well as health risks (IEA, 2010) and reduces energy consumption for the same task.

A challenge to improving residential heat access is the "urban-rural divide." Heat appliances in rural regions are generally more expensive and challenging to diffuse than in urban settings. For example, access to modern fuels that require infrastructure investments such as gas pipes and conduits will benefit from economies of scale in urban applications. Attempting to install such gas lines in rural regions with large distances between customers and sources of gas can be prohibitively expensive. There exist several solutions for this problem. Some residential projects, such as solar water heaters or improved cookstoves, can be implemented in a repeated way in both rural and urban communities. Another market strategy is to use the more accessible urban market as an investment springboard to then reach rural areas. The improved Sri Lankan biomass cookstove, called Anagi ("success"), has achieved profitability and scalability in this way – reaching net sales of 6 million cookstoves and improving the lives of customers (GVEP, 2009).

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As described in the *World Energy Outlook*, 2010 Universal Modern Energy Access Case, 445 million people switch to LPG stoves by 2015 and an additional 730 million people switch to LPG by 2030[12]. Even with such substantial increases in LPG use, the total world oil product demand would increase by only 0.9% of the projected global oil demand in 2030. Further oil demand from the additional 1.2 billion people using LPG is roughly equivalent to only 5% of oil demand in the United States today. Also, "it is widely accepted that improved stoves and greater conversion efficiency would result in emissions reductions" (IEA, 2010a). However, the problems of security of supply, volatility in price and emissions remain.

Industry

Small-scale industry, such as small shops and "backyard" manufacturing, makes much use of access to modern heat. In many cases, a reliable source of heat energy is a prerequisite for a successful business operation. Synergies exist between industrial and residential sector access. One example is small-scale pottery makers who also sell improved cookstoves to their communities at profit. The small industrial enterprise uses modern heat access to create these ceramic cookstoves, and these cookstoves then cascade modern heat access to the surrounding populations. In addition, employment and income have been noted to rise significantly with a small-scale industrial seed operation like that mentioned. The increased income then leads to higher appliance ownership and ability to pay for modern heat infrastructure service – continuing the virtuous cycle (GVEP, 2009).

Renewable heat

Renewable heat offers the main benefits of energy security and stewardship of the environment. Emission reductions in new projects will be achieved by implementing renewable heat technology. Some renewable technologies are in Table 2.

Barriers to renewable heat projects will stem from its cost compared to other sources, public acceptance and ensuring that *renewable* also means *sustainable*. Some societies may view renewable energy technologies as "second class" and therefore resist acceptance. This has been seen in South Africa, where solar thermal and solar electric technologies were rejected even when competitive costs and other benefits were presented (Niez, 2010).

In many cases a country's energy security will improve significantly as a result of more renewables and a more diversified energy mix. An anomaly in this regard is Sub-Saharan Africa. Although much of the energy used for heat consumption in this region is from *renewable* biomass sources, the current practise of collecting and using the renewable fuel is entirely *unsustainable*. Deforestation is a very real concern for the populations in the countries in this area since it may severely limit the ability to find fuel for cooking. Proper management of resources and subsidised efficient cookstove programmes are necessary.

In most cases, fossil fuel subsidies will need to be phased out in order to encourage the deployment of renewable heat. Such cost-competitiveness efforts can also produce opportunities

[12] The *World Energy Outlook*, 2010 Modern Energy Access Case quantifies the number of people who need to gain access to modern energy services and the scale of the investments required by 2030. It includes interim targets and is very much related to the Millennium Development Goals. The quantified targets (in access to electricity and access to clean cooking facilities) for both rural and urban communities are outlined in the *World Energy Outlook*, 2010.

for the creation of jobs and business opportunities in addition to meeting energy goals. Many renewable heat applications have been implemented profitably in multi-billion-dollar markets. Deployment of solar water heating in China has benefited from strong and sustained government support, and Box 1 is a prime example.

Box 1 China is the largest market for solar water heating in the world

China uses about 80% of the world's total installed solar heater collector area – a market with USD 6.3 billion in sales in 2008. Most products are made up of small water tanks and panels installed on buildings to heat residential water with solar energy. By 2008, installed capacity had grown nine times over the 1998 level of 15 million km^2. The IEA projects China's solar heat use to grow another 450% by 2035 in the New Policies Scenario. Solar water heating now covers over 3% of residential water heating demand in China and so absolute growth will be significant. The future market potential is very large since heat used for China's residential water heating is equal to about 31% of total energy consumption by US industry (about 123 Mtoe per year) (IEA, 2010a). The remarkable success of solar water heaters in China is attributed to firm and consistent long-term national goals for installation targets ensured by means of tax rebates or exemptions, preferential pricing and credit guarantees (NREL, 2004).

Note: The New Policies Scenario takes into account the broad policy commitments and plans that have been announced by countries around the world to address either environmental or energy-security concerns. National announcements to reduce greenhouse-gas emissions, for example, are included (IEA, 2010a).

Residential

Community biogas installations will play a role not only in reducing global emissions but also in making energy more accessible. A biogas system consists of a biogas digester, gas pipes to homes and some payment mechanism for consumption. Digesters take organic waste such as agricultural manure and ferment this into usable gaseous fuels. These fuels are then sent through pipes to the end users, who usually pay prior to use. Since community biogas systems are renewable and most often sustainable, they fit well within the renewable heat category. In addition, biogas will be one of the fundamental pillars in enhancing energy access.

The application of solar hot water heating technology is present globally and significant deployments are already occurring in emerging economies and developing countries. Places that do not experience long periods of below-freezing temperatures can use the simplest and most cost-effective kinds of this technology.

Geothermal heat use is most prevalent in colder countries for use in combined space and water heating applications, especially ones with favourable access to large geothermal aquifers. Geothermal heat is also useful in warmer climates in industrial applications as well for space cooling using chiller technologies. Geothermal energy has had great growth in countries such as Indonesia and the Philippines with volcanic heat resources close to the surface. District geothermal heating is expected to increase thanks to emerging needs in Eastern Europe. Countries in Eastern Europe are facing the need to renovate aging coal-fired district heating systems while having to reduce emissions (IEA, 2011f). These countries also have access to large geothermal aquifers.

Industrial

Fundamental transitions to renewables for heat in large-scale industrial applications will face many challenges due to high temperature requirements. Processing of basic metals, chemicals and non-metallic minerals are the largest energy users within industry and all require more than 50% of heat to be over 400°C (Veerapen and Beerepoot, 2011). In this segment, synergies with renewables such as supporting high-temperature coal-fired process with biomass are possible and encouraged. Just 30% of industrial applications require medium-temperature heat (100°C to 400°C) and 27% have low heat demand (less than 100°C). These low-temperature applications are great fits for industrial-scale solar thermal installations or geothermal heat. In addition, combined heat and power generation offers an easy way to integrate renewable sources flexibly.

Combined heat and power generation (CHP) takes form of a plant that extracts not only electricity but also heat from fuel. CHP plants can significantly increase the efficiencies of existing heating installations. CHP can take the form of upgrades or new plants with net-zero or even revenue-generating (net-positive) energy savings. Such technologies will contribute to vital emissions reductions in the near to intermediate term. Small and medium industrial processes such as solar drying technology can play a role in overall development by improving health and increasing productivity (Conserval Engineering Inc., 2005).

Thermal efficiency

Overall, upgrades to existing heat processes (*e.g.*, steel smelting, building heating) are needed to prevent both modern and developing countries from polluting and wasting energy reserves. Thermal efficiency increases are by far the most cost-effective means of managing current energy consumption, often returning initial investments in a few years. A country striving to improve its thermal efficiency simultaneously benefits from enhanced energy security thanks to an uncoupling of economic growth and energy demand. Key long-term competitiveness for a country and company can stem from a very dedicated effort to enacting efficiency goals in heat use. This option could lead to achieving the goal of a 40% reduction in energy intensity by 2030. The largest impact in energy intensity reduction will stem from efficiency improvements in the industrial and residential sectors.

Residential

Many higher-efficiency products already exist such as advanced building envelope seals and insulation. These products must be rapidly distributed on a large scale to achieve energy savings and reduce worldwide emissions. For example, the IEA *Energy Technology Perspectives* BLUE Map Scenario projects 77% of China's energy savings and 54% of CO_2 emission reductions by 2050 could come from efficiency improvements in space heating, cooking and water heating (IEA, 2010b). Steps in this direction must favour improvements in new and existing residential buildings and especially in multi-family complexes popular in the BRICS countries. Much of the building stock in emerging countries will be new, creating advantages for new efficiency regulations and business. OECD countries, by contrast, must rely on renovations to improve efficiency. Ensuring proper maintenance of installed heat appliances will benefit all populations. By reducing the losses in heating buildings, less fuel is burned, so emissions are reduced and money is saved.

Industrial

Fossil fuels (coal, natural gas and petroleum, in decreasing order of importance) now provide for the majority of industrial heat use and will likely continue to do so to 2050 on a global basis. Efficiency improvements to equipment and processes will offer least-cost options to reducing CO_2 and noxious emissions in industry (IEA, 2010a). As fossil fuel prices have become increasingly volatile recently, industry must make use of best available technologies in all countries to reduce dependence and hedge against price variations.

Best available technologies have been applied already in non-OECD countries on large scales. There are examples where emerging economies or developing countries have deployed technologies that are comparable for energy efficiency on a global scale and where significant effort is needed to bring them in line. China's industrial energy savings potential in the cement sector is less than that of a number of developed countries and is at the global average, while in the steel sector, it is second highest and above the global average (IEA, 2010a). The fact that China is the largest global producer of both commodities shows the importance of industrial energy efficiency.

A view to sustainable resource use is not solely the responsibility of governments, but of industry as well. Within the industrial sector, the five most energy-intensive sectors are and will continue to be iron and steel, cement, chemical and petrochemical, pulp and paper, and aluminium. The five industries emit 77% of the total direct CO_2 emissions from industry and account for two-thirds of the total industrial energy used (IEA, 2010a). Demand for industrial materials is expected to double or triple, but the energy demand need not. A case in point is the cement industry. Cement producers decreased energy intensity for output by one-half while tripling production since 1971 (IEA, 2010b). Although it may be assumed that increased production tends to improve efficiencies this is not always the case. Strong commitment to efficiency gains by companies and government is always required.

The private-public interface for heat

Many of the heating technologies discussed above are now widely available and accessible, and have been implemented profitably in prior projects. Deployment of solar water heaters and biomass digesters in China and effective supply chains for improved cookstoves in Sri Lanka are strong examples of the private sector potential in heat energy. Targeting energy-poor households is difficult but has been achieved in many cases. Lessons learned are remarkably similar from all stakeholders with prior experience in heating. A summary of these keys to success, listed by technology application, follows the summary table of main activities for the private sector in heat energy subsystems (Table 3).

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Table 3 Main activities of private sector heat entities

Core business
Social investments and philanthropy
Advocacy and public engagement

	Large multinational corporation	Medium-scale regional company	Local private company (community-based)	NGO
Modern heat access: Access to modern fuels	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Advocacy and public engagement
Modern heat access: Improved cookstoves	Social investments and philanthropy; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Social investments and philanthropy; Advocacy and public engagement
Deployment of local residential renewable (RE) heat	Social investments and philanthropy; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement
Deployment of industrial RE heat	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement		
Increasing thermal efficiency of residential buildings	Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Advocacy and public engagement
Increasing thermal efficiency of industrial plants	Core business; Advocacy and public engagement	Core business		Advocacy and public engagement
Capacity building	Social investments and philanthropy	Social investments and philanthropy	Core business; Social investments and philanthropy	Core business
Public education	Social investments and philanthropy	Social investments and philanthropy	Core business; Social investments and philanthropy	Core business

Four main private sector entities are identified as having potential to play a lead role in improving access to heat energy: large multinational corporations, medium-scale regional companies, local private companies (community-based) and NGOs. Table 3 summarises suggested roles, according to major capacity and knowledge of specific entities, and clearly shows areas in which collaboration is needed; it is meant to spark discussion about activities of the private sector participants and provide the basis for developing pathways to success. The authors acknowledge that some private sector players are already engaged beyond what is shown in the table and some exceptions to this summation exist.

Private and public sector roles differ but are highly complementary. Governments must prepare the stage for successful and practical implementation by the private sector. A successful government framework can provide:

- Local technicians, operators and owners who are trained and developed in co-operation with the companies and government.
- A willingness to co-operate professionally.
- Local governmental support in advocacy, publicity and education.
- Long-term and reliable financing infrastructure.
- Clear visions and quantitative targets with the appropriation of funds for each goal.

All of the above points are addressed in co-operation between government and private participants. Governments should build capacity within their jurisdictions, as was the case when India's Bureau of Energy Efficiency trained local auditors. These auditors were valuable in calculating financial benefits from efficiency projects backed by international investors (T'Serclaes, 2009). Private participants should provide feedback to governments about such capacity needs and offer technical advice.

Modern heat access

Manufacturers, global and domestic will play a significant role and will do so along side regulations and policy established by the public sector. Where infrastructure deployment is involved to deliver gaseous fuels, both technology and business models for sustainable operation will be needed and approaches employed globally could be leveraged. The investments required will require financial investment and long term commitment from the public sector and input and advocacy from the private sect will be needed to support this. All actors can play a role in broad stakeholder engagement, especially including consumers, that will be needed to ensure acceptance of new technology and long-term, safe operation and maintenance of appliances and infrastructure.

Collaboration is particularly vital in modern heat access initiatives such as improved cookstoves. The Global Alliance for Clean Cookstoves has gathered many lessons in that area. A successful supply chain is a must for improved cookstoves in rural regions, and requires that the "institutions and companies involved make use of employees with knowledge of local market developments, installation and maintenance processes" (GVEP, 2009). The skills and knowledge within local communities can be of great value to the manufacturer of the technology to be deployed. Exploiting existing supply chains with strategic partnerships can also prove useful, especially when trying to reach rural populations. Pratki (India), a cookstove manufacturer and retailer, partnered with SELCO (India) due in part to its existing supply chain in selling solar powered lights to rural populations. Nascent supply chains for energy access in such rural areas will often need subsidies to get started (GVEP, 2009). Such early-stage investments by philanthropic entities are welcome by the governments and enterprises involved in the daunting task of installing more effective heating technologies.

Box 2 The Anagi improved cookstove

An estimated six million improved Anagi cookstoves have been sold to date in Sri Lanka since 1991. The stoves burn traditional biomass with higher efficiency and significantly less indoor smoke thanks to their improved design. Modern and innovative subsidised business models were used such as marketing with "try before you buy."

Donor support over two decades from IDEA, DGIS, NORAD, SIDA,[13] and Sri Lanka's Ministry of Power and Energy, Ministry of Environment, and Ministry of Plantation and others was recognised as indispensible to the success of the marketing of the stove. The availability of microfinancing has also proved important in such commercial approaches. Another successful but newer effort is the improved cookstove initiative, which was created, funded and supported mostly by Envirofit International, the Shell Foundation and Accenture Development Partnerships. Key lessons from this partnership included the input from supporting organisations on business model review and supply chain construction support (GVEP, 2009).

Renewable heat

Beyond the technology developers, much private sector involvement in renewables is located at the deployment and product diffusion stages. Introducing new technologies to communities will pose the "entrenched" problem. Communities that have made use of traditional stoves or coal for a long time may find it difficult to completely switch their lifestyles, which centre on fuel gathering and maintenance, to accommodate a new technology such as a biogas grid. It is thus imperative for any new energy project to be convincing to communities. The end-users must be convinced that their original methods are subpar and must be improved, and see that the new technology will be better, allowing them more safety, lower costs, free time, etc.

At the same time, training and building capacity in local regions is important, especially in highlighting and targeting local population priorities (UNEP, 2011). In fact, local engagement is one of the keys to success in thermal projects particularly when installing technologies very new to the community (World Bank, 2010). An excellent example of successful local engagement comes from inland China, where several biogas grids provide high quality and renewable opportunities for local communities. These communities have benefited from pre-paid 'smart cards' that minimise the chance of stolen receivables or unreliable payments. Customers must charge their cards with prepayment for a set amount of gas. These cards are then used to open the home valves connecting to the biogas grid – releasing exactly as much biogas as was pre-paid. In all, such novel and profitable business ideas hold great potential for renewable infrastructure.

Thermal efficiency

A significant benefit for efficiency improvements in developing countries lies in technology sharing. Indeed, the "development trajectory" of developing countries can be very different from that of the developed economies due to the possibility of "leapfrogging" and avoiding mistakes by learning from others' experiences. Neighbouring or similar countries share lessons with particular

[13] Integrated Development Association, Dutch Ministry of Foreign Affairs, Norwegian Aid Agency for Development, and the Swedish International Development and Cooperation Agency, respectively.

effectiveness. So-called South-South technology transfer, especially within private-public partnerships, is a successful tool in implementing the energy revolution in the developing world.

In industrial efficiency especially, a concerted effort between private and public participants is necessary, since simply relying on private innovation will not do because better heat technologies are not always developed in favour of less-expensive alternatives. Upfront capital subsidies can make large industrial efficiency investments more palatable and lower the risk on return. BRICS countries and other rapidly developing countries can make the biggest impact by integrating best available industrial technologies due to current production levels and rates of growth in these industries. These best technologies should be actively explored just as any strategic advantage would be.

India's National Mission for Enhanced Energy Efficiency introduced financial instruments in 2009 to facilitate energy efficiency development called the Partial Risk Guarantee Fund and the Venture Capital Fund for Energy Efficiency. Such risk mitigation instruments apply well to residential, service and industrial sectors. This example demonstrates that successful heat projects often tend towards close and professional partnerships between industries and governments. Private participants co-operate at arm's length with public entities, through programmes such as guaranteed loans and risk guarantee funds. Financial support such as loan guarantees coupled with technical support can offer risk mitigation for investors and have proved to be very effective (T'Serclaes, 2010).

Electricity

Context and current challenges

Electricity provides energy for a wide range of services and is a universal energy carrier, the backbone of many societies. Electricity represents 17% of overall global energy demand and is expected to increase to 23% by 2050 (IEA, 2010b). According to the IEA BLUE Map Scenario, electricity demand is growing between 30% and 37% in OECD member countries from 2007 until 2050 compared to 104% to 509% in non-OECD regions in the same time period.

Electrification can help achieve economic and social objectives. Electricity provides lighting, refrigeration and appliance power that would be difficult to replace with other forms of energy. The intermediate conversion of primary energy sources (*e.g.,* wind, fossil fuels) into electricity also increases the flexibility of using mechanical power through efficient electric engines (Bates, 2009). Electricity increases productivity by reducing labour-intensive and time-consuming tasks and promotes health and education. Electricity access is essential for human development and a necessary – but not the only – motor for economic development.

Modernisation of electricity systems and expansion to meet growing demand must continue globally with a vision of sustainability from environmental, economic and security perspectives, especially in emerging economies and developing countries. Strategic planning and a long-term vision are required to build the foundation for a flexible, scalable and adaptable electricity system. Emerging economies and developing countries have the opportunity to build up a modern electricity system that meets future requirements, but the pathway for these countries will be different from the one followed in the past. This is due to evolving technical, financial, political, social and environmental conditions that are yielding new opportunities and challenges to simply achieving access to reliable and affordable electricity.

Access to electricity

Currently 1.4 billion people (about 20% of the global population) lack access to electricity (IEA, 2010a) and a further 1 billion have only intermittent access.[15] Universal access to electricity would increase CO_2 emissions until 2030 by only 1.3% if electricity is substituted for the traditional fuels used to supply basic needs (*e.g.,* candles, LPG, kerosene). CO_2 emission would rise by 0.9% if the generation mix of the 450 Scenario[16] is applied. These increases are disproportionately modest compared to the number of people benefiting (IEA, 2009b).

Even where access to electricity exists, frequent power outages are a common problem in emerging and developing countries and make it impossible to provide a continuous electricity supply. These power outages are often from load-shedding, a frequent practice to compensate generation deficiencies by partly cutting off some load to users. Table 4 confirms that power outages are more frequent in non-OECD countries and damage economic outputs. The economic

[15] http://www.unglobalcompact.org/Issues/Business_Partnerships/Private_Sector_Forum_2011.html.

[16] The 450 Scenario corresponds to the long-term stabilisation of the atmospheric concentration of greenhouse gases at 450 parts per million of CO_2-equivalent (eq), which corresponds to a 50% chance of restricting the increase in the global average temperature to 2°C.

impact stresses that any investment to strengthen the electricity system and increase the amount of electricity for productive use enhances company incomes. Thus the affordability of electric services also increases and assures the financial viability of the service (AGEEC, 2010).

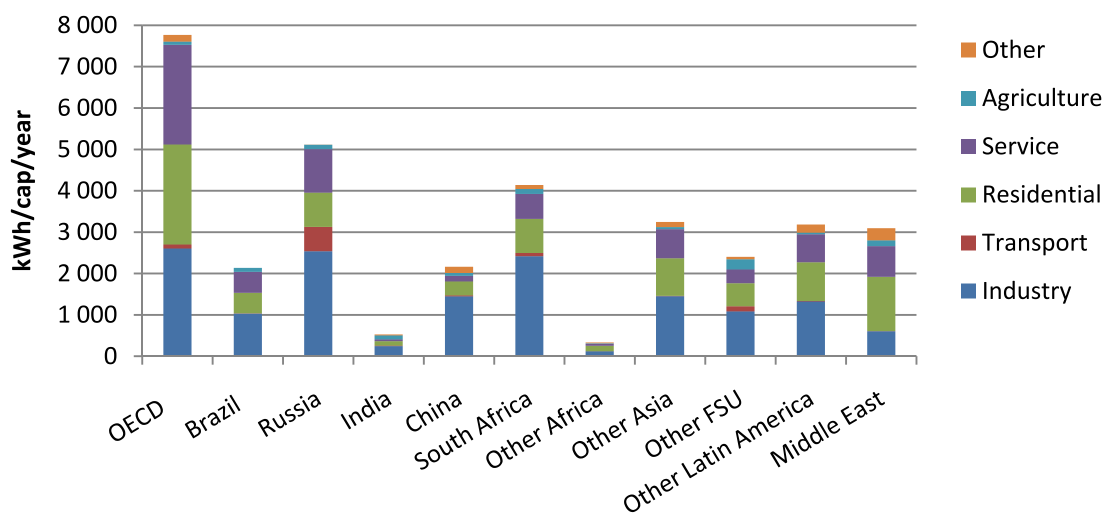
Table 4 Electricity system reliability and economical impact of outages (a typical month)

Region	Number of Power Outages in a Typical Month	Duration of Power Outages (hours)	Value Lost Due to Power Outages (% of Sales)
OECD	…	3.51	2.25
East Asia and Pacific	4.96	3.2	3.08
Eastern Europe and Central Asia	5.39	4.54	3.78
Latin America and Caribbean	2.82	7.09	5.14
Middle East and North Africa	14.3	3.46	5.57
South Asia	42.18	4.56	10.68
Sub-Saharan Africa	10.45	6.64	6.52
World	8.99	5.36	5.28

Source: (World Bank, 2011).
Note: Due to a lack of consistent annual data, the table represents a regional summary of individual survey results of firms carried out from 2003 to 2010.

Electricity consumption per capita varies substantially around the world as illustrated in Figure 5. OECD countries consume most and on average around 7 800 kWh/capita/year. India and Africa, excluding South Africa, consume least (less than 600 kWh/capita/year). This demonstrates differences both between OECD countries and others, and also within the BRICS countries and developing countries. This continues to reinforce that one size fits all does not apply to this situation and that further regional analysis is required.

Figure 5 Annual electricity consumption per capita, 2008



Source: (IEA, Statistics).

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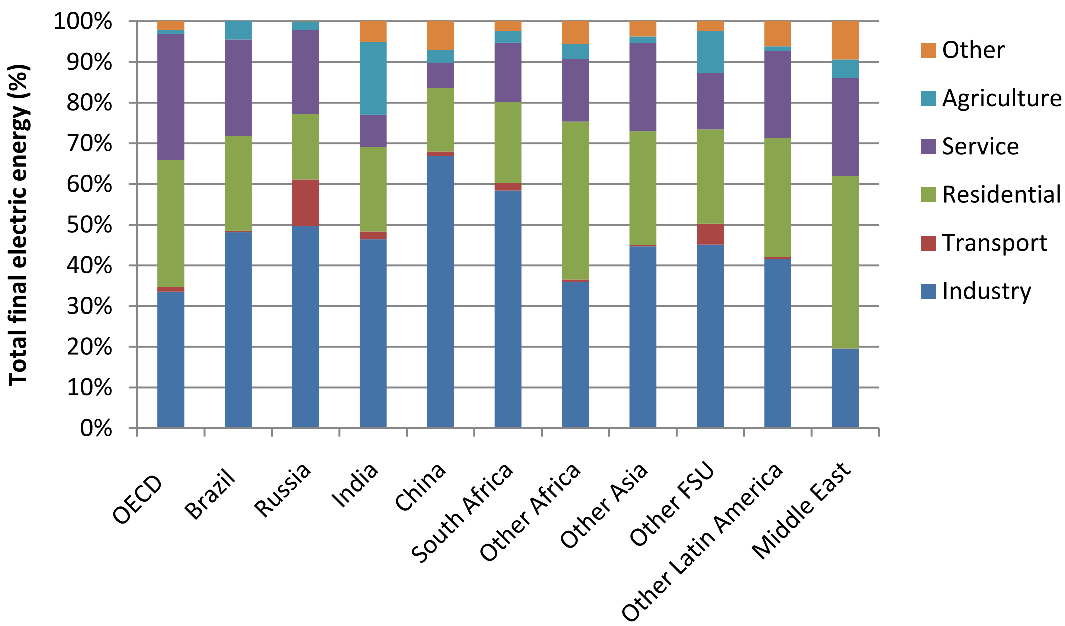
Sector electricity end-use

Electricity usage in different end-use sectors (*i.e.*, industrial, transport, residential, service, agriculture and others) varies across regions and countries as shown in Figure 6. The share of electricity used by industry is 47% to 50% in Brazil, Russia and India, and 59% in South Africa and 67% in China (compared to an average of 33% in OECD countries). Industry in the Middle East uses less than 20% of the electricity and between 35% and 45% in all other regions.

The share of transport in electricity is highest in Russia (12%) and other former constituents of the Soviet Union (5%) because of extensive railway and pipeline transport networks. Agriculture is an important consumer in India and other former Soviet Union constituents (10%, excluding Russia).

The share of the agricultural sector in Russia and India is higher than in other regions. This indicates their economies' dependence on agriculture and probably the extensive use of electric devices, which stresses the importance of such efficient machines as irrigation pumps.

Figure 6 By-sector electricity end-use in countries and regions, 2008



Source: IEA Statistics.

The two graphs demonstrate the level of complexity in the electricity energy system. The per-capita analysis on overall electricity demand can provide a comparison of relative amounts of electricity available if distributed evenly across the population. But as more fully demonstrated in Figure 6, the high proportion of use in the industrial sector precludes wide use by individuals. The OECD and Middle East countries show the largest combined residential and service sector electricity proportions, while China has the largest proportion of industrial demand and smallest proportion of combined residential and service sector electricity demand. High electrification in the industrial sector does not ensure access to electricity for other sectors, but the infrastructure deployed for industry could be used to service residential and agriculture sectors.

Electrification programmes must also meet different needs in urban and rural communities. The majority of the population without access to electricity (85%) lives in rural areas (IEA, 2010a). This is mainly due to the challenges of delivering the necessary infrastructure in areas with low population density that are often a long distances from large-scale generation sites. About 95% of population growth over the next 30 years is expected to occur in urban areas (World Bank, 2010a).

Even in many urban centres where the infrastructure is in place, rapid urbanisation rates call for additional connections, increased generation capacity and the necessary electricity network upgrades and new infrastructure. Conditions for investments for energy companies might be more favourable in urban areas because the average income, electricity consumption and population densities in cities are generally higher than in rural populations and because infrastructure is partly developed. Solutions for rural populations will differ in many cases from urban solutions and may require building of demand and infrastructure. Slums in adjacent to urban areas, although decreasing in relative numbers, continue to expand and are increasing in absolute numbers. People living in slums often struggle to gain legal and dependable electricity connections, which creates a breeding ground for electricity theft and informal electricity markets (World Bank, 2009). In both urban and rural environments, the consumer's ability to pay for energy services is reduced among the poor, reducing opportunities to gain access to electricity.

Role of technologies and barriers for deployment

Some emerging and developing economies have regions with well-developed electricity systems while others do not have reliable systems in place or have not even installed the necessary infrastructure. These countries also typically face specific challenges characterised by high growth in electricity demand, high commercial and technical losses in a context of rapid economic growth and development, dense urban populations and dispersed rural populations. This context triggers specific challenges that can potentially be met by technology solutions through the adoption of new products and improving existing ones. Solutions available today, such as smart grids and modern renewable energy technologies, were not around for OECD countries at the similar stage of development. Non-OECD countries need to exploit long-term opportunities to move quickly towards sustainable energy systems and avoid technology lock-ins, especially since electricity infrastructure is characterised by long lifetimes.

Electrification

Electrification is the process of building up an electricity system that can transfer electricity from generation to users. In an urban context, grid extension is the logical choice and electrification approaches are very similar around the world. In the rural context, there is a broader range of options and, in order of increasing consumers connected, the following options are available: stand-alone installations, micro-grids and grid extensions.

It should be noted that electrification projects are often a nation-building effort and not carried out for development purposes alone. Benefits might, however, trickle down to the general population by making a grid connection possible, leveraging the infrastructure installed for the industrial purposes to enable wider electrification initiatives. It should be noted that electrification

is not enough though to increase access to electricity as the connection cost can be a barrier for low-income families.

Grid extension is generally the least-cost option to connect urban areas, rural areas with high population densities and areas with energy-intensive activities. Capital costs are reduced by increasing economies of scale of the connections. Grid extension projects are often leveraged by rapid expansion of generation plants burning fossil fuels (as in China) and the opportunity to tap into significant hydropower potential (especially in Africa as a renewable energy source with low generation cost). Other drivers for grid extension include supply and development of the industrial sector as well as leveraging already installed overcapacity (as was the case in South Africa). The successful realisation of grid extension projects will depend primarily on the following factors (AGECC, 2010):

- Strong long-term government support.
- Refurbishment of existing infrastructure, simultaneous expansion of generation and transmission capacity.
- Resilient grid operation to support the additional capacity and demand.
- Guaranteed fuel supplies over plant lifetimes.

When it is not fully clear that grid extension is the logical solution, the choice of a specific energy technology for rural electrification depends on the targeted country and on whether it is a whole region, community, business, farm or household that is to benefit. But this is not the only concern. Factors that influence the choice of technology include customer and load density; relative distance to the national or regional grid; landscape; the availability of natural resources such as wind, sun, water and forests; economic and financial aspects (including consumer ability and willingness to pay), and the availability and maturity of any chosen technology (Niez, 2010).

In this context, self-sufficient electricity grids that connect supply and demand but are not part of a regional or national electric grid, referred to as off-grid systems, can provide an alternative. The number of users served might vary from single users (stand-alone system) to whole villages (mini-grids). Remote, sparsely populated and/or low-income regions make grid extension economically unviable and the alternatives provide access to electricity that can be deployed relatively quickly without the need to increase generation capacity.

Compared to stand-alone systems, which can consist of only a handful of components, mini-grids add operating complexity and costs, including load balancing, but they can bring increased functionality and decreased average cost of connections. By aggregating generation assets at community levels in mini-grids, they become available for household use during nonworking hours (AGECC, 2010).

The role of stand-alone grids and mini-grids is very important to achieve universal electricity access. Until 2030, the New Policies Scenario[17] estimates that 952 TWh of additional electrical capacity is required to meet the needs of delivering electricity to developing and emerging economies. Offgrid and mini-grid installations represent 18% and 42%, respectively, of this required capacity (IEA, 2010a). The deployment of stand-alone systems and mini-grids should

[17] This scenario takes into account the broad policy commitments and plans that have been announced by countries around the world, to tackle either environmental or energy-security concerns. National announcements to reduce greenhouse-gas emissions, for instance, are included (IEA, 2010a).

again be scalable, adaptable and flexible to avoid technology lock-ins and allow them to be integrated potentially into a national electricity grid. Stand-alone and mini-grid deployment occur in parallel with grid extensions.

Smart grids can play an important role in the deployment of new electricity infrastructure in developing countries and emerging economies by facilitating integration into larger systems and providing lower operational costs. The continuous integration of single local and regional systems into an interregional or national system requires standardisation and interoperability to be scaled up to the next level with higher amounts of supply and demand. Each successive step can increase reliability and the amount of power available if managed in a way that allows a seamless transition for the community (IEA, 2011a).

Electricity grid losses

Table 5 shows global transmission and distribution (T&D) electricity losses in 2008. Many regions have losses that are higher than the global average of 9%. Losses in India are reported at 23%, although anecdotal evidence has indicated that it is much higher in many regions, and power theft is estimated to be the main reason for this large number.

Table 5 Regional electricity system use and losses, 2008

	Own use in plants	Pumped storage	T&D losses	Total losses
World	5%	0%	6%	11%
OECD	4%	1%	6%	11%
Brazil	4%	0%	16%	20%
Russia	7%	0%	10%	18%
India	7%	0%	23%	30%
China	8%	0%	6%	14%
South Africa	6%	0%	8%	15%
Other Africa	4%	0%	13%	16%
Other Asia	4%	0%	8%	12%
Other FSU	9%	0%	12%	21%
Other Latin America	3%	0%	16%	18%
Middle East	5%	0%	12%	17%

Note: At pumped storage plants, electricity is used during periods of low demand to pump water into reservoirs to be used for electricity generation during times of peak electricity demand.

Source: IEA Statistics.

Electricity losses are an issue for all systems, and if left unchecked can have substantial negative financial impacts. Technical losses must be addressed in both the urban and rural settings. High losses are often caused by insufficient maintenance at any point along the supply chain and unqualified technicians. As lost electricity results in lost revenue, financing to operate, maintain and upgrade systems will also be reduced.

Electricity theft, which is more common in urban settings, has the same impact on the financial viability of a system, but the solutions will be different. Connections in urban areas and nearby

places may be unavailable or not affordable because of high upfront connection costs compared to income levels. Many dwellings connect illegally to the grid, referred to as power theft, or connect informally through someone with a legal connection. The latter is not considered theft and is thus not illegal in many countries, because the electricity consumed is metered and billed through the legal connection. The concern with this approach, in addition to safety, is that the user with the informal connection may pay an excessive unregulated price for an unsatisfactory service and relies on the goodwill of the unregulated provider (Maurer and Nonay, 2009). Another common problem in slums is that often the settlements are unauthorised and the inhabitants unregistered, which substantially complicates the planning process.

Monitoring the grid and electricity flows in these cases is very limited with current technologies. Smart grid technologies might be the key to reduce power theft and support the planning process. Advanced metering infrastructure with remote meter reading enables the diagnoses of excessive power consumption in the grid and can make possible the tracking down of power theft.

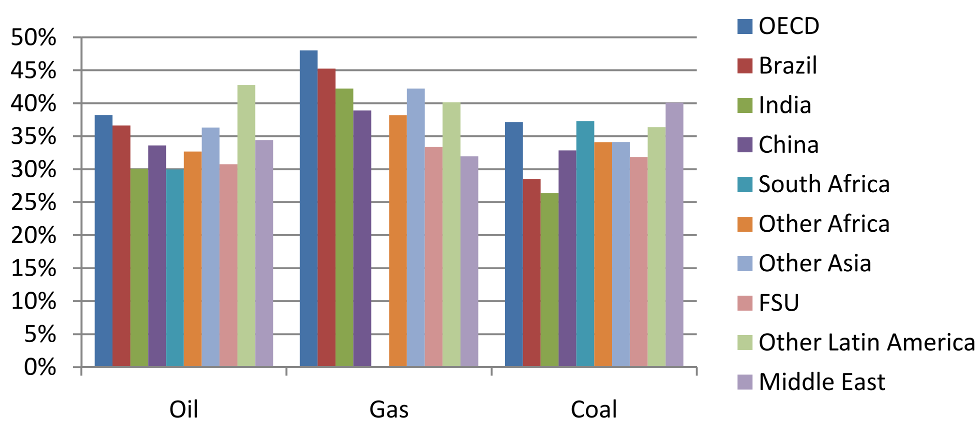
Technical losses must be addressed through proper design and a long-term commitment to operations and maintenance. Electricity theft can be addressed best in the context of sensible social development objectives with strong government support.

Generation and renewables

Efficiencies of fossil-fuelled power generation

In 2008, the share of electricity generated from fossil fuels was 68% globally and 74% in non-OECD countries. Coal was the dominant fossil fuel and represented 41% globally and 46% in non-OECD countries. Gas represented 21% and 20% and oil 6% and 8 %, respectively. It is expected that fossil fuels will continue to play an important role in the medium to long term. The efficiencies of a number of regions are shown in the figure below, which highlights that the energy efficiencies are generally lower in most non-OECD countries than in OECD countries.

Figure 7 Efficiencies from fossil fuel power plants in key regions and countries, 2008



Source: IEA Statistics.

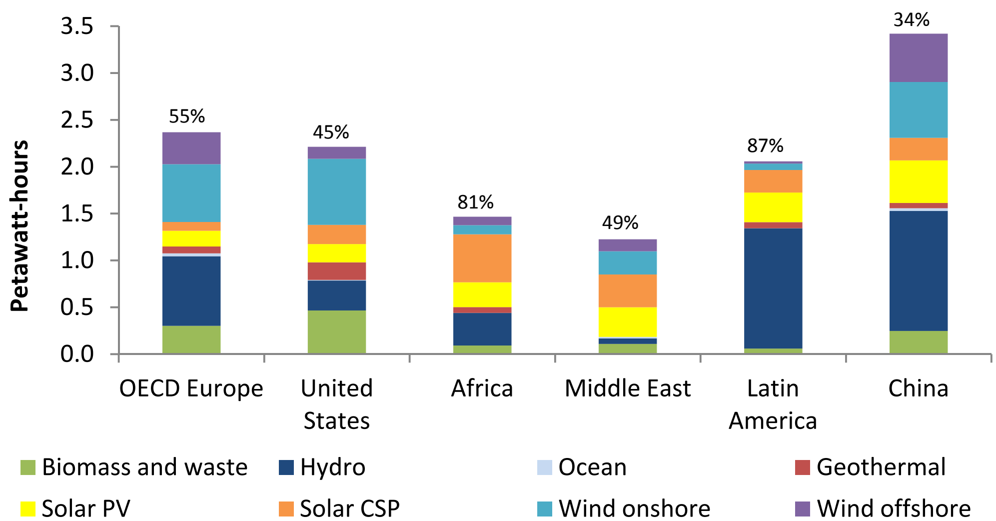
Note: Generation efficiencies are based on net calorific values (using lower heating values) and gross electricity production (including auxiliary electricity consumption and losses in transformers).

Increasing energy efficiency of fossil fuel power plants reduces operational cost and CO_2 emissions while increasing energy security for countries that import the fuels. Possible explanations for lower efficiencies include outdated generation technologies. The necessary capital for state-of-the-art technologies such as combined cycle gas turbines is not always available and the equipment requires regular maintenance in order to maintain design efficiencies.

Deployment of renewable energy sources

High operating costs and the volatility of fossil fuel prices, along with the hope of moving to low-carbon energy, point towards generation technologies from renewable energy sources. Figure 9 highlights the importance of renewable energies in the future generation mix in all regions.

Figure 8 Renewable generation in the BLUE Map scenario for key countries and regions, 2050



Note: Percentages above columns show the share of renewable energies in total electricity generation.
Source: IEA 2010.

The mass deployment of these technologies has triggered a considerable drop in prices. The upfront costs of renewable energies are usually higher compared to fossil fuel generation technologies but the operation cost is close to zero for some renewable technologies such as solar photovoltaic (PV) panels and wind turbines. They also require relatively little maintenance. This is not true for other renewable energy systems, like biomass gasifier engines. The deployment of renewable energies must be planned according to regional social, environmental and meteorological conditions, and each must be considered regarding its inherent operating characteristics. The availability of solar irradiation depends on the latitudes. At some latitudes where access to electricity is low (*e.g.*, Sub-Saharan Africa), solar irradiance is available throughout the year, but obviously never continuously throughout the day. Wind varies significantly by region and cannot be assumed to be adequately available in all areas. Storage assets can compensate partly and increase the availability of electricity. Hydropower projects can entail population

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displacement and threaten the environment, and are affected by hydrological variations and seasonal dry periods. Biomass technologies[18] depend on growing seasons (World Bank, 2008).

Renewable technologies, such as small hydro, solar, wind and various types of bioenergy, are well suited for mini-grid and offgrid applications. Diesel generators and hybrid diesel systems set-ups also play important roles to manage the variability of the renewable resources.

End-use technologies

Technologies that provide things like lighting, refrigeration, cooling and mechanical power through electric engines are used in all end-use sectors. The most prevalent end uses across all sectors are electric motors. They are responsible for 40% of global electricity consumption and are used to drive pumps, fans, compressors and other mechanical equipment (Boteler, *et al.*, 2009). Oversized motors, badly integrated components and the incapability to follow changing loads and limit standby electricity consumption all translate into inefficiencies.

Electricity consumption should be minimised by efficient devices. Efficient end-use technologies are therefore an inherent part of the electricity value chain. Even if the upfront costs are slightly higher, efficient equipment can produce energy savings over the product's lifetime. The industrial sector is often more responsive to these financial savings. In residential and service sectors, the need for cooling is constantly increasing. As emerging and developing economies, many in warmer regions, shift towards service economies demand for cooling will further increase. Lighting improves education, increases productivity and enhances security (street lighting). Offgrid lighting for households with solar portable lights using LED technology is well suited to meet the needs of the poorest communities (Lighting Africa, 2011). The use of efficient pumps to increase agricultural output through improved irrigation can reduce hunger and save water. In remote areas, end-use technologies can be powered directly by a PV panel. The Solar Electric Light Fund has successfully deployed water irrigation pumps powered by PV panels in Benin. The sustainable systems are expected to be cost-advantageous after 2.3 years compared to gasoline or diesel engines (SELF, 2011).

The private-public interface for electricity

The private sector stakeholders in the electricity subsystem include a range of interested parties: large and small companies, social enterprises, individuals, community-based organisations and non-governmental organisations. Four main segments of the private sector that can play a leading role in improving access to electricity have been identified: large multinational manufacturers (vendors), utilities/ESCOs, local private companies (community-based), and NGOs. Some have unique roles, reflecting specific capacities and expertise, but many activities will require collaboration in the private sector players as well as with other stakeholders (Table 5). The table is not meant to report about current activities of the private sector participants, but rather to stimulate discussion and provide a foundation for creating roadmaps.

[18] UN Energy Decision Support Tool for Sustainable Bioenergy (DST) provides guidance to governments to develop sustainable bioenergy policies and strategies.

Table 6 Main activities of private sector entities in electricity

Legend: Core business / Social investments and philanthropy / Advocacy and public engagement

	Large multinational manufacturer	Utility/ESCo (system operator)	Local private company (community-based)	NGO
Rural electrification	Social investments and philanthropy	Core business; Social investments and philanthropy	Core business	Social investments and philanthropy; Advocacy and public engagement
Urban and near-urban (slum) electrification	Core business; Social investments and philanthropy	Core business; Advocacy and public engagement	Advocacy and public engagement	Advocacy and public engagement
Deployment of small RE assets	Core business; Social investments and philanthropy; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement
Deployment of large RE assets	Core business; Advocacy and public engagement	Core business; Advocacy and public engagement	Core business	Core business
Increasing efficiency of fossil fuel plants	Core business; Advocacy and public engagement	Core business		Advocacy and public engagement
Capacity building	Social investments and philanthropy	Social investments and philanthropy	Core business; Social investments and philanthropy	Core business
Public education	Social investments and philanthropy	Social investments and philanthropy	Core business; Social investments and philanthropy	Core business

The needs of emerging economies and developing countries are urgent and concern a large number of people. The private sector has a number of active roles in the provision of electricity services and the implementation and operation of projects. Although technology will contribute in development of electricity systems, much of the technology is readily available; therefore, near-term private sector roles will more likely include action to develop business models and financing approaches, as well as supply chains for new energy solutions. Their leadership and experience should also be present in the policy dialogue and engage in consumer education and capacity-building efforts. The expected strong demand and market growth for electricity in non-OECD countries provides opportunities for both national and international manufactures and utilities, but also for innovative entrepreneurs. The highly regulated nature of electricity services dictates

that the public sector will be a key player in all aspects of activities involving deploying electricity technology.

Electrification

Given the large scale of most access to electricity initiatives, this is an area in which governments need to take the first steps – and demonstrate long-term commitment. The private sector will look for policy signals such as giving electricity-access plans high priority on the political agenda and the setting of national targets for universal access. Once such policy elements are in place, the private sector has been shown to respond with innovative approaches at various scales and in diverse geographic areas.

Ghana, for instance, has seen a steady increase in access to electricity since the launch of the National Electrification Scheme and a target to achieve universal access by 2020. Brazil's *Luz para Todos* (Light for All) provided electricity to two million rural households between 2003 and 2009. Significantly, this was achieved without asking electricity consumers to pay for any network expansion; rather financing was provided by loans funded by concession fees and fines to electricity supply companies, as well as tariffs collected from all electricity consumers and subsidies (Niez, 2010).

It must be acknowledged that electrification projects do carry a specific long-term risk for private sector participants in that most of them target (or at least include) the very poor who cannot afford to pay the full price for the service. Early government action is needed to minimise such risks, but several policy strategies are proving effective, particularly those that take a more holistic approach such as upgrading (rather than eradicating) slums by providing not just electricity but also road, water and sewage infrastructure. The government of Kenya adopted a holistic approach in the Kenyan Slum Upgrading Program (KENSUP) that focuses on the provision of basic infrastructure, be it water, sanitation, roads or electricity. Another innovative example is the *Ecoelce* programme in Brazil, in which electricity clients with low incomes can exchange recyclable waste to help reduce their electricity bills. This programme provides a practical approach to reduce electricity costs to users while delivering broad social and environmental benefits.

Both the public and private sectors can support capacity building to facilitate the introduction of electricity services. Provision of courses on managing household budgets increases the consumer's ability to pay for essential services such as electricity, while communicating the benefits of electricity increases the use of electric devices (*e.g.* lighting, refrigeration mechanical power) and thus ensures demand, which improves investment conditions.

Electricity theft is also a concern for the private sector, particularly in more densely populated urban and near-urban areas. It can be mitigated by introducing penalty and reward systems (ESMAP, 2007), but smart metering may offer a more efficient approach. At present, smart meters are primarily designed to be integrated into developed electricity systems and provide several functionalities. Supported by the right public policies, a low-tech meter designed to track only electricity theft could aid in providing a more reliable power supply while also supporting viable and sustainable business models.

Vietnam provides a case study in which close collaboration was able to increase access to electricity from 15% to 95% in just 15 years because of the leadership of a strong state utility (EVN) and an effective partnership between it and local utilities (World Bank, 2010b). Some examples of

roles various parties might play in such a programme are largely dictated by the structure of the investment and influenced by the chosen business model (World Bank, 2008):

- The private sector owns the electricity system (*e.g.* a micro-grid), planned it and is operating it. The rates charged must be high enough to make the project viable and at the same meet the willingness-to-pay levels of the consumer. Subsidies can increase the profitability.
- The government provides funding directly or manages a fund aggregated by organisations for private-sector projects. Community-based businesses might additionally receive assistance and training in technical and financial questions by public entities or other private companies.
- A public utility or government-contracted energy service company (ESCO) operates the electricity system. A regulated rate paid by consumers is imposed by the government. Economies of scale reduce capital costs, but the regulatory framework is more complicated to set up and competition is reduced. Hence volume savings might be offset by institutional inefficiencies.

Reform of subsidy programmes is another important policy area. A World Bank study has found that subsidising the upfront capital costs – rather than consumption – is more effective to promote investment in electrification projects (World Bank, 2008). In general, tariff subsidies disproportionately benefit the higher-income and higher-electricity-consuming social classes. In fact, connection costs to the electricity grid are still a major barrier (IEG, 2008). Alternative tariff structures could include the cost in monthly payments. Another way to increase affordability in off-grid electrification projects is to provide lower power without compromising quality. Access to electricity increases economic output and income; in some cases, the benefits resulting from connection enable the user to later upgrade to higher power.

Well-planned electrification programmes can deliver other economic and social benefits. In addition to providing access to electricity, the South African Integrated National Electrification Programme (INEP) created 6 000 jobs in fiscal year 2008/09 and approximately 32 995 jobs since its creation in 2001 (South African Department of Energy, 2009).

Generation and renewables

In many emerging economies and developing countries, significant new capacity or upgrading of existing capacity will be needed to support universal electrification. The projected increased demand provides strong incentive for private companies; however, the need to transform the entire energy system creates additional risk. It is difficult to know which generation options will be most financially viable 40 years from now – *i.e*. the average lifespan of generation facilities. At present, many of these countries use fossil-based generation technology that operates at efficiencies below that of OECD countries. This context creates significant opportunity for the private sector to support the upgrade of such technology. As stated in other sections, much of the technology needed for such improvements can be cost effective, but must be supported by long-term operational commitments and regulatory certainty in order to de-risk investments.

Some emerging economies have acquired production capacities by integrating into global value chains – and are now recognised as industry leaders in some low-carbon technologies. The global economy is abandoning the idea of North-South technology transfer and evolving towards a South-South exchange that better reflects the needs of and opportunities within emerging and developing countries. Overseas sales of Shanghai Power Corporation soared from 13% in 2006 to

45% in 2009, mainly because of exports to developing countries of supercritical and subcritical technologies (Tan and Gang, 2009).

The role of renewables in electricity generation is increasing globally. Many non-OECD based industries are leading the production of renewable energy technologies. China is the largest exporter of wind turbine towers, of static converters that change solar energy into electricity, of solar batteries for energy storage in off-grid photovoltaic systems, and of the concentrators used to intensify solar power in solar energy systems (WTO, 2009).

Policies favouring the deployment of electrification and renewable energy should be laid out to provide an open market that attracts investment and delivers benefits. Emerging economies, especially Brazil, India and China, have stimulated investment in clean-energy technologies by adopting a wide range of policy measures (such as taxes and subsidies) and strong frameworks.

India has committed to a preferential tax rate of 15%, half of the standard rate, for renewable energy projects (IEA, 2010b). Exemption on duty taxes on the import of renewable energy equipment or similar support boosts trade and economic development. Existing fossil fuel subsidies must be redirected in favour of renewable energies (IEA, 2011b). Public and consumer education are vital to raise awareness and participation. Misconceptions, such as the former perception in South Africa that renewable energy meant rural energy (Niez, 2010), can considerably slow down government or private initiatives.

End-use technologies

The market for end-use technologies operates at a global scale. Private companies can foster the manufacturing of efficient appliances along with the necessary instructions and after-sales service to ensure appropriate application and long-term operation. The deployment must be supported by governmental efficiency standards to reduce availability of inefficient technologies and increase availability of efficient technologies. This is necessary to increase economies of scale, which will reduce prices and reduce investments in inefficient technologies that have lower up-front costs, but higher long-term costs and greater environmental impacts.

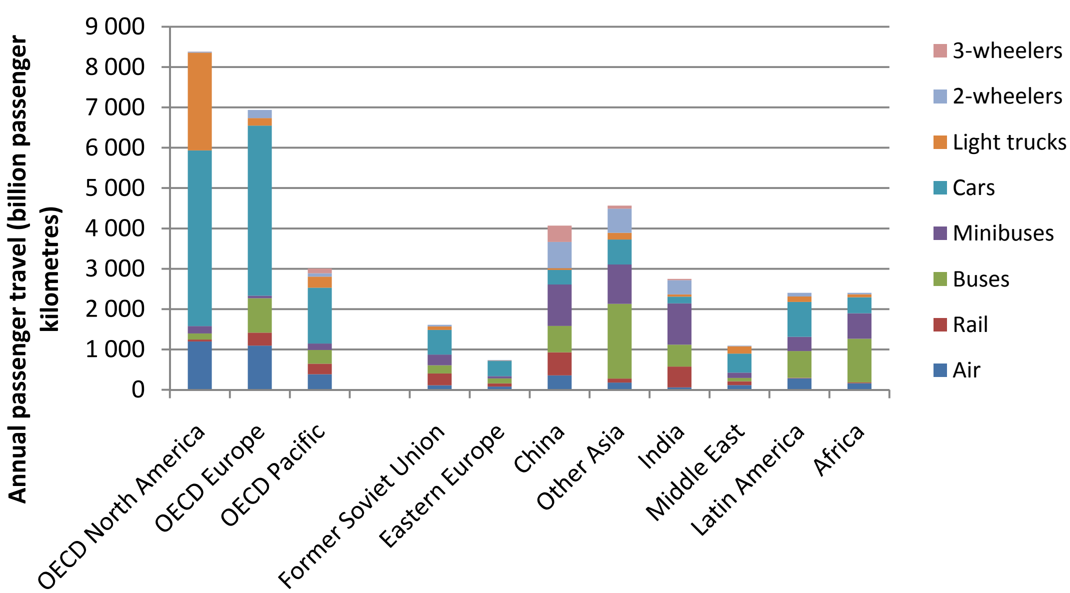
In the delivery of solar home systems, off-grid and mini-grid solutions, the private sector will need to ensure that highly energy efficient end-use technology is applied to ensure maximum functionality. In this case, it is typically found that the extra cost associated with highly efficient end-use equipment is cost effective when the entire electricity application is considered. As the number of these types of systems increases, there will be an increased market size for a larger number and wider range of such end-use technologies.

Transport and mobility

Context and current challenges

The transport sector represents 27% of final energy use in the world and accounts for nearly 23% of worldwide CO_2 emissions (IEA 2010b). Patterns of travel vary tremendously around the world, as do the levels of travel per capita.[19] Given high car ownership levels in OECD countries, an average of around 5 000 kilometres per year is travelled by car (except in OECD Pacific). In emerging economies and developing countries, no country or region has been found with more than 5 000 km of travel overall, across all modes (Figure 10). However, travel in emerging economies is rising rapidly (largely due to increased car ownership), and within 10 to 20 years will begin to approach levels in OECD countries. On the other hand, in poorer countries it may take many decades before a large share of the population has access to motorised modes such as cars, motorcycles and buses.

Figure 9 Estimated total annual passenger kilometres (pkm) by mode and region, 2005



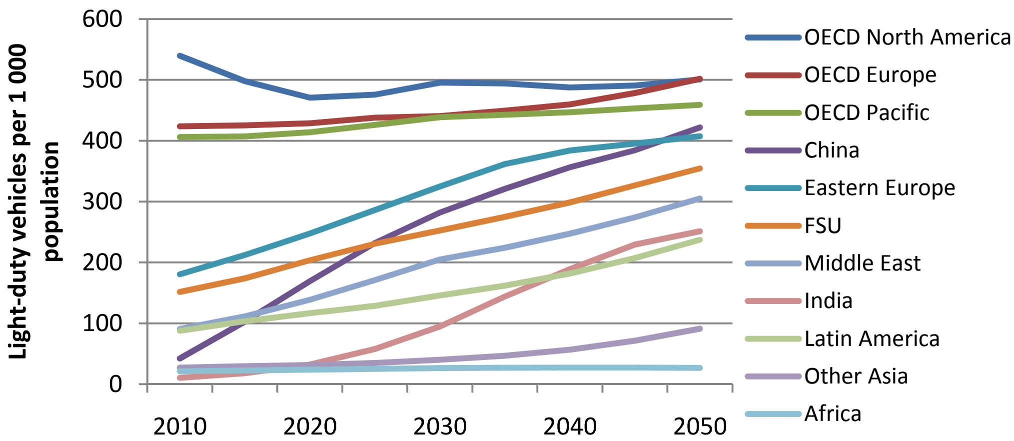
Source: (IEA, 2009c).

Expectations for car ownership are further illustrated in projections through 2050 as shown in Figure 11. It shows that most major emerging economies, such as China and former Soviet Union

[19] The discussion in this section focuses on passenger mobility. Freight activity, although included in the energy balances presented, is left out because these transport systems operate on a global scale and tend to be much more technologically and logistically homogeneous. Passenger transport systems, which are overwhelmingly local or regional in nature, are more technologically diverse and therefore warrant more of a discussion in this paper. Future work could include freight activity for completeness.

constituents, will approach OECD car ownership rates in the future. Some, however, like India, will lag behind (although major metropolitan areas of India are expected to reach high ownership levels). Africa and the Middle East are expected to remain at relatively low levels.

Figure 10 IEA projection of car ownership per 1 000 population, by major country/region



Source: IEA, 2010b.

There are a number of implications of such projections for travel and sustainability of travel. The one is that for those countries that acquire a high degree of car ownership, a relatively high percentage of travel (apart from air travel) is expected to be provided by personal vehicles (this is also true of two-wheelers, already a high share of travel in some countries, particularly in Asia). Thus in order to reduce the related negative impacts, it will be critical to ensure that the vehicles themselves are sustainable, with fuel economy improvements and shifts to more sustainable fuels.

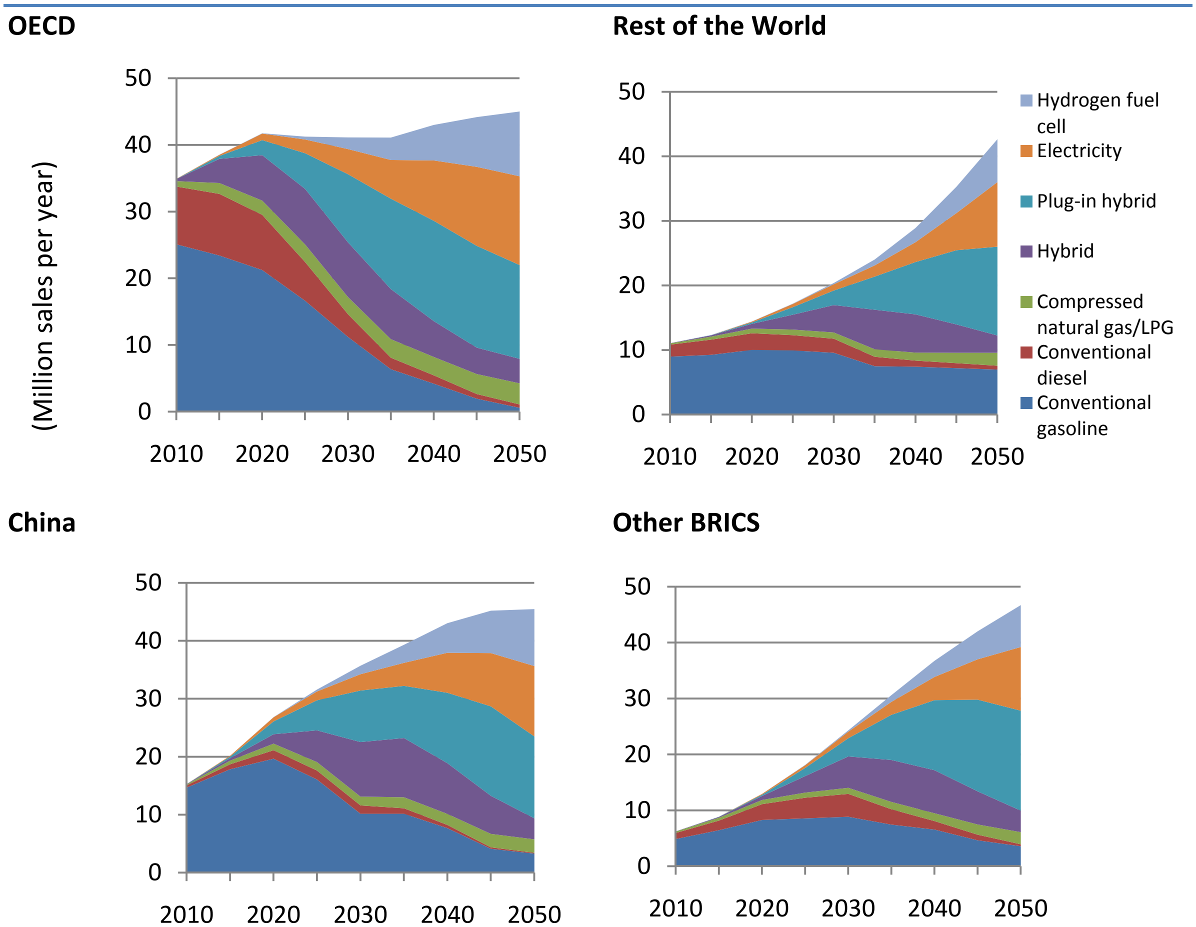
A second is that in countries that do not obtain high car ownership levels (about 400 to 500 light duty vehicles (LDVs) per 1 000 population by 2050), it will be very important to provide other means of transport. Especially important will be high-quality, affordable bus systems, such as can be provided by bus rapid transit (BRT). Infrastructure to facilitate non-motorised travel (bicycles and walking) – in particular to ensure the safety of these modes – will also be very important. Providing for transit and non-motorised travel options in all countries will be important for sustainability; the difference between high car ownership and lower car ownership countries is simply a matter of degree and share of population affected.

IEA BLUE Map targets for transport are a two-thirds reduction in transport CO_2 emissions in 2050, compared to our baseline projection for that year (and 25% below the 2008 level). In order to achieve this, a combination of new vehicle technologies, new fuels and facilitation of transit and non-motorised modes will be key. Such a future is consistent with far lower vehicle-related pollutant emissions, far lower oil dependence and imports for most countries, and better mobility and economic opportunities for large segments of populations. In the last category are those who do not and probably will not have access to cars in the foreseeable future, which is expected to be a large share in most countries, even in 2050. On the urban travel side, particularly for other

developing countries, a focus on providing high-quality bus systems will be a key focus. In rural areas, better access to bicycles, low-cost personal motor vehicles and better regional bus systems will be important.

Especially in emerging economies, strong fuel economy improvements and a shift towards vehicle electrification are the most important areas of focus. The worldwide shift overall towards advanced technologies is shown in Figure 11, reflecting a major migration to electric vehicles (EV's) after 2030. While less developed countries may not be able to afford some advanced technologies (like electric vehicles) in the very near term, there is hope that costs will decline and that all countries will have access to them in the coming decade. In urban areas, the value of vehicle electrification is augmented by their potentially strong contributions to urban pollution reduction. Small, low- cost EVs may be possible and appropriate for many countries. China and India both have manufacturers focusing on developing vehicles for this niche.

Figure 11 Passenger light-duty vehicle sales by technology type/region for BLUE Map



Source: IEA, 2010b.

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Role of technologies and barriers for deployment

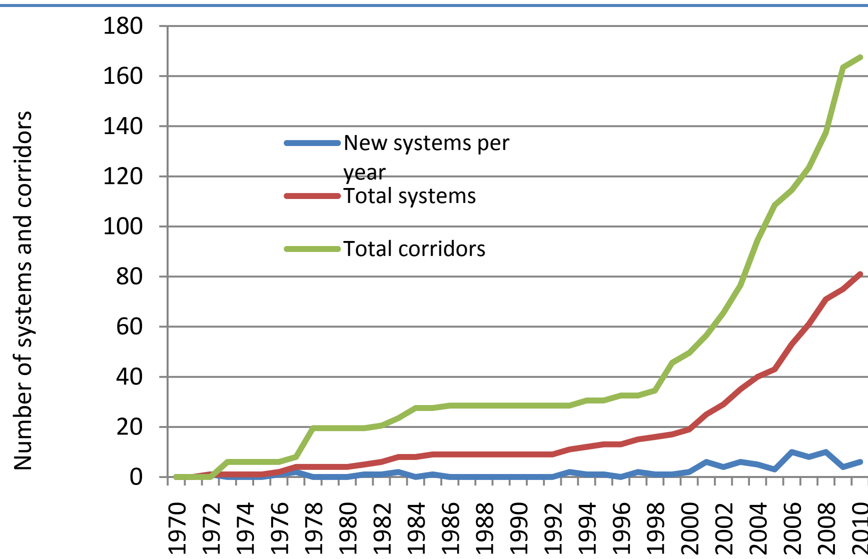
While there is a wide range of technologies that will be important for achieving low-carbon, sustainable transport, a number of areas stand out. These are public transit (and the technologies to support excellence in transit service), vehicle fuel economy improvement, the adoption of plug-in electric vehicles, non-motorised transport and bio fuels.[20] The following sections cover technology and related issues in each of these areas, and their expected role in rapidly *industrialising* countries compared to other developing countries. Some discussion is also provided of urban/rural considerations.

Public transit and bus rapid transit

Given that even in 2030 (IEA, 2009c), more than half the people in the developing world will not have access to a car, public transit systems will be critical for providing mobility services. Perhaps the most important type of public transit system will be BRT, due to its low cost and wide applicability, along with potentially excellent performance.

BRT systems were first popularised in Curitiba, Brazil, and in Bogotá, Colombia, where high-speed and articulated buses, rapid boarding and dedicated lanes combine to create highly efficient transport systems. These have high load factors and much shorter trip times than other modes in these cities (including cars) can offer. The growth in the number and size of BRT systems has risen sharply in the past 10 years (Figure 12).

Figure 12 New bus rapid transit systems per year worldwide



Source: IEA analysis.

[20] Besides vehicle and fuel technologies, demand-side management is a crucial component when considering transport and energy. Demand-side measures including land-use planning and management are integral to such interventions as BRT and are included, but not specifically delineated in this discussion.

However, the rapid growth in BRT hides the fact that many more cities have explored BRT but not adopted it so far due to concerns regarding traffic disruption, political unpopularity and cost. In each of these areas, BRT has provided major benefits at low cost, but it is not always apparent to policy makers (or the public) in advance that this will be the case. Since BRT requires dedicated lanes for buses, lanes often must be taken away from other users (primarily car drivers). Strong political will is required to push through BRT plans, often at an initial political cost, but localities generally are very happy about them once they are in operation.

BRT systems have benefited in recent years from major improvements in key technologies. These include better bus tracking and dispatching (GPS-based), smart-card fare systems with integration with other travel modes, such as metros and non-BRT buses, and real-time schedule information that allow passengers to see when the next bus will arrive. Synchronisation of traffic lights to reduce bus waiting times at red signals is also in use in some systems. Such technologies have helped BRT to provide highly efficient transport in the places that have applied them fully.

The IEA recently estimated that if BRT were deployed in the 1 000 largest cities in the world (74% of which are in non-OECD countries), a shift of up to 31% of trips onto BRT could be achieved in these cities in the 2030-2050 time frame.

While BRT is urban-oriented, some of the concepts can be used in intercity and rural areas as well. High-capacity, high-quality coaches are increasingly able to transport people between cities at relatively low cost and should be encouraged for intercity and rural mobility. Investments in intercity rail routes can also help improve mobility outside of major urban centres.

Vehicle fuel economy

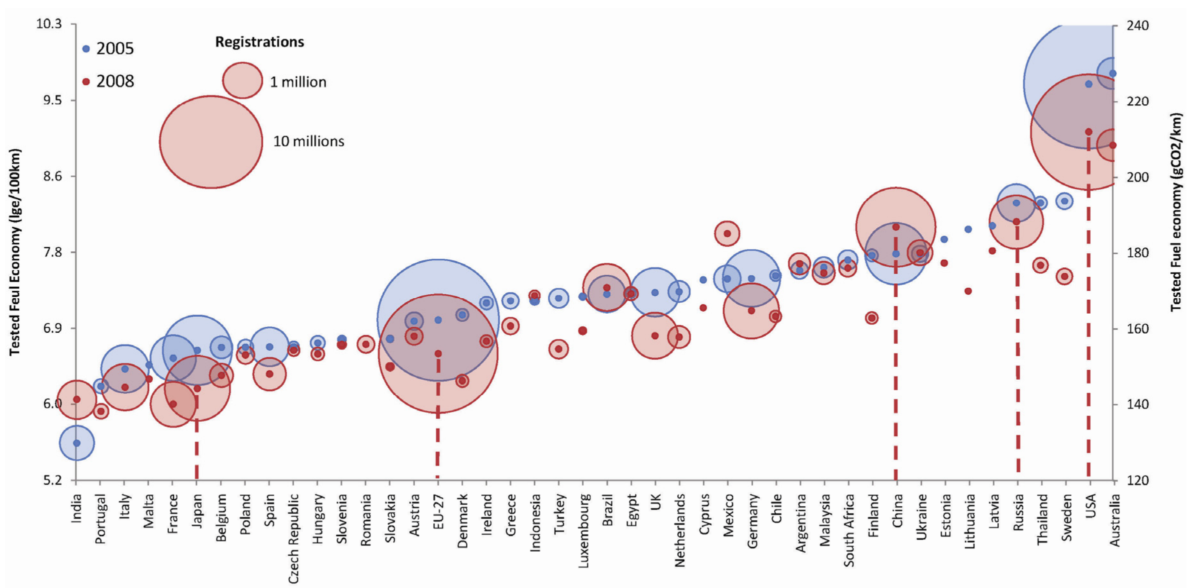
In all countries, but especially in rapidly motorising countries, it is imperative that cars become much less energy intensive over the next 10 to 20 years. Rapidly motorising countries run the risk of unmanageable oil-related balance-of-payments issues and, in some places, costs associated with subsidising fuels. The IEA is a partner alongside the FIA Foundation, the International Transport Forum, and UNEP in the Global Fuel Economy Initiative (GFEI) (www.globalfueleconomy.org), which has set a global target of a 50% reduction in new-car energy intensity by 2030 compared to the 2005 levels. Since the average new car in 2005 worldwide had a fuel economy level of about 8L/100km (29.4 miles per gallon), this means cars would have to reach 4L/100km (58.8 miles per gallon) by 2030. This will be very challenging, requiring an improvement of nearly a 3% per year in new-car fuel economy, on average, in every country.

As research by GFEI and others shows, however, there are abundant, cost-effective technologies available to help achieve this target. They include engine efficiency technologies, lightweight materials, improved body aerodynamics and improved vehicle components such as air-conditioning and low-rolling-resistance tyres. The most efficient vehicles, such as various hybrids, already come very close. The challenge will be to make the average vehicle in 2030 similar to the very best today. A related challenge will be to avoid letting vehicles get ever larger and more powerful, as this offsets the fuel economy benefits of the available technologies.

Achieving a 50% fuel economy improvement target by 2030 will not require major new technologies, but it will require strong policies. Getting more countries on board with standards or other strong policies (such as a fuel economy or CO_2-based vehicle tax system) becomes a very high priority. Governments with strong fuel economy standards (such as the EU and Japan) have

seen rapid improvements in fuel economy in recent years, while other countries that have not had strong standards (the United States, Australia) have seen little improvement. China has implemented standards that eliminate the worst models and will tighten these over time to push all models towards better efficiency. India appears close to adopting a standard. Unfortunately, to date no other major emerging economy or for that matter any developing country has adopted fuel economy standards. Estimated new LDV fuel economy levels for a wide range of countries are shown in Figure 14. Some emerging economies, such as India, are at the efficient level. Others, such as Russia, appear to be at a much higher fuel consumption level. Some developing countries (such as Thailand) also appear to be relatively fuel-inefficient.

Figure 13 New light-duty vehicle fuel economy in countries worldwide



Source: IEA, 2011c.

Electric and plug-in hybrid electric vehicles

OECD countries are getting ready to (and most have begun to) launch new technologies for light-duty vehicles. In particular, electric plug-in vehicles are the focus of intensive policy efforts. Collectively, OECD countries have sales targets of about five million electric and plug-in hybrid vehicles (PHEVs) per year in 2020. These vehicles offer the possibility of very low or zero petroleum fuel use, very low or zero pollutant emissions, and very low CO_2 emissions (though this will be region-specific and depend on the electricity generating mix). Thus they are particularly relevant to countries with a low-carbon electricity mix and for urban areas where their zero-pollutant emissions quality can provide important environmental benefits.

Because electric vehicles (and especially their batteries[21]) are currently expensive, it is not expected that these vehicles will succeed in the market without strong government policies, including research, development and demonstration (RD&D), investments and coordination in installing infrastructure, and incentives (to consumers to purchase the vehicles and manufacturers to produce them). The combined OECD spending just from 2010 to 2012 is expected to be on the order of USD 20 billion (IEA data).

In the rapidly industrialising countries such as China, India, Russia and Brazil, most consumers cannot afford EVs or PHEVs now, but some can, and the percentage that is expected to rise rapidly over the next 10 years. Thus it makes sense for these countries to begin planning now and be ready to move rapidly towards embracing electric vehicles once the markets in OECD countries are established (and costs hopefully come down significantly). China is already moving quickly and has the biggest EV target in the world – five million on the road by 2020. China also has over 140 million electric bikes, which is an increasingly popular transport mode in the developing world. (EV Update 2011) India has established an EV planning office within the Ministry of Heavy Industries. Other countries are also looking into key steps towards EV advance planning.

In other developing countries, it makes sense to play more of a waiting game. Perhaps by 2015 markets in other countries will have helped bring costs down substantially and made lower-cost electric vehicles available worldwide. By 2020 there should also be an initial supply of used EVs available for import.

Other new fuels can also help. In particular, natural gas and liquid petroleum gas (LPG) are low-emission (and sometimes low-cost) fuels, and can provide important air quality benefits. The retrofitting required for vehicles to run on these fuels, however, can be expensive, and sometimes the changes are of poor quality, leading to higher emissions than would be optimal.

The IEA BLUE Map projection for EVs, broken out by major region, shows through 2020, and even 2030, the vast majority of EV and PHEV sales are expected to occur in OECD countries and China. This is so although by 2030 there are expected to be nearly five million sales per year in other BRICS countries and about 2.5 million in the rest of the world. After 2030, sales in other BRICS countries are projected to take off, and by 2050 there should be 30 million sales per year, with 24 million more in China. Together the five BRICS countries are expected to account for over half of the world's EV/PHEV vehicle sales. OECD sales are expected to have flattened, while the rest of the developing world is expected to show large increases after 2040, reaching 25 million in 2050. Together more than 100 million EV/PHEVs under the projection are sold worldwide in 2050.

It should be stressed that this is not a prediction, but simply a backcast – part of a low-carbon scenario for transport. But it does reflect the expected size and buying power of the different regions, in terms of where the plug-in vehicles are likely to be sold over time. Together these vehicles are expected to cut global CO_2 emissions by over 2 gigatonne (Gt) in 2050, roughly in proportion of sales by region. This represents an important part of the overall CO_2 reductions in transport.

[21] A crucial element of batteries for electric vehicles is lithium, a rare metal that is found mainly in South America, but with enough supply to meet projected demand for at least the next 20 years.

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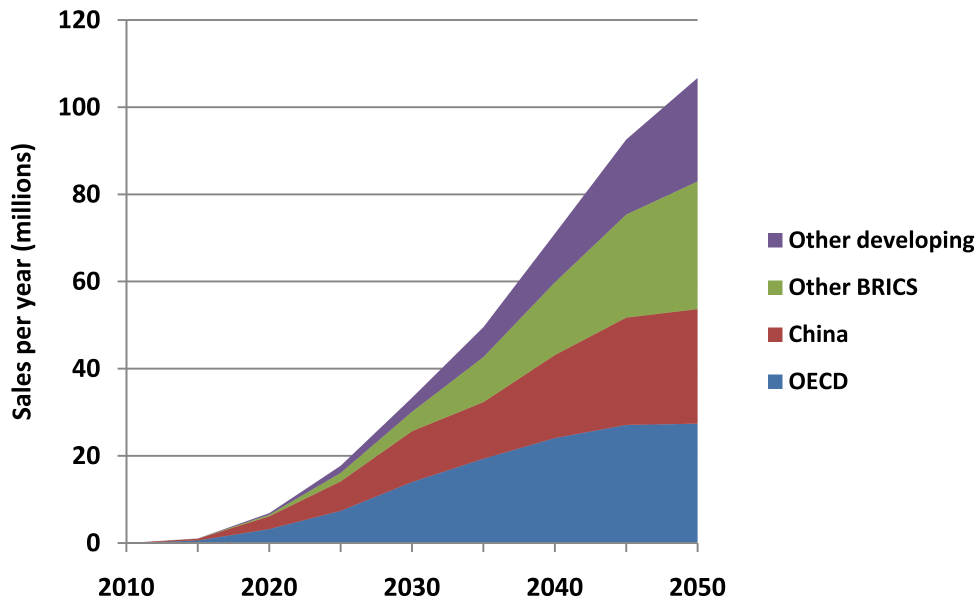
Figure 14 EV/plug-in hybrid vehicle sales by region, IEA BLUE Map Scenario



Source: IEA, 2009c

Non-motorised transport

The most sustainable of all transport modes are those that have no motors, *i.e.*, bicycles as well as walking. These modes account for a high share of trips in many countries, and they are also very important in cities all over the world and become increasingly important as cities move towards more sustainable transport. The main issues associated with walking and cycling are encouraging people to use these options, and to do this they must be convenient and safe. Unfortunately, in many cities and even in many rural areas, they are much less convenient and safe than they should be because of a lack of infrastructure such as sidewalks and bike lanes. Adding this infrastructure should be a high priority and a standard part of road and urban planning and construction in all jurisdictions around the world. The United Nations Environment Programme has a plan called Share the Road that promotes investment policies for sustainable urban transport, with a particular focus on walking and cycling road infrastructure (UNEP, 2010).

Biofuels

Biofuels for transport (*e.g.,* ethanol, biodiesel, biogas) could play an important role in decarbonisation in the sector and a minor role in improving air quality. They can also help with rural economic development. As a fuel substitution measure, they are unlikely to have any direct impact on mobility (although locally produced fuels may increase the viability of some forms of transport), though in the future some biofuels may become cheaper than petroleum fuels, and they can contribute to better energy security. The reduction of costs at a national level for countries that import fossil fuels is also of value, especially in light of recent price increases and global unrest.

A key issue for biofuels is where and how they are grown or produced. There is considerable controversy over whether currently available biofuels (typically derived from grain or oil seed crops) are produced sustainably at this time, whether they provide much net CO_2 reductions, and whether they may have adverse impacts on food security and agricultural markets. The answers depend on each situation, but current biofuels do not now provide significant net benefits. There are exceptions such as sugar cane ethanol in Brazil, where at least the costs are low and CO_2 emissions reductions appear to be substantial.

The IEA published the Biofuels Roadmap in 2011 (IEA, 2011), which calls on governments to move towards advanced biofuels, derived primarily from biomass waste products and dedicated biomass feedstocks rather than oils derived from food crops. Such advanced biofuels, however, are unlikely to emerge in large quantities before 2015 or perhaps 2020, and in early years the production costs are likely to be fairly high, so these are best thought of as longer-term options. In the longer term, issues such as land use, competition for waste and residues, and invasive species concerns will also have to be addressed.

In the meantime, each country needs to determine whether increasing the use of currently available biofuels would provide net benefits, with careful attention to secondary impacts such as land use change. Tools such as the UN-Energy – Bioenergy Decision Support tool produced by the FAO and UNEP could provide guidance on policy processes and investment appraisal.

The public-private interface for transport and mobility

The previous sections have described key technologies in the transformation of transport, in particular bus rapid transit, fuel economy improvement and electric vehicles. But how will countries stimulate the very different types of investments and activities needed to achieve their goals? BRT tends to be urban and managed by cities. Fuel economy policies tend to be managed by national governments and can involve primarily standards or can include financial mechanisms. Electric vehicles will require extensive direct investments and incentive programmes by both city and national governments, though national governments may be expected to take the lead on funding.

Within transport, the key private sector participants are large multinational manufacturers, large multinational, national and local system operators, and NGOs. Some will have unique roles, but as outlined in more detail below, most activity areas will require the expertise of several actors (Table 7). This table summarises suggested roles, according to major capacity and knowledge of specific entities, and clearly shows areas in which collaboration is needed; it is meant to spark discussion about activities of the private sector participants and provide the basis for developing pathways to success. The authors acknowledge that the some private sector players are already engaged beyond what is shown in the table and some exceptions to this summation exist.

Regarding electric vehicles and the electrification of the transport sector in general (including trains, trams and electric buses), utilities also play a key role. Non-motorised transport encompasses the development of the required infrastructure as well as operation and maintenance of transport modes such as public bicycle rental stations. Biofuels is a key sector but falls outside the traditional participants in the transport sector. The important segments in biofuels

include the petrochemical industry, researchers and NGOs, largely working in the core business and advocacy roles.

Table 7 Main activities of private sector entities in the transport sector

Activity	Role	Large multinational manufacturer	Large multinational system operator	National/Local system operator	Utilities	NGOs
Fuel economy of vehicles	Core business	X				
	Social investments and philanthropy					
	Advocacy and public engagement		X	X		X
Introduction of EVs	Core business	X				
	Social investments and philanthropy					
	Advocacy and public engagement	X	X	X	X	X
Public transport infrastructure (BRT)	Core business	X	X	X		
	Social investments and philanthropy					
	Advocacy and public engagement		X	X	X	X
Public transport system operation	Core business		X	X		
	Social investments and philanthropy					
	Advocacy and public engagement		X	X		
Non-motorised transport	Core business			X		
	Social investments and philanthropy			X		
	Advocacy and public engagement			X	X	X
Capacity building	Core business			X	X	X
	Social investments and philanthropy	X	X	X	X	
	Advocacy and public engagement					
Public education	Core business					X
	Social investments and philanthropy	X	X	X	X	
	Advocacy and public engagement					

Public transit and bus rapid transit

In successful examples in emerging economies and developing countries, the private sector has played an important role in establishing and operating BRT. Unlike traditional transit in OECD countries, which are operated by municipalities, most BRT systems use a licensing approach in which multiple transit companies provide services. Well-designed licensing systems have resulted in very high-quality BRT service in many cities, although it is important that the city has access to companies that can fulfil such requirements. In some countries this has been difficult, but creative approaches to encourage consolidation of small companies or partnerships with foreign

companies can help. The private sector also can be encouraged to provide auxiliary services (such as concessions) and advertising to help pay for the costs. Without such private sector involvement, it is unlikely that BRT could thrive.

The key is for national and municipal governments to create BRT system planning, operating and financing structures that maximise the benefits of this private sector involvement. Similar public sector roles are needed to achieve widespread use of public transit, metro systems and conventional bus systems. Governments will need to make the major investments and provide the policy framework that will demonstrate sustainable business opportunities in the context of these transport modes. While much of the direct planning will occur at the local (urban, metropolitan) level of government, national governments will need to support local efforts through policies and funding. National transport plans that reward localities financially for meeting certain goals can play a key role. Direct subsidies for important projects such as building BRT systems can also help.

BRT systems in Curitiba (Brazil), Bogotá (Colombia) and elsewhere have demonstrated that once the capital investment costs are covered by government, private entities can cover operating costs and turn an attractive profit through fare revenues.

Vehicle fuel economy

The automotive industry has an opportunity to capitalise on consumer interest in increased fuel efficiency in a number of ways. It can voluntarily improve its vehicle fleet fuel economy, more aggressively market its more efficient vehicles and provide better information to consumers. Industry can also work with governments to establish sensible policies that both save fuel and minimise the costs of those policies, for example, by encouraging harmonised policies and requirements across countries. Renault, for example, has lobbied for a harmonisation in European vehicle CO_2 tax policies, which currently vary considerably among the 27 EU countries. Ultimately though, voluntary fuel economy improvement programmes have been found to be inadequate; national standards and tax policies appear necessary to successfully lower the fuel intensity of passenger cars.

The fact that automobile markets are large and fairly homogenous makes it logical for national governments to take on the role of establishing fuel economy policies and standards, as has been done in the United States, Canada, the European Union, Japan, China, and Korea. Tax policy is also typically set nationally – including in the European Union, where each country sets its own policy. Both elements of policy can help to require manufacturers and encourage consumers to move towards more efficient vehicles. These policies are among the most important for countries to cut oil demand, lower oil dependence and CO_2 emissions, and move towards more sustainable transport systems.

Electric and plug-in hybrid electric vehicles

Vehicle manufacturers, electric utilities and third-party providers all have strong roles to play in EV developments in OECD, BRICS and developing countries. As this is a rapidly emerging technology area, the needs are very similar in all countries.

Vehicle manufacturers, of course, must develop the vehicle technologies and ensure the supply of vehicles meets targets for increased deployment in countries and cities. As of June 2011, many

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cities were complaining that the vehicle supply was inadequate (IEA, 2011e). Manufacturers must also help to develop business models and strategies to make vehicles more affordable, such as shifting higher upfront costs to monthly payments that are offset by the lower running costs of EVs. Electric utilities (often private or quasi-public) must be involved and help with investments in recharging infrastructure, and must take a leading role in developing "smart grid" systems. The pay-off is that utility-level technologies will help to maximise the benefits of EVs with regards to load management. Third-party providers – i.e. companies that develop EV-related services – can help to connect the dots between the stakeholders. They could be, for example, companies that provide recharging infrastructure and metering installations that allow both EV owners and electricity providers to track and optimise electricity use during recharging.

The role for public sector players is to establish policies and set targets to which private entities can respond. As mentioned, many OECD countries and China have targets for large numbers of EVS on the road by 2020. These countries need to invest in RD&D and infrastructure (especially electricity infrastructure) to ensure that both supply and capacity exists for charging vehicles. They should also use incentives to encourage consumers to buy these vehicles. Since EVs will be expensive at first, countries with a large base of consumers who can afford the cost will play an important role as "early adopters". Over time, their efforts should bring down the costs for others, in part through opportunities for technology transfer. A key aspect will be for national governments to work together, as they do through the Electric Vehicles Initiative (CEM, 2011), and to work with municipalities and regions to organise plans and responsibilities.

Non-motorised transport

As with public transport, the private sector can participate in non-motorised transport through manufacturing, operating rental facilities and offering related third-party services. Together with NGOs, private entities can play a significant role in advocating for the construction the necessary infrastructure (such as bicycle lanes and sidewalks), which is largely at the discretion of governments through policy decisions. This infrastructure is fairly low cost compared to that of other transport sectors, but appropriate planning of cities and communities (another policy choice) is needed to make it easy to cycle/walk to destinations. The shorter trips are, the more likely people will walk or cycle so planning should aim to provide a wide range of services in a relatively small area. As mentioned, a main challenge for facilitating non-motorised transport is to ensure the safety and convenience of these modes.

Biofuels

A key objective to moving towards greater use of biofuels, as mentioned, should be the global uptake of advanced biofuel production technologies, typically with biomass (grasses, trees) as the feedstock rather than food crops (grains, oils). Developing the production technologies will require financial support from both governments and the private sector. These actors can also lead the broad-based collaboration needed to test these new technologies, which can also include a role for academia. Such collaboration must include north-south and south-south co-operation. These new fuels may be expensive over the next decade, but gaining experience year by year will help to identify the best approaches, drive down costs and ultimately help more countries prepare for much larger scale adoption.

Conclusions

To many, access to modern energy will imply the provision of a “public good” to members of a given society. Hence, governments will be expected to take a heavy share of the responsibility and make substantial investments in diverse areas such as research, development and demonstration (RD&D) in support of innovation in energy technologies and development of new infrastructure to deliver modern energy services.

But this paper demonstrates that the private sector is best placed to lead deployment of proven technologies and that there is a strong case for substantial returns on their investment. In fact, sustainable energy access must be built upon sustainable business models for the provision of energy services. In reality, the public and private sectors will both play significant roles in developing energy systems in emerging economies and developing countries; neither could achieve the stated aims by acting in isolation. Moreover, all segments within each sector must find ways to contribute, often through public-private partnerships at different levels, at different times and in relation to different energy uses.

Leveraging the strengths of each sector is the key to success. Yet experience shows that, indeed, governments must take the lead by establishing consistent policy and regulation that supports the development of sustainable energy systems. Governments with effective policy have a higher rate of success in partnering with multilateral organisations (such as development banks) that help meet the challenge of adequate financing. The combination of consistent policy and adequate financing can stimulate private-sector engagement.

The above discussion has demonstrated significant differences between the three energy subsystems of heat, electricity and transport. Additionally, within each energy subsystem, there are a number of focus areas that need to be addressed in order to provide sustainable energy for all.

Complexity and the size of subsystem investments impact the role of involved stakeholders, especially the private sector. Deployment of cookstoves can be done with significantly less capacity building and long-term engagement of the private sector from a technological point of view, but market strategies to create more sustainable markets are a key role in the area of philanthropy for the private sector, in partnership with governments and NGOs. Within the electricity subsystem, deployment (above the micro-/mini-grid level) requires large investments, long-term stability, key operational and back-room processes, often necessitating the establishment relationships with global companies. Stand-alone electricity systems can gain experience and knowledge from many global stakeholders, but an increased level of local market knowledge and involvement is needed as well. The deployment of transport systems will involve direct deployment of proven technologies in many cases, but opportunities for niche applications could see new developments with targeted technologies for emerging economies and developing countries. Large transport systems with long-term infrastructures, such as BRT, require the engagement of multinational and local companies in the deployment and operation.

These few examples show the value in an initial exercise to map out the type of technology and engagement by business in each of the energy subsystems, demonstrating a broad and varied landscape of challenges and opportunities. The three key types of private sector engagement by the United Nations Global Compact – core business, social investments and philanthropy, and

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advocacy and public engagement – provide a good framework to organise the required efforts by the private sector, but more work is needed in this area to turn this discussion into action.

Next steps

This effort does not fully develop the needs and pathways required in each of the energy subsystems, or describe in great detail the role of the private sector. A number of initiatives could be carried out to continue the development of the steps that are needed to provide energy access:

- A detailed roadmap of each energy subsystem, including specific roles of government and private sectors, and allowing for differing types of countries, technologies and technology pathways. Such an initiative could be used to identify practical methods for private sector involvement, providing a springboard to turn discussion into action.
- Further development of an energy system typology to address needs in the various categories (such as BRICS, LDCs, developing countries and urban versus rural needs).
- Continued and deeper engagement across both the development and energy communities, including a range of participants from both private and public sectors to determine practical solutions for problems illustrated in this report.
- A number of areas are not discussed in detail in this report (freight transport, agriculture- based energy needs, small and medium-scale industries, for example). These areas should be reconsidered in the energy system discussion to produce a more inclusive debate.

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Abbreviations and acronyms

BRT	bus rapid transit
CNG	compressed natural gas
CO_2	carbon dioxide
CSP	concentrated solar power
ESCo	energy service company
ETP	*Energy Technology Perspectives*
EV	electric vehicle
H_2	hydrogen
LDC	Least Developed Country
LPG	liquefied petroleum gas
NGO	non-governmental organisation
PHEV	plug-in hybrid electric vehicle
PV	photovoltaic
T&D	transmissions and distribution
UNGC	United Nations Global Compact
WEO	*World Energy Outlook*

Units of measure

Gt	gigatonne
ktoe	thousand tonne of oil equivalent
kWh	kilowatt-hours
Mtoe	million tonne of oil equivalent
Petawatt	one thousand gigawatts
pkm	one passenger kilometre (one kilometre travelled by one passenger)
ppm	parts per million
toe	tonne of oil equivalent
TWh	one million megawatt-hours or one billion kilowatt-hours

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Regional definitions

Africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, the United Republic of Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia and Zimbabwe.

ASEAN

Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

Asia

Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Chinese Taipei, Fiji, French Polynesia, India, Indonesia, Kiribati, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vanuatu and Vietnam.

BRICS

Brazil, Russian Federation, India, China and South Africa.

Central and South America

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, the Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguilla, Saint Lucia, St. Vincent-Grenadines and Suriname, Trinidad and Tobago, Uruguay and Venezuela.

China

China refers to the People's Republic of China including Hong Kong.

Developing countries

China, India and other developing Asia, Central and South America, Africa and the Middle East.

Former Soviet Union (FSU)

Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

Latin America
Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican , Republic Ecuador, El Salvador, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Lucia, Saint Pierre et Miquelon, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, and Venezuela.

Least Developed Countries (LDC)
Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, São Tomé and Príncipe, Senegal, Sierra Leone, Solomon Islands, Somalia, Sudan, Timor-Leste, Togo, Tuvalu, Uganda, United Republic of Tanzania, Vanuatu, Yemen, and Zambia.

Middle East
Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates and Yemen. For oil and gas production, it includes the neutral zone between Saudi Arabia and Iraq.

OECD member countries
Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Israel, Japan, Republic of Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

OECD Europe
Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, and the United Kingdom.

OECD North America
Canada, Mexico, and the United States.

OECD Pacific
Australia, Japan, Republic of Korea, and New Zealand.

Other Africa
Africa excluding South Africa (see *Africa*).

Other Asia
Asia excluding China and India (see *Asia* and *China*).

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Other Former Soviet Union (Other FSU)

All Former Soviet Union countries excluding the Russian Federation (see *Former Soviet Union*).

Other Latin America

All Latin America excluding Brazil (see *Latin America*).

Sub-Saharan Africa

Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, the United Republic of Tanzania, Togo, Uganda, Western Sahara, Zambia and Zimbabwe.

Transition economies

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, the Federal Republic of Yugoslavia, the former Yugoslav Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russian Federation, Slovenia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

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