

Energy Technology R&D Needs of Emerging Economies

*Experts' Group on R&D Priority Setting and Evaluation Workshop,
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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
 - Improve transparency of international markets through collection and analysis of energy data.
 - Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
 - Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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Experts' Group on R&D Priority Setting and Evaluation

Research, development and deployment (RD&D) of innovative technologies is crucial to meeting future energy challenges. The capacity of countries to apply sound tools in developing effective national research and development (R&D) strategies and programs is becoming increasingly important. The Experts' Group on R&D Priority Setting and Evaluation (EGRD) was established by the Committee on Energy Research and Technology (CERT) to promote development and refinement of analytical approaches to energy technology analysis, R&D priority setting, and assessment of benefits from R&D activities.

Senior experts engaged in national and international R&D efforts collaborate on topical issues through international workshops, information exchange, networking, and outreach. Nineteen countries and the European Commission participate in the current programme of work. The results and recommendations provide a global perspective on national R&D efforts which aim to support the CERT and feed into analysis of the IEA Secretariat.

For information specific to this workshop (agenda, background information, and presentations) see www.iea.org/newsroomandevents/workshops/workshop/name,32866,en.html.

For information on the EGRD see www.iea.org/aboutus/standinggroupsandcommittees/egrd/.

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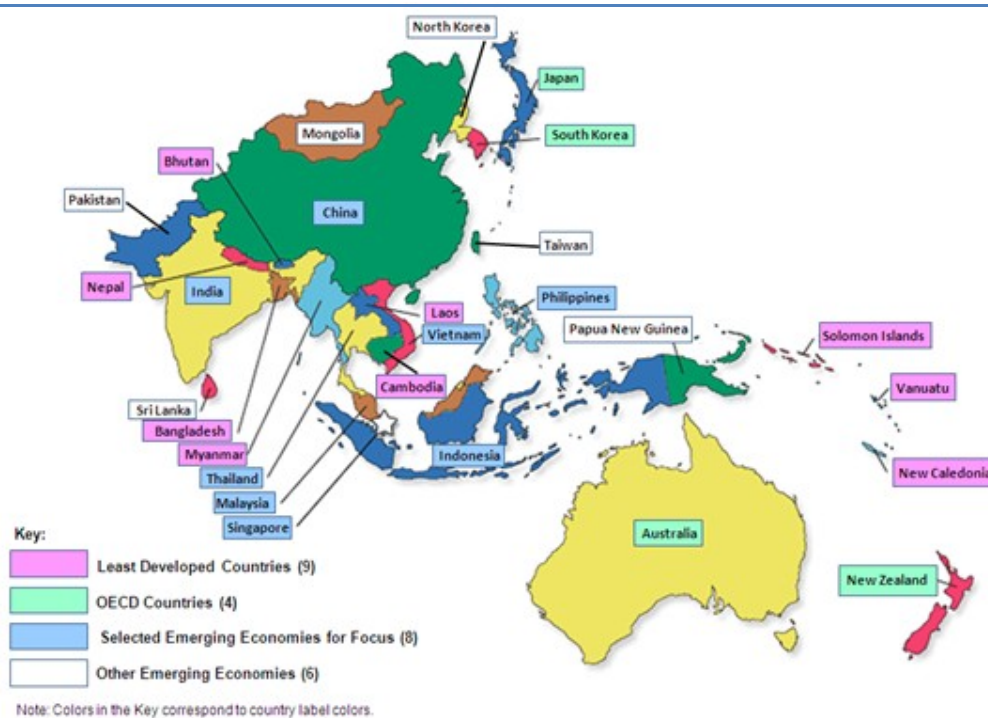
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Executive summary

The Experts' Group on R&D Priority Setting and Evaluation (EGRD) examined the clean energy technology R&D needs of select emerging economies in the Asia-Pacific region (Figure 1).

Page | 4 **Figure 1 • Asia-Pacific Region** (names of emerging economies for focus shown in blue)¹



Source: United States Department of Energy.

All countries face common challenges, including the need for energy security, environmental protection, and affordable energy. These challenges, coupled with rapidly growing energy demand and rising aspirations of societies in the Asia-Pacific region's emerging economies have led many nations to develop and implement national energy policies and strategies to address specific challenges. International R&D cooperation can help expose nations to mechanisms and lessons learned that might not otherwise be available through national activities. It can yield benefits for nations seeking cooperative and innovative alternatives to domestic R&D efforts.

Based on the information gained during the workshop, emerging economies of the Asia-Pacific region broadly seek energy systems and technologies comparable to or better than those of more mature economies. However, energy systems can differ in scale, extent of electricity networks, cost, and mix (depending on local resources). The R&D needs of emerging economies in the region include:

- **Policies** that support clean energy technology R&D, such as integrating R&D plans with high-level government support based on a multi-disciplinary approach; phasing out fuel subsidies; rationalization of energy prices to attract private capital; develop a capable workforce with expertise in operations and maintenance of clean energy systems through training and skills improvement; establish future resource needs through long term plans, combined with the

¹ Countries that participated in the workshop include Australia, China, India, Indonesia, Japan, Korea, Malaysia, Singapore, and Thailand. Philippines and Vietnam were not able to participate in the workshop, although further information for these two countries was gathered and is included in this report in order to broaden comparisons and findings.

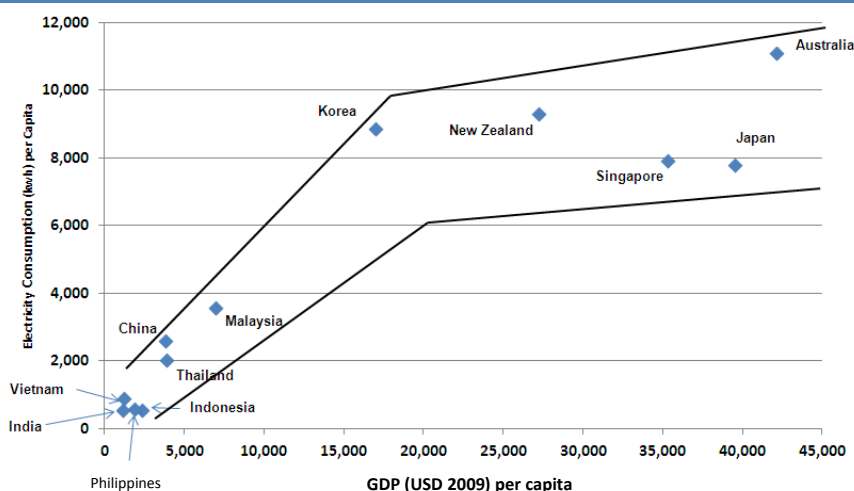
actions needed to work towards deployment or investments needed to broaden the resource base.

- **Technologies** that capitalise on existing national resources, including efficient coal-fired power plants, carbon capture and storage (CCS), wind (onshore and offshore), biofuels, and ocean/tidal energy; reduce consumption such as energy efficiency programmes and measures, smart grids, or transportation; and provide “island power”— clean energy that improves access to power for those living in rural populations, such as solar heating to purify water, solar-powered refrigeration for food and medicines, and clean cookstoves.
- **Platforms** that support mechanisms for financing to overcome risks and provide attractive returns for investors and that enable international cooperation, including technology transfer mechanisms; information sharing systems to collect and disseminate information on renewable and clean energy technologies and best practices; international support for pilot/demonstration projects; internships and researcher exchanges with other countries; and international exhibitions of R&D equipment, instruments, and materials.

Drivers, needs, and opportunities

World energy consumption trends indicate a shift toward greater consumption among emerging economies that are not members of the Organisation for Economic Cooperation and Development (OECD). Population growth, per capita increases in gross domestic product (GDP), and continued urbanisation, especially in emerging economies, are key trends that are driving rapid growth in electricity consumption and final energy use (Figure 2). These recent trends have also added to concerns about environmental quality, including urban air quality, sanitation and deforestation, water quality and supply, and access to electricity. Such challenges—which pose a disproportionately heavy burden on the least developed countries—may be best addressed by regional efforts tailored to regional, bilateral, or national circumstances rather than relying on global markets to produce viable technology solutions.

Figure 2 • Relationship between electricity consumption and gross domestic product



Source: World Bank (2009), *World Development Indicators*, databank WDI-GDF, Washington, D.C., United States.

The growth in non-OECD energy consumption and related emissions presents an opportunity to improve international coordination on energy policy and technologies. Such coordination at the global or regional level should leverage the experience and expertise of OECD countries to apply

successful implementation models from around the world, but only by first understanding the unique circumstances and needs of non-OECD countries. Financial support schemes similarly depend on the ability for governments to identify opportunities for improving energy efficiency while at the same time setting fiscal and financial policies that may attract international investment.

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Experts participating in the IEA Implementing Agreements (IAs) work to find solutions to current energy challenges of energy security and environmental protection. These groups enable both OECD and non-OECD countries and the private sector to partner together in accelerating research results and to share experiences. The Committee for Energy Research and Technology (CERT) endeavours to bridge the gap between technology policy and the research results of these groups. Other international collaborations and institutions beyond OECD countries support emerging economies' policy initiatives and financial investments.

Emerging economy perspectives

Emerging economies in the Asia-Pacific region face a unique set of challenges in the development of clean energy resources and technologies. Energy resource endowments (see Appendix A), political frameworks, governance issues, market policies and mechanisms, and the level of coordination among national entities serve to shape the approaches that each country takes to developing clean energy technologies. A variety of renewable energy technologies are available and renewable energy use is growing fast—particularly in the Philippines, and Indonesia—albeit from a relatively small base. Coal, natural gas and, where available, hydropower are the main sources for power generation among the emerging economies in the region.

Although every nation differs in terms of size, needs, and priorities, examining experiences from other countries that have implemented clean energy R&D programmes provides insight into the needs that drive the formulation of strategies, priorities, and policies. This context also helps show how different energy situations form the basis for prioritizing energy technology research and development to meet urban and rural energy demand. This is embodied in the national energy policies and strategies that have been developed by these emerging economies—including well-defined clean and renewable energy and energy efficiency targets—in order to secure a clean and sustainable development path.

OECD country perspectives

OECD countries can provide examples of successful energy programs that governments of emerging economies can consider adopting when developing their own programmes. Individual OECD countries also provide bilateral technical or financial assistance. For example, the Australian Renewable Energy Agency (ARENA) and Japan's New Energy and Industrial Technology Development Organisation (NEDO) carry out projects aimed at building skills and capacities and technology transfer, respectively. Korea similarly has carried out many successful clean energy programmes in emerging economies. These nations provide examples of mature technology "push" and market "pull" mechanisms and energy technology roadmaps and programmes that can serve as models for developing countries.

Collaboration between OECD and non-OECD countries can accelerate energy technology innovation in part because multidisciplinary approaches that arise from different national perspectives encourage new thinking about energy technology issues. In order to be effective, efforts must be undertaken considering the priorities and interests of all parties.

Financial sector perspectives

Clean energy technology R&D activities are more successful when supported by dedicated resources and careful planning among multiple stakeholders, including collaboration and contributions from the public and private sectors. Successful R&D efforts are also characterised by ensuring the proper resources are deployed and the appropriate policies and mechanisms are in place to nurture R&D projects to commercialisation. There is a need to distinguish between different forms of investment—private equity and public market investments. The lack of clear roles and responsibilities between actors representing government, academia, the private sector, and other NGOs may hinder investment in clean energy R&D efforts.

Cross-cutting and integrated perspectives

New technologies must excel in a variety of areas in order to be useful, effective, and scalable in an emerging economy. They must be affordable, technically effective, robust and reliable, culturally appropriate, and widely applicable. These requirements tend to be independent of market conditions, and the institutional, social, and cultural factors that may inhibit uptake. This emphasises the need to focus on bringing technology to markets and should not underestimate the importance of information exchange and sharing experience, best practice, and analysis. Because there is not a one-size-fits-all model for international collaboration on R&D, a range of cooperative solutions and policies and programmes should be pursued.

Robust domestically focused programs can also have significant impacts in bringing technologies to market. In developed economies, great strides have been made in areas like efficient appliances through stricter standards and labelling and recognition programmes like the United States' Energy Star programme or Korea's mandatory energy efficiency labelling programme. These successes have application in emerging economies, but may not be directly transferrable due to lack of access to electricity, lighting, and clean water.

Discussion and conclusion

International collaboration on clean energy R&D has the potential to improve energy security, environmental protection, and economic growth in emerging economies in the Asia-Pacific region. Collaboration supports innovation that focuses not only on new technologies, but also addresses the availability and feasibility of disseminating and implementing technologies. Careful planning, delineated roles and responsibilities, and involvement of both public and private sectors can help countries develop and deploy energy technologies and supporting R&D programs and policies. Designing technology strategies that leverage international experiences and align with local energy circumstances can help maximise the societal benefits of clean energy technology R&D. Finally, technology must account for human factors, including training and maintenance, in order to deliver on promised gains in energy production and efficiency.

Background

Future energy systems must meet rapidly growing needs for energy in an expanding global economy. The IEA publication *Energy Technology Perspectives 2012 (ETP 2012)* indicates that, if current energy trends continue, global energy demand and emissions of carbon dioxide emissions (CO₂) may be expected to double by 2050, resulting in a warming of average temperatures by 6 degrees centigrade (°C). The ETP 2012 indicates further that much of this growth is likely to arise from non-OECD countries.

Twenty years ago the community of nations collectively agreed that countries should avoid the most serious consequences of climate change. This was codified by an international treaty in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) which has since been ratified by more than 190 countries. The central goal of the UNFCCC is to stabilise concentrations of greenhouse gases in the Earth's atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system². Apart from climate change, energy security, reliability, affordability, efficiency, and a host of more immediate energy-related environmental concerns loom large in future energy planning in all countries.

The *ETP 2012* takes a long-term view of the energy and environmental challenges of the 21st Century. It outlines a critical role for technology and innovative solutions across a range of uncertainties. Most energy demand and environmental emissions over the course of this century will come from equipment and infrastructure not yet built—a circumstance that poses significant opportunities to improve efficiency, build out infrastructure and equipment in a sensible way, and reduce or eliminate future emissions.

The task of bringing forth practical technologies that are reliable, affordable and meet acceptable environmental constraints is too large for a just few countries, or even the entire R&D community. Today, technological innovation arises from many sources and many countries. A recent report³ suggests that emerging economies are increasing their share of global innovation and RD&D, which is predominantly funded by governments including investments by state-owned enterprises, and may have control over larger amounts of energy RD&D funding than the governments of the IEA member countries. Further, some technological challenges faced by emerging and smaller economies are unique and shaped by local or regional circumstances.

The clean energy R&D needs of emerging economies are not well understood and may not be receiving adequate support. Yet, technological innovation has the potential to transform the future of the global economy in fundamental ways that can address not just climate change concerns, but also energy security, air quality, and many energy-related economic, social and environmental concerns.

² United Nations (1992), United Nations Framework Convention on Climate Change (UNFCCC). New York, United States.

³ IEA (2013), *Tracking Clean Energy Progress 2013*, OECD/IEA, Paris, France.

Introduction

Under the auspices of Experts' Group on R&D Priority-Setting and Evaluation (EGRD), and in cooperation with China's Ministry of Science and Technology (MOST), an international workshop was held in China to assess the clean energy technology R&D needs of the emerging economies in the Asia-Pacific region. While many such needs may be well aligned with those of fully developed economies, emerging economies also encounter unique situations as a result of their stage of development, modes of economic development, endowments of natural resources, quality of fuels, demographics and urbanisation, cultural aspects of energy use, and other country-specific circumstances.

Some of the needs for energy R&D of these economies differ in significant and unique ways. This workshop explored the drivers underlying energy demand in these economies, assessed clean energy technology needs, gathered insights on R&D investment priorities, discussed modalities for international research and development (R&DRD) cooperation, and summarised implications for both IEA member and non-member country R&D portfolio planners and technology investors.

This workshop aimed to achieve the following outcomes:

- identify drivers of future energy demand in the emerging economies of the Asia-Pacific region;
- identify clean energy technologies and associated R&D gaps and opportunities particular to the region;
- characterise attributes of desired future energy systems, noting common and distinctive features;
- gather insights on R&D investment priorities of emerging economies, individually and collectively;
- explore existing and preferred "modalities" for enhanced international R&D cooperation; and
- list considerations for R&D portfolio planners.

Assessing the common and unique needs and opportunities of emerging economies in the Asia-Pacific region can help gather insights on energy R&D investment priorities at the national and regional levels. This provides context for understanding the functions of and relationships between key entities in the private sector, public sector, financial sector, industry, and other actors that play vital roles in the clean energy technology R&D process.

When examining R&D needs of economies in the region, it is important to understand the natural resource endowments, national demographics and other region and country-specific elements that dictate opportunities and drivers. Discussing the range of regional circumstances and R&D priorities also presents an opportunity to compare and contrast the current energy situations and development paths of a variety of emerging economies that may be under-represented in the global R&D portfolio. While the focus of this summary report is conveying workshop findings regarding the R&D needs for clean energy technologies, the supporting structures and policies are also included to provide a more comprehensive overview of emerging economy R&D needs.

Report structure

The report first provides an overview of clean energy technology R&D in emerging economies, followed by an investigation of the energy situations, drivers, needs, and clean energy technology R&D strategies of selected countries present at the workshop. Perspectives are provided from

selected OECD countries, from the financial sector, and from other organisations involved in clean energy technology R&D. Lastly, emerging economies' R&D needs are summarised in a discussion of the workshop's findings (see pages 52-54).

Clean energy R&D: drivers, needs and opportunities

Projected growth in energy consumption and energy-related carbon emissions under a “business-as-usual” (BAU) scenario highlights the importance of a comprehensive approach with policy, finance, and technological solutions. Globally, residential and commercial buildings represent one-third of global final energy use, and roughly the same portion of energy-related carbon emissions. Population growth and continued urbanisation, especially in emerging economies, will contribute to rapid growth in final energy use in these sectors. Similar trends exist in the transportation sector. World energy consumption trends also indicate a shift toward greater consumption among non-IEA countries. The industrial sectors of OECD countries represent one-third of global industry related CO₂ emissions. By 2050, non-OECD countries' industrial sectors may represent 80% of total industrial emissions.

The trends and drivers identified above indicate a need for better coordination internationally on energy policy. Such coordination should leverage the experience and expertise of OECD countries to apply successful implementation models around the world, but only by first understanding the unique circumstances and needs of recipient countries. To identify the potential opportunities for improving energy efficiency while creating the returns needed to attract international investment, sound financial support schemes and policies are required. Finally, more international collaboration beyond OECD countries in energy technologies will support and be supported by these policy initiatives and financial investments. The IEA Secretariat helps bridge the gap between energy technology experts by supporting the multilateral technology initiatives known as Implementing Agreements (IAs) to help address the world's energy needs.

Finally, much of the infrastructure and energy systems that will drive final energy consumption during the remainder of this century have not yet been built. This circumstance presents an enormous opportunity to implement best available technologies into the new projects that will accommodate growing populations and developing economies. Innovation from energy R&D will ensure continuing improvement across the globe.

The importance of meeting clean energy R&D needs of emerging economies

Mr. Peter Cunz, Chair, Committee on Energy Research and Technology

<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDCunz.pdf>

The IEA has a global reputation as a well-known and credible reference and a hub for collaboration. World energy consumption trends have reflected shifts more towards non-IEA countries. This shift demonstrates the importance of international collaboration beyond the Organisation for Economic Co-Operation and Development (OECD) for energy technology. The expected worldwide growth in energy use and energy-related CO₂ emissions in the residential, commercial buildings, transportation, and industrial sectors under a BAU scenario highlights the need to address these significant trends with a mix of policy, finance, and technological solutions.

Collaboration beyond OECD member countries is strongly supported in the energy technology network⁴. Scientists and researchers are familiar with co-operation beyond country borders. Although energy technologies are widespread, energy policy is not as international in scope or implementation. This makes it difficult to align common strategies and efforts of nations striving to lessen their contribution to the impacts of climate change.

⁴ Comprised of the Committee on Energy Research and Technology (CERT), the working parties, the experts' groups, and the Implementing Agreements.

The Committee on Energy Research and Technology (CERT) coordinates and promotes the development, demonstration, and deployment of energy technologies to meet challenges in the energy sector. Through multilateral technology initiatives known as Implementing Agreements, the IEA provides member governments with a mechanism that helps bridge the gap between energy technology experts around the globe in order to help meet the world's energy needs.

It is important to note that collaboration is not the only requirement to advancing energy technology development—significant investments will be needed. According to the *Energy Technology Perspectives (2012)* (ETP 2012) 6-degree scenario (BAU scenario), approximately USD 19 trillion will be invested by 2020. This scenario assumes that the average global temperature change from pre-industrial levels is limited to 6 degrees centigrade (°C) in the long term. In the more aggressive 2-degree scenario (2DS), which assumes extensive transformations in the energy sector and other key non-energy sectors of the global economy, global temperature change is capped at 2°C. In order to reach the goals outlined in the 2DS scenario, an additional investment of USD 5 trillion is needed globally, and for China alone the investment requirements are higher than for all OECD member countries combined. Even with such large additional investment requirements to meet the 2DS outcomes, the resulting fuel savings create financial savings of roughly the same amount (USD 5 trillion).

The magnitude of the needed investments signals the need for significant “bankable” opportunities to attract capital from institutional and private investors. Much like any business, “green business” investments are only as attractive as the profits they return. However, investors tend not to invest in early-stage technologies or in small projects due to the inherent risks and high transaction costs involved. The lack of clarity, predictability, and general uncertainty surrounding financial support schemes, their life-cycles and mechanisms further hinders the flow of capital.

It is also important to avoid raising the price of CO₂ emissions in some regions and not in others, as this prohibits any progress towards greater competitiveness on the global stage. This presents the biggest challenge to a low-carbon future: agreement on how to share the uneven costs and benefits of clean technology across generations and countries. In order to address these distributional issues, international harmonisation of policy is required, with a focus on harmonising investment and business rules to help lower the costs of investment.

Though investment capital may be available on world markets, the current economic environment and the lack of certainty regarding return on investment (ROI) demonstrates the need for a compelling investment vehicle. The views and perspective of industry and the requirements of the financial sector and financing entities must be better understood and communicated, and the linkage between industry, finance, and policy must be improved. In addition, the OECD and large non-OECD economies should collaborate in an attempt to safeguard the global environment for future generations. Collaborative research, development, and demonstration (RD&D) must be implemented and knowledge of energy technologies disseminated throughout large non-OECD economies in order to share the responsibilities with the OECD and work towards a cleaner future.

A comparative analysis of clean energy technology contexts and challenges in the region

Dr. Robert C. Marlay, Deputy Director, Climate Change Policy and Technology, United States Department of Energy

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<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDMarlay.pdf>

Much of the projected growth in global energy demand and emissions of greenhouse gases is likely to arise from newly emerging economies and other countries of the developing world, according to ETP 2012 (Figure 3). Yet, the clean energy R&D needs of these economies are not well understood and may be under-represented in the global R&D portfolio. Identifying and capturing the efficiency opportunities in these countries will be crucial for future energy systems to provide adequate global energy supply.

Bringing the R&D needs of emerging economies to the forefront of international planning will require careful analysis of many factors including:

- identifying and understanding drivers of future energy demand in the Emerging Economies of Asia;
- characterising attributes of desired future energy systems, noting common and distinctive features;
- identifying clean energy technologies and associated R&D needs and opportunities;
- forming insights on energy R&D investment priorities of emerging economies, individually and collectively;
- identifying R&D gaps and opportunities particular to the region;
- listing considerations for future IEA member and non-member country R&D portfolio planners; and
- exploring existing and preferred “modalities” for enhanced international S&T cooperation.

Rising aspirations for electricity use per capita drive the IEA projections that non-OECD Asian economies will dominate future growth in global energy demand. Rising population and trends towards urbanisation further underpin the expected growth from these countries. Rural electrification in several large countries, India and Indonesia in particular, will give access to electricity to large portions of the population currently without access.

Large increases in energy demand portend greater emissions and potential damage to the environment. Urban air quality is likely to suffer, affecting the health of rising urban populations. Further concerns over water, sanitation, and deforestation will also need to be addressed, and forecasts suggest that fresh water supply will be a growing issue.

Climate change presents daunting challenges that may have large impacts on energy infrastructure and systems as well as potentially profound longer-term effects on civil society. Addressing these challenges, however, presents great opportunities to shape the future with innovation and new technology, especially considering that most energy demand and associated emissions over the course of this century will come from equipment and infrastructure not yet built.

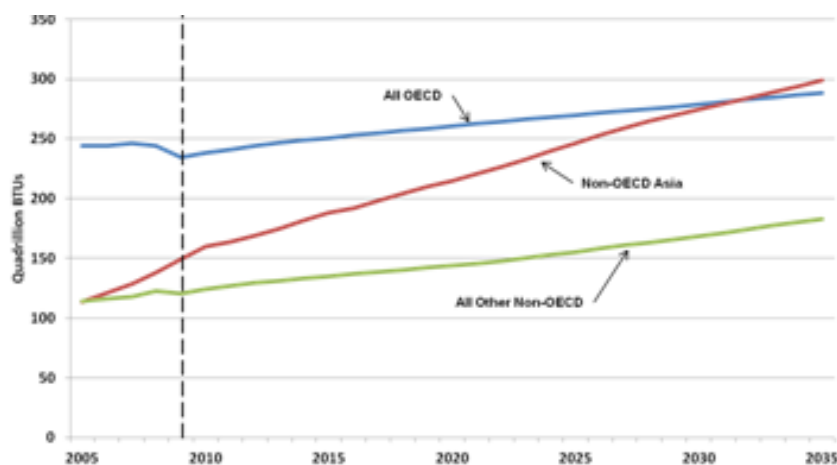
Energy and economic circumstances vary among the individual emerging economies of Asia and the Pacific region. Countries have various quantities of natural resources available, and they utilise a wide range of different primary energy sources to meet their particular energy and

electricity requirements. They are at vastly different levels in terms of adopting renewable sources of energy (Figure 4). At one end of the spectrum, New Zealand generates 56.5% and 16.4% of its electricity with hydropower and other renewable energy technologies, respectively, while the Republic of Korea produces only 1.2% from all these sources combined.

Electricity is produced mainly from coal, natural gas, and hydropower. Nuclear power plays a relatively minor role in the selected countries. Almost all forms of renewable energy are available and used. Renewable energy is the fastest growing form of energy, but it is starting from a relatively small base. In the Asia-Pacific region, renewable energy (excluding hydropower) is fastest growing in Philippines, New Zealand, and Indonesia.

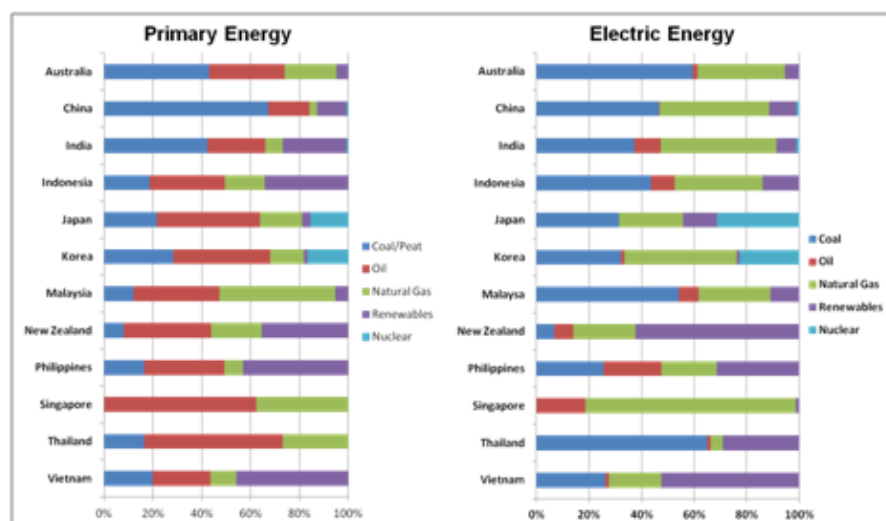
Traditional fuels are expected to account for nearly 80% of primary energy use in Asia and the Pacific in 2030. According to the World Energy Outlook (2011), investment in the power sector over the next 25 years is expected to reach USD16.9 trillion. Nearly two-thirds of this investment is expected to occur in non-OECD countries.

Figure 3 • Increases in primary energy demand by region



Source: Gruenspecht, H. (2011), *International Energy Outlook 2011*, United States Energy Information Administration (EIA), Washington, D.C., United States.

Figure 4 • Energy supply mix by country



Source: IEA (2009), *World Energy Statistics*, Paris, France.

Clean energy R&D: emerging economy perspectives

Anticipated growth in developing countries' energy demand and the associated contributions to GHG emissions and climate change have elevated the importance of clean energy technology R&D. Emerging economies face a unique set of challenges in the development of clean energy resources and technologies. Energy resource endowments, political environments, market policies and mechanisms, and the level of collaboration among national entities will likely shape the approaches that each country takes to developing clean energy technologies. This illustrates the influence of regional and national circumstances in the development of clean energy technology solutions.

Emerging economies share a common goal in their aspirations for broader access to clean energy and electricity. The implementation of aggressive energy conservation and renewable energy deployment targets can provide the needed impetus for clean energy technology development, but success of these efforts hinges on the presence and strength of enabling policies and organisations and the prioritisation of R&D needs and opportunities.

Emerging economies and their respective energy situations, development strategies, and available mechanisms for enabling clean energy technology R&D differ in terms of size, needs, and priorities. Country-specific backgrounds and needs drive the formulation of strategies, priorities, and policies. Different energy situations help form the basis for prioritizing energy technology development to meet urban and rural energy demand.

Emerging economy perspectives: China

Mr. Zheng Fangneng, Director of Energy, Department of High and New Technology Development and Industrialisation, Ministry of Science and Technology

Note: Presentation slides are unavailable. A summary of China's 12th Five Year Plan provides more information http://apcoworldwide.com/content/PDFs/Chinas_12th_Five-Year_Plan.pdf

Today, China is largely dependent upon fossil fuel energy resources to meet its growing demand for energy. The nation's long term dependency on fossil fuels—specifically on coal—is exemplified by the mix of proven energy resource reserves as of 2010 that include coal (93%), petroleum (2.9%), and natural gas (3.7%). When considering the location of resource deposits and power generation infrastructure, the distribution of energy resources across the country is unbalanced. Coal is typically transported from North to East and power is transported from West to East, where population centres are located. Despite this imbalance, China is the world's largest energy producer (3.18 billion tonnes of coal equivalent [tce]) and the second largest energy consumer (3.48 billion tce) and China's demand for energy has been growing at a rapid pace since 2000.

Though coal plays a critical role in meeting China's energy needs, the nation's fossil fuel dependency also includes petroleum and natural gas. Oil consumption in China is growing and it is now ranked as the world's second largest oil consumer (457 million tonnes of oil); the world's third largest oil importer (260 million tonnes of oil); and oil dependency is at roughly 58%. In addition, natural gas consumption in China is on the rise and a major project focused on exploration and development of shale gas is also expected to be launched. In terms of electricity generation, China now ranks as second in the world in total power generation capacity (over 1,050 GW). Although there is a heavy dependence on fossil fuels, renewable energy deployment is also increasing. Deployment goals for 2015 exist for wind energy (100 GW), biomass (13 GW), photovoltaic (PV) solar energy (20 GW), as well as solar thermal energy (1 GW).

Looking forward, a few strategic requirements have been laid out as necessary components of a strategy for China's near- and long-term development. These requirements include: efficiency improvements and related energy savings; promoting renewable and nuclear power to meet 15% of primary energy consumption; carbon intensity (carbon emissions per gross domestic product, or GDP, of consumption) reductions of 40% to 45% by 2020; increase share of non-fossil fuel energy from 10% (currently) to 15% to 18% by 2020; and technological innovations that will drive roughly 40% to 45% of carbon emissions reductions.

In addition to the strategic goals, China's strategy involves a linkage between energy development and climate change mitigation measures. In the medium- to long-term, these strategies include prioritizing energy conservation; greater reliance on domestic resources and markets to meet energy demand; and energy development that relies on technology and innovation. These strategies also include a focus on harmonizing energy consumption and environmental protection efforts and will benefit from encouraging cooperation based on mutual benefits.

The development and implementation of policies and laws will be critical for building the foundational basis for developing China's energy technologies. Given this consideration, there are several examples that include China's 15-year Medium- to Long-Term Plan for the Development of Science and Technology that was initiated in 2006. Other key policies and plans include a medium- to long-term plan to develop China's energy industry and a renewable energy law initiated in 2006, a medium- to long-term outline for renewable energy development initiated in 2007, and an energy conservation plan that was released in 2008. In addition, China has also agreed to and developed policies to cope with climate change that include signing the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and signing the Kyoto Protocol in 1998. In 2004, the Chinese Ministry of Science and Technology (MOST) published the nation's scientific and technological actions to address climate change, and in 2007 China's State Council published China's National Climate Change Program.

China's 12th and most recent Five-Year Plan (FYP 2011-2015) builds on the progress of the above-mentioned policies and plans that have been initiated over recent decades. The 12th Five-Year Plan lays out seven key tasks:

- strengthen the exploration and development of domestic resources (e.g. development of coal, conventional oil and gas resources, shale gas and coal-bed methane, hydropower, wind, solar power, and other renewable energy sources);
- promote efficient and clean energy conversion (e.g. development of clean coal, promotion of coal washing and deep processing, development of the refining and processing industry, and development of natural gas for power generation);
- promote energy supply mode changes (e.g. distributed energy, smart grid, new energy vehicles, energy supply facilities);
- accelerate construction of energy storage and transportation facilities to improve reserve emergency support abilities;
- implement energy and livelihood projects and promote balanced, basic public energy services in urban and rural environments;
- comprehensive promotion of energy conservation, efficiency, and strengthened management of energy use;
- encourage reforms in electricity, coal, oil, natural gas, and other key areas and rationalise energy pricing mechanisms to entice private capital flows in the energy industry, and

promote technological progress and deepen international cooperation to safeguard energy security.

The latest Five-Year Plan also includes new energy intensity and carbon intensity reduction targets and a comprehensive work plan released by the State Council detailing 50 specific measures that will support progress towards the energy intensity target and absolute reduction targets for criteria pollutants (e.g. chemical oxygen demand, ammonia, sulphur dioxide, and nitric oxides). The 12th Plan focuses on energy technology development in several key areas that include: renewable energy, smart grid, clean coal, advanced nuclear energy, hydrogen fuel cells and storage, and other energy saving technologies.

Among the technologies that are a focus of the 12th FYP, a few technologies have garnered extra attention and are considered to be priority projects:

- Smart grids: Grid connection for large-scale renewable and distributed sources; electric vehicle applications' impact on the electric grid; large-scale energy storage technologies and systems; demonstrations of integrated smart grid technologies; and smart dispatching technologies, intelligent operation and control of the grid;
- Clean coal: Promotion of large-scale, coal-based multi-generation demonstration plants for gasification, liquefaction and chemical products; development in key technologies and equipment for ultra supercritical (USC), Integrated Gasification Combined Cycle (IGCC), and circulating fluidised bed (CFB) power generation; and demonstration of pollutant control technologies;
- Solar energy: Development of technologies, processes, and equipment for manufacturing of solar materials and systems; development of key technologies for large-scale solar systems; improved standards for quality assurance and control; enhanced efficiency of crystal silicon cells above 20%, silicon-based membrane cells above 10%, and lower cost investment per kilowatt-hour (kWh);
- Wind power: Industrialisation of technology for overall units, specifically for 3-5 MW wind turbines; development of prototype for large-scale 10 MW wind turbine; large-scale common test and verification platform; design, construction, operation, and maintenance of off-shore wind; connection to grid.

Aside from these priority projects, China has also identified four key tasks to advance different classes of energy technologies that include select renewable energy technologies (e.g. geothermal, ocean energy, biomass); advanced nuclear technology (e.g. safety equipment and technology, advanced fuel cycle technology); advanced hydrogen storage technology and fuel cell technology; and energy conservation and storage (e.g. heat recovery from industry; high-efficiency buildings; chemical and physical storage).

The range of technologies that are garnering R&D resources and focus demonstrate a concerted effort to integrate clean energy into a sustainable development path for China. Wind power—both on-shore and off-shore—is an important element in and a priority of China's clean energy development path. Off-shore wind is seen as a potentially significant contributor to China's energy mix, particularly in coastal areas where power can be fed directly to load centres. China is one of the few countries in the world with large-scale offshore wind projects. In 2009, China launched its largest off-shore wind project (100 MW) near Shanghai and another is being built near Jiangsu.

Despite investments and other resources flowing towards the variety of clean energy technologies described above, energy efficiency improvements still present a feasible opportunity to improve energy performance. While the current Chinese strategy and framework

is channelling more resources to the four priorities outlined above, energy savings is involved in all projects and this does not reflect a lack of focus on energy efficiency and its potential benefits. One example of China's attention to energy efficiency is manifested in the nation's manufacture and export of household appliances around the world. Appliances must comply with the standards of the importing country as well as international standards, and in the development of Chinese products, these standards must improve over time.

China and the international community have many common interests. Information sharing can improve cooperation and strengthen efforts to reduce CO₂ emissions and mitigate climate change; undertake R&D on clean energy technologies; and improve commercial cooperation in the energy sector. In this regard, China has demonstrated its commitment to cooperation with the IEA and international collaboration in energy development activities. All of the key stakeholders should be involved in collaborative efforts in order to maximise the benefits for all.

Renewable energy R&D trends in Thailand

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<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDTwarath.pdf>

Today, Thailand depends largely on petroleum products (36%) and natural gas (44%) to meet its energy consumption needs. The nation currently is a net importer of energy—over 80% of the value of its imports is spent on crude oil—and imports account for nearly 20% of GDP. In addition to crude oil, Thailand imports electricity, coal, natural gas, and petroleum.

Thailand has recently established goals to reduce energy intensity by 25% by 2030 and is focusing on eliminating oil subsidies. Given the nation's domestic petroleum products resources, Thai producers benefit from market forces setting energy prices.

Recent strategic considerations in energy policy have resulted in Thailand's Alternative Energy Development Plan (2012-2021). Committed to the development of a low-carbon society, the country has set a target of 25% of renewable energy to meet the nation's energy consumption needs by 2021. While resource constraints may limit projects to smaller-scale deployment and applications, urban areas such as Bangkok may be feasible targets for development and deployment of cost-effective rooftop PV systems. Currently available technologies may help renewable energy serve up to 20% of Thailand's energy consumption needs today, but additional efforts are needed to increase that figure to meet the 25% goal.

In order to meet this goal, a range of technologies will be needed including solar, wind, small and mini-hydropower, bioenergy, biofuels, and other technologies (e.g. tidal wave power, geothermal power). Despite the pivotal role these technologies will play in meeting this target, efforts will also rely on government funding of R&D activities and encouraging the private sector to lead the charge with investments in key areas. Government strategies to encourage private sector investment—specifically in bioenergy—may include feed-in tariffs, tax incentives, and other economic incentives to spur private sector investment in and development of projects.

Critical areas requiring R&D for furthering renewable energy development in Thailand include development of second- and third-generation biofuels, increased local presence and development of existing technologies, innovation and creation of new technologies. Regardless of Thailand's existing expertise and strength in the field of bioenergy, the development of new biofuels and community-level applications for biofuels, biogas, and biomass present opportunities ripe for cooperation with other international actors.

Meeting the R&D needs of the critical areas identified above will rely on cooperative efforts such as the cross-ministerial coordination between the Ministry of Energy (MOEN) and MOST-Thailand. In this example of ministry-level collaboration, MOEN and MOST-Thailand integrated renewable energy research plans and established a committee to approve and monitor projects. As part of the 2011 Memorandum of Understanding (MOU) between agencies, they also agreed to draft an action plan on Science Technology and Innovation (STI) for Renewable Energy Development (2012-2016). This plan focuses on three sectors: biofuels in transportation (i.e., biodiesel, ethanol, substitute for diesel fuel); electricity and heat (i.e., solar, wind, biomass, biogas, municipal solid waste/MSW); and new forms of energy (i.e., hydrogen, geothermal, ocean energy, energy storage).

As a result of the action plan on STI and Renewable Energy Development, 196 projects have been or will be initiated. The focus is on projects to develop a fuel to replace diesel (45 projects), ethanol-related activities (37 projects), and efforts to further develop solar energy (30 projects). These efforts involve 36 organisations from five ministries: Ministry of Agriculture and Cooperatives; MOEN; Ministry of Industry; MOST-Thailand; and Ministry of Education. Over the next five years, at least USD 187 million will be spent on these renewable energy development projects, most of which will be spent on biofuels.

In an effort to prioritise technology development and deployment efforts, MOST-Thailand conducted a study through the National Science Technology and Innovation Policy Office and with support from the United Nations Development Program (UNDP) and the Global Environmental Fund (GEF). In this report, MOST-Thailand analyzed and prioritised the technology requirements in a report titled Technology Needs Assessments (TNA) and Technology Action Plans Report for Climate Change Mitigation/Adaptation in Thailand. This study produced a mapping (Figure 5) of different technologies based on impacts of the technology (y-axis) and the technologies' readiness level in terms of commercial deployment (x-axis). The following technologies were identified as priority technologies, given their expected impacts and readiness level: solar photovoltaics (PV), second generation biofuels, waste energy capture, biomass for electricity and mass transport, smart grid, and solar thermal energy (i.e., for cooling and hot-water towers).

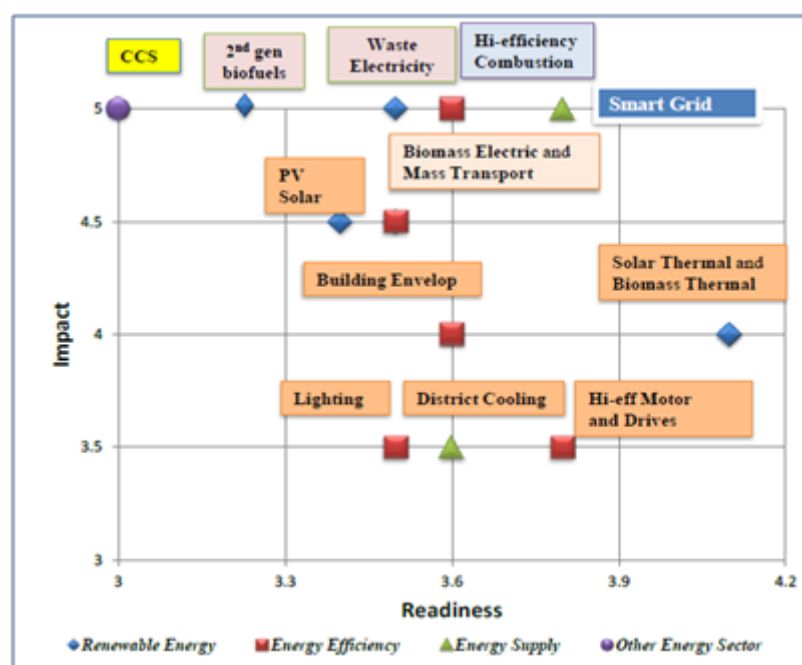
Thailand's key research objectives for a range of technologies are described below.

- **Biofuels:** As part of the new fuels development plan, efforts are focused on reducing costs of ethanol; improvement of cultivation efficiencies for ethanol and biodiesel; and development of non-food sources for biofuels.
- **Solar energy technology:** Improvements to system integration via development of hybrid systems (PV and biomass) and building-integrated PV; low-cost solar hot water and cooling systems on a small scale; study of PV module recycling; and development of installation codes and safety and performance standards.
- **Wind energy technology:** R&D for low-wind speed technologies and energy storage via deep-cycle lead acid batteries; development of micro-scale wind resource maps; installation codes and safety and performance standards; assessments of grid stability; and development of a real-time forecasting system.
- **Small-scale biomass:** Growth of fast-growing crops; development of biomass collection machines; and development of multi-feedstock gasifiers.
- **Biogas for transportation:** Establishment of performance and safety standards for equipment, installation, and production; development of gas desulphurisation technologies.

- MSW with local community focus: Development of waste separation technologies; small-scale power production technologies.
- battery and recycling; reduced cost of fuel cells), smart grids (low-cost smart meters, control systems; align technologies with international standards for smart grid devices) and geothermal and wave technology (energy potentials and prototype plants).

In 2011, R&D funding spent per GDP was an estimated 0.2%. Efforts to raise this figure to 1% of GDP (including private sector investments) will help create jobs and help the broader economy. Given the range of R&D projects that are or will be underway, it is important to consider the various benefits that can result from this type of work. Economic and social benefits may include savings on energy imports, higher crop yields and incomes for farmers and stabilised agricultural prices. Environmental benefits are represented by reductions of CO₂ emissions. Technology benefits include, but are not limited to increased consistency between renewable energy R&D and development policy, in addition to increased competitiveness of technologies and innovations in Thailand.

Figure 5 • Results of Thailand's technology needs assessment



Source: Ministry of Energy of Thailand.

Energy technology R&D needs of Indonesia

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<http://www.iea.org/media/workshops/2012/egrdbeijing/WEBEGRDVerina.pdf>

Indonesia's final energy consumption has been relatively flat compared to its growth in GDP, which implies a fall in energy intensity. Although it has dropped in the last five to ten years, it remains higher than other countries. Primary energy supply has increased significantly in the last two years in part due to large increases in coal. At nearly 40%, oil still represents the largest share of the primary energy supply. Biomass makes up 20% of primary energy: however, this is largely informal use of firewood and charcoal in rural areas. Renewable energy makes up only a small portion overall, and hydropower has seen little growth in supply.

On the consumption side, industry and residential end-uses were 33% and 30% of the final energy consumption as of 2010. Transportation took another 23%, leaving only 14% for commercial and other uses. Indonesia has seen growing energy demand over the past decade as peak load increased nearly 63% between 2000 and 2010. Meanwhile, the transmission and distribution losses have dropped from 11.65% in 2000 to 8.89% in 2010.

Indonesia has approximately 22 year supply of oil reserves at 2010 production rates, 46 years of natural gas, and at least 76 years of coal. Despite these resources, Indonesia has also installed capacity of approximately 13% of estimated potential large-scale hydropower, 28% of mini/micro-scale hydro, and only 3.2% of biomass. Installed capacity of solar and wind energy pale in comparison to the installed capacity of these other renewable sources, thus leaving great potential for both.

Both production and export of coal have increased more than 350% between 2000 and 2010. Production and export of crude oil have both fallen over the same period, while imports of crude have remained relatively constant, such that Indonesia is nearly a net-importer of crude oil. Production of natural gas dropped to a decade-low of just more than 500 000 million barrels of oil equivalent (mboe) in 2007, but rose quickly and steadily to a high of just more than 600 000 mboe in 2010. Meanwhile, exports of liquefied natural gas (LNG) have remained largely flat near 200 000 mboe per year, and export of natural gas via pipeline has grown steadily, but at levels well below LNG exports.

The Ministry of Energy developed future energy projections based on three different policy scenarios: business as usual (BAU), energy security focused, and climate change mitigation focused. All three projection scenarios foretell oil falling sharply from its current 47% of energy supply to between 21-26% in 2030. However, even under the mitigation scenario, oil and coal combine to provide more than half the primary energy supply. These projections vary however on whether coal or natural gas will make up the bulk of the difference.

Oil, gas, and coal are important commodities in Indonesia's energy sector, both as energy resources and as sources of national income. Although coal is predicted to replace oil as the dominant primary energy supply, imports could still increase the supply of oil from 422 MBOE in 2010 to 997 MBOE in 2030 under the BAU scenario. Even assuming aggressive measures to implement energy conservation and clean energy resources, the oil supply could reach 909 MBOE in 2030. In Indonesia, the industrial and transportation sectors are expected to remain the largest energy consuming sectors of the economy.

Many barriers exist to improving energy conservation and clean energy development. In particular, many new technologies have high capital costs, and are considered high risk. The unattractiveness of these investments becomes even more pronounced by considering the large subsidies for existing energy supplies. Deploying energy efficient technologies requires expertise to realise the potential financial gains. If projects perform poorly due to lack of knowledge, other potential users may lose confidence in the applicability of the technologies. Furthermore, immature clean technologies do not have the robust infrastructure (e.g. in maintenance expertise and replacement equipment) needed to support ongoing operation. Finally, Indonesia has unique socio-economic and geographic hurdles among large countries given its land mass is spread out across an archipelago that includes hundreds of large and small islands and under-developed regions. Such disparity results in differences in research between large islands and small islands, the latter being more focused on things like micro-grids. Further government incentives are needed to support uptake of renewable energy in these areas.

With limited resources — budget, educated workforce, industrial partners — R&D projects must be prioritised based on insightful analysis. That is, any imported technologies must suit the situation given available resources and local conditions. Currently, deployment of many projects

occurs because of the business prospects, and not as an outgrowth of R&D. In general, industry in Indonesia lacks interest in clean energy R&D or in partnering on related activities.

Lastly, the research institutions are largely government-owned and operate under a budgeting system that may not be adaptable to rapidly changing technologies and associated R&D activities. Compounding this difficulty, research priorities have shifted with each new administration leading to abrupt ends to research paths and wasted efforts. For example, five years ago, many institutions were focused on fuel cell technology, but now work on electric vehicles. Previous research on jatropha trees may not be sustained.

The industrial sector needs not only more efficient equipment and machinery, but also integrated energy management systems to deliver financial and environmental benefits. The transportation sector will likely continue its dependence on liquid fuels for the next two decades. Synthetic fuels from coal or biofuels from biomass or algae could displace some of this need. The electricity supply will need to come from local fuels on a small scale with robust performance (read: mature infrastructure) in part because of the distributed nature of land areas in Indonesia and the difficulty for engineers to travel and perform needed checks and maintenance.

In order to deploy new clean energy technologies, several approaches to cooperative R&D could prove successful. Establishing a continuous platform for information exchange in R&D activities; opening internships and researcher exchanges with other countries; hosting an international exhibition of R&D equipment, instruments, and materials; and supporting pilot/demonstration projects could all improve the outlook for clean energy R&D.

Technology needs for sustainability – the Malaysian initiatives

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Note: The presentation is not available.

Between 1960 and 2010, agriculture declined from around 40% of the economy to less than 10% as manufacturing and services greatly increased their shares. Meanwhile, Malaysia's GDP has increased rapidly. Not surprisingly, projections for total primary energy consumption estimate compound annual growth rates of 3% overall. Growth rates of consumption of coal, oil, gas, and other solid fuels are expected to be in line with the overall compound annual growth rate. Hydropower, however, is expected to grow at 14% per year, albeit from a very small starting point.

Malaysia has a total installed capacity of more than 25 gigawatts (GW) of electricity generation as of 2012. Peak demand is projected to grow 3 to 4% per year through 2030, and generation capacity will likely grow at least that rate. While gas powered plants make up 58% of the generation capacity, and coal fired plants only 33%, insufficient supply of gas limits electricity production such that 46% of electricity is generated from coal, and only 44% from gas. Moreover, some of the gas powered plants end up fuel switching to oil and distillates.

The oil crisis of the late 1970s precipitated a shift in the generation mix away from predominantly oil. By the late 1990s and into the 2000s, gas became the dominant primary source. In recent years, and in projections, coal use increases sharply, displacing gas.

Through a series of policy decisions to fix the price of natural gas to the power industry (beginning in May 1997), large industry (beginning in October 2002), and Gas Malaysia (beginning in October 2002), gas has been heavily subsidised compared to the Singapore residual fuel oil spot price. In 2009, the total subsidy to peninsula Malaysia alone was USD 3.8 billion. New policy shifts aim for a return to market pricing by 2016.

By 2009, Malaysia's natural gas industry had produced a total of 13.2 trillion cubic feet (TCF) of gas resources. The remaining natural gas resources of 33.2 TCF are smaller in size, scattered, remotely located offshore, and have high carbon dioxide content. These factors make developing new gas resources more technically challenging and add to the overall cost. In general, falling production rates have resulted in increased imports and less supply available to the power sector. This pattern is repeated across the Southeast Asia region, as indigenous supply is unlikely to meet rising demands.

Recently, through its national oil company, PETRONAS, the government of Malaysia announced the development of a number of LNG Regasification Terminals: Offshore Tanjung Keling, Melaka (2012), Onshore Pengerang, Johor (2016), Onshore Lahad Datu, Sabah (2015) and, Onshore Lumut, Perak (planning stage). Completion of the terminals will give open access to third party importers for LNG supplies, replacing PETRONAS's monopoly of gas supply to domestic and industrial end-users with a competitive supply landscape. While the price of natural gas has fallen substantially in the United States, prices remain high in Asia.

The long term plan for energy security is based on the policy shift towards gas at market prices. High prices in Southeast Asia portend a move toward greater coal consumption as well as construction of nuclear plants (Malaysia currently has none). The generation mix under this scenario is not sustainable or realistic as it will raise environmental concerns, and it requires addressing international regulations, site availability, and operating flexibility. Moreover, development of nuclear power, currently opposed by the opposition government party, would require a comprehensive regulatory regime and waste management and other infrastructure, not just a pilot project.

Malaysia has voluntarily committed to a reduction of 40% in energy intensity (emissions per GDP) by 2020 from 2005 levels. This may be achieved only through transfer of technology and access to finance from wealthy nations. Anticipated growth in the low-energy intensive services sector will help, however.

Malaysia's national green technology policy is built around four pillars: attaining energy independence and promoting efficient energy use (energy), minimizing impacts of growth on the environment (environment), enhancing national economic development through the use of technology (economy), and improving the quality of life for the population (society). The strategic thrusts of this campaign are to:

- strengthen the institutional frameworks;
- provide a conducive environment for green technology development;
- intensify human capital development in green technology;
- intensify green technology research and innovations; and
- promote and raise public awareness.

The Ministry of Energy, Green Technology and Water, formed in April 2009, launched the National Green Technology Policy in July of the same year and developed a roadmap to achieve their goals. Sectors within the scope of the effort include: energy, buildings, water and waste management, manufacturing, transportation, and green information and communication technology (ICT) sectors.

The overarching problems in energy and environment are heavy dependence on fossil fuels, inefficient buildings, and a waste management system unable to cope with a growing volume so refuse ends up in drainage systems instead. Potential solutions can be found in developing

renewable resources, promoting more efficient buildings with advanced lighting and electronics, and improving use of recycled materials and recycling waste.

Increasing green businesses' contribution to Malaysia's GDP from 2% in 2010 to 8% by 2025 will require growth in green technology as a sector and development of green technology entrepreneurship. The implementation timeline is broken down into three waves. The first wave, from 2011 to 2015, comprises policies like energy consumption caps for industry; government led energy efficiency implementation across its agencies; feed-in-tariffs to boost adoption; and improved project financing to provide investment security through long term favourable pricing. The second wave, from 2016-2020, includes development of smart grids, biomass projects, and creation of sector-wide quotas for energy efficiency targets. Finally, the third wave, from 2021-2025, focuses on expanding access to the electric grid and developing carbon capture and storage. The Tenth Malaysia plan describing policies for 2011-2015 introduced a feed-in-tariff of 1% and established a renewable energy fund from this FIT. Smart grid efforts are also underway. Developing these technologies will allow easier integration of the existing grid with new renewable energy generation and balance the cost of energy with the desired level of reliability of power supply.

As a small, fast developing country, Malaysia faces great challenges in its energy sector. It must balance meeting high energy demand growth, energy supply security, costs of generation and electricity tariffs, and meeting CO₂ emission targets through sustainable development. The R&D areas and technology solutions needed in the energy sector are prioritised as follows:

- developing renewable energy and energy efficiency technologies;
- reaching price parity between renewable energy technology and conventional solutions;
- implementing smart grid initiatives;
- developing clean coal; and
- developing carbon capture storage.

Clean energy in India: R&D opportunities and needs

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http://www.iea.org/media/workshops/2012/egrdbijing/07India_ASagar.pdf

India's coal use has historically been high and, according to its 12th Five Year Plan, it is expected to double in the upcoming years. Coal imports are also expected to rise. The latest Five Year Plan also outlines plans to aggressively develop a range of clean energy technologies, including hydroelectric power, nuclear power, and renewable energy.

Between 1981 and 2011 India has achieved a 43% reduction in energy intensity. An evolution of the fuel mix for electricity is expected as the nation moves towards lesser reliance on fossil fuels and greater use of renewable energy resources. In terms of electricity generation and supply, there is an 8.5% electricity generation shortage in India and an 11% shortage at peak hours. However, domestic energy production is expected to continue to rise in India, which can help bolster trends of increasing household access to energy—specifically clean energy sources—in both rural and urban settings.

Evaluating low-carbon energy scenarios for the future demonstrates the significant savings that can be achieved compared to the oft-cited BAU case which assumes a similar trajectory for future development and energy use as the one that is currently being followed. As the interim report of the Indian Planning Commission's Expert Committee for Low-carbon Strategies for Inclusive

Growth cites, in the case of power sector (India's single-largest GHG emitting sector), a variety of generation technologies will be needed in order to move this sector to a lower-carbon pathway. These include more efficient coal-based power generation (e.g. retrofits to sub-critical coal plants, economisers, air pre-heaters, new supercritical and ultra-supercritical power plants), a variety of renewable energy technologies (e.g. solar and thermal PV systems; advanced wind turbines and associated tools for assessing resources and planning farms), and nuclear power.

Aside from integrating new energy technologies into the nation's energy mix, a range of sector-specific opportunities, which offer enormous opportunities for emissions reduction through increased energy efficiency, exist in India's key economic sectors. Buildings, for example, offer important energy savings opportunities, given that roughly over 70% of India's buildings infrastructure (residential and commercial) that will exist in 2030 has yet to be built.

The most promising options available for unlocking building energy consumption savings include more efficient appliances (both residential and commercial), building-integrated management systems, high-reflectivity paints and windows, and incorporation of renewable energy. Based on energy-use projections, lighting and air conditioning present the greatest opportunities for energy savings in both the commercial and residential buildings sector, although energy-efficient fans and refrigerators are also important for the residential buildings. Efforts have been made to create building standards for India's stock, but the fragmented nature of the Indian building industry has limited the focus thus far to commercial buildings.

The industrial sector also presents opportunities for energy savings in its energy-intensive plants in industries such as iron and steel and cement manufacturing. Industrial technology options for saving energy in iron and steel production include raw materials processing, improved core technology, and improving energy recovery and conservation measures. In the cement production industry, technology options for achieving energy savings include waste heat recovery and improved cement formulation.

The Government of India has launched several clean energy initiatives recently:

- **National Mission on Enhanced Energy Efficiency:** In place since 2007, this initiative focuses on improving energy security, increasing resource-use efficiency, and mitigating climate change. Specific elements focus on industrial energy efficiency (Perform, Achieve, and Trade); market transformation for energy efficiency (MTEE); and financing energy efficiency projects.
- **Jawaharlal Nehru National Solar Mission:** Geared towards developing and deploying clean energy technologies, this initiative aims to deploy large-scale solar power, off-grid solar power, solar heaters, rural lighting, and promote R&D as it works to improve energy security, mitigate climate change, and advance industrial development.
- **National Biomass Cookstove Initiative:** Helps increase access to energy by developing and disseminating clean cook-stoves; explores new technology and deployment models; and will involve testing facilities, standards development, and monitoring and assessment. By working towards meeting health objectives, this initiative will also improve environmental conditions.

To present the broader R&D context in India, there has been a slight and slow rise of total R&D per unit of GDP in India. Traditionally, private sector investment was low, but this has changed: private investment now has increased to roughly one-third of total R&D investment in the country. In India's R&D landscape, as of 2005 to 2006, expenditures on R&D by major scientific agencies were led by the Defence Research and Development Organisation and the Department of Space—the Ministry of New and Renewable Energy spent the least among the agencies analyzed. Even though R&D expenditures by public agencies may not be significant (and may be too low to meet India's goals), a range of clean energy R&D activities are underway in the public

and private sectors focusing on topics such as cleaner and more efficient coal conversion, energy-efficient appliances, wind energy, solar energy (PV), and electric vehicles.

India is also involved in international cooperative efforts on clean energy technology such as the Clean Energy Ministerial (CEM)⁵ and the United States-India Clean Energy R&D Center. In addition, activities that generally follow initiatives from different ministries and agencies are naturally increasing coordination among government entities.

It is important to note the high rate of growth of the Indian economy when considering the foundation needed to develop a clean energy economy. Much of the base for this has yet to be installed, but particular attention should be paid to “greenfield”⁶ deployment. The existing stock of capital has significant room for improvement, and many improvements have been made in recent years, albeit in selected areas. Despite developments in clean energy technologies, clean energy access—specifically, adequacy and affordability considerations—remain an important issue. These factors collectively demonstrate the significant opportunities that exist for clean energy technologies to help improve the Indian energy sector and the greater economy.

Though opportunities exist, there is a need for strengthened analytical and technical capabilities, especially with a systems perspective. This will likely require systematic identification of technology and R&D needs by sector and by actor (e.g. size of operations), with special attention paid to energy-efficient generation and end-use technologies and renewable energy technologies. Given that the opportunities exceed available resources and capacity, prioritisation is essential as is the need to incorporate broader developmental considerations into the calculus of the issue (e.g. energy access, employment, food security). Improved understanding of the gaps and barriers to be overcome for successful scale-up will help deployment efforts, along with information sharing systems to collect and disseminate information on renewable energy technologies.

In addition to the key needs and considerations discussed above, there are other issues facing cooperative R&D efforts. Because there is no single model for cooperative R&D, the appropriate model likely depends on the technology that is being researched. It should be noted that international cooperation can help reduce costs and increase efficiencies.

Uncertainty is also an issue clouding the role of public RD&D (e.g. the role of government as driver or facilitator), especially regarding uncertainty in early-stage private investments in clean energy technologies. Relationships to the Climate Technology Centre and Network under the UNFCCC and Climate Innovation Centres being established by the World Bank must also be part of the clean energy technology R&D discussion, and stable funding sources (e.g. bilateral donors, multilaterals, or the Global Environment Fund) will be critical to sustained focus in this area. Strengthening analytical capabilities, especially with a systems perspective of technological opportunities and assessment of feasibility and options to pursue will be crucial to appropriately allocating resources to maximise the impact of clean energy R&D efforts.

⁵ The Clean Energy Ministerial (CEM) is a global forum to share best practices and promote policies and programs that encourage and facilitate the transition to a global clean energy economy. The 23 participating CEM governments account for 80 percent of global greenhouse gas emissions and 90 percent of global clean energy investment.

⁶ “Greenfield” sites lack any constraints imposed by prior work done to that site. “Brownfield” sites, in contrast, are abandoned or underused industrial or commercial facilities or sites available for re-use.

Clean energy efforts in Singapore

Mr. Zhen-hui Eng, Deputy Director, Policy and Planning, Energy Planning and Development Division, Energy Management Authority

Note: The presentation is not available.

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Singapore is a well-developed urban centre among the Association of Southeast Asian Nations (ASEAN) countries. In 2011, Singapore's GDP reached approximately USD 261 billion. Despite a population of approximately 5.2 million, the population density in Singapore is over 7 200 people square kilometre—one of the highest ratios in the world. As a result, international trade is vitally important to the Singapore economy. Nearly USD 800 billion in trade was conducted in 2011. One advantage of being a highly urbanised, small country is that it can implement broad changes relatively quickly. The country's energy and environmental plans are built around three overarching goals: energy security, energy competitiveness, and environmental sustainability.

Singapore's energy supply is dominated by imported natural gas, which accounts for approximately 78% of total electricity generated. A new LNG import terminal is expected to be in service by end-2013. Petroleum products represent 18.4% of electricity generation, and all other energy sources make up the remaining 3.6%. Demand for electricity is largely from the industrial and commercial sectors. Demand in these sectors has grown over the last three years. Household demand has remained stable, while transportation demand has increased slightly.

In order to achieve a sustainable energy future, Singapore has adopted four key targets: improving market competitiveness, diversifying fuel mix, investing in energy research, deployment and development, and promoting energy efficiency. Electricity generated from solar PV is currently seen as the most viable clean energy option for the building sector. Although installed capacity of grid-connected solar PV systems grew rapidly between 2008 and 2012 (albeit from a very low starting point), it still presents only a small percent of total electricity supply. Its use generally coincides with summer months when demand — and electricity rates — peak. While solar comes with the typical benefits of lower environmental impact than fossil fuels, it also has the typical drawbacks: intermittent, small and distributed, and high upfront capital costs with long payback periods.

The Singapore government has policies in place to encourage development and deployment of renewable energy. The government published a Handbook for Solar Photovoltaic Systems, which provides information on licensing, market and technical requirements as well as building and structural issues relating to implementation of solar PV systems. The government has also made regulatory concessions that lower the hurdle for solar installations from the consumers' perspective. For example, a simplified credit treatment provides all non-contestable consumers that have generation capacity of less than 1 megawatt (MW) with a payment for energy sold to the grid without their having to register and participate in the market. Meanwhile, other sources that might seem promising in the urban environment like waste-to-energy have faced significant challenges, such as lack of infrastructure (e.g. no biogas plant) and difficulty collecting appropriate waste.

Singapore has begun a demand response trial program under their Smart Energy Challenge in order to test the technical operations of demand response as well as to gauge interest from consumers. So far, response has been promising as 18 companies have signed on from commercial and industrial sectors and with a total load reduction potential of 33 MW. Efforts to reduce electricity load typically involve shutting down non-essential operations such as resetting the temperature of chillers or air-conditions and turning down of lifts, escalators, water features, and water pumps. Singapore has also embarked on an energy efficiency program which has

achieved some similarly notable success. For example, Bodynits International Pte Ltd used a Grant for Energy Efficient Technologies to upgrade its existing air-cooled chiller plant to reduce its annual energy costs approximately 20%. Finally, Singapore has begun implementing smart grid technologies with its Intelligent Energy Systems (IES) pilot project. The project installs two-way communication smart meters (phase one, completed) and begins testing whether households will better manage electricity consumption (phase two, implemented through 2013).

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Research efforts have been implemented by Singapore's institutions at each stage along the typical development cycle. In the private sector, an "eco-system" of expertise and commercial R&D has an established presence in Singapore. Large international companies with focus on solar, fuel cells, biomass, wind, carbon, marine renewable energy technologies, smart grids, and other services all operate in Singapore.

Clean energy R&D: OECD country perspectives

The emerging economies of Southeast Asia may well look to more developed neighbour countries for examples of successful energy programmes, as well as for technical or financial assistance from governments that have experience implementing such programs. OECD member nations in the region— Australia, Japan, and Korea – have successfully developed clean energy technologies based on policy and financial frameworks. In part, they have achieved these successes through greater internal coordination. Australia has brought multiple programs under one umbrella known as the Australian Renewable Energy Agency (ARENA), and Japan has established the New Energy and Industrial Technology Development Organisation (NEDO). NEDO has demonstration projects in Japan as well as in countries in North America, Europe, Africa, and elsewhere in Asia. Korea similarly has many ongoing collaborative projects both domestically and in the region.

Collaboration among the countries of the region can accelerate energy technology innovation for many reasons, but must be done in the interest of all parties involved. Multidisciplinary approaches that arise from differing national perspectives encourage new approaches to energy and efficiency issues. In order to achieve energy efficiency gains, though, the priorities of the participating countries must be in alignment. The IEA Implementing Agreements are a good example in this regard.

Energy technology R&D collaboration with emerging economies - some Perspectives (Australia)

Dr. John Söderbaum, Director, Science and Technology, ACIL Tasman

<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDSoderbaum.pdf>

Australia is fortunate to have abundant conventional and renewable energy resources with potential for domestic production of all major energy sources except oil (Figure 6). Electricity demand in Australia has been falling in recent years in part because electricity prices have been rising considerably, but also because of recent programs to better insulate homes, although some of the drop in demand may be attributable to recent milder, wetter summers. Prices have risen largely because of the need to build more transmission and distribution to account for the growing divide between peak demand and average demand. The recent carbon tax has also pushed prices up slightly. Electricity prices, particularly for residential customers, steadily increased in line with inflation between 1981 and 2007. Since 2007, however, residential prices have increased more sharply. For business customers, electricity prices grew more slowly than inflation, but increases in prices since 2007 have brought the overall increase since 1981 in line with overall inflation.

The energy sector produces the majority of greenhouse gas emissions in Australia, accounting for 75% of the total. Agriculture represents 16%, industrial processes another 6%, and waste the remaining 3%. Within the energy sector, electricity generation is responsible for 35% of the overall total emissions.

Australia is heavily dependent on coal and has limited hydropower resources, but it is in the midst of a large push to expand renewables. In 2012, Australia published its *Energy White Paper 2012* laying out four energy priorities:

- strengthening the resilience of Australia's energy policy framework;
- Reinvigorating the energy market reform agenda;

- developing Australia's critical energy resources – particularly gas; and
- accelerating clean energy outcomes.

The Australian Government provides support for renewable energy technology development through its numerous programs. Several innovation programs and institutes support basic research and development while many policies like feed-in-tariffs, renewable energy targets, and a price on carbon help accelerate market uptake of technologies. Meanwhile, the Australian Renewable Energy Agency (ARENA) supports renewable energy technology development (Figure 7). Such a combination of government support for R&D and implementation of policies and strategies geared towards increasing market penetration of specific technologies could serve as a model for emerging economies. However, this is but one example of public sector involvement in the technology “push” and market “pull” forces at work in the technology development process.

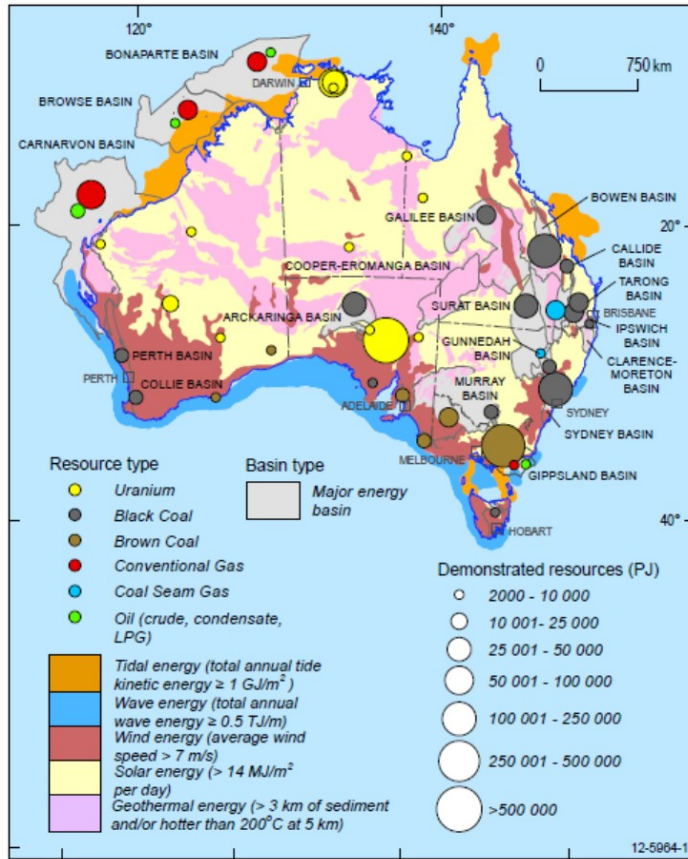
ARENA is a newly founded agency which brings several programs to develop clean energy under one agency. Its objectives lie mainly in improving the competitiveness of renewable energy technologies and increasing the supply of renewable energy. The foundations of ARENA are built in nine distinct programme areas: Solar Flagship Programs, Australian Centre for Renewable Energy (ACRE) and other Department of Resources, Energy and Tourism (RET) Solar Projects, Renewable Energy Demonstration Program, Geothermal Drilling Program, James Cook University project and Advanced Biofuels Investment Readiness (ABIR) Programme, Second Generation Biofuels Research and Development Program, Energy Renewables Program, Renewable Energy Venture Capital Fund, and the Australian Solar Institute (ASI).

Given this relative focus on solar energy, ARENA strategic initiatives consist of a few large-scale renewable energy demonstration projects in regional and remote locations. The supporting initiatives are smaller in scope and address specific roadblocks such as system integration, intermittency, storage, technology demonstration and testing facilities. These projects are mostly carried out by ASI. Finally some complimentary initiatives are broad based and cross-cutting, forming a comprehensive program to support knowledge sharing about renewable energy solutions.

ARENA has had success in implementing its mission in part because it is an independent body with close connections to the government; its funding is guaranteed by legislation, and it is active across a wide spectrum of innovation. Further success is expected, but not yet confirmed, from maintaining active engagement with proponents, remaining a flexible and nimble approach, and establishing and maintaining formal international engagement arrangements. Examples of Australian projects involving international collaboration include a cooperative effort between Australia and China on developing clean coal technology and a collaboration between Australia and India on solar energy technology.

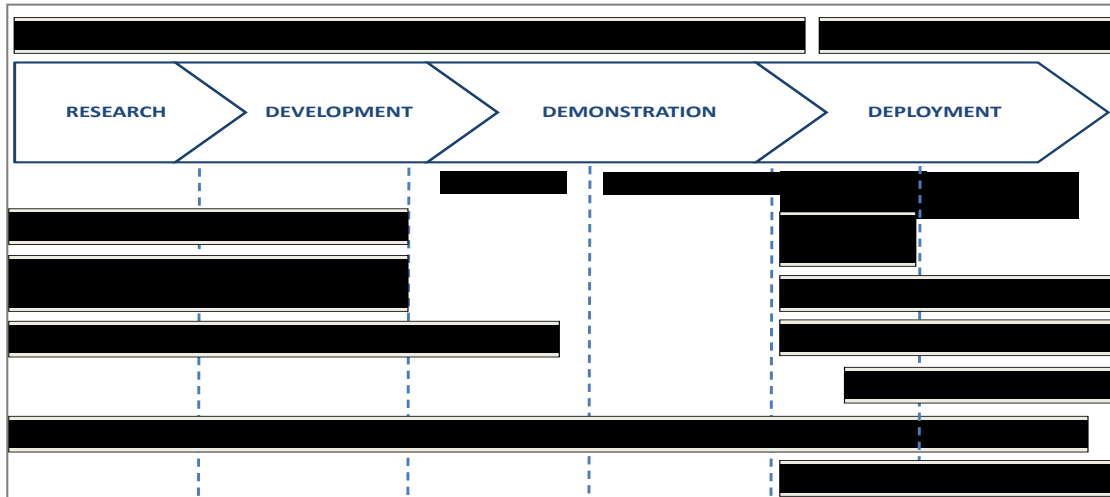
International engagement in particular promotes energy trade and investment, shapes international policy and processes, and enhances understanding of energy policies and programs, and accelerates energy innovation through cooperation on technology RD&D and commercialisation and by exchanging knowledge and building capacity and expertise.

Figure 6 • Locations and sizes of Australian energy resources



Source: Australian Department of Resources, Energy and Tourism.

Figure 7 • Australian government support for renewable energy technology development



Source: ACIL Tasman, Australia.

Promotion of clean energy technology R&D in Asia based on NEDO's experience (Japan)

Mr. Eiichi Homma, Director General, International Projects, International Affairs Department, New Energy and Industrial Technology Development Organisation (NEDO)

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<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDHomma.pdf>

The New Energy and Industrial Technology Development Organisation (NEDO) of Japan promotes R&D of energy, environmental, and industrial technologies. NEDO's mission is to address energy and global environmental issues and enhance Japan's industrial competitiveness. Funded by the Ministry of Economy, Trade and Industry (METI), NEDO coordinates with policy-making authorities and supports a consortium of academia, industry, and public research labs. This structure facilitates implementation of METI's policies through R&D and demonstration projects. While NEDO is not a research organisation it combines industry, government, and academic knowledge and leverage of international networks to achieve its goals. In this respect, the NEDO model promotes coordination as the key to finding innovative solutions to the challenges we face today.

NEDO operations include technology development activities which usher technologies through the three distinct phases: first, the technology seed development activity, then transitioning to the status of a national project (mid- to long-term high-risk R&D projects), and finally to practical application. R&D at NEDO is organised into six distinct categories: energy, information and communication technologies (ICT), new manufacturing technology, life science, nanotechnology and materials, and environmental technology. Within NEDO, demonstration projects are categorised as energy, environment, or medical systems.

The 2011 Strategy for Energy Efficiency Technologies prioritised wide-ranging energy efficiency technologies and selected technologies that can significantly contribute to Japan's energy-saving efforts. Key technologies are also being developed for the industrial sector (e.g. technologies to improve system energy efficiency; minimise energy loss), transportation sector (e.g. intelligent transport systems, or ITS; and next-generation vehicles), and residential and commercial sectors (e.g. zero energy buildings or homes; and stationary fuel cells). In addition, research focusing on cross-sector technologies (e.g. next-generation heat pump systems, power electronics) is also included in the NEDO portfolio of R&D projects. For example, modules for energy storage in batteries are being developed in order to meet specific targets for certain parameters of battery performance. These specifications dictate specific energy (in Watt-hours per kilogram), specific power (in Watts per kilogram), and cost (in yen per kilowatt-hour).

Another example of NEDO R&D projects focuses on fuel cells and hydrogen—NEDO led the world's first large-scale demonstration of residential fuel cells. In this effort, NEDO implemented R&D projects, disseminated studies of infrastructure (i.e. appropriate regulation and standardisation) and demonstration for residential fuel cells. The R&D produced successful results and ENE-FARM commercial sales started in 2009. As of March 2012, some 28 000 units (including those covered by applications for a subsidy) had been sold. Other R&D projects focus on high-efficiency clean coal—Japan has achieved the world's highest efficiency levels for coal-fired thermal power generation technology.

In addition to its domestic activities, NEDO also conducts overseas demonstration projects. These efforts are aimed at addressing global energy and environmental issues, identifying R&D needs through site projects, and providing information and feedback to domestic industries for designing policy measures. Activity in these three areas helps facilitate private investment to accelerate technology commercialisation, identify R&D gaps in host countries by implementing

projects at the local level, and accumulate knowledge to enhance R&D in industries and improve the design of policy measures.

Over time, NEDO projects have evolved from standalone technologies to a more systems-based approach involving smart communities. In the 1990s and 2000s, projects were mostly active in China, India and the Association of Southeast Asian Nations (ASEAN). This included 23 energy efficiency sites and 5 solar PV sites for demonstration projects. Other implementation sites for demonstration projects include Myanmar, Laos, Vietnam, Philippines, Indonesia, Singapore, Malaysia, Cambodia, and Thailand, covering a range of technologies (Figure 8).

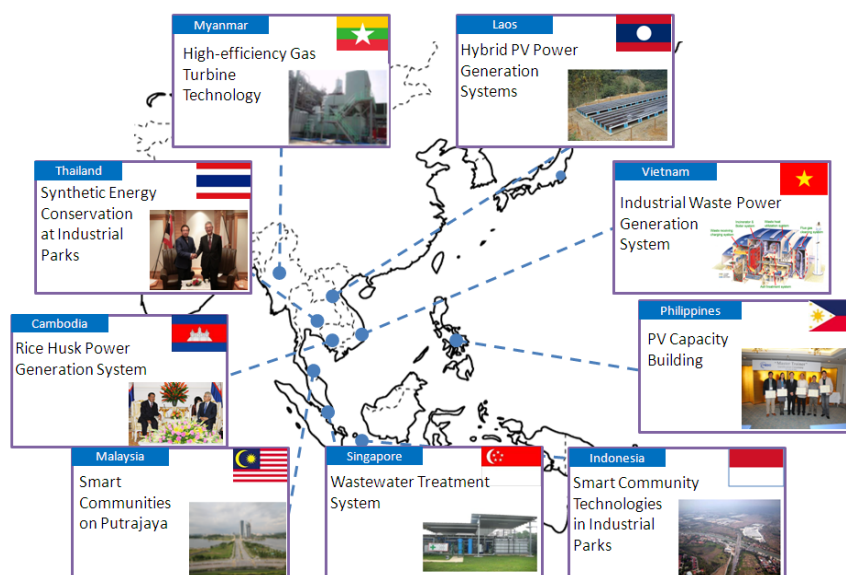
NEDO is also running several renewable energy, energy efficiency, and capacity building projects in India out of their central office in New Delhi. These standalone technology projects typically focus on industry and power sector technologies as a means of transferring the Japanese “state-of-the-art technology” to other nations. Of the 44 NEDO demonstration projects in Asia, 407 projects have been carried out on a commercial basis and have the potential to achieve energy savings on the order of 5 million tonnes of oil equivalent (toe) per year and 22.8 million tonnes of CO₂ reductions in emissions per year. However, to facilitate the spread of technologies on a commercial basis following the demonstration projects, important related policies must be implemented (e.g. subsidies, regulations, and feed-in-tariffs).

The shift in NEDO's focus to demonstration projects for smart communities is global in scope. NEDO is implementing projects across the world (e.g. smart grid demonstration project in New Mexico, US; smart community demonstration projects in France and Spain; CSP feasibility demonstration project in Tunisia; large-scale PV demonstration project at industrial complexes in India; smart grid feasibility demonstration project in Gongqingcheng, Nanchang City in China). A smart community project in China, for example, aims to achieve economic growth and builds towards a low-carbon society through a low-carbon traffic management system, smart grid technologies, and energy savings and environmental quality improvement in urban activities, all linked by an integrated energy management system (EMS).

These smart community demonstration projects focus mainly on the buildings, transportation, and electric power sectors for opportunities to integrate and localise various technologies including: renewable energy micro-grids; intelligent transportation systems (ITS); heat supply networks; smart houses and remote management; and smart offices, smart grids and energy management systems. These demonstration projects also involve collaboration with industry, including developing overseas ties and enhancing strategies; improving measures to achieve global standardisation; and establishing roadmaps (e.g. Japan Smart Community Alliance).

In the short-term, the market pull approach (i.e. subsidies, regulations for users) is more effective than R&D, but in the long-term both technology-push (including R&D) and market-pull forces are necessary. This illustrates the need for appropriate initiatives to facilitate energy efficiency in an effective manner. For different sectors of an economy, achieving a low-carbon energy future may mean different things. For industry, this has taken the form of state-of-the-art technology for manufacturing processes in key industrial sectors (iron and steel, cement, chemicals, pulp and paper); for the transportation and buildings sectors the approach involves smart communities consisting of energy efficient technologies and renewable energy technologies. In terms of power generation, clean coal technologies (i.e. ultra-supercritical (USC) combustion systems, integrated gasification combined cycle [IGCC], and Integrated Gasification Fuel Cells) and renewable energy technologies (solar PVs, concentrating solar power [CSP], wind, geothermal) will be explored.

Figure 8 • Sites of NEDO's Demonstration Projects of Standalone Technologies in the ASEAN region



Source: New Energy and Industrial Technology Development Organisation, Japan.

Korea: A Bridge between emerging economies and OECD

Dr. Seungyoung Chung, Senior Researcher, Korea Institute of Energy Technology Evaluation and Planning

<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDChung.pdf>

Korea has the potential to act as a bridge between the region's emerging economies and the OECD, to help these countries address the variety of challenges to developing and implementing clean energy technology, and to help unlock their potential. One driver of clean energy technology in the region is the availability of hydro, wind, and solar power among others. Two significant hurdles are the lack of infrastructure needed to expand the electric grid and increase the efficiency of off-grid sources and the lack of investment to build capacity. Cultivating a clean energy industry in the region has to be prioritised with increased investment from the private sector and detailed energy policies that will apply continuously to support new development.

Medium to long term energy technology plans are indispensable. Such plans must reflect domestic energy supply trends and anticipated technology levels identify the critical energy technology fields, and offer comprehensive plans for energy efficiency, renewable energy, and resource development. One way Korea has encouraged clean technology development is use of detailed R&D roadmaps. In the past, Korea had established multiple plans for long term development, first with the Renewable Energy Technology Development Plan (1988), then with the 10-Year Energy Technology Development Plan (1997), and finally with the Resources Technology Development Plan (2000). Together, however, R&D investment was inefficient due to a lack of linkage among the plans. Learning from that experience, Korea created its First National Energy Technology R&D Plan in 2006 and the Second Plan in 2011.

The Second National Plan improves on the first in its consideration of an R&D support system, industry development, commercialisation, and infrastructure. Seeing a need to improve feedback in the mid- to long-term cycle of development, Korea reinforced capability to develop mid- to long-term strategy and established systematic outcome analysis system. The Second Plan put

greater focus on government support for mutually beneficial projects with small and medium businesses and not just larger companies.

To address the lack of market uptake despite increased R&D investment, the new strategy puts a premium on taking leadership in a global market by securing fundamental technology. Lastly, the Second Plan promotes greater investment in human resources and strategic international collaboration. Taken together, the government R&D strategy reflects market needs as it is based on the investment direction of the private sector. It was developed by marrying the implementation plan based on policy direction with the action plan to achieve R&D objectives. Quantitative targets developed in a series of three Energy Technology Strategy Roadmaps (Green Energy, GHG Reduction, and Natural Resources) underpin these R&D objectives.

The purpose of the Green Energy Strategy Roadmap is to enhance Korea's competitiveness in global green energy through technology innovation. Fifteen key technology fields were identified as priority in three categories: supply (PV, wind power, fuel cell, biofuel, clean fuel, IGCC, carbon capture and storage (CCS), clean thermal power generation, and nuclear power), delivery (smart grid, energy storage), and utilisation (green car, high-efficiency new lighting sources, energy efficient buildings, and heat pumps).

The purpose of the GHG Reduction Technology Strategy Roadmap is to help achieve the national GHG reduction target through industry oriented energy technology R&D. It follows a pattern similar to that of the Green Energy Strategy Roadmap in identifying four priority categories: process improvement (petrochemical processes, high-efficiency dyeing processes, and non-CO₂ processing technologies), parts advancement (high efficiency home appliances, high efficiency IT devices), business model creation (unutilised energy, co-generation systems, geothermal heat) and common equipment (next-generation dryers, combustion machines, heat exchangers, fluid machineries, electric motors, superconductivity, and energy materials).

The Resources Development Technology Strategy Roadmap aims to enhance energy security through attaining core technology. It identifies eight key technology fields for energy and resource development in two categories: mineral resources (metallic minerals, non-metallic minerals, mineral resources exploration, and mine resources development) and oil and gas (unconventional oil, unconventional gas, conventional oil and gas, and oil and gas exploration).

Korea has several ongoing projects and completed energy projects in collaboration with its neighbouring countries (Figure 9). The 2012 budget for international collaborative R&D on energy reached USD 20USD million. Currently 46 international collaboration projects on energy are underway, and average funding for each project is USD 0.3 million per year for two to three years.

The following photo illustrates collaboration with China on a 1 MW Concentrating Solar Power Development Project (2006-2012). The Korea Institute of Energy Research provided the heat absorber and heat storage technology. The Institute of Electrical Engineering in China provided the tower, the heliostat, and the power plant.

To summarise, from the Korea perspective, the emerging economies have great potential in clean energy technology, but face daunting challenges to clean technology development. In practice, medium to long term energy technology R&D plans are indispensable and the experiences of IEA member countries on the formation of such plans should be shared with emerging economies. Furthermore, joint R&D projects between IEA member countries and emerging economies are necessary to nurture the clean energy industry of emerging economies.

Figure 9 • Development project with China (1 MW concentrating solar power)



Source: Korea Institute of Energy Research.

Clean energy R&D investment: financial sector perspectives

Clean energy technology development requires significant resources and careful planning among key stakeholders to be successful. Key stakeholders must work together to ensure the proper resources are deployed and the appropriate policies and mechanisms are in place to successfully nurture R&D projects to market commercialisation.

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While both public and private sector financing and collaboration are needed, there is a need to distinguish between different forms of investment—private equity and public market investments. The lack of clear roles and boundaries for government, academia, the private sector, and other NGOs can hinder R&D efforts. Though certain investments may be more appropriate for government, a careful balance between public and private sector financing must be struck. Public opinion represents another important factor in the deployment of new technologies, given sometimes significant opposition to certain renewable energy technologies.

Aside from the sheer magnitude of investment that is required for clean energy technology R&D, this investment must be made in the right technologies. New energy technologies such as on-shore wind and solar PV are becoming increasingly more competitive, and in some areas on-shore wind is competitive with conventional fossil fuel-based power. Though Japan and India are both significant investors in new energy systems, China is by far the largest investor in the region. In each case, different types of investors will be needed to advance the state of clean energy technology in the region. Private, public, and asset investors each have a role to play in deploying distributed or large-scale renewable energy technologies and related infrastructure.

Clean energy R&D investments: wind energy investment in Asia

Mr. Justin Wu, Head, Wind Industry Research, Bloomberg New Energy Finance

Note: The presentation is not available.

An estimated 40% of the world's total investment in new clean energy is made in the Asia-Pacific region, investment which has more than quadrupled in recent years. Japan and India are among the major investors in this region, but China overwhelmingly has taken the lead. Renewable energy investment trends witnessed changes from 2004, before which several renewable energy technologies shared the investments fairly evenly. Starting in 2004, wind energy technology gained significant momentum and, more recently, solar energy technology has increasingly attracted investments. Investments in wind turbine manufacturing in the Asia-Pacific region—mostly in China—now account for 63% of total global manufacturing investments. In the solar energy industry, similar trends have been observed: 89% of global solar photovoltaic (PV) cell production and 80% of global solar PV module production takes place in the Asia-Pacific region and has shifted towards China, giving rise to a new export market in the region.

The fast-growing investments in the renewable energy industry have been reflected in the energy markets. Renewable energy investments have made on-shore wind technology very competitive, and in some areas it is nearly competitive with gas- and coal-based power generation. While solar PV technology is becoming increasingly competitive, it still cannot compete with traditional sources of energy. Additionally, off-shore wind technology is lagging far behind other traditional energy technologies.

Wind power products manufactured in China are mainly used domestically. However, most of the solar products manufactured in China are exported. This is caused by differences in the supply

and value chains. In the solar energy industry, Asia has largely driven the value chain, but in the wind energy industry many key components are still developed by European companies.

Turning energy technology trends into reality

Page | 38 Mr. Levien J. de Legé, Managing Director, ECN Asia

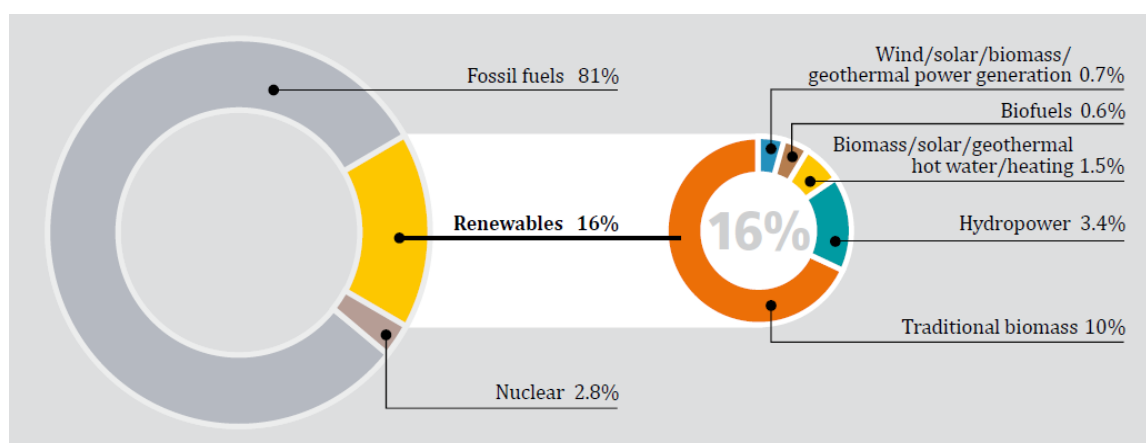
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The REN21 *Renewables 2011 – Global Status Report* showed that in 2009 renewable energy sources represented only 16% of global final energy consumption (Figure 10) though capacity is growing quickly. From 2005 to 2010, solar PV grew by 49% annually with higher growth when considering only grid-connected projects. Wind power and CSP experienced annual growth rates of 27% and 25% over the same period respectively. Biofuels production also expanded rapidly as biodiesel production increased 38% annually and ethanol production increased around 23% annually.

The high growth rates are partly attributable to reductions in costs among many different renewable technologies, especially, solar PV, bio-ethanol, onshore wind, and offshore wind. Most of the growth is concentrated in electricity generation where about half of the new capacity worldwide is based on renewable energy. Furthermore, clean energy investment levels have reached over USD 200 billion per year, and are growing fastest investments in Asia.

In other regions of the world, policy makers have set targets that aspire to 60% renewable energy by 2050, but too often fail to detail how such levels can be attained. What may be needed to reach such levels are breakthrough technologies in each type of renewable energy. One of the clearest avenues to achieving this innovation and increased capacity is through better international collaboration that avoids the stove piping where every country, every region or every company has their own R&D programme.

Figure 10 • Renewable energy share of global final energy consumption, 2009



Source: Renewable Energy Policy Network for the 21st Century (REN21) (2011), *Renewables 2011 – Global Status Report*, United Nations Environmental Programme, Paris, France.

Technology and practice: integrated mechanisms to support sustainable energy use

Mr. David Hathaway, Vice President, China Operations, ICF International

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http://www.iea.org/media/workshops/2012/egrdbeijing/ICFPaneldiscussion_TechnologyandPractice.pdf

A number of key ideas are important to consider in sustainable energy use. First, technology drives energy savings and people who manage technology can drive energy savings. Also, problems during planning and installation of technology within facilities can result in non-optimised systems that do not save energy. There are already too many existing energy-intensive facilities in the economy that can only be addressed through new technology and retrofits. For this reason, integrated policy and/or program frameworks that address both technology and energy management and operations are critical to ensuring maximum energy efficiency is achieved.

While start-up costs of building a facility may be significant, energy savings can only begin after a facility begins operating. However, individual sites operate differently. Moderate variation in energy intensity at similar facilities is expected, but variations sometimes indicate much larger problems in operations and management (Figure 11, note the logarithmic scale on the x and y axes).

Typical problems in application of technology include over-sized fans (60% of fan systems are oversized), over-sized chillers (oversized by 50% to 200%), improper installation and poor maintenance, and, surprisingly, buildings can exceed code but still not perform as intended.

Insights from extensive work on building energy efficiency in Asia indicate that many premium building designs fail to perform as expected due to poor occupant behaviour, human interventions or overrides, and failure of integrated systems controls resulting from lack of maintenance, trained technicians, or software updates. These issues have highlighted the need for research on better integrated system designs, including performance monitoring and reporting and simpler operating interfaces.

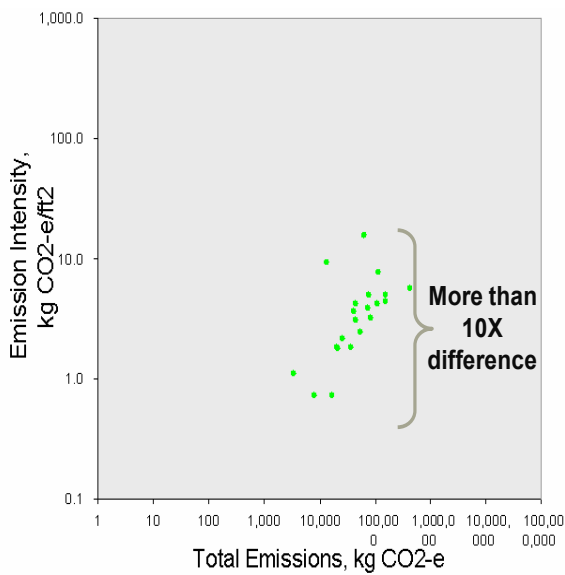
One of the challenges facing energy saving technology is that one technology at different sites can operate at vastly different energy levels. Findings show that the most energy-efficient buildings in the United States (40% more efficient than average) typically do not have the most efficient technology. However, these buildings do have aggressive operations and maintenance programs. Possible conclusions could be that technology may not be the first place to look for savings, given that buildings with less efficient mechanical systems and building materials can still achieve savings and high performance. Conversely, buildings with all of the right equipment can still be operated inefficiently.

Instead of finding the right technology or the right people to maintain and operate it, people and technology have proven to generate more savings when properly used together than employing only the right people or the right technology. Energy saving measures can also be integrated to achieve meaningful energy savings. However, aside from implementing specific measures or hiring people to manage efficient technologies, other useful tools and analyses can enhance performance assessment and improvement efforts. Results from a case study of three variations of energy saving strategies implemented across three similar sites owned by the same company showed that people and technology achieved actual savings of 23%, while people or technology alone achieved savings of 16% and 3% respectively (Figure 12). This chart illustrates the stark

contrast between energy savings when implementing labour- and capital-based strategies independently compared to an approach that deploys both labour- and capital-based solutions.

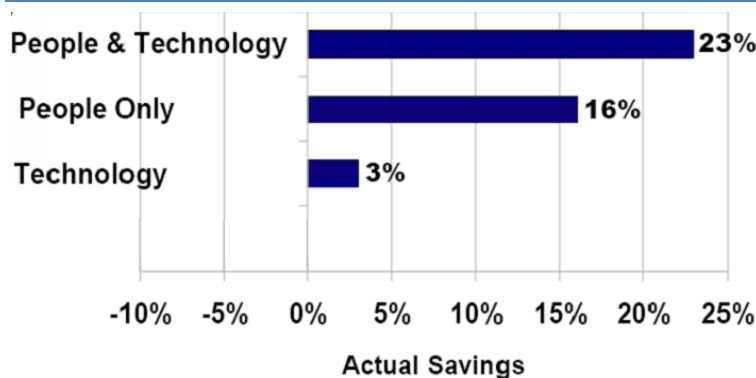
In order to achieve integrated energy savings, industry engagement programs need to accompany R&D and new technologies. Holistic assessment platforms that do not only look at technology specifications will more effectively assess overall site energy use, and can provide meaningful comparisons (e.g. energy performance benchmarking). In addition, subsidy and retrofit programs should be accompanied by technical assistance for improving operational energy use. For example, the United States Environmental Protection Agency (EPA) study showed disconnects between technology and performance.

Figure 11 • A single firm's energy intensity across homogeneous sample of facilities



Source: Chart provided by David Hathaway, ICF International. Subject to third party copyright.

Figure 12 • Findings from case study: industrial energy efficiency savings from capital and labour improvements



Source: Natural Resources Canada, "Dollars to Sense" energy management workshops.

Clean energy R&D investments: public and private sector drivers

Mr. Weigang (Greg) Ye, Founding Managing Partner, Delta Capital

Note: The presentation is not available.

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Between 2006 and 2010, investments in clean technology were largely driven by private investments, most of which sought to build capacity and reduce costs. As a result, China now produces more than 50% of clean energy related products. In 2011, however, public sector investment began to catch up to private investments, but the former focused more on market adoption. For example, feed-in-tariffs that help remove barriers set by grid companies to connect solar projects. These market adoption efforts are an important complement to capacity building.

During much of the past five to six years, clean technology products were very expensive compared to conventional electric generation sources. In the last two years, the capital markets became rather pessimistic about clean technology, although, recently, costs have been getting close to grid parity. Despite the improvement, clean technology investment over the past couple years has been quite challenging. Nevertheless, there is reason to be cautiously optimistic about investments in technologies that can help bring clean technology to grid parity faster.

Better cooperation between the public and private sectors is needed for continued clean technology development. For fundamental R&D, government collaboration with the private sector is most likely to succeed, and therefore needs to be further strengthened. The private sector is best suited to continue investment in increasing the capacity of production and lowering cost while public funding should be injected to accelerate market adoption. The two efforts combined can produce the functioning business model to spur private investment in a project. For example, distributed wind and solar projects look promising to investors, but without a suitable business model, projects will have trouble getting financed.

Clean energy R&D: cross-cutting and integrated perspectives

In order to be useful, effective, and scalable in an emerging economy, new technologies must excel in a variety of areas. They must be affordable, technically effective, robust and reliable, culturally appropriate, widely applicable, and cost effective. These requirements tend to be independent of the market, institutional, social, and cultural factors that further inhibit uptake. In developed economies, great strides have been made in buildings and equipment through stricter standards and labelling and recognition programmes like the United States' Energy Star programme, or India's Super-efficient Equipment Programme. The industrial sector has similarly benefited from programs such as China's Top 1,000 Energy-Consuming Enterprises Programme.

Successes in programmes like these have application in emerging economies, but additional challenges remain. These include the lack of access to electricity, lighting, and clean water. Global markets may not develop the targeted technologies that can provide modern energy services to the under-served. International collaboration has the potential to address this possible market shortfall by supporting innovation that focuses not only on new technologies, but also addresses the availability and feasibility of dissemination and implementation of the technology.

Technology perspectives on clean energy R&D needs of emerging economies

Dr. Jayant Sathaye, Lawrence Berkeley National Laboratory

<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDSathaye.pdf>

Although different regions of the world and different sectors of the global economy vary in their energy use and environmental impact, all sectors and regions have the potential to contribute to climate change mitigation efforts. Several countries are involved in efforts to improve energy efficiency in appliances; industrial energy efficiency; affordable, clean, quality-assured off-grid lighting; affordable safe drinking water; fuel-efficient cook-stoves; and affordable solutions to water poisoning.

There are numerous barriers and challenges to increasing penetration of climate change mitigation technologies in the global marketplace. Some key barriers include lack of information, lack of access to capital, misplaced incentives or flaws in market structure, decisions influenced by custom and habits, transaction costs, externalities, and imperfect competition. These and other factors can influence a technology in the following ways:

- market potential (i.e. expected penetration absent of new policy or implementation measures);
- economic potential (i.e. deployment if all cost-effective technologies are implemented, from consumers' perspective); and
- socio-economic potential (i.e. market adoption if all cost-effective technologies were implemented, from a social perspective).

Even if all market, institutional, social, and cultural factors—whose removal is cost-effective from a societal perspective—were removed, some technologies might not be widely used simply because they are still too expensive. In order to be useful, effective, and scalable for emerging economies, technology innovation must be affordable, technically effective, robust and reliable, culturally appropriate, widely applicable and cost effective.

One area that offers significant potential for energy savings is energy efficiency in appliances. Rapidly growing global electricity demand is led by emerging economies, and about half of this electricity consumption is from appliances and equipment. Four appliance categories are expected to continue to constitute roughly 40% of residential sector electricity consumption: lighting, refrigeration, air conditioning, and televisions. Given these findings, more investment in efficient appliances and equipment would be cost-effective and would also reduce greenhouse gas (GHG) emissions.

Globally, there has been rapid improvement in efficiency of televisions (TV). Differences between regions are limited, and there is relative worldwide similarity in TV screens such as liquid crystal displays (LCDs) and LCD-backlight technologies. In addition to the ongoing TV market transition toward those that are backlit with light-emitting diodes (LED), TV electricity consumption can be further reduced by 20% to 40% cost effectively.

If one considers room air conditioning, a number of available efficiency improvements to air conditioning (AC) units could save over 70% of energy consumption compared to a base case model. Other options may be viable too, such as occupancy sensors and demand response (DR) measures such as “smart ACs” linked to the smart grid. DR measures and smart ACs could further reduce energy consumption by 20% to 30%.

Refrigerators are among the appliances most frequently targeted by efficiency standards and policies, and significant cost-effective improvement potential still exists for emerging economies. A few available technology options include improving compressor efficiency, variable-speed compressors to adjust output based on external conditions, adaptive defrost and anti-sweat heaters, top-mounted condensing coils, direct-current fan motors, and smaller-sized and separate compressors for fresh food and freezer storage.

Ceiling fans present another opportunity for efficiency improvements. Not surprisingly, China and India represent more than half of the worldwide energy consumption by ceiling fans (total 156 TWh) in 2012. Extra attention should be paid to improving alternating current induction motors, efficient blades, and brushless direct current to reduce power consumption in a cost-effective manner.

A case study of India's Super-efficient Equipment Programme (SEEP)—initiated in 2010 by the Indian Bureau of Energy Efficiency (BEE)—demonstrates one possible approach to unlocking efficiency gains through appliances. Ceiling fans, refrigerators, AC units and TVs were accepted candidate appliances for the program, but fans were chosen as the primary technology for initiating a demand-side management program to provide discounts to manufacturers. This effort is current underway and is now supported by the World Bank, the BEE, and regulatory commissions.

The industrial sector is often a focus of energy efficiency programmes. Lessons learned from these efforts benefit countries such as India and China which have significant energy intensive industrial operations.

The EPA Energy Star programme is a symbol for energy efficiency, and since 2000 the programme has expanded to include voluntary partnerships between industries and government and now includes over 500 industrial partners. The Energy Star programme provides tools and recognition for industrial partners (e.g. Energy Guides and Energy Performance Indicators [EPIs]) that meet the partnership commitments. These include improving energy performance; benchmarking and tracking energy use; developing and implementing a plan to improve energy performance; and educating staff and the public on partnership.

In India, five major industries (iron and steel, cement, ammonia, aluminium, pulp and paper) accounted for over 60% of total final energy use in industry in 2005. In China, the industrial

sector consumed over 60% of China's total primary energy consumption. These estimates help provide context for the scale of potential energy and emissions reductions in key industries in these countries. Even though China has had success with the Top 1 000 Energy-Consuming Enterprises Programme initiated in the 11th Five Year Plan, it remains to be seen how it will address the energy consumption of other businesses. The 12th Five Year Plan aims to build off this success with a new Top 10 000 Energy-Consuming Enterprises Programme which covers approximately two-thirds of China's total energy consumption.

Electricity access is still not widely available in the developing world—roughly 22% of the global population does not have access to electricity. According to survey results, over half of the households in Sub-Saharan Africa use paraffin and kerosene for cooking and lighting. Desirable characteristics of lighting devices for off-grid regions include affordability, cost-effective recharging methods, adequate light intensity, portability, battery life, ease of use and maintenance, safety, and security. One example of an initiative tackling these issues is the Solar and Energy Access Program (SLED)—a global market transformation initiative with initial focus on replacing fossil fuel-based light sources with sources such as LEDs. This effort builds on a joint initiative led by the International Finance Corporation (IFC) and the World Bank known as Lighting Africa. SLED is now called the Global Lighting and Energy Access Partnership (Global LEAP), which was launched by 10 partner organisations at the third Clean Energy Ministerial (CEM) in 2012.

In addition, over 1.2 billion people worldwide lack access to safe drinking water, highlighting the need for improved access to basic services for the entire globe. One option to explore is greater deployment of highly efficient ultra-violet (UV) disinfection techniques, which can use up to 6,000 times less primary energy than that needed to disinfect water by boiling on a biomass cook-stove. Similar opportunities exist to deploy fuel-efficient cook-stoves to replace stoves used by over 2 billion people that burn solid fuels, mostly with very low efficiency. The type of cookstoves used is very much driven by the type of food a population eats. An example of a region-specific technology solution is the Berkeley-Darfur Stove (BDS), designed specifically for that particular area. It only costs USD 20, saves USD 330 in annual fuel (i.e. wood) costs, and lasts at least five years, each unit offsetting roughly two tonnes of CO₂ equivalent per year.

Among other challenges that energy-efficient technologies can help address is the lack of an affordable solution to water poisoning. Arsenic in drinking water poses a large problem to populations around the world, particularly in Bangladesh. A technology solution called the ECAR 100L device has demonstrated excellent performance from preliminary results from field tests done in rural West Bengal in 2010 and 2011. This technology has proven to be approximately five times more cost-effective than the next-cheapest alternative for removing arsenic. In addition, a modular ECAR device with 10 times more throughput was successfully tested in Kolkata, India, in the summer of 2012.

These regional and multi-national cooperative efforts demonstrate the importance of international collaboration. Governments, private sector entities, and non-governmental organisations (NGOs) all have important roles to play in technology R&D, but the greatest benefits can be achieved when working together for the global good.

Innovation and clean energy R&D needs of emerging economies

Dr. Ambuj Sagar, Dean, Alumni Affairs and International Programs, Indian Institute of Technology

<http://www.iea.org/media/workshops/2012/egrdbjijing/WEBEGRDSagar.pdf>

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Developing countries will be facing climate change challenges implementing both mitigation and adaptation measures. At the same time, these nations have pressing development challenges in terms of providing energy services and amenities, including adequacy, affordability, efficiency, and modernity. These challenges are interlinked and technology can play a major role in addressing them.

The modification and adaptation of existing commercial and emerging technologies and products is the most popular approach, but there is still a need for creation of technologies and products for meeting local needs (i.e. energy access) that may not be developed by global commercial markets. This highlights the need for accelerated deployment of existing technologies and exploration of technologies for supporting the longer-term needs of developing countries.

Regarding options and approaches to collaborating on R&D, a few key variables are important to consider. The focus must be on collaboration—an R&D model can be very different between sectors and can also vary by the nature of the activity. When considering those performing the R&D, it is important to consider whether this is better executed by private sector firms, government, academia, or non-profits or non-governmental organisations (NGO). A range of collaboration models also present options for bilateral, consortia, or network-based frameworks. Similarly, funding sources and models can vary in structure and effectiveness.

In terms of supporting infrastructure and capital, capacity building efforts are not limited to developing countries. Globally, there is a need for an integrated approach to promoting good technologies to world-wide markets and not just in developing countries. Despite the fact that gaps in human capital and technology availability also exist in developed countries, there are rich and diverse institutional resources in developed countries that are not as readily available in developing countries.

It is important to keep in mind the purpose of collaboration as it will affect the approach that is taken in performing R&D, whether the purpose is to mitigate climate change or to increase economic development. To this effect, an inducement price or advanced market commitment can be used to spur investment in addition to R&D or market-pull forces. There are many collaboration models that can be explored depending on purpose and nature of the sector or needs of the targeted users of the technologies resulting from R&D.

In the case of long-term R&D, a global R&D facility focused on climate change could be needed, particularly given the tension between national competitiveness on clean energy technologies and the need for global adoption of these technologies. This challenge may push efforts beyond collaborative R&D, perhaps to an approach of “innovation cooperation.” This type of approach may help address some critical issues facing technology deployment. For example, once a technology exists, what does it take to get them implemented, particularly in a developing country context? This is a difficult question to answer when considering that innovation systems and investments, as well as the scale, scope, and coordination of R&D efforts are weak in developed countries.

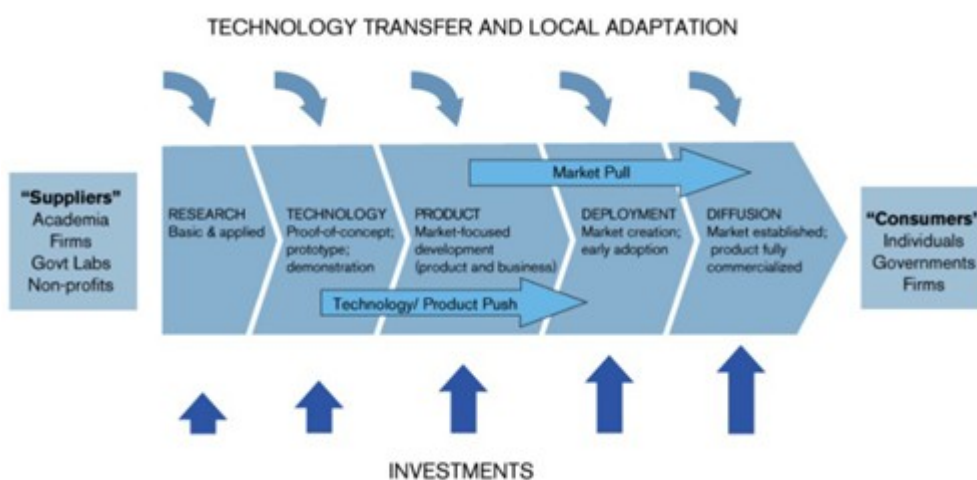
The “innovation cooperation” perspective must focus on both availability and feasibility of implementation of technology. This necessitates technology innovation capabilities that are shaped by local needs and rooted in a local institutional context beyond the realm of R&D. It is important to think about the process of successful innovation beyond R&D from various

perspectives (e.g. technology, company, financing, market, policy). This can help emphasise the fact that a range of activities may need to be undertaken in each area to make sure technology actually gets implemented (Figure 13). Flexibility is key and a local and international engagement is needed involving a range of organisations and experts. Successful efforts need a focus on scalable opportunities and development of co-benefits for the all stakeholders involved.

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Overall, it is important not to focus just on the commercialisation of a technology, but also the unaddressed needs particularly related to local energy access. Collaborative R&D can be very helpful, but much depends on the objective of the effort and the nature of the technology being developed. It is important to think beyond the bounds of collaborative R&D to include a focus on innovation cooperation- as well.

Figure 13 • Elements of the innovation process



Source: Chart provided by Ambuj Sagar, Indian Institute of Technology. Subject to third party copyright.

Integrated approaches to energy efficiency technology in China

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<http://www.iea.org/media/workshops/2012/eqrdbeijing/EGRDHEPing.pdf>

When considering energy saving potentials of energy efficiency technologies, whether in Chinese industries or others, effective policies can help catalyze markets. Policies targeted at the development, deployment, and pricing of a given technology can help improve the cost-effectiveness of a technology to the point where it outperforms conventional technologies for the same or even lesser cost. The deployment of new, more energy efficient technologies can also produce significant energy, environmental, and economic benefits. During the 11th Five Year Plan, total energy savings of 320 million tonnes of coal equivalent (tce) was achieved from deployment of 26 energy efficiency technologies, contributing to 64% of industrial energy savings over that period. Over the duration of the 11th Five Year Plan, energy consumption per unit of value-added for industrial products was reduced by 20.6%, which contributed to 78% of the national energy intensity reduction.

China's 12th Five Year Plan has set a new goal to achieve 16% energy intensity reduction, and relies on a mix of sector restructuring and deployment of energy efficiency technologies to achieve this goal. As outlined in the 12th Five Year Plan, energy saving potential is greatest in the power sector, buildings sector, iron and steel sector, and chemicals sector. In terms of the energy saving potential of different technologies, energy system optimisation is expected to be the main

contributor to savings, followed by boiler and furnace improvements, waste heat and pressure systems, and motor systems.

Despite the significant benefits that can be achieved through deployment of energy efficiency technologies, there are numerous barriers and challenges facing energy efficiency technologies promotion. The lack of standards for identification, screening, selection and dissemination of energy efficiency technologies is a critical barrier. There is also a need for tailor-made incentive policies to promote energy efficiency technologies specifically. In addition, enterprises' lack of awareness of energy efficiency technologies and the benefits they produce are hindering efforts at increased market adoption. Related barriers include the weak coordination among key stakeholders for promoting these technologies and the lack of services or other infrastructure for providing information on energy efficient technologies.

In order to address these barriers, integrated approaches for promotion of energy efficient technologies are needed. This might include establishment of technical and management standards for energy efficient technologies to widen channels for collection of these technologies. Technical standards would also help improve identification, screening, and selection of technologies. A mechanism for energy efficient technology dissemination will also be critical in addition to the establishment of a database for information disclosure and update and a mechanism for monitoring and evaluation. An integrated approach to addressing these technology barriers might also involve exploration of a technologies trading system.

In addition to these measures, improved coordination among key government agencies is instrumental. This includes identification of leading ministries—possibly the Chinese National Development and Reform Commission (NDRC)—and close collaboration with the Ministry of Finance, Ministry of Industry and Information Technology, Ministry of Housing and Urban-Rural Development, Ministry of Science and Technology, and other key ministries. This level of cooperation will also need a mechanism for information sharing and exchange among the ministries, and may even require setting up a national coordination office for development of overall strategies and implementation of energy efficient technologies. The development of a national strategy for the promotion of energy efficient technologies would greatly benefit these efforts, including a channel for approved projects for energy efficient technologies.

In terms of policy approaches, a national subsidy to support demonstration projects, development of a production base, and commercialisation of major new energy efficient technologies would be a sign of improving incentive policies. This may also involve the establishment of a national fund for energy efficient technologies. In addition, financial institutions will be needed to establish specialised funds to support energy efficiency technologies.

Another key area is to develop capacity building for energy efficient technology promotion. This includes cultivation of professional personnel in universities, research institutions, and enterprises for the R&D, application, and management of key energy efficient technologies. Efforts should also focus on holding intra-industry and inter-industrial exchange meetings to improve information sharing and exchange, in addition to building capacity of third party organisations to help identify, collect, monitor, and evaluate energy efficient technologies.

Finally, information disclosure and international cooperation will likely play a significant role. This may involve broadening the approaches for information disclosure through media, advertisement, and the internet, spreading and learning about best practices and energy efficient measures from other countries, and encouraging proactive action on behalf of stakeholders (e.g. industry associations).

The Practice of Solid State Lighting & Renewable Energy in Emerging Economies

Mr. Fu Yuan, Executive Secretary, International Solid State Lighting Alliance

Note: The presentation is not available.

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Lighting accounts for 19% of global electric consumption, more than 2 651 terawatt hours (TWh) per year, generating 1 900 million tonnes of CO₂ annually. As ever greater numbers of the world's population moves to urban areas, buildings and streets account for around three-quarters of all energy used for lighting. Any increase in lighting efficiency to deliver the same or greater lighting using less energy represents an enormous potential for energy savings. Commercial buildings present the greatest opportunities for adoption of energy efficient lighting technologies.

Considering a life-cycle analysis of energy use associated with solid state lighting (SSL), it was found that most of the energy consumption takes place during use of the product (as opposed to during the manufacturing process). LEDs continue to achieve increased efficiency in terms of lumens per watt, and decreased cost in dollars per lumen. However, to be truly successful, LEDs will have to address much more than lumens per watt or dollar as they must perform in a variety of settings and scenarios. LED technology has been driven by its application first in portable displays such as mobile phones, then in larger displays like televisions and monitors, and finally for lighting. Projections for Europe have suggested that LED use will reach 80% of consumption for lighting by 2020.

In developed countries, lighting consumes around 20% of electricity; in developing countries from 10 to 15%; and in under-developed countries only 5%. In 2010, lighting consumed 13% of electricity in China, though that portion is rising with increasing urbanisation. For this reason China has listed SSL as a strategic technology that will act as an integral component in future sustainable economic development. SSL has many advantages to being a disruptive technology applicable on a large scale with impact to broad industrial sectors.

The SSL industry itself represents a strategic emerging sector in part due to its lengthy supply chain. The technology brings together many components from raw materials to epi-wafers and the packing module and from applications in many sectors both as a part of retrofit projects and at new installations. Development of this industry has been progressing for many years—industrial output grew 30% from 2010 to 2011—but the next three to five may prove most crucial.

While the lifetime costs of LEDs are lower than conventional lighting, the current high upfront installation costs is a challenge. Construction projects represent the majority of sales for most LED companies in China. Though the product development has progressed quickly, the lack of mature marketing channels has been a hindrance.

The 12th Five-Year-Plan describes the main objectives for SSL as enhancing the SSL industry's innovation capability and capacity, gradually promoting demonstration and application, and greatly improving the industry service and support systems. Key projects to achieve these objectives include:

- Standardisation, Testing & Certification System Establishment Project;
- Key Generic Technologies Industrialisation Project;
- Key Equipment & Materials Domestic Manufacture Project;
- Application Demonstrations & Dissemination Project; and the
- Industry Support & Service System Establishment Project.

The expected pathway to complete market uptake begins with government implementation and office lighting; followed by commercial, industrial, and public-space lighting; then street and tunnel lighting, and finally penetrating residential lighting. From there, applications in the agriculture, medical, defence, and transportation sectors may be further developed. China aims to phase out incandescent lamps by October 2016.

Solar power panels, controllers, inverters, and batteries, can be costly in developing nations seeking off-grid solar lighting solutions, given the high costs of all the components. Using LED technologies instead of other lighting solutions will not increase costs because the lamp makes up a small portion of the overall cost and because the improved efficiency and longer life of LEDs will bring down lifetime costs.

In practice, solar lighting has applications both in residential lighting and as lighting in public spaces as street lights. Off-grid solutions are most obviously needed in rural areas and where electricity generation is not readily available. Deployment of the technologies will require governments to provide education about the solar and LED technology and demonstrations of its utility, while private companies can most likely provide the products and operational support.

The International Solid State Lighting Alliance (ISA) is an international collaboration using global initiatives, effort and resources to accelerate and foster the development of the global SSL industry and its applications and enhance people's lives and create a green and sustainable society. In December 2012, ISA facilitated international collaboration among emerging economies at the BRICS (Brazil, Russia, India, China, and South Africa) E3 (Emerging Economies, Emerging Markets, and Emerging Technology) Summit. To further collaboration, the summit participants proposed establishing a network for the BRICS countries on SSL (BSNet) to better coordinate planning industry development and devising relevant policies and incentives.

Overview and Outlook of China's Agricultural Bioenergy Development

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<http://www.iea.org/media/workshops/2012/eqrdbeijing/IEAZhaoLixin.pdf>

China has abundant agricultural biomass resources in the forms of crop straw, animal waste, energy crops, and agricultural products processing waste. On 21 January 2011, the Ministry of Agriculture issued the National Crop Straw Resources Survey and Evaluation Report, which found that the total collectable resource of crop straw is about 687 million tonnes of which 69% overall is used, with 31% used for feed and 18.72% used for energy fuels (300 million tonnes annually). Animal waste is a similarly high volume at 243 million tonnes of manure as well as 163 million tonnes of urine produced annually from industrial livestock and poultry farming. Many herbaceous energy crops are suitable for planting in China such as sweet sorghum, cassava, sweet potato, and rapeseed. Moreover, China has more than 7 million hectares of cultivated land reserves. Finally, agricultural waste, mainly from grain processing plants, food processing plants, sugar mills, and breweries is produced in large quantities from relatively dense locations making collection simple.

China has already put in place several laws, policies, regulations and incentives related to biomass that clearly laid out provisions on biomass energy development. These laws include the Law on Agriculture, the Law on Renewable Energy, and the Law on Energy Conservation. National policies further develop the plans for biomass development at the national level. These policies are established in the Medium and Long-Term Development Plan for Renewable Energy in China,

2007; Agricultural Biomass Industry Development Plan, 2007; Suggestions on Promotion of Comprehensive Utilisation of Crop Straws, 2008; and the Management Method on Subsidy of Utilisation of Crop Straw, 2008. At the local level, many provinces have put forth their own policies on rural energy. One incentive for biomass created Green Energy Demonstration Counties where 108 counties were awarded the designation and receive the equivalent of about USD 4 million to apply to development of biogas, gasification, densified biofuels, and rural energy service systems. These projects were expected to run from 2011 to 2013.

The biogas sector has developed quickly in recent years. By the end of 2011, 41.7 million rural Chinese households had biogas digesters installed, and 81,000 agricultural waste biogas projects had been constructed with a total biogas capacity of 17.1 billion cubic meters per year. The biogas plants use a variety of processes to convert animal manure, crop straws, and mixed agricultural wastes. Crop straw can be made into pellets and briquette fuels with high energy efficiency and low emissions by mechanical compaction making it convenient for storage and transportation. Use of this densified fuel technology is expanding, and currently China has about 100 biopellet plants capable of producing 3 million tonnes of pellets and briquettes.

By end-2010, the installed capacity of biomass power generation was about 5.5 GW. Constrained by grain output, China no longer develops grain-based production of ethanol fuels. Instead, non-grain ethanol production has grown into its own industry and has begun to achieve major technological breakthroughs. For example, a bio-ethanol plant based on cassava fermentation was built in Guangxi in January 2008, with a capacity of 200 000 tonnes per year. By April 2008, ethanol gasoline for vehicles was available all over Guangxi. Recently, the annual capacity of biofuel ethanol production reached 1.62 million tonnes. However, cellulosic ethanol remains relatively immature and in need of technological advances.

To further develop its biomass utilisation, China has undertaken several key international cooperation projects with partners like the Netherlands, the United States, the Asian Development Bank, and the World Bank.

While the current outlook for biogas has benefited from increasing attention to technology development and application of biomass energy as well as rapid development of the industry, several problems persist. Biogas availability is decreasing, and biogas plants are under-utilised because of poor economic benefits. The industry suffers from inferior equipment technology and low level of industrialisation. Policies and incentives need to be improved, and subsequent service abilities must be strengthened. The recent focus on construction has left little attention for management. On the other hand, several development prospects improve the outlook for biogas, such as achieving economies of scale, industrialisation, and commercialisation.

Furthermore, raw materials for production will be diversified, utilisations of biogas products will be more focused on efficient, high-value, and comprehensive end uses, and the operation and management model of biogas plants will be specialised. For biomass thermal use, the Mid- and Long-Term National Renewable Energy Development Plan calls for 50 million tonnes of biopellets/briquettes to be produced annually by 2020. Reaching this target will require R&D of biomass collection, storage, transportation system, and high-efficiency burners. Bioethanol development will depend on high-yield, good quality, strong resistance energy crop planted across a large areas; industrial-scale production equipment and technology using sweet sorghum; ethanol production technology with degradation of cellulose; and R&D of low-cost and high efficient hydrolase.

China has resources and technical potentials for large-scale development of biomass energy, which is helpful to ensure energy security as well as sustainable social and economic development in the future. The development of the biomass energy industry will provide more

employment opportunities, improve rural production and living environment and promote rural economic development.

Figure 14 • Vehicle fuel biogas plant producing (Anyang, Henan Province)



Source: Chinese Academy of Agricultural Engineering.

Discussion and Conclusion

This increased appetite for energy is underpinned by rising populations and urbanisation and increasing aspirations for energy access for all its citizens. Meeting these energy needs presents a significant challenge that is further amplified by growing environmental concerns. These concerns are dominated by urban air quality, but also include water supply and quality, sanitation, and deforestation, among others. In addition, climate change presents potentially profound long-term effects on societies, with expected impacts on energy infrastructure and systems. In addressing these challenges, there are vast opportunities to shape future energy systems with clean energy technologies and infrastructure.

Regional and national circumstances shape the manner in which the energy demand and environmental challenges are addressed. The non-OECD nations in the Asia-Pacific region that participated in the workshop share similar characteristics. Each E economy is largely based on fossil fuels (coal, oil and gas), whether by exploiting resource endowments (with the notable exception of Singapore), exporting and importing further fossil fuels, and fossil fuels for electricity generation. Fossil fuels are expected to account for nearly 80% of primary energy use in Asia and the Pacific in 2030.

Hydropower provides additional electricity generation capacity, and almost all other forms of renewable energy are used where available. These include and used, from small, specific installations (solar-powered refrigerators) medium sized operations (e.g. converting biomass to biofuels), and large installations capable of providing electricity to the grid (though these are less frequent). Renewable energy is the fastest growing source of energy, particularly in the Philippines, New Zealand, and Indonesia, though installations remain small (less than ~1MW). Most nations in the region have developed national energy policies and strategies with well-defined renewable energy and energy efficiency targets to address the challenges that they each face. Energy efficiency represents significant potential for energy savings across the region. In addition, all the emerging economies plan to expand clean energy use and energy efficiency, with many and most having approved plans or targets for renewable energy.

A common need among the Asia-Pacific emerging economies is the desire for more international cooperation and collaboration. This may include international support for pilot/demonstration projects to improve the outlook for clean energy R&D; opening internships and researcher exchanges with other countries; international exhibitions of R&D equipment, instruments, and materials, and information sharing systems to collect and disseminate information on renewable energy technologies.

Overall, international collaboration has the potential to improve energy security, environmental protection and economic growth by supporting innovation that focuses not only on new technologies, but also addresses the availability and feasibility of dissemination and implementation of the technologies. Opportunities for international R&D cooperation should be targeted and explored to improve the dissemination of best practices and achieve results that may otherwise be unachievable if sought after in isolation.

Technologies

Key technologies listed are areas of focus for many domestic and collaborative R&D programs in the region. These are illustrative and not meant to represent technology needs of all emerging economies, or even all emerging economies in the Asia-Pacific region. It is critical that technologies are well suited to implementation based on national resource endowments, cultural needs, and the ability to support a technology from a financial and human capital standpoint.

Many of the identified needs fit closely with a few specific emerging economies' resource endowments and geography.

The following are identified as strong R&D technology needs for the emerging economies that form the basis for this report:

- Clean Coal and carbon capture and storage (CCS): Most countries have some coal resources and are interested in retrofitting or transition to clean coal options with minimal increases in carbon emissions.
- Electricity networks: R&D in this area includes improvements to energy access and development of micro-grids, particularly for island nations and rural villages.
- "Island power": Reduced-scale power generating applications (~30 MW) are necessary to address rising demand for electricity in rural population centres do not have access to nationwide grids. R&D in this area has the potential to expand access to electrification and reduce the requirement for diesel-powered generators.
- Biofuels: Many of the emerging economies are located in a tropical region with up to three growing seasons and can benefit greatly from opportunities to use biomass as a fuel input.
- Energy efficiency: Large inefficiencies exist in areas including transmission, distribution, building, and lighting. R&D needs focus on implementation of energy efficiency programs and ensuring that efficiency gains are maintained and do not degrade over time. As many of these countries are located in tropical areas, further R&D is needed to achieve energy efficiency gains in appliances, particularly dehumidification, refrigeration and air conditioning.
- Transportation: Billions of people in these emerging economies rely on individual or small-scale modes of transportation such as bicycles, two- and three-wheeled scooters, cars, minivans and small buses that relying heavily on fossil fuels. Further deployment of electric motors for all these transport modes could provide effective transportation solutions. For example, China has made progress with deployment of electric scooters.
- Engineering and design should take into consideration human behaviour such as building energy system controls and interfaces with occupants and operators. For example, the Leadership in Energy and Environmental Design (LEED) building certificates were found to perform poorly (10% of design standard) due not only to a difference in building codes and environmental differences (e.g. a high rate of humidity), but also due to lack of trained operators, lack of software updates, and neglect. Further potentials: provided a country has sufficient R&D capacity and access to financing, ocean/tidal, offshore wind, and smart grids provide considerable potential to alleviate lock-in to electricity generation capacity based on fossil fuels.
- A final focus for R&D is the broad portfolio of energy-related innovations suitable for improving quality of life in small village settings or poor populations, such as cookstoves, water lifting, water purification, PV-powered refrigeration, and sanitation.

Platforms

Platforms to support international cooperation and collaboration could increase the effectiveness of R&D investments. These include:

- technology transfer mechanisms;
- information sharing on both technology and best practice;

- international support for demonstration projects to improve the outlook for clean energy R&D;
- opening internships and researcher exchanges with other countries;
- international exhibition of R&D equipment, instruments, and materials; and
- information sharing systems to collect and disseminate information on renewable energy technologies.

Policies

Each country is sovereign and responsible for development of their domestic energy policies. However, international collaboration can provide opportunities for information exchange, multiply the benefits from R&D programmes, including communicating best practices and lessons learned. Policies that could support successful R&D in the region would include the following elements:

- developing integrated R&D plans based on a multi-disciplinary approach. A well integrated R&D plan would ensure that proposed programmes are culturally appropriate, reflect current and planned resource endowments, and involve communities in discussions of energy policy;
- removing fossil fuel subsidies to balance the energy pricing mechanism in order to attract or drive private capital to the energy industry;
- developing skills and capacities to create a knowledge workforce leads to success of energy efficiency programmes, proper operation and maintenance of clean technologies;
- providing as much certainty as possible concerning long-term (e.g. 5 to 10 years) funding for R&D; and
- monitoring and evaluating R&D programme results to enable timely adjustments to funding levels and strategies when necessary.

Both public and private investment is critical, and the appropriate levels of each depend on the degree of maturity of the technology and the financial risks associated with development. While large-scale and distributed energy applications provide a broad set of opportunities for meeting urban and rural energy needs, the associated risks and need for attractive returns for investors are also important considerations for deployment at all scales. Bringing together the right partners who can be flexible in their specialised roles can help ensure that gaps are appropriately filled and priorities are properly recognised and acted upon.

Designing technologies and their deployment strategies to fit with local energy systems, circumstances, and level of public acceptance can help maximise the social benefits that energy technology R&D efforts produce. Although there is no one-size-fits-all model for international R&D collaboration, the importance of exchanging information, experiences, and analysis should not be underestimated.

Annex A: Country comparative analysis

Varied Natural Energy Resources

	Coal	Oil	NG	Fissile material	Geo-thermal	Solar ¹	Wind	Hydro	Biomass	Ocean ²
Australia	P,E	P,NI	P, NE	P,E	A	A	A	A	A	AM
China	P,NI	P,NI	P,NI	A,P,I	A	A	A	A	A	A
India	P,NI	P,NI	P,I	A,P,I	Plan	A	A	A	A	Plan
Indonesia	P,E	P,NI	P,E	NU	A	AM	AM	A	AM	NU
Japan	I	P,NI	P,I	I	A	A	A	A	A	Plan
Rep of Korea	P,I	P,NI	P,I	I	A	A	A	A	A	A
Malaysia	P,I	P,NE	P,NE	NU	Plan	AM	Plan	A	A	Plan
New Zealand	P,E	P,NI	P	NU	A	A	A	A	A	Plan
Philippines*	P,NI	P,NI	P	NU	A	A	A	A	A	Plan
Singapore	NU	NI	I	NU	Plan	A	AM	NU	AM	Plan
Thailand	P,NI	P,NI	P,I	NU	A	AM	AM	AM	A	NU
Vietnam ¹	P,E	P,NI	P,I	NU	Plan	AM	A	A	A	Plan

P	=	Producer
NE	=	Net exporter
E	=	Exporter
NI	=	Net importer
I	=	Importer

A	=	Available - in use
AM	=	Available - minimum use
NU	=	Not used
Plan	=	Planned

1. Solar includes photovoltaics, concentrating solar power, solar heating and cooling, and local applications.
2. Ocean includes wave and tidal devices.

Sources:

Renewable Energy and Energy Efficiency Partnership (REEEP) (2013), data extraction from the Clean Energy Information Portal (REEGLE) November 2012, Vienna, Austria.

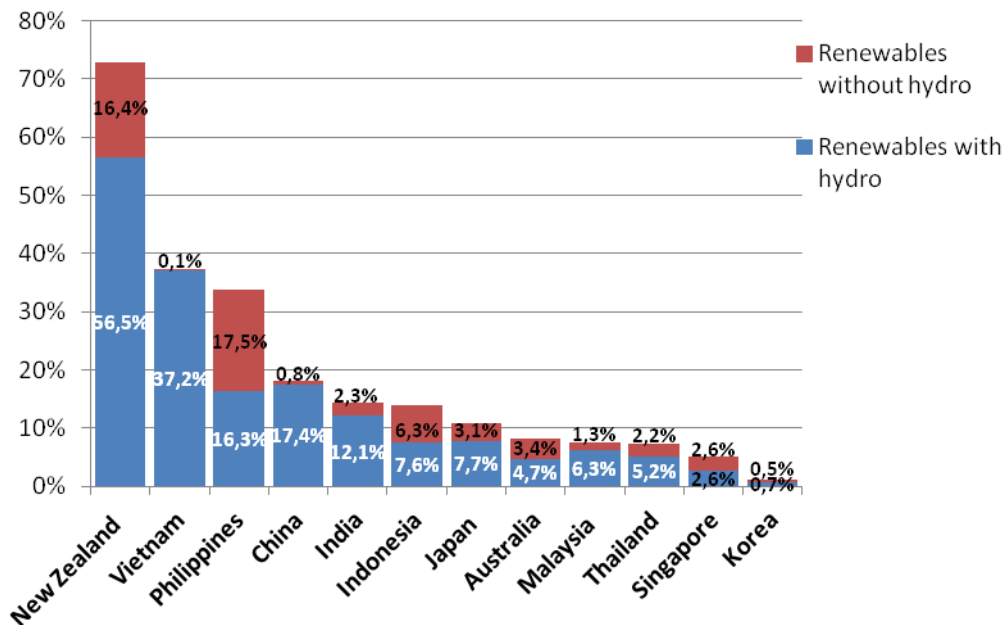
United States Central Intelligence Agency (2012), *World Factbook*, Washington D.C., United States.

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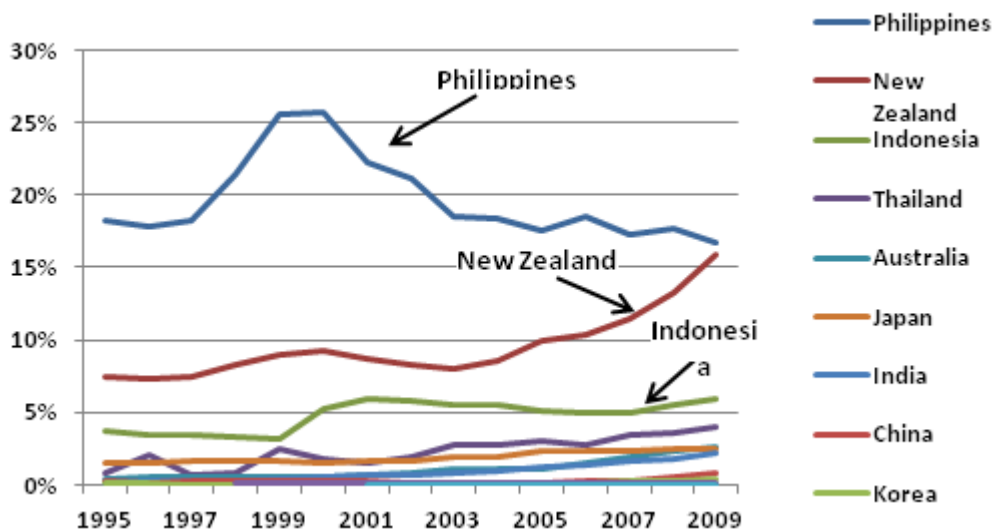
American Nuclear Society (2012), "Nuclear News," issue March 2012, La Grange Park, United States.

Figure 15 • Percent of electric generation from renewable sources (2009)



Source: United States Energy Information Administration (EIA), (2010), *International Energy Statistics*, Washington, D.C., United States.

Figure 16 • Annual growth in renewable electric energy (excluding hydro)



Source: World Bank (2009), *World Development Indicators*, databank WDI-GDF, Washington, D.C., United States.

Annex B: Acronyms, abbreviations and units of measure

Acronyms and abbreviations

ASEAN	Association of Southeast Asian Nations
ASI	Australian Solar Institute
BAU	business-as-usual
BEE	Bureau of Energy Efficiency, India
CCS	carbon capture and storage
CEM	Clean Energy Ministerial
CERT	Committee on Energy Research and Technology
CO ₂	carbon dioxide
CSP	concentrating solar power
DOE	Department of Energy, United States
EGRD	Experts' Group on R&D Priority Setting and Evaluation
EPA	Environmental Protection Agency, United States
GDP	gross domestic product
GEF	Global Environmental Facility
GHG	greenhouse gas
ICT	information and communication technologies
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
LNG	liquefied natural gas
METI	Ministry of Economy, Trade and Industry, Japan
MOEN	Ministry of Energy, Thailand
MOST	Ministry of Science and Technology (various)
MSW	municipal solid waste
NEDO	New Energy and Industrial Technology Development Organisation, Japan
OECD	Organisation of Economic Co-operation and Development
PV	photovoltaic
R&D	research and development
RD&D	research, development and demonstration
S&T	science and technology
SSL	solid-state lighting
UNFCCC	United Nations Framework Convention on Climate Change

Units of measure

BOE	barrels of oil equivalent
GW	gigawatt
kWh	kilowatt-hour
MW	megawatt
TCE	tonnes of coal equivalent
TCF	trillion cubic feet
TOE	tonnes of oil equivalent
TWh	terawatt-hour
W	watt

Annex C: Agenda

ENERGY TECHNOLOGY R&D NEEDS OF EMERGING ECONOMIES			
AGENDA			
28 November 2012			
Tangla Hotel (Ruby Room, 3rd floor), 19, Fuxingmenwai Street, Chang'an Avenue, Beijing, PR China			
OPENING REMARKS			
9:00	1	Mr. Chen Jiachang, Deputy Director General, High-Tech. Development and Industrialisation,(MOST) Mr. Rob Kool, Manager, International Sustainable Development, NL Agency (Netherlands), Chair, Experts' Group on R&D Priority-setting and Evaluation	
GLOBAL PERSPECTIVES ON EXISTING CLEAN ENERGY TECHNOLOGY R&D INVESTMENTS AND THE IMPORTANT ROLE OF EMERGING ECONOMIES			
9:20	2	The Importance of Meeting Clean Energy R&D Needs of Emerging Economies	Mr. Peter Cunz, Senior Expert, Swiss Federal Office of Energy, Chair, Committee on Energy Research and Technology
9:50	3	A Comparative Analysis of Clean Energy Technology Contexts and Challenges in the Region	Dr. Robert Marlay, Deputy Director, Climate Change Policy and Technology, Dept. of Energy (United States), Vice-Chair, EGRD
<i>10:15 Break</i>			
COMPARATIVE ANALYSIS OF CLEAN ENERGY R&D			
Moderator: Dr. Robert C. Marlay			
10:45	4	China	Mr. Zheng Fangneng, Director, Division of High and New Technology Development and Industrialisation, Ministry of Science and Technology
11:30	5	Thailand	Dr. Twarath, Deputy Director-General, Department of Energy Development and Efficiency, Ministry of Energy, Thailand
12:15	6	Indonesia	Dr. Verina J. Wargadalam, Senior Researcher, New & Renewable Energy Technology, Ministry of Energy and Mineral Resources, Indonesia
<i>13:00 Lunch on 2nd floor at Café D'or</i>			
COMPARATIVE ANALYSIS OF CLEAN ENERGY R&D (cont'd)			
Moderator: Mr. Ruisheng Yue, Secretary General, International SSL Alliance			
14:30	7	Malaysia	Mr. Azhar Omar, Senior Director, Electricity Markets and Supply Regulation, Energy Commission, Malaysia
15:15	8	India	Mr. Ambuj Sagar, Dean, Alumni Affairs & International Programmes, Indian Institute of Technology
<i>16:00 Break</i>			
16:30	9	Singapore	Mr. Zhen-hui Eng, Deputy Director, Policy and Planning, Energy Planning and Development Division, Energy Management Authority
17:15	10	Session wrap-up	Dr. Marlay
<i>18:00 End Day 1</i>			

ENERGY TECHNOLOGY R&D NEEDS OF EMERGING ECONOMIES**AGENDA****29 November 2012****REGIONAL PERSPECTIVES: SELECTED OECD COUNTRIES***Moderator: Mr. Ludwig Vandermaelen*

9:00	11	Panel Discussion Dr. John Soderbaum, Director, Science and Technology, ACIL Tasman Mr. Eiichi Homma, Director General, International Projects, International Affairs Department, New Energy and Industrial Technology Development Organisation, Japan Dr. Seungyoung Chung, Senior Researcher, Korea Institute of Energy Technology, Evaluation and Planning
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10:30 Break

REGIONAL PERSPECTIVES: INVESTORS*Moderator: Dr. Herbert Greisberger*

11:00	12	Panel Discussion Mr. Justin Wu, Head, Wind Industry Research, Bloomberg New Energy Finance Mr. Levien J. de Legé, Managing Director, ECN Asia Mr. David Hathaway, Vice President, China Operations, ICF International Mr. Weigang (Greg) Ye, Founding Managing Partner, Delta Capital
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12:15 Lunch on 2nd floor at Café D'or

COMPARATIVE ANALYSIS OF CLEAN ENERGY R&D*Moderator: Dr. Robert C. Marlay*

10:45	13	China	Mr. Zheng Fangneng, Director, Division of High and New Technology Development and Industrialisation, Ministry of Science and Technology
11:30	14	Thailand	Dr. Twarath, Deputy Director-General, Department of Energy Development and Efficiency, Ministry of Energy, Thailand
12:15	15	Indonesia	Dr. Verina J. Wargadalam, Senior Researcher, New & Renewable Energy Technology, Ministry of Energy and Mineral Resources, Indonesia

13:00 Lunch on 2nd floor at Café D'or

REGIONAL PERSPECTIVES : SELECTED ORGANISATIONS*Moderator: Mr. Fu Yuan , Executive Secretary, International Solid State Lighting Alliance*

13:15	16	Technology Perspectives on Clean Energy R&D Needs of Emerging Economies	Dr. Jayant Sathaye, Lawrence Berkeley National Lab
14:00	17	Innovation and Clean Energy R&D Needs of Emerging Economies	Dr. Ambuj Sagar, Dean, Alumni Affairs & International Programmes, Indian Institute of Technology
14:45	18	Integrated Approaches to Energy Efficiency Technologies in China	Dr. He Ping, Programme Director, Industry, China Sustainable Energy Program
15:30	19	The Practice of Solid State Lighting & Renewable Energy in Emerging Economies	Mr. Fu Yuan, Executive secretary, International Solid State Lighting Alliance
16:15	20	Overview and Outlook of China's Agricultural Bioenergy Development	Ms. Zhao Lixin, Director, Institute of Energy and Environmental Protection, Chinese Academy of Agricultural Engineering, Ministry of Agriculture of China

KEY QUESTIONS

Moderator: Dr. Birte Holst-Jorgensen

17:00	21	<p>Discussion</p> <ol style="list-style-type: none"> 1. <i>What is the general economic mix and outlook for your country or region (e.g. natural resource endowments, export and import balances, or grid capacity)?</i> 2. <i>What are the important features of your current energy situation and long-term energy strategy?</i> 3. <i>What are the most important energy-related environmental concerns?</i> 4. <i>Do you have distinct urban and rural energy planning or infrastructure needs?</i> 5. <i>What role do you envision for innovation and advanced technology to help you meet your energy, economic, and environmental goals?</i> 6. <i>What do you see as key R&D gaps and opportunities, and investment priorities?</i> 7. <i>What model do you prefer for cooperative R&D with other countries?</i> 	
17:45	22	Key messages for the synthesis report	<i>Moderator</i>
18:00	23	Conclusions	<p><i>Mr. Li Xin Director, Division of International Organisations and Conferences, Department of International Cooperation, Ministry of Science and Technology, P.R. China</i></p> <p><i>Mr. Rob Kool</i></p>

18:00 Meeting Close

Annex D: Speakers and moderators

Name	Position and affiliation
Chung, Dr. Seungyoung	Senior Researcher, Korea Institute of Energy Technology, Evaluation and Planning
Cunz, Mr. Peter	Senior Expert, Swiss Federal Office of Energy, Chair, Committee on Energy Research and Technology
De Legé, Mr. Levien J.	Managing Director, ECN Asia
Eng, Mr. Zhen-Hui	Deputy Director, Policy and Planning, Energy Planning and Development Division, Energy Management Authority
Greisberger, Dr. Herbert	Head, Department of Energy and Climate Change, Energy and Environment Agency of Lower Austria
Hathaway, Mr. David	Vice President, China Operations, ICF International
He, Dr. Ping	Program Director, Industry, China Sustainable Energy Program
Holst-Jorgensen, Dr. Birte	Deputy Director, Management Engineering, Technical University of Denmark (DTU), Vice Chair, Experts' Group on R&D Priority Setting and Evaluation
Homma, Mr. Eiichi	Director General, International Projects, International Affairs Department, New Energy and Industrial Technology Development Organisation, Japan
Kool, Mr. Rob	Manager, Int'l Sustainable Develop., NL Agency (Netherlands), Chair, Experts' Group on R&D Priority-setting and Evaluation
Li, Mr. Xin	Director, Division of International Organisations and Conferences, Department of International Cooperation, Ministry of Science and Technology, P.R. China
Marlay, Dr. Robert	Deputy Director, Climate Change Policy and Technology, Dept. of Energy (United States), Vice-Chair, EGRD
Omar, Mr. Azhar	Senior Director, Electricity Markets and Supply Regulation, Energy Commission, Malaysia
Ruisheng, Mr. Yue	Secretary General, International Solid State Lighting Alliance
Sagar, Dr. Ambuj	Dean, Alumni Affairs & International Programs, Indian Institute of Technology
Sathaye, Dr. Jayant	Lawrence Berkeley National Lab
Soderbaum, Dr. John	Director, Science and Technology, ACIL Tasman
Sutabutr, Dr. Twarath	Deputy Director-General, Department of Energy Development and Efficiency, Ministry of Energy, Tha
Vandermaelen, Mr. Ludwig	Belgian Delegate to the Experts' Group on R&D Priority Setting and Evaluation and the Committee on Energy Research and Technology, International Energy Agency
Wargadalam, Dr. Verina J.	Senior Researcher, New & Renewable Energy Technology, Ministry of Energy and Mineral Resources, Indonesia
Wu, Mr. Justin	Head, Wind Industry Research, Bloomberg New Energy Finance
Ye, Mr. Weigang (Greg)	Founding Managing Partner, Delta Capital
Yuan, Mr. Fu	Executive Secretary, International Solid State Lighting Alliance
Zhao, Ms. Lixin	Director, Institute of Energy and Environmental Protection, Chinese Academy of Agricultural Engineering, Ministry of Agriculture of China
Zheng, Mr. Fangneng	Director of Energy, Department of High and New Technology Development and Industrialisation, Ministry of Science and Technology



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