



Clean Energy Technology R&D Needs of Emerging Economies in Asia


15 November 2012

A Comparative Analysis of Clean Energy Technology Contexts and Challenges In the Region

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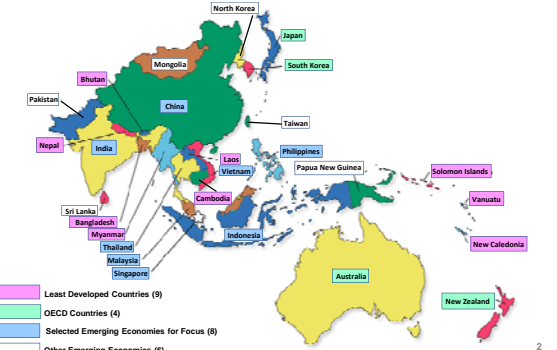
IEA Experts' Group on R&D Priority Setting and Evaluation (EGRD)

Organized by
 International Energy Agency
 In Conjunction with
 Ministry of Science and Technology
 Beijing, China
 28-29 November 2012



Asia-Pacific Region

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Least Developed Countries (9)
 OECD Countries (4)
 Selected Emerging Economies for Focus (8)
 Other Emerging Economies (6)

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Desired Meeting Outcomes

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

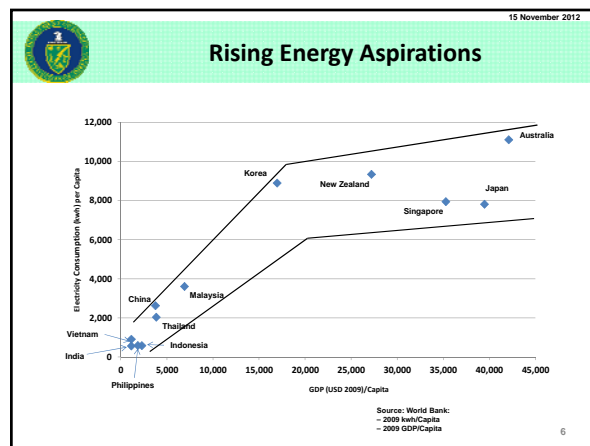
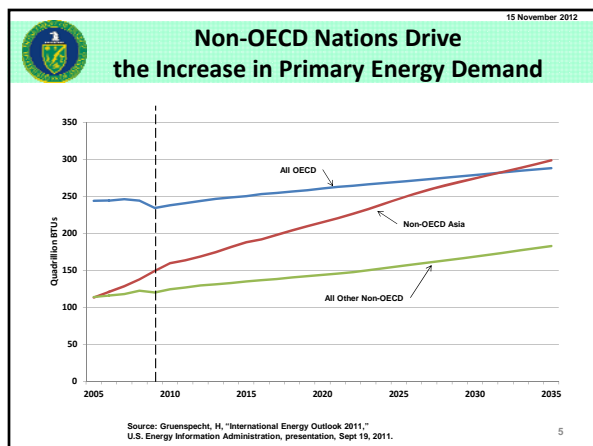
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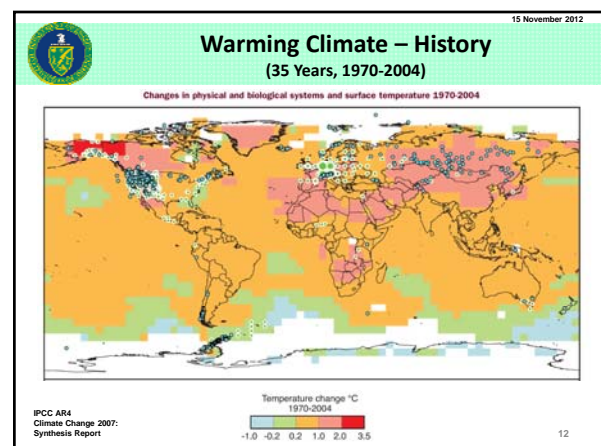
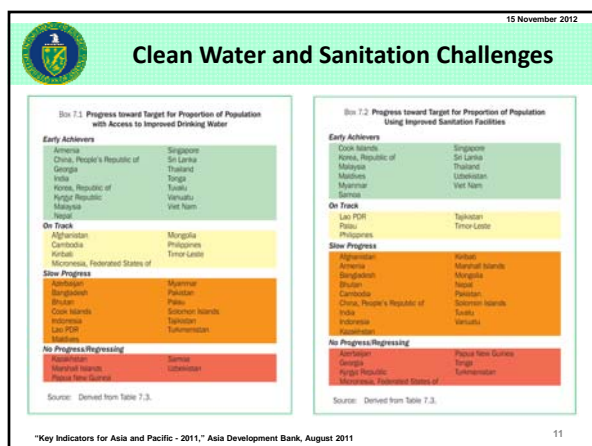
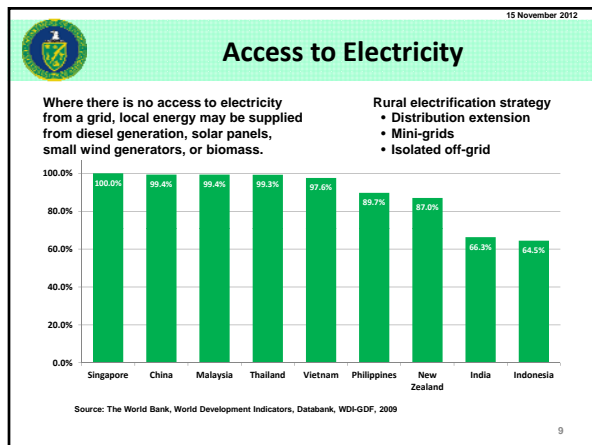
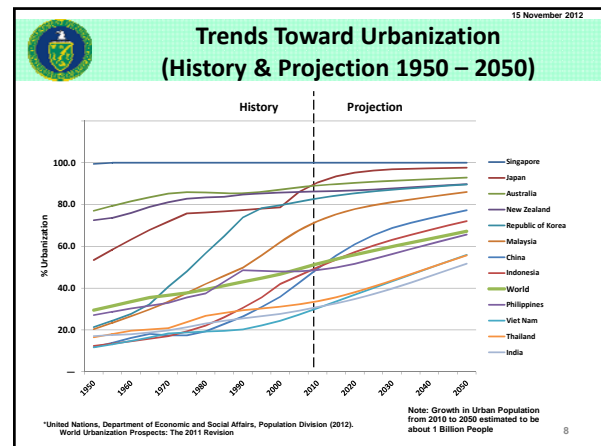
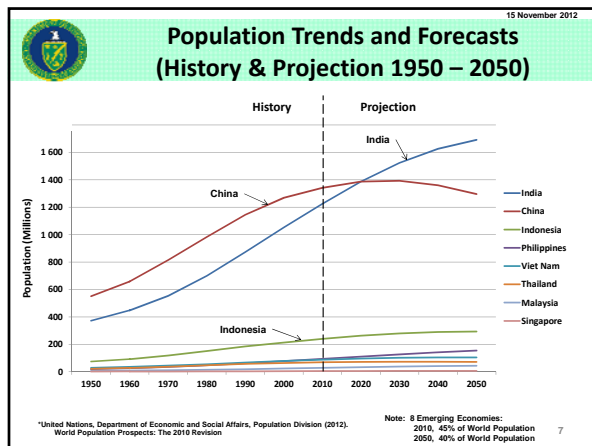


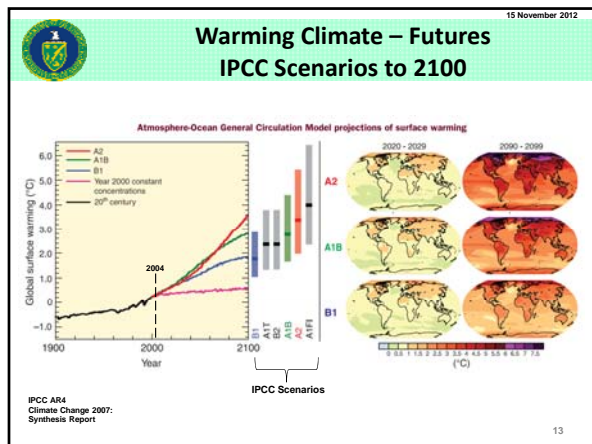
REGIONAL CONTEXTS AND CHALLENGES

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Climate Impacts on Energy Systems

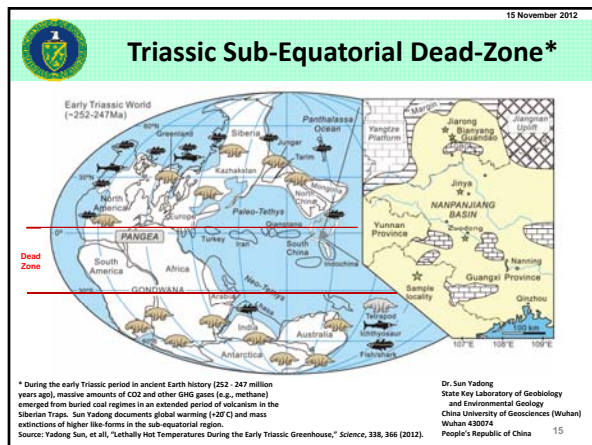
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Technology	Δ Air Temp	Δ Water Temp	Δ Water Availability	Δ Wind Speed	Δ Sea Level	Floods	Heat Waves	Storms	Sum
Coal	1	2	1-3	—	—	3	1	—	9
Oil	1	2	1-3	—	—	3	1	1	10
Natural Gas	1	2	1-3	—	—	3	1	1	10
Nuclear	1	2	1-3	—	2*	3	1	—	11
Hydropower	—	—	1-3	—	—	3	—	1	6
Wind	—	—	—	1-3	3*	1	—	1-3	8
Photovoltaic	1	—	—	1	—	1	1	1	5
CSP/Solar tracking	—	—	2	2	—	1	1	2	8
Biomass/biofuel	1	2	2	—	3*	3	1	—	12
Geothermal	—	1	—	—	—	1	—	—	2
Ocean	—	1	—	—	1	N/A	—	3	5
T&D Grids	3	—	—	1	3*	1-2	1	2-3	12
End Use	2	—	—	—	—	—	3	—	5

Δ = change in; CSP = concentrating power
 * Higher severity in coastal or low-lying areas
 Notes: 3 = Severe impact; 2 = medium impact; 1 = limited impact; N/A = not applicable

Asian Development Bank (2012), "Climate Risk and Adaptation in the Electric Power Sector" Table 15

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- ### Context Summary
- 15 November 2012
- Non-OECD Asian Economies will Dominate Future Global Energy Demand
 - Accompanied by Rising Aspirations for Electricity use per Capita
 - Underpinned by Rising Population & Trends Toward Urbanization
 - Attended by Growing Concerns About the Environment
 - Dominated by Urban Air Quality Concerns, but also
 - Other Concerns: Water, Sanitation & Deforestation
 - Forecasts Suggest Fresh Water Supply Will Be a Growing Concern
 - Energy Access Remains a Challenge in Some Countries
 - Climate Change & Global Warming Present Daunting Challenges
 - With Expected Impacts on Energy Infrastructure and Systems, and
 - Potentially Profound Longer-Term Effects on Civil Society
 - Hugh Opportunities to Shape Future with Innovation & New Technology
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ENERGY PARTICULARS

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Varied Natural Energy Resources*

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	Coal	Oil	NG	Fossil Material	Geo-thermal	Solar**	Wind	Hydro	Biomass	Ocean***
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	P, E	P, NI	P, I	NU	Plan	AM	A	A	A	Plan

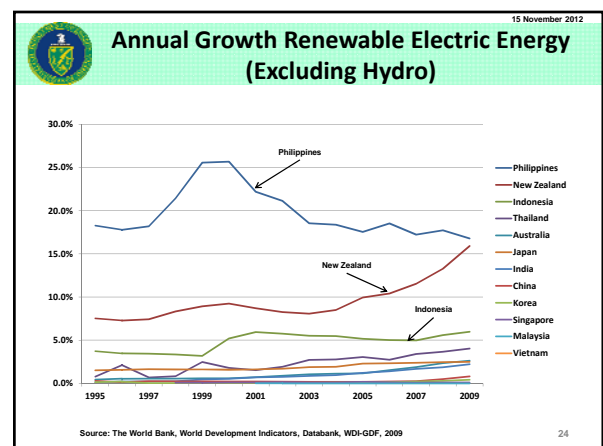
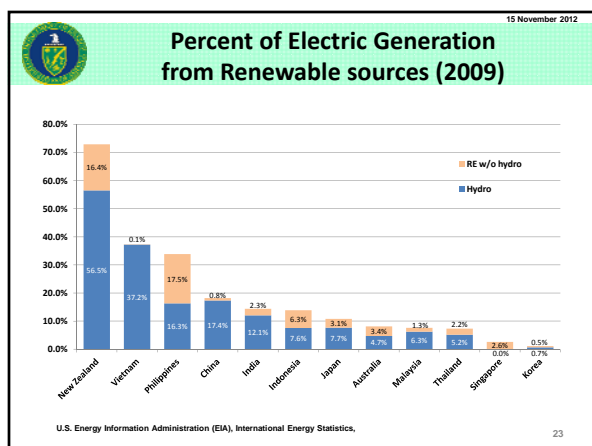
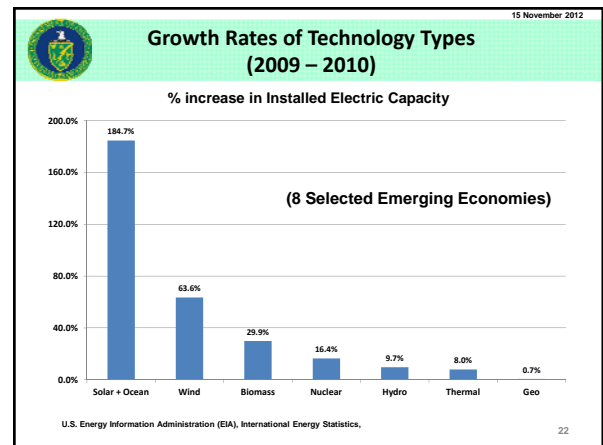
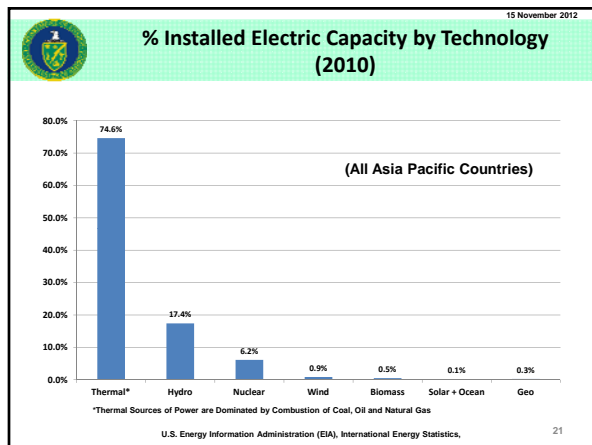
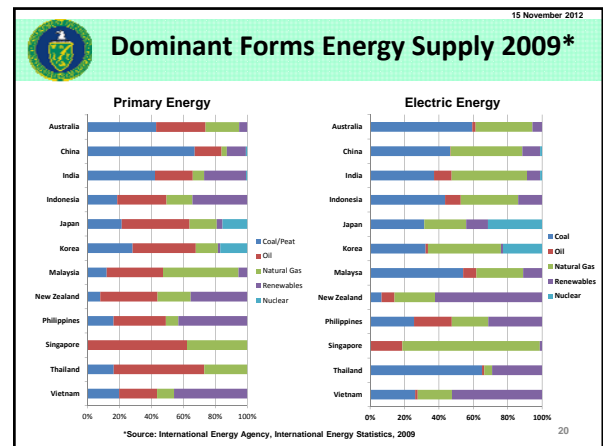
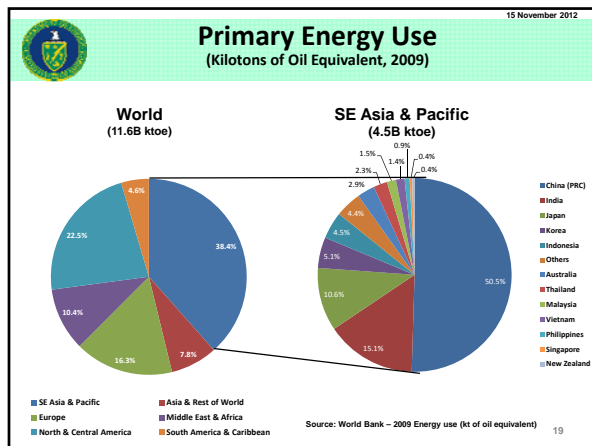
P = Producer
 NE = Net Exporter
 E = Exporter
 NI = Net Importer
 I = Importer

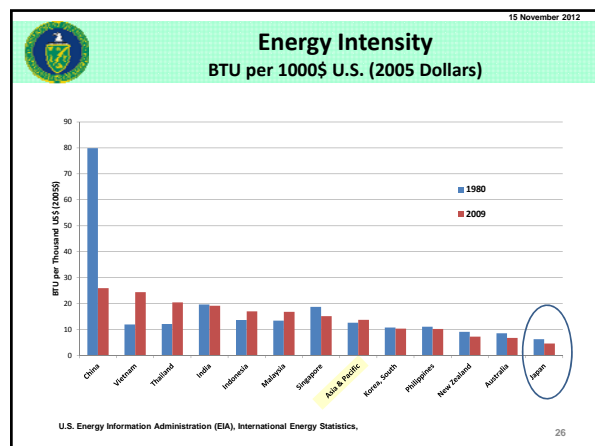
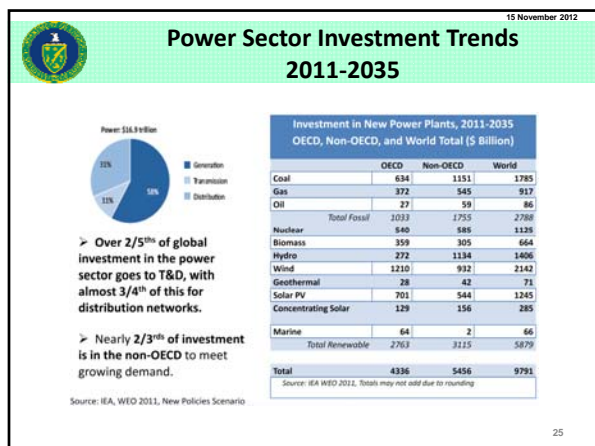
A = Available - in use
 AM = Available - minimum use
 NU = Not Used
 Plan = Planned

**Solar: Includes PV, CSP, and local applications
 ***Ocean: Includes Wave and Tidal

*Sources: Renewable Energy and Energy Efficiency Partnership (REEEP) - REEGLE
 CIA World Factbook, 2012
 Asia Development Bank Key Indicators, 2011
 US-DOE-EIA, International Energy Statistics, 2010
 American Nuclear Society, "Nuclear News," March 2012

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- ## Energy Circumstances Summary Focus Mainly on 8 Emerging Economies
- All, Except Singapore, Have Developed Coal, Oil and Gas Resources
 - All are Importers or Net-Importers of either Coal, Oil or Gas
 - Electricity is Produced Mainly from Coal & Natural Gas and, Where Available, Hydro
 - Nuclear Power Plays a Relatively Minor Role in Selected Countries
 - Almost all forms of Renewable Energy are Available and Used
 - Renewable Energy is Fastest Growing, but from a Relatively Small Base
 - Renewable Energy (Excluding Hydro) 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 (ADB 2009)
 - Investment in Power Sector over the Next 25 Years is Expected to be \$16.9 Trillion USD (IEA-WEO 2011)
 - Two-Thirds will be in Non-OECD Countries
 - Compared to Japan, Lots of Room for Energy Efficiency Improvements
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TECHNOLOGY PATHWAYS FOR THE 21ST CENTURY

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CHARGE TO PARTICIPANTS

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Clean Energy Technology Pathways for the 21st Century

	NEAR-TERM	MID-TERM	LONG-TERM
GOAL #1 Energy End-Use & Infrastructure	<ul style="list-style-type: none"> Hybrid & Plug-in Hybrid Electric Vehicles Engineered Urban Designs High-Performance Integrated Homes High-Efficiency Appliances High-Efficiency Boilers & Combustion Systems High-Temperature Superconductivity Conventional 	<ul style="list-style-type: none"> Fast-Catch Vehicles and Hybrids Low-Emission Aircraft Smart-Grid Lighting Ultra-Efficient Windows "Smart" Buildings Transportation Technologies for Energy-intensive Industries Energy Storage for Load Leveling 	<ul style="list-style-type: none"> Widespread Use of Engineered Urban Designs & Engineered Housing Energy-Managed Communities Integration of Distributed Heat Pumps Advanced, Wide Techniques Superconducting Transmission and Equipment
GOAL #2 Energy Supply	<ul style="list-style-type: none"> 100% Commercialization Stationary Hy Fuel Cells Cost-Competitive Solar PV Decarbonization of Coal-based District Heating Generation Advanced Process Reactor and Fuel Cycle Technology 	<ul style="list-style-type: none"> Fusion Reactor Scale-Up Hy Co-Production from Coal/Biomass Low-Wind-Speed Systems Advanced Bioethanol Community-Scale Solar Small-Scale Nuclear Plants Process Plant Plant Demonstration 	<ul style="list-style-type: none"> Zero-Emission Fossil Energy Hy & Electric Economy Widespread Renewable Energy Decarbonized Energy & Fuel Widespread Nuclear Power Process Plant Plants
GOAL #3 Capture, Storage & Sequestration	<ul style="list-style-type: none"> CCFL & IGCC Post-Combustion Capture Pre-Combustion Capture Enhanced Oil Recovery Storage Reservoir Characterization Safe Construction Mineralization of Direct Injected CO₂ 	<ul style="list-style-type: none"> Design: Storage Process Scale City Transport Infrastructure Safe Storage & Land Use Green City, Biological Impacts Addressed 	<ul style="list-style-type: none"> Track Record of Successful CO₂ Storage Experiments Large-Scale Demonstration Carbon & CO₂ Based Products & Materials Safe Long-Term Ocean Storage
GOAL #4 Other Gases	<ul style="list-style-type: none"> Methane to Markets Precision Agriculture Advanced Refrigeration Technologies PM Control Technologies for Vehicles 	<ul style="list-style-type: none"> Advanced Landfill Gas Utilization Safe Municipal Processes Substitutes for HFC Carbonate Heat Transfer (CCT) for Industrial Storage in Green Engines 	<ul style="list-style-type: none"> Integrated Waste Management System Advanced Air Conditioning, Processing & Recycling Large-Scale Refrigeration Safe Heat Refrigeration/AC Systems
GOAL #5 Measure & Monitor	<ul style="list-style-type: none"> Low-Cost Sensors and Communications 	<ul style="list-style-type: none"> Large-Scale, Secure Data Storage Systems Advanced Monitoring to Reduce Process and Emissions 	<ul style="list-style-type: none"> Fully Operational Integrated M2M Systems Advanced, Secure, Reliable, Interoperable Data (Cloud/Storage, Mobile)

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- 15 November 2012
- ## Charge - - Illuminate These Topics
- What are the drivers underlying future energy demand in this region?
 - What are the similarities and the distinctions between energy systems of the developed and emerging countries?
 - What, if any, are key barriers inhibiting accelerated development and deployment of clean energy technologies?
 - What insights are on R&D investment priorities of emerging economies, individually, collectively?
 - What are the preferred modalities for enhanced international S&T cooperation?
 - What implications are there for future IEA and non-member country R&D portfolio planning, cooperation and collaboration?
 - What are the most important actions that IEA and its Member Countries could make in enhancing R&D collaboration with emerging economies?
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BACK-UP



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Pathways for Energy End-Use & Infrastructure


	NEAR-TERM	MID-TERM	LONG-TERM
Transportation	<ul style="list-style-type: none"> Hybrid & Plug-in Hybrid Electric Vehicles Class Diesel Vehicles Alternative and Fuel Flexible Vehicles Increased Batteries, Energy Storage Power Electronics Engineered Urban Designs Reduction in Vehicle Miles Traveled Improved Air Space Operations 	<ul style="list-style-type: none"> Fuel Cell Vehicles and H₂ Fuels Efficient, Clean Heavy Trucks Self-driving Vehicles Advanced Transport Systems Integrated Regional Planning Low-Emission Aircraft Intelligent Transport Systems 	<ul style="list-style-type: none"> Zero-Emission Vehicle Systems Optimized Multimodal Mobility & Freight Transport Whole-of-life of Engineered Urban Design & Regional Planning Very Low Aviation Emissions (all GHGs)
Buildings	<ul style="list-style-type: none"> High Performance, Integrated Homes Energy Efficient Building Materials High-Efficiency Appliances Solar Control Windows 	<ul style="list-style-type: none"> "Smart" Buildings Solar Skin Lighting Ultra-Efficient HVACs Intelligent Building Systems Smart, Net-Neutral Buildings 	<ul style="list-style-type: none"> Energy Managed Communities Low-Power Sensors with Wireless Communications
Industry	<ul style="list-style-type: none"> Improved Processes in Energy-Intensive Industries High-Efficiency Boilers and Combustion Systems Greater Waste Heat Utilization Improved Recyclability and Greater Use of Biomaterials Bi-Based Feedstocks 	<ul style="list-style-type: none"> Transformational Technologies for Energy-Intensive Industries GHGs Managed Industries Superconducting Electric Motors Advanced Thermoelectric Systems Advanced Separation Technologies Low-Emission Cement Alternatives Water and Energy System Optimization 	<ul style="list-style-type: none"> Integration of Industrial Heat, Power, Process and Technology High-Efficiency Air-Backed Manufacturing Development of Bio-Feedstocks Chemical Products & Materials
Electric Grid & Infrastructure	<ul style="list-style-type: none"> Distributed Generation Smart Metering & Controls for Peak Shaving Long Distance DC Transmission High Temperature Superconductivity Demonstrations Power Electronics Composite Conductor Cables 	<ul style="list-style-type: none"> Energy Storage for Load Leveling Smart Grid Systems Advanced Cables and Power Electronics 	<ul style="list-style-type: none"> Superconducting Transmission and Equipment Distributed Power Electronics Wireless Transmission



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Pathways for Clean Energy Supply


	NEAR-TERM	MID-TERM	LONG-TERM
Fossil Power	<ul style="list-style-type: none"> CCAC Commercialization Advanced Gasification Solid Oxide Fuel Cells More Efficient, Lower Cost, Cleaner Coal Plants 	<ul style="list-style-type: none"> Pre-Combustion Technology for Cleaner Coal-Based Electricity Generation Zero-Emission Gas Plants (Pre-combustion) H₂ Co-Production from Coal/Water 	<ul style="list-style-type: none"> Zero-Emission Fossil Energy
Hydrogen	<ul style="list-style-type: none"> Integrated Hydrogen Fuel Cell Systems Costs & Standards Demonstrations of Renewable Hydrogen Production 	<ul style="list-style-type: none"> Low-Cost H₂ Storage & Delivery H₂ Production from Renewables H₂ Production from Biomass Renewable H₂-Powered Fuel Cell Vehicles 	<ul style="list-style-type: none"> H₂ & Electric Economy
Renewables	<ul style="list-style-type: none"> Lower Cost Wind Power Bio-based, Dense of Cellulosic Ethanol Photovoltaics on Buildings Cost-Competitive Solar PV 1st Generation Biofuels Distributed Generation Systems 	<ul style="list-style-type: none"> Low-Wind Speed Turbines Advanced Bioethanols Catalytic Systems Community Scale Solar PERCUTANEOUS SPLITTING Energy Storage Options 	<ul style="list-style-type: none"> Wide-spread Renewable Energy Bi-Engineered Biomass Bi-Engineered Energy & Path
Nuclear Fission	<ul style="list-style-type: none"> Advanced Fission Reactor and Fuel Cycle Technology New Fuel Forms and Materials 	<ul style="list-style-type: none"> Gen IV Nuclear Plants Closed Proliferation-Resistant Fuel Cycles Minimization of Waste Requiring Geological Disposal 	<ul style="list-style-type: none"> Wide-spread Nuclear Power Advanced Concepts for Waste Reduction
Fusion Power	<ul style="list-style-type: none"> Greater Understanding of Plasma Demonstrations of Burning Plasma (ITER) Identification of Technology Options International Effort in High-Temperature Plasma Research 	<ul style="list-style-type: none"> Fusion Pilot Plant Demonstration 	<ul style="list-style-type: none"> Fusion Power Plants



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Pathways for CCUS


	NEAR-TERM	MID-TERM	LONG-TERM
Carbon Capture	<ul style="list-style-type: none"> CCF and CDF Pre-Combustion Capture Pre-Combustion Technologies Post-Combustion Oxygen Separation Technologies 	<ul style="list-style-type: none"> Capability to Capture Most CO₂ Emissions Renal Capture Technologies Low-Cost Storage Biomass Coupled with CCS 	<ul style="list-style-type: none"> Global to Scale CO₂ Conversion Capture CO₂ Directly from Atmosphere
Geologic	<ul style="list-style-type: none"> Reservoir Characterization Safety, Health, and Environmental Risk Assessment Understand Underground CO₂ Reservoirs & Monitor Processes Enhanced Oil Field Methods Large Scale Demonstration CO₂ Transport Network Design 	<ul style="list-style-type: none"> Resilient Storage Power Safe Well Sealing Technology Demonstrated Mineralization Solid Carbonates Reliable and Accurate Inventory Monitoring Well-Customized CO₂ Transport Infrastructure 	<ul style="list-style-type: none"> Sufficient CO₂ Storage Capacity Peak Demand of Renewable CO₂ Storage Expansion
Terrestrial	<ul style="list-style-type: none"> Reforestation Soil Conservation Vegetation in Urban Settings 	<ul style="list-style-type: none"> Scale Upstream & Land Use Integration among CO₂, CH₄ & N₂ Supermarket Decision Support Tools MAAM Tools to Validate Terrestrial Sequestration Bio-based & Recycled Products 	<ul style="list-style-type: none"> Biological Sequestration Large-Scale Sequestration Advanced Bioeconomy Carbon & CO₂ Based Products & Materials
Ocean	<ul style="list-style-type: none"> Effective Dilution of Direct Injected CO₂ 	<ul style="list-style-type: none"> Demon CO₂ Biological Impacts Addressed Carbonate Dissolution / Alkalinity Addition 	<ul style="list-style-type: none"> Scale Long-Term Ocean Storage



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Pathways for Reducing Non-CO₂ Greenhouse Gases

	NEAR-TERM	MID-TERM	LONG-TERM
Methane from Energy & Waste	<ul style="list-style-type: none"> Biomass / Landfill Technology Enhance Networks New Drilling Techniques for Recovery of Coal Seam Methane Leak Detection, Measurement, and Mitigation Technologies for Oil & Natural Gas Systems 	<ul style="list-style-type: none"> Advanced Landfill Gas Capture (e.g., Fuel Cells, Microturbines, Combustion, and Collection Technologies) Advanced Gas Mining for Domestic Resource Expansion Advanced and Low-Temperature CO₂ Methane at Remote Well Sites 	<ul style="list-style-type: none"> Integrated Waste Management System with Automated Surface Processes & Bioreactors Automated Gas Mining for Domestic Resource Expansion Smart Pipelines and Self-Regulating Pipelines
Methane & N ₂ O from Agriculture	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency and Reduced Loss Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency
High GWP Gases	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency
N ₂ O from Combustion	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency
Ozone Precursors & Black Carbon	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency 	<ul style="list-style-type: none"> Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency Enhanced Nitrogen Use Efficiency



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Pathways for Measuring GHG Emissions

	NEAR-TERM	MID-TERM	LONG-TERM
Energy Production & Efficiency Technologies	<ul style="list-style-type: none"> MAAM Specifications and Performance Standards Low-Cost Sensors and Communications Sampling, Interlocks, & Estimates 	<ul style="list-style-type: none"> Sensor Networks Remote Sensing Prototype Direct Measurement in Real-time Process and Estimates 	<ul style="list-style-type: none"> Fully Operational Sensor and Satellite Networks that Feed the Integrated Architecture
Carbon Capture, Storage, & Sequestration	<ul style="list-style-type: none"> MAAM Specifications and Performance Standards Low-Cost Sensors and Communications Sampling, Interlocks, & Estimates Ability to Assess the Integrity of Geological Reservoirs Improved Leak Detection from Optical and Pipelines 	<ul style="list-style-type: none"> Sensor Networks Remote Sensing Prototype MAAM Techniques for Agricultural Reservoir 	<ul style="list-style-type: none"> Fully Operational Sensor and Satellite Networks that Feed the Integrated Architecture
Other GHGs	<ul style="list-style-type: none"> MAAM Specifications and Performance Standards Low-Cost Sensors and Communications Sampling, Interlocks, & Estimates 	<ul style="list-style-type: none"> Sensor Networks Remote Sensing Prototype MAAM Techniques for Agricultural Reservoir 	<ul style="list-style-type: none"> Fully Operational Sensor and Satellite Networks that Feed the Integrated Architecture
Integrated MAAM Systems Architecture	<ul style="list-style-type: none"> Identification of Metrics, Criteria, Sources, and Requirements for Measurements Comprehensive Design of Integrated Systems Architecture and Technology Needs 	<ul style="list-style-type: none"> Model and Data Specification Large Scale, Secure Data Storage System Data Visualization Tools MAAM Processes Incorporated into Design of Climate Change Technologies 	<ul style="list-style-type: none"> Fully Operational Integrated MAAM Systems Architecture (Sensors, Networks, Data, Visualization and Storage, Models)