

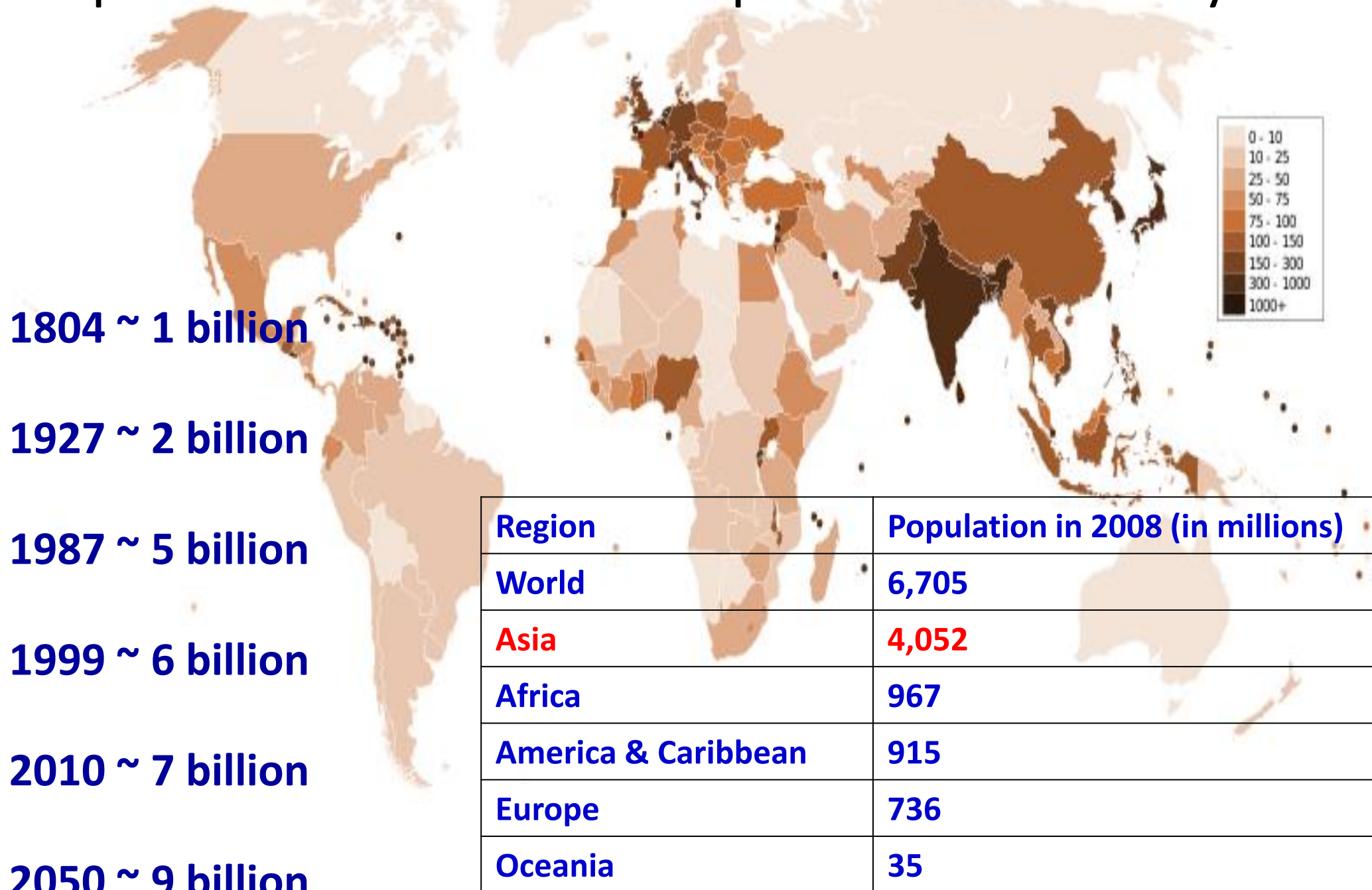
Singapore's Perspectives on Energy and Future Cities



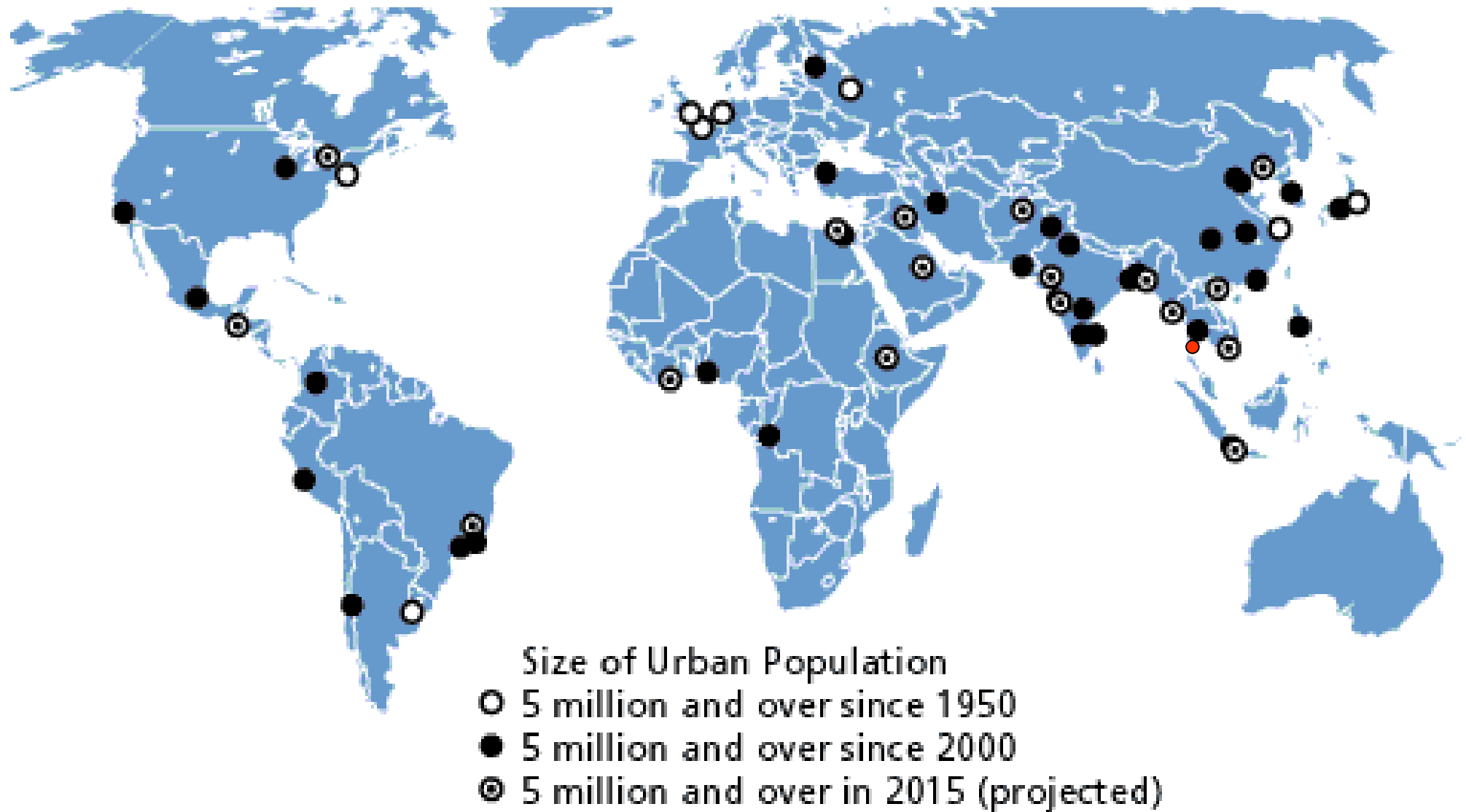
Professor Seeram Ramakrishna, FREng
Vice-President (Research Strategy)
National University of Singapore

Zero-Carbon Energy Kyoto 2010, 19-20 August

Rapid Growth of Human Population in recent years



Half the global population now lives in urban areas
25 cities with over 10 million population;
300 cities with over a million population



Urban Challenges

- BY 2030, 90% of the world's population growth will occur in cities

Demographic change

Increasing mobility

- Traffic will increase significantly

Health care

- Elder care & Increase urban air pollution, Infectious diseases

Urbanization

- 2007, 50% of the world population living in cities

Increasing scarcity of natural resources

- Cities account for 60% of world's water use . Food supply is an additional challenge

Demand for safety and security

- Malfunctions pose high risks to urban economies.

- Cities account for 80% of the world's greenhouse gases, while covering only 0.4% of earth's surface

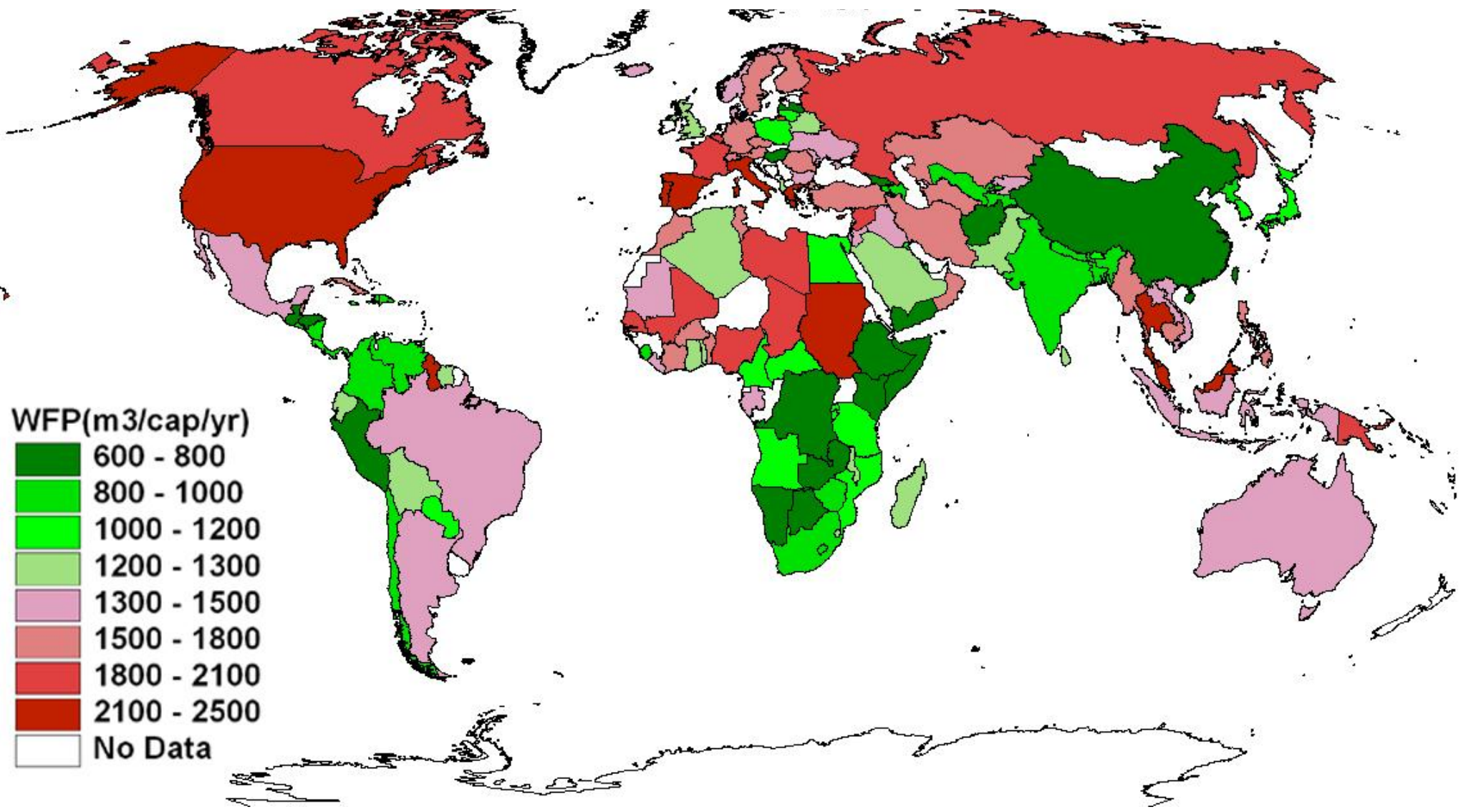
Need for environmental care



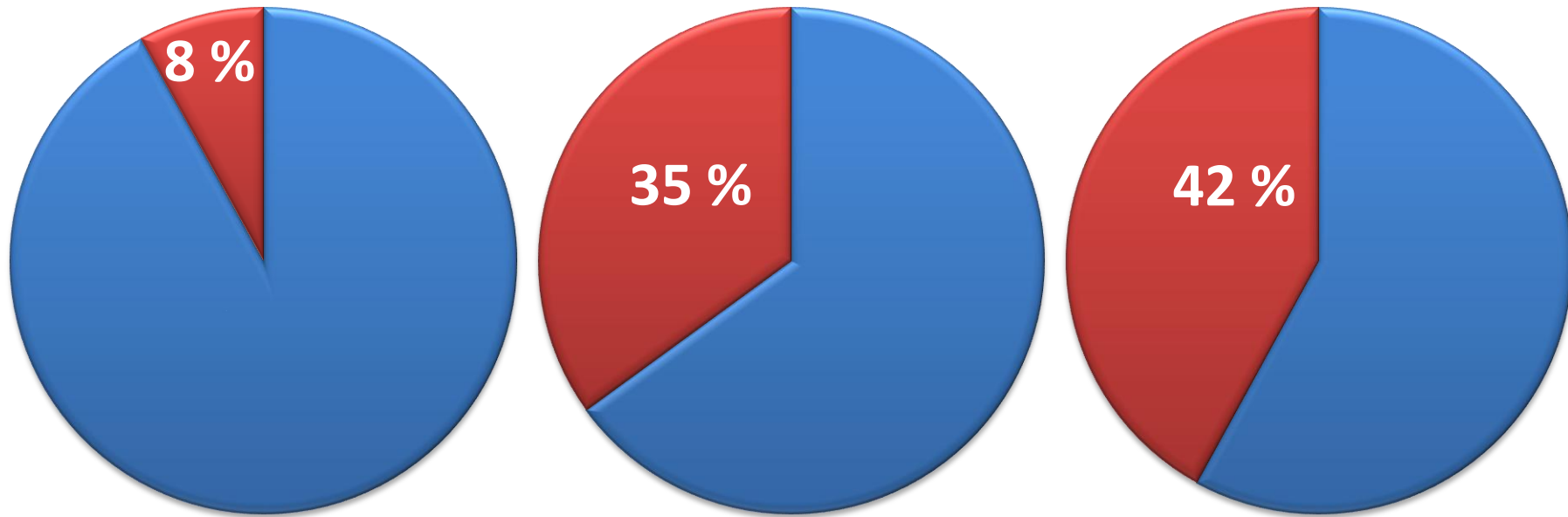
Image © 2005 Sanborn
© 2005 Sanborn

Google

Water Consumption:
Global Average ~ 1240 cubic meters per year per person
USA ~ 2500; China ~700



Water Shortages



Year	1995	2025	2050
Population affected by Water Shortages	0.46 Billions	2.8 Billions	4 Billions
% of World	8%	35%	42%

Food consumption (global average): kcal per day per person

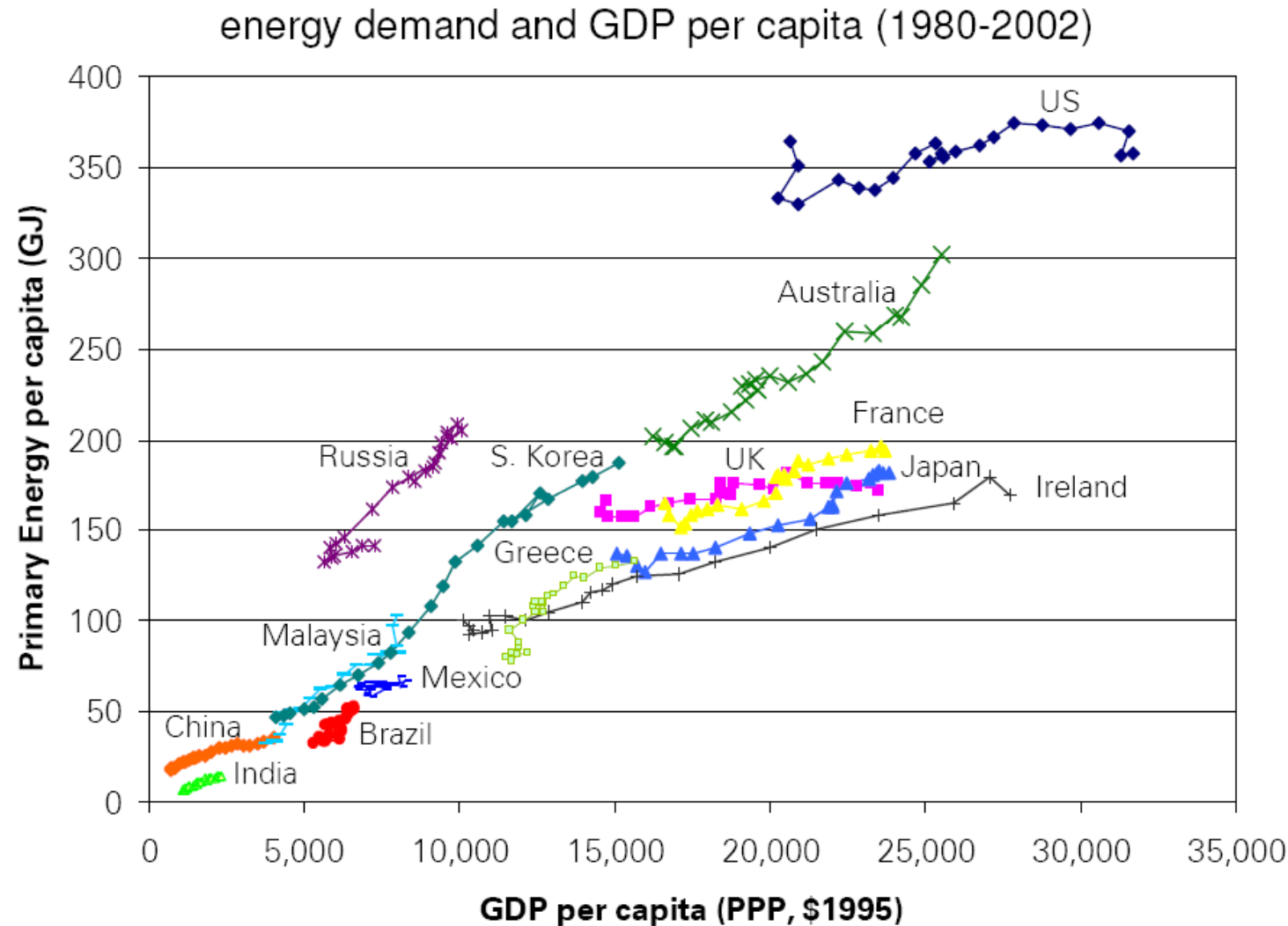
Year 1965: ~ 2300

Year 2000: ~ 2800

Year 2030: ~ 3000

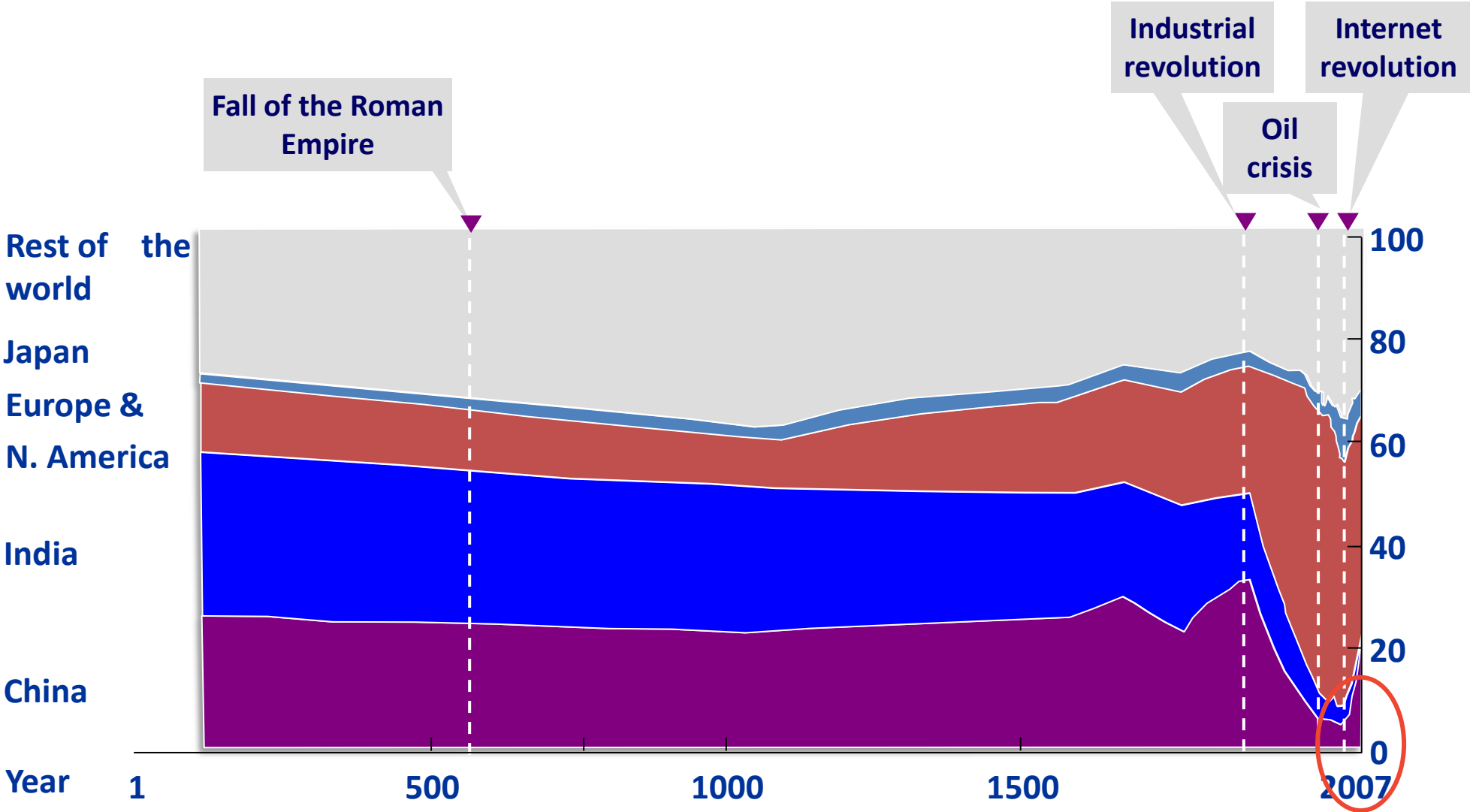
Electricity Consumption, kilowatt-hours per person

World Average:
~2600 (year 2005)
~2000 (year 1990)
USA: ~13,600
Japan/Korea/
Singapore: ~8300
Mexico ~2000
China ~2000
India ~500



Source: UN and DOE EIA

Changing Composition of World GDP



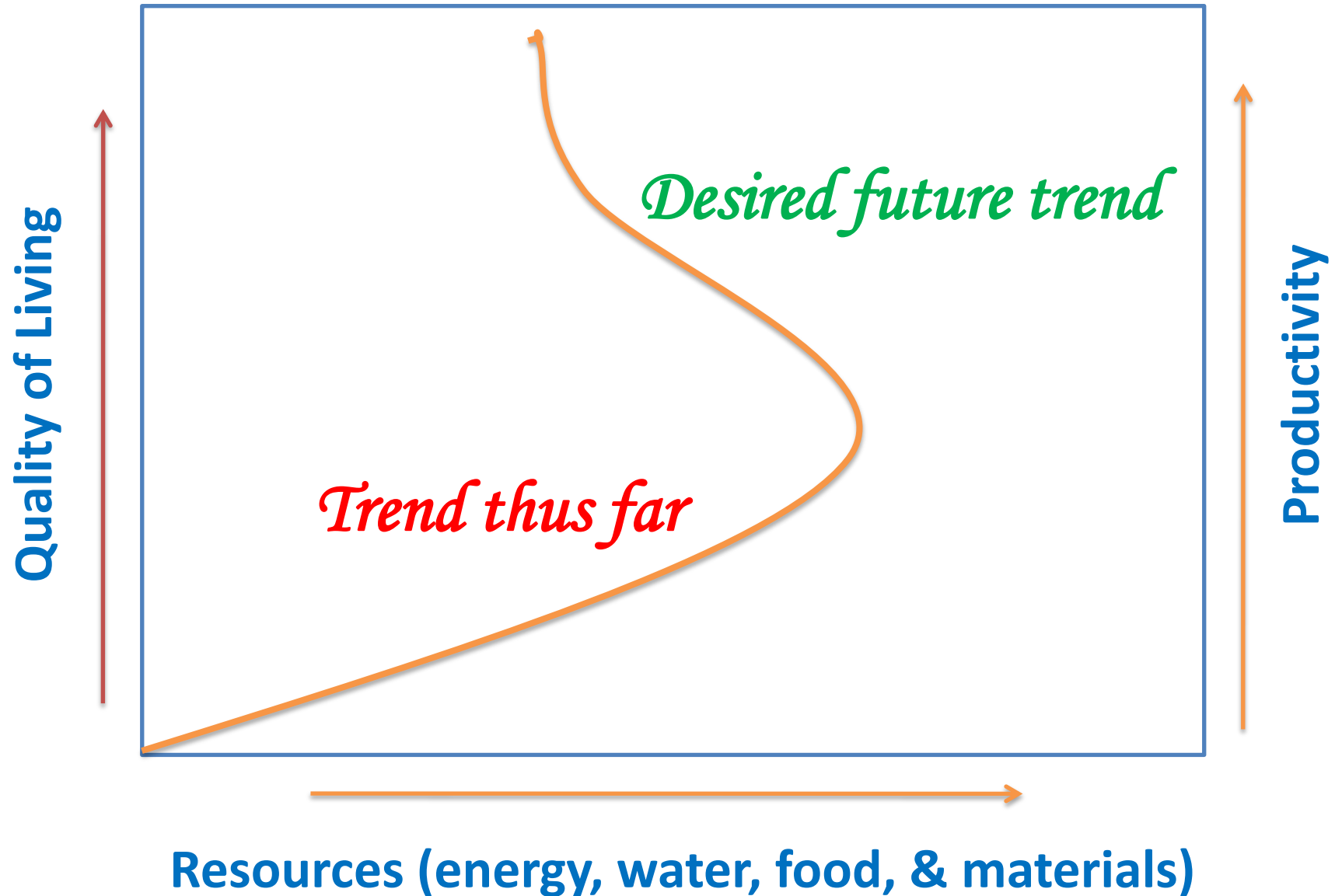
Source: Angus Madison's 'Historical Statistics for the World Economy: 1-2004 AD', Deutsche Bank Global Market Research. Courtesy Pedro Rodeia, McKinsey

GLOBAL INNOVATION LANDSCAPE (Year 2010)



Source : *The Changing Face of Innovation : Shifting to Asia?* by Seeram Ramakrishna and Daniel Ng

Expectations on Researchers



More such information can be found in this book



Introduction



ASEAN

- ASEAN Energy Resources



Singapore

- Singapore – Unique Situation
- Challenges and Drivers for Change
- National Strategy and Policy



NUS

- Collaborations
- New Opportunities
- Contributions

Summary

Regional and International
Collaboration is the key success factor



ASEAN

- ASEAN Energy Resources



Singapore

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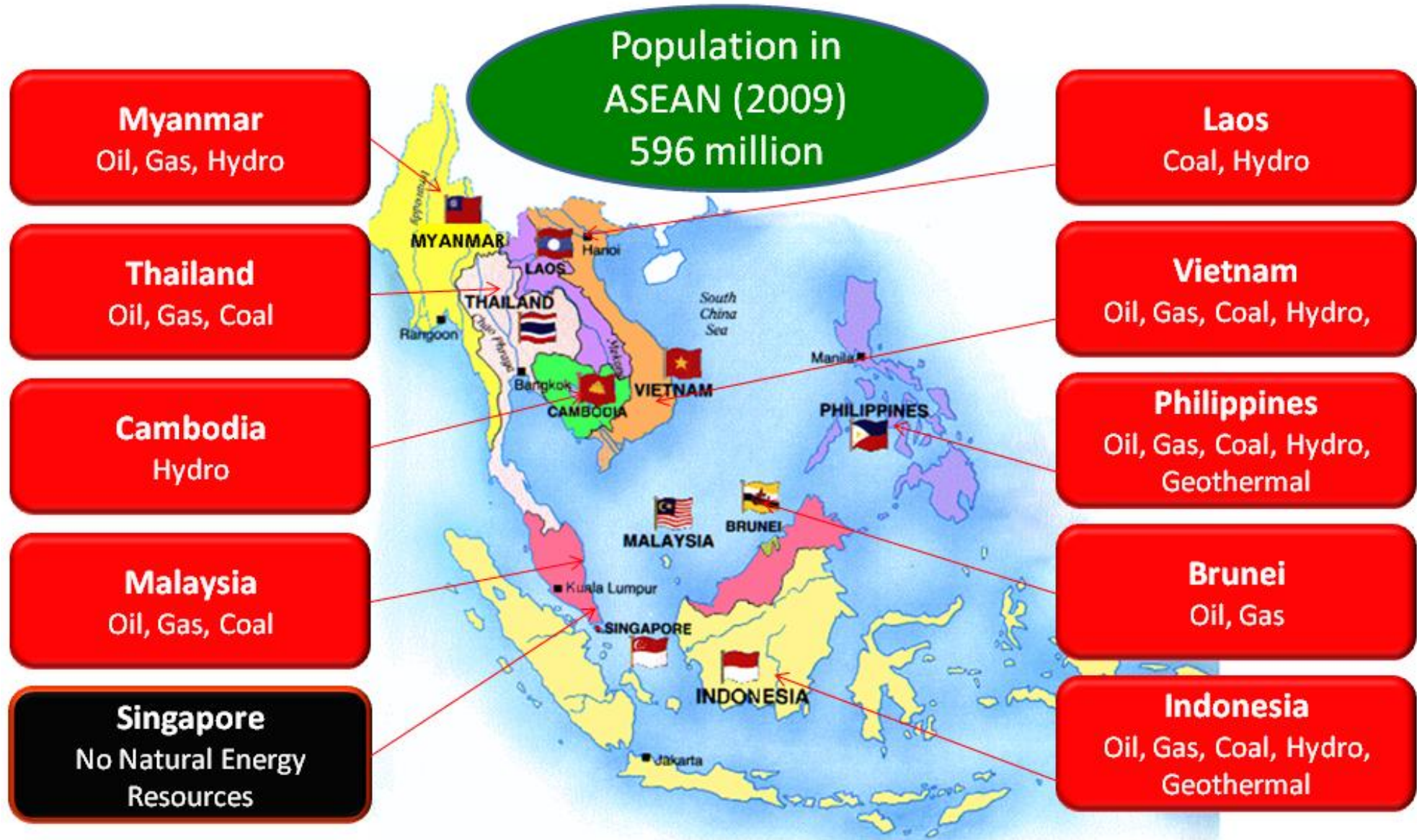


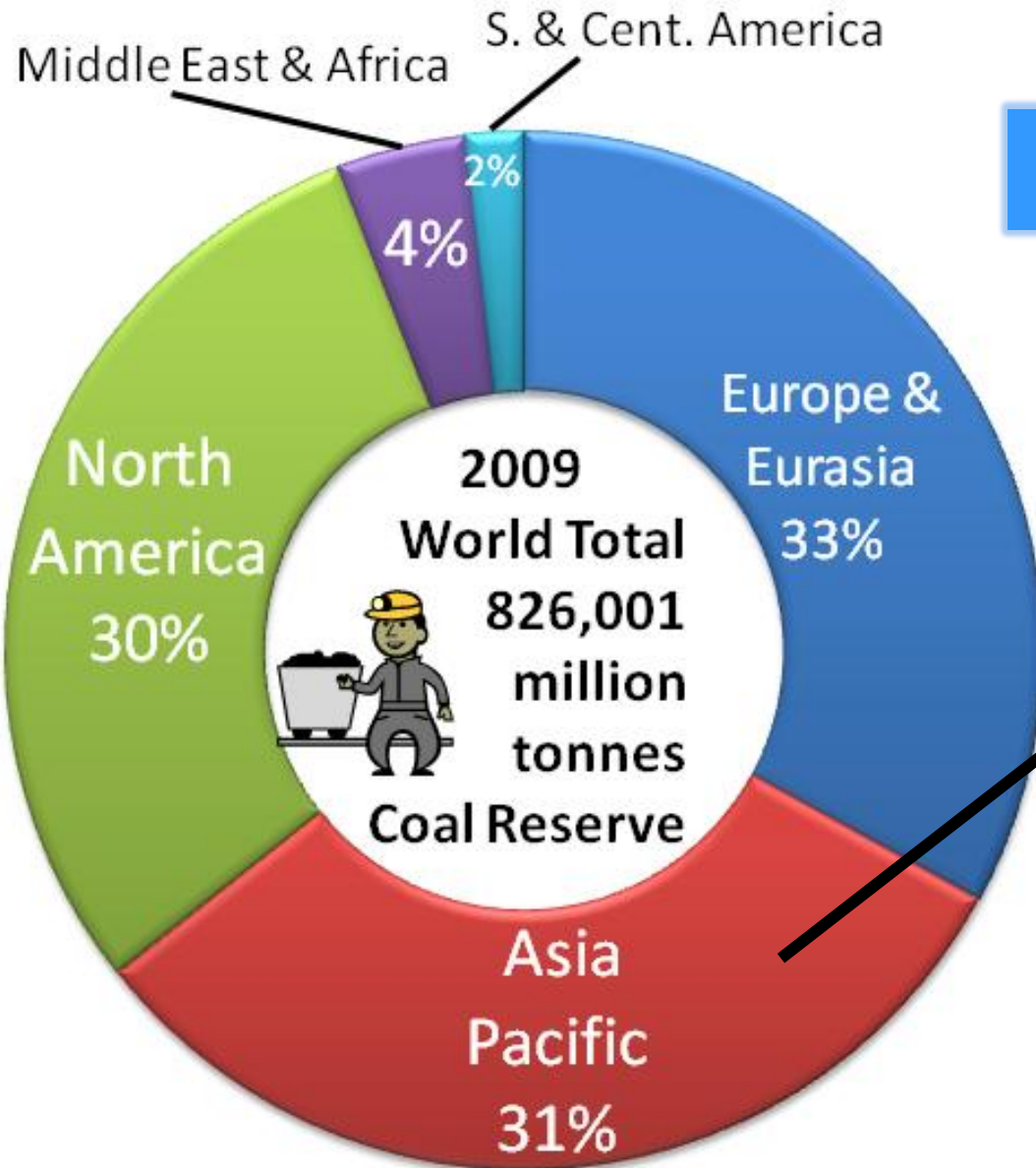
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Collaboration is the key success factor

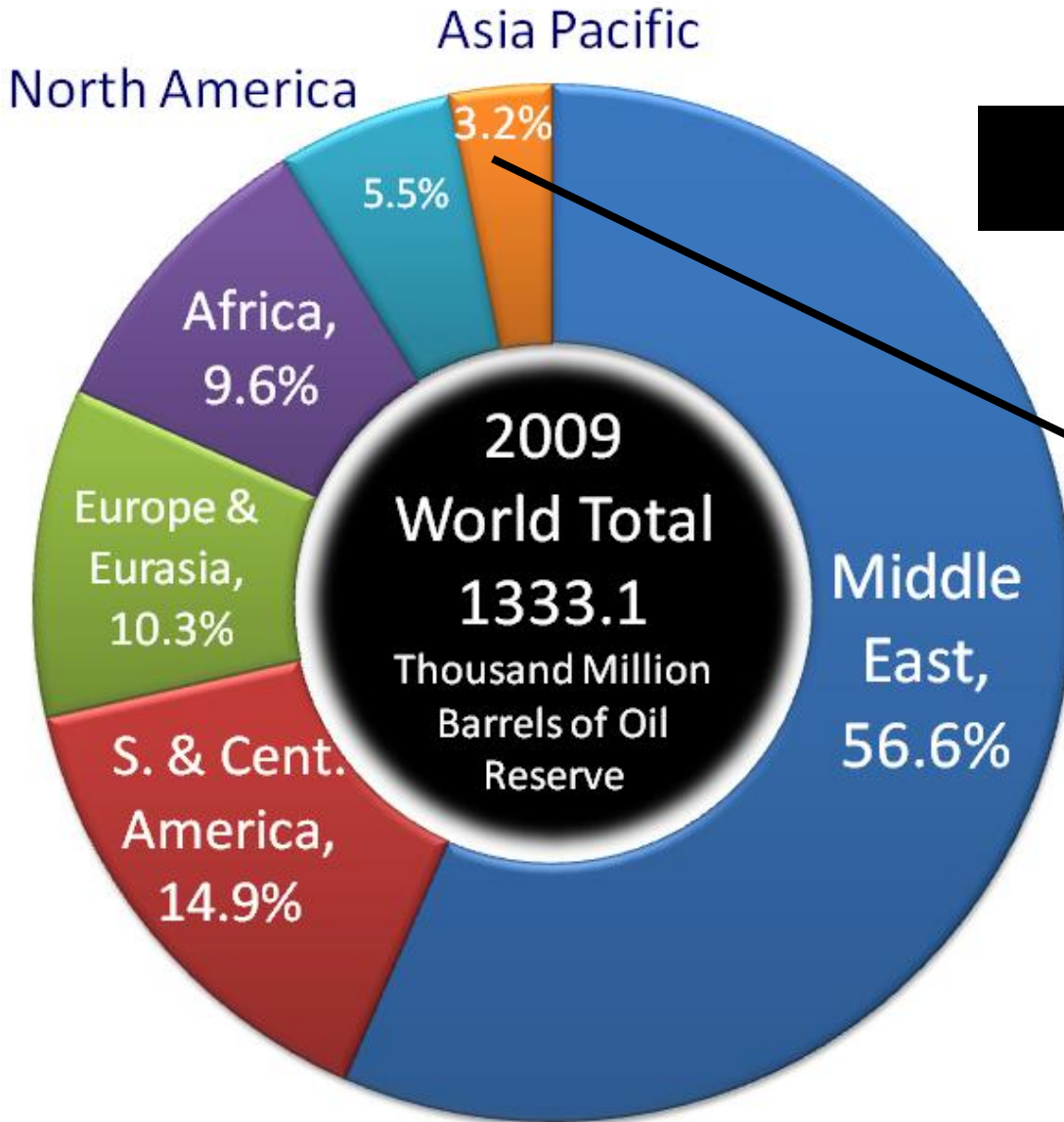




Proved Coal Reserve - 2009

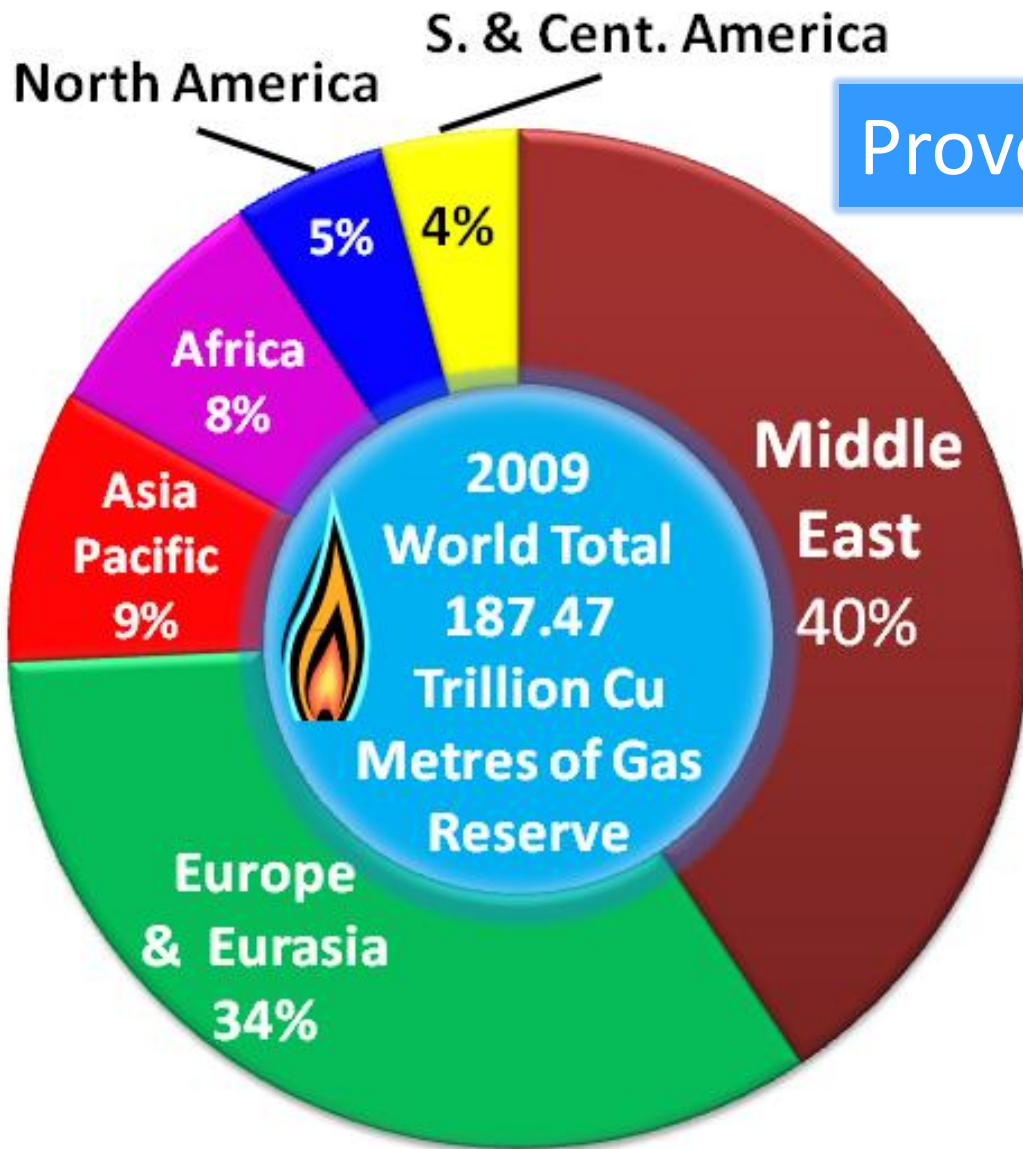
% of World Share of Coal Reserve

Asia Pacific	31%	259,253 Million Tonnes
ASEAN	.71%	5,832 Million Tonnes



Proved Oil Reserve - 2009

% of World Share of Oil Reserve	
Asia Pacific	3.2%
	42.2 Thousand Million Barrels
ASEAN	1%
	15 Thousand Million Barrels



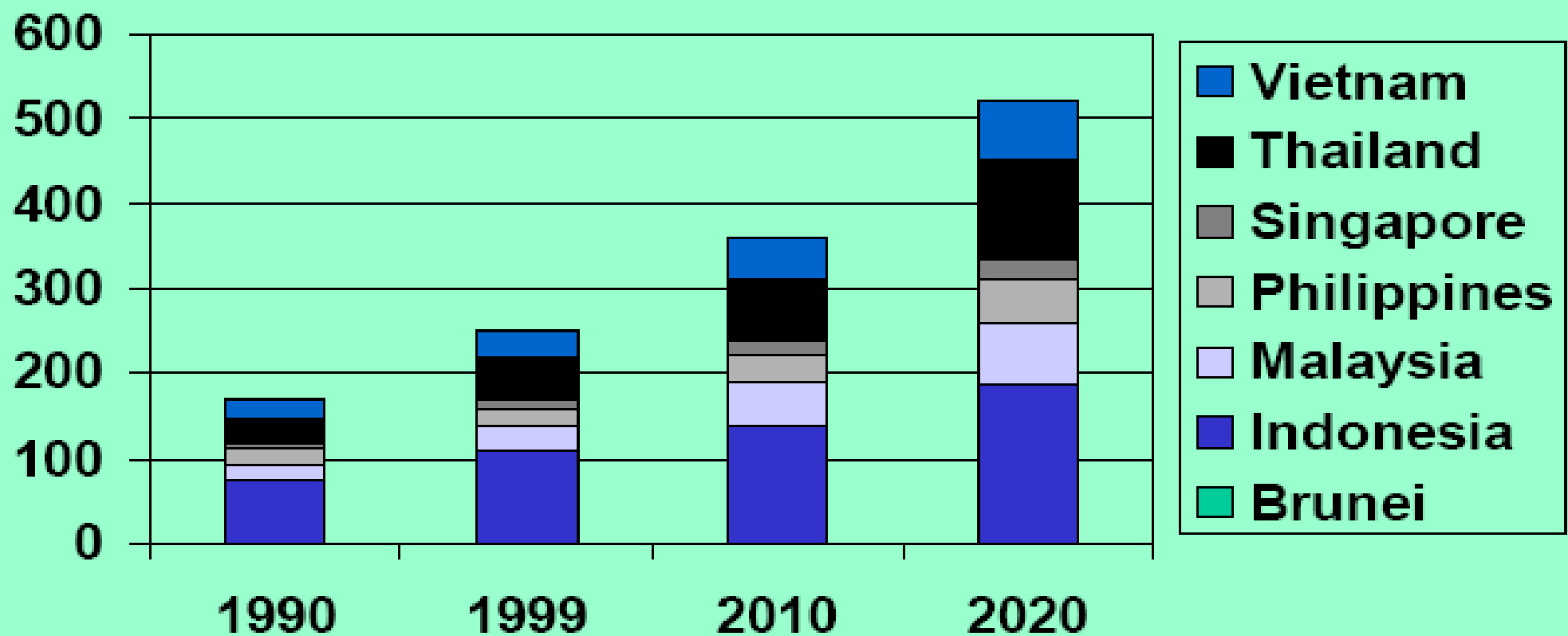
Proved Natural Gas Reserve - 2009

% of World Share of Natural Gas Reserve

Asia Pacific	9%	16.24 Trillion Cu Metres
ASEAN	4%	7.52 Trillion Cu Metres

Energy Demand in ASEAN Countries

ASEAN Energy Demand
(million tonnes of oil equivalent)



Source: Asia Pacific Energy Research Centre, Tokyo

ASEAN

% share of world coal Reserve - 2009

0.7%

% share of world Oil Reserve - 2009

1%

% share world Nat Gas Reserve - 2009

4%

ASEAN will be net importer of energy



ASEAN

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Singapore

Unique Situation



Land Area	707 sq km or 273 sq mi
Population	4.99 million
Ranked	2 nd Most Innovative Countries – by BCG
GDP (2009)	S\$265.1 Bi (USD 182.7 Bi)
Per capita GDP	USD 36,631 (2009)
2008 Fuel Cost for Electricity	S\$8.2 Billion

Singapore

Unique Situation – Energy Hub



Oil Trading Hub

- Largest in Asia
- Third largest in the World
- USD 375 bi Oil Contract Annually

Oil Refining Centre

- Third biggest Oil Refining Centre
- 1.385 bi barrels per day

Marine Bunkering Centre

- World busiest Bunkering Centre
- 31.5 mi tonnes

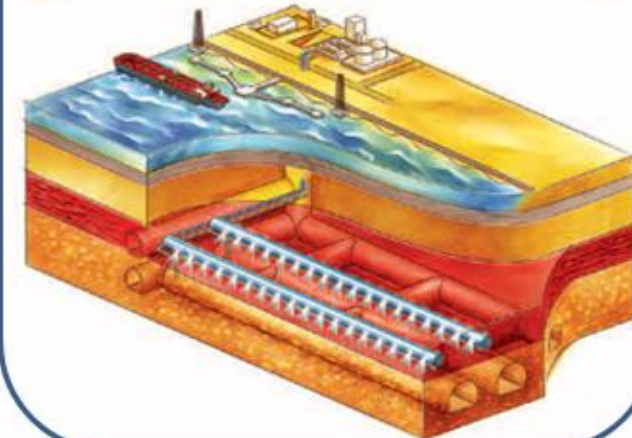
S\$1.5 bi
LNG Terminal
(2013)
at Jurong Island
(30 hectares)



initial capacity
of 3.5 million
tonnes per
annum



Jurong Rock Cavern
Underground/undersea
facility to store
1.47 mi cubic metres of
crude oil & condensate
(2014)



Singapore

Challenges and Drivers for Change



Our Challenges

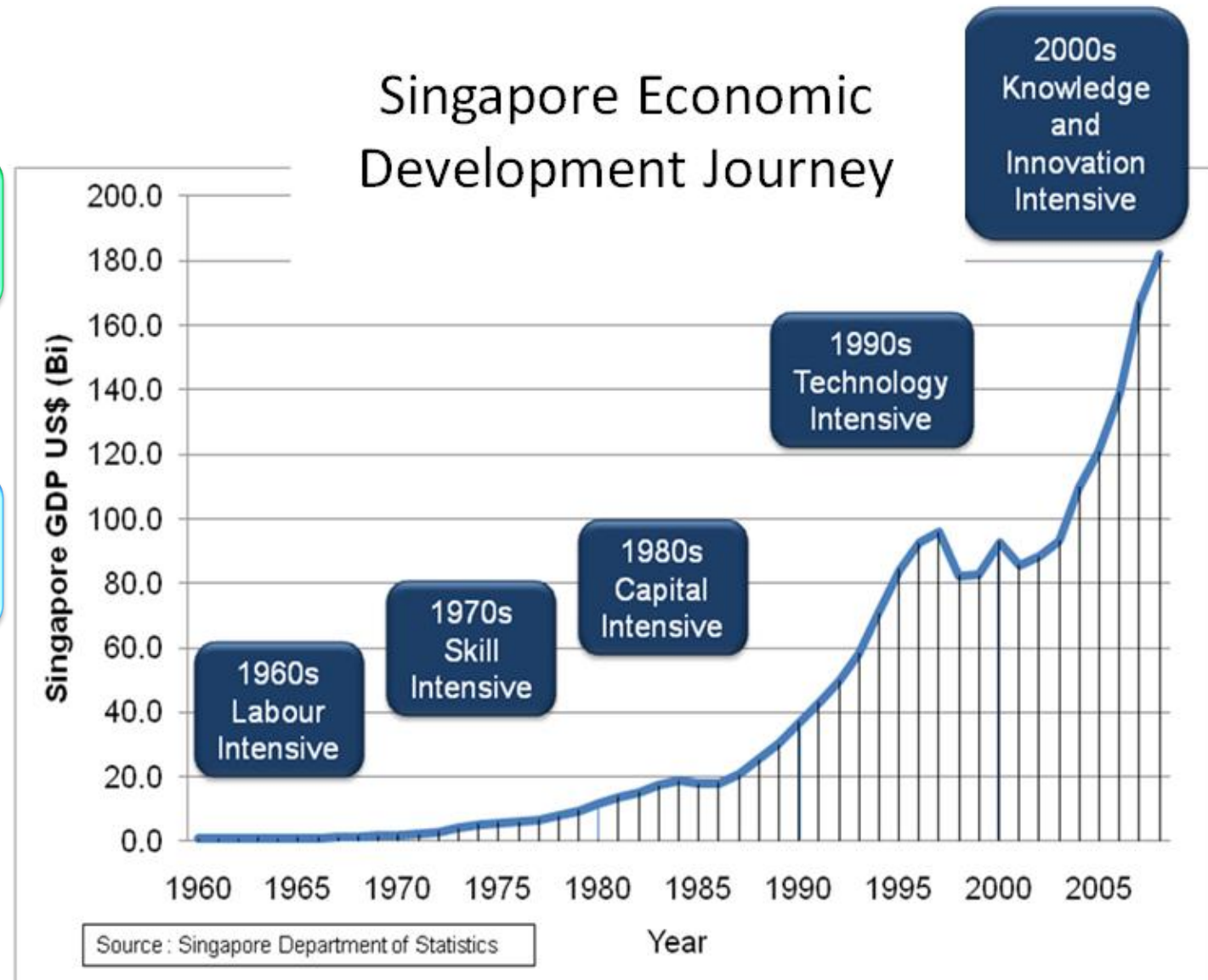
Sustainability

- Economic Growth

Safeguarding

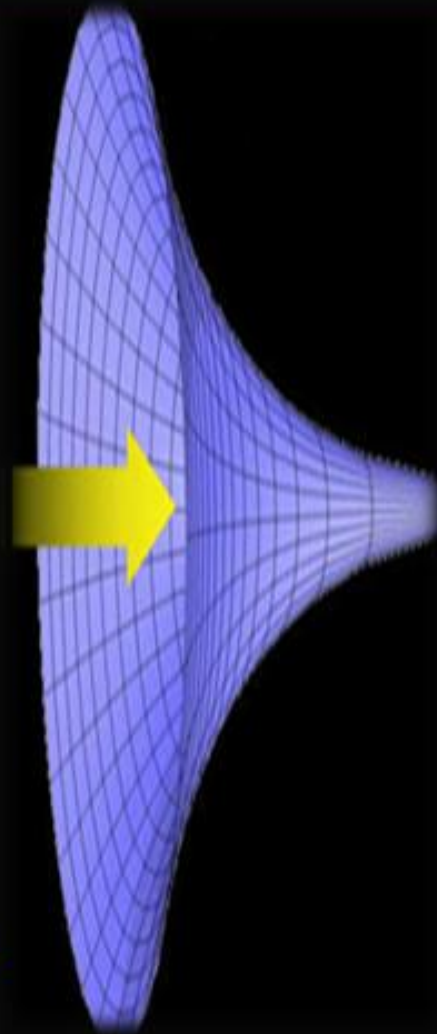
- Energy Security
- Natural Environment

Singapore Economic Development Journey



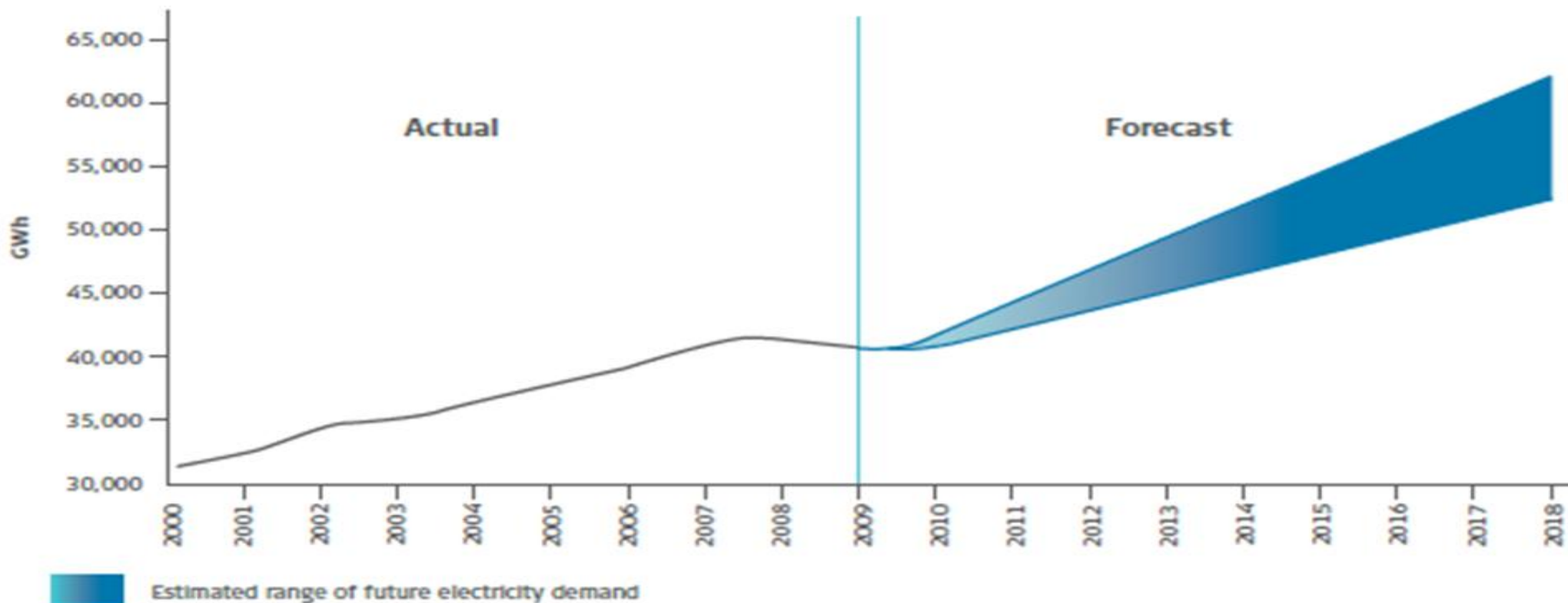
Drivers for Change

- Limited Land
- No Natural Energy Resources such as:
 - Coal
 - Oil
 - Gas
 - Hydro
 - Wind
 - Tidal
 - Geothermal
 - Biomass Power



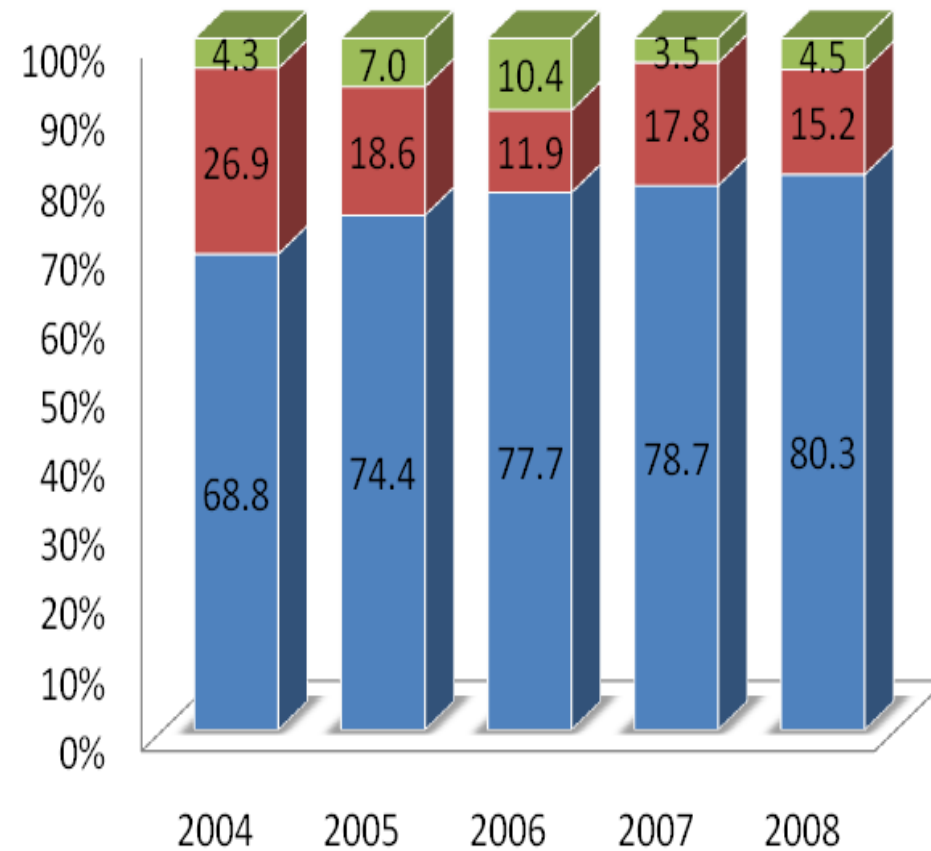
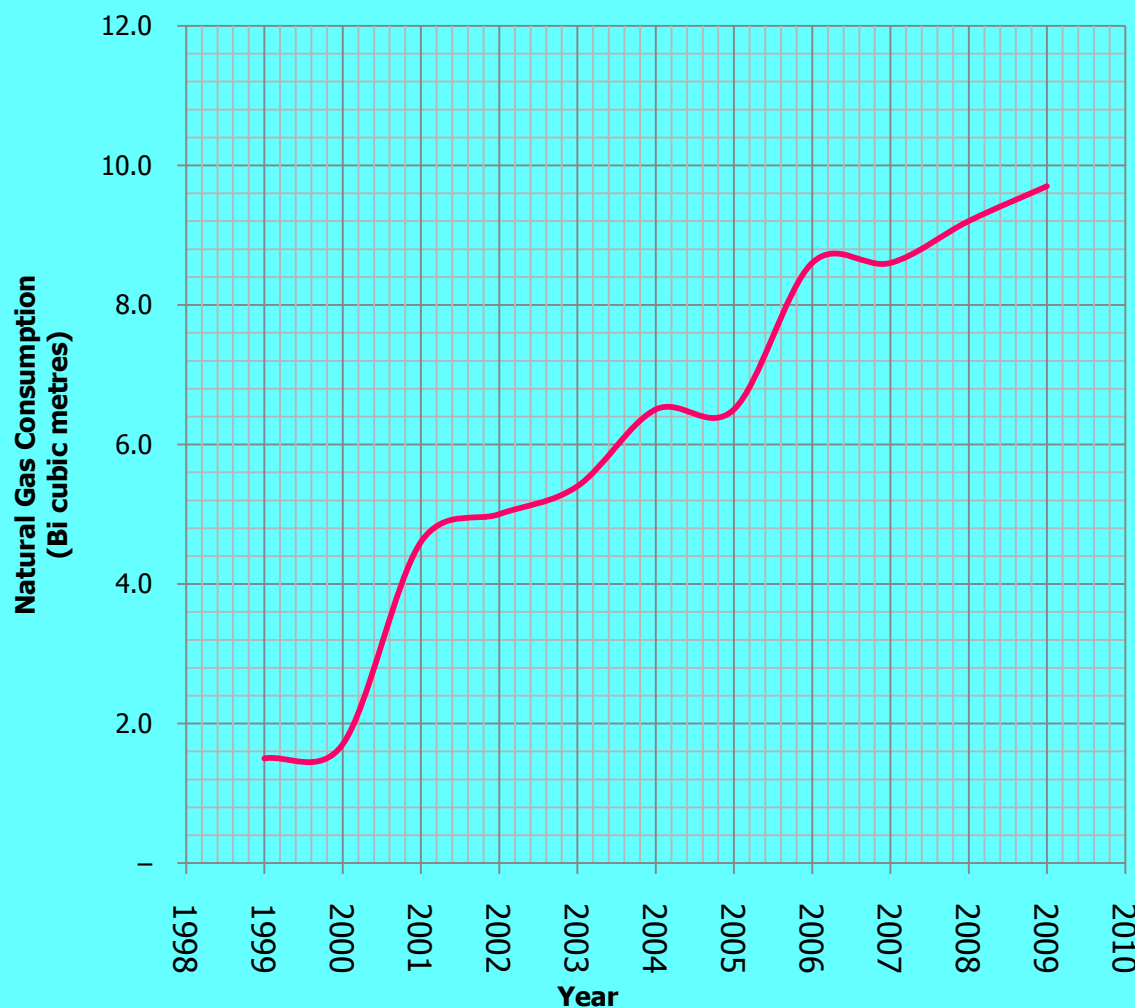
- Energy Security Options:
 - Natural Gas
 - Waste to Energy
 - Solar
 - Biofuels
 - Nuclear
- Enhance Energy Efficiencies
- Increase Electrification for Urban Mobility
- Use more climate-neutral energy sources for built environment

Forecasted Demand based upon GDP and Population projections



Expected Rate of Annual Increase
2.5% to 3.0% for period from 2009 to 2018

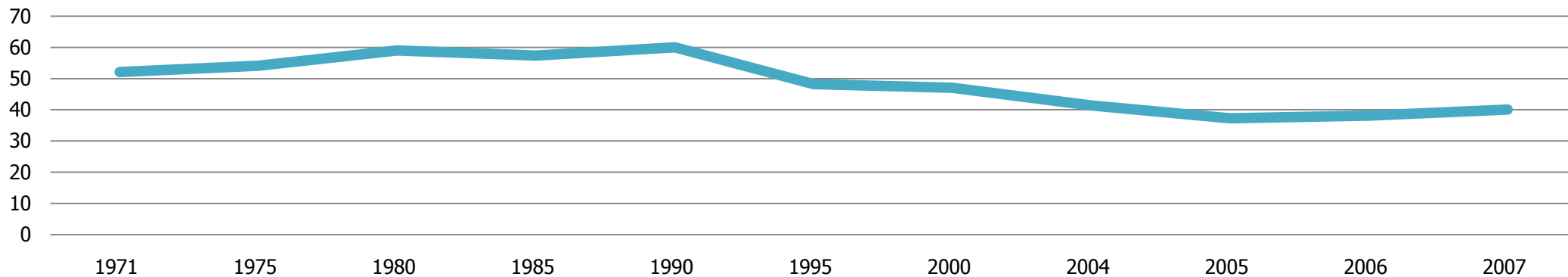
Diversifying Fuel Sources for Electricity Generation



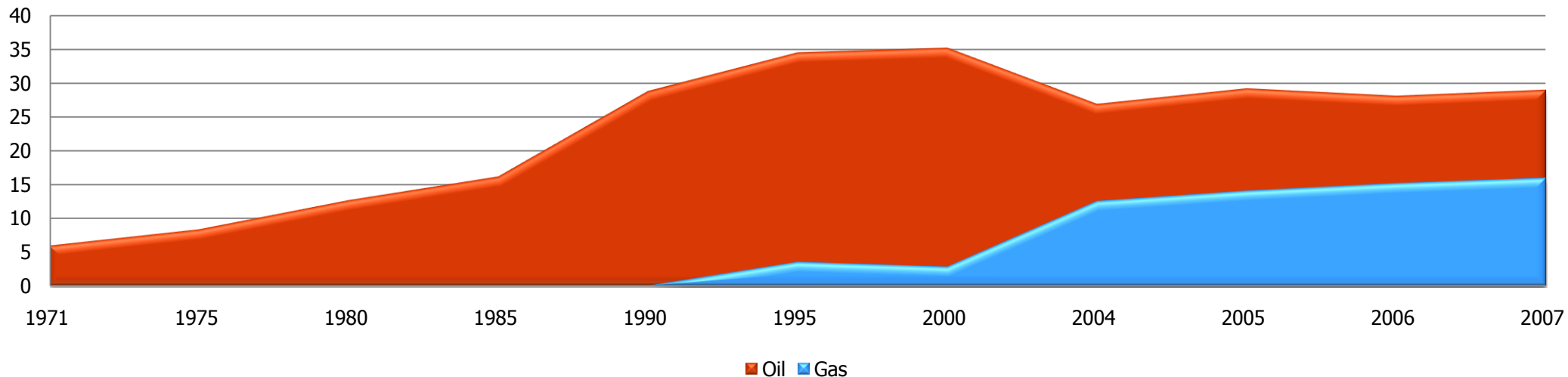
■ Natural Gas ■ Fuel Oil ■ Others
**Fuel Mix for Electricity
Generation**

Natural Gas emits 40% less CO₂ than Fuel Oil per unit of electricity generated

CO₂ emissions/ TPES (tonnes per terajoules)



CO₂ Emissions by Fuel (million tonnes of CO₂)



Singapore

Whole-of-Government Approach



Energy Policy Group
Role of Coordinator



Economic Competitiveness

MINISTRY OF FOREIGN AFFAIRS
SINGAPORE

Energy Security



Climate Change & Environment

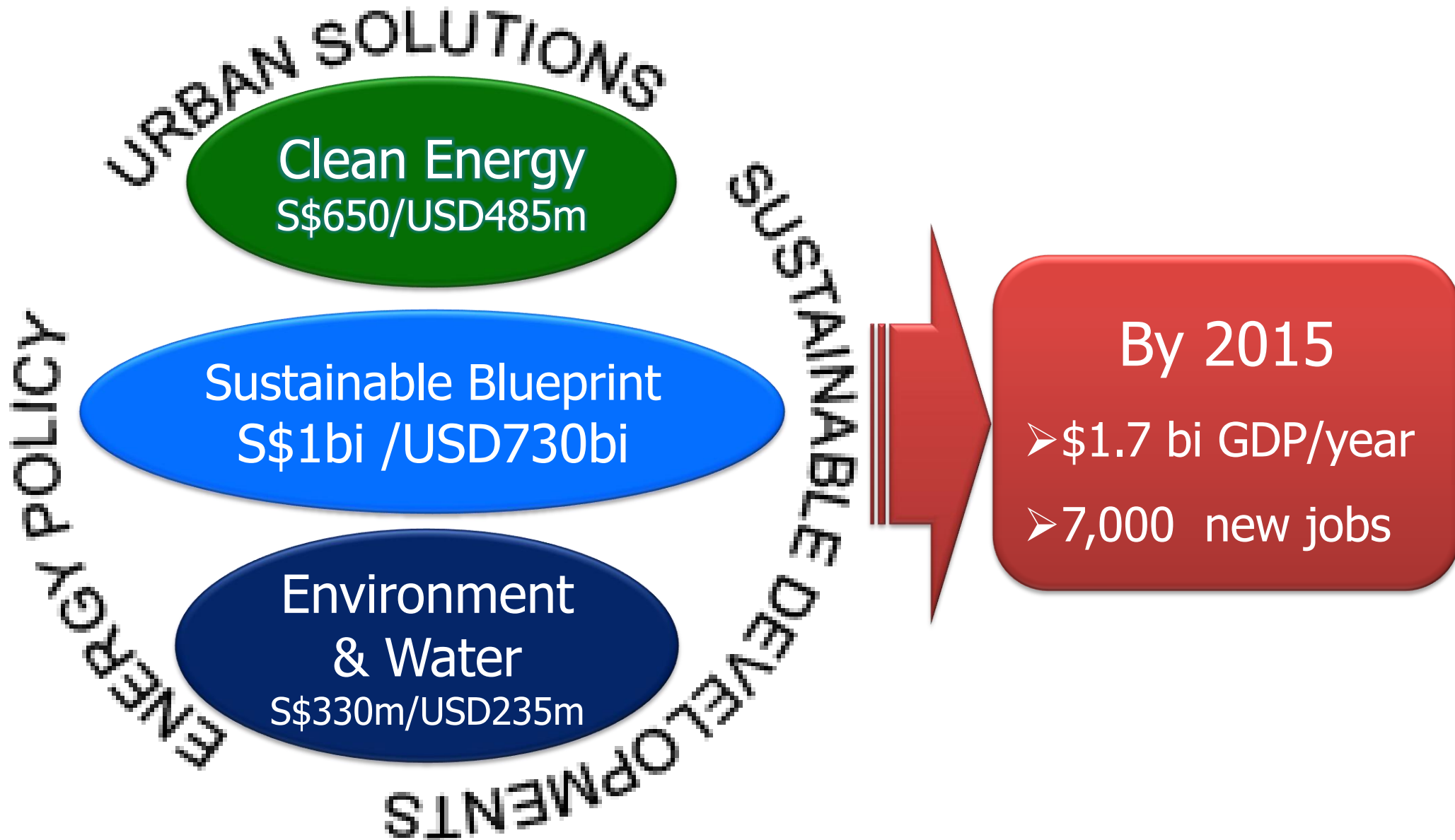
Energy Efficiency



Energy Industry Development

Clean Energy

Economic Development Board

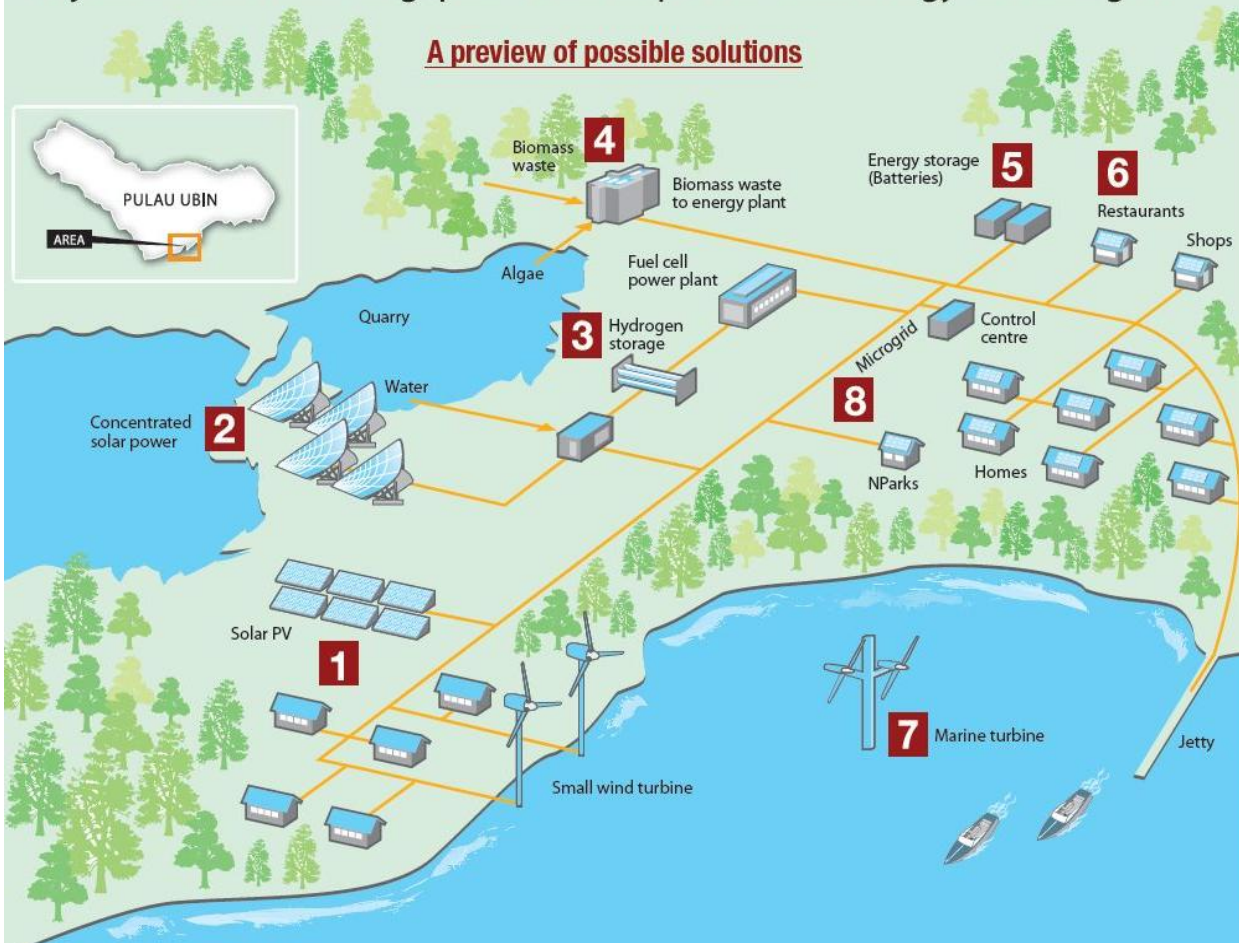


Living Lab on Pulau Ubin Island – 10 Sq Km

Powering Pulau Ubin with Clean and Renewable

Project aims to make Singapore a launch pad for new energy technologies

A preview of possible solutions



- 1** – Solar
- 2** – Solar
- 3** – Hydrogen Storage
- 4** – Biomass Waste
- 5** – Energy Storage
- 6** – PV
- 7** – Marine Turbine
- 8** – Microgrid

Singapore

Test-bedding and Living Laboratory for Clean Tech



- 50 hectares
Cleantech Park
- Catalyze
development of
Cleantech industry
and capabilities
- for companies to
conduct R&D, test-
bedding,
prototyping and
light manufacture

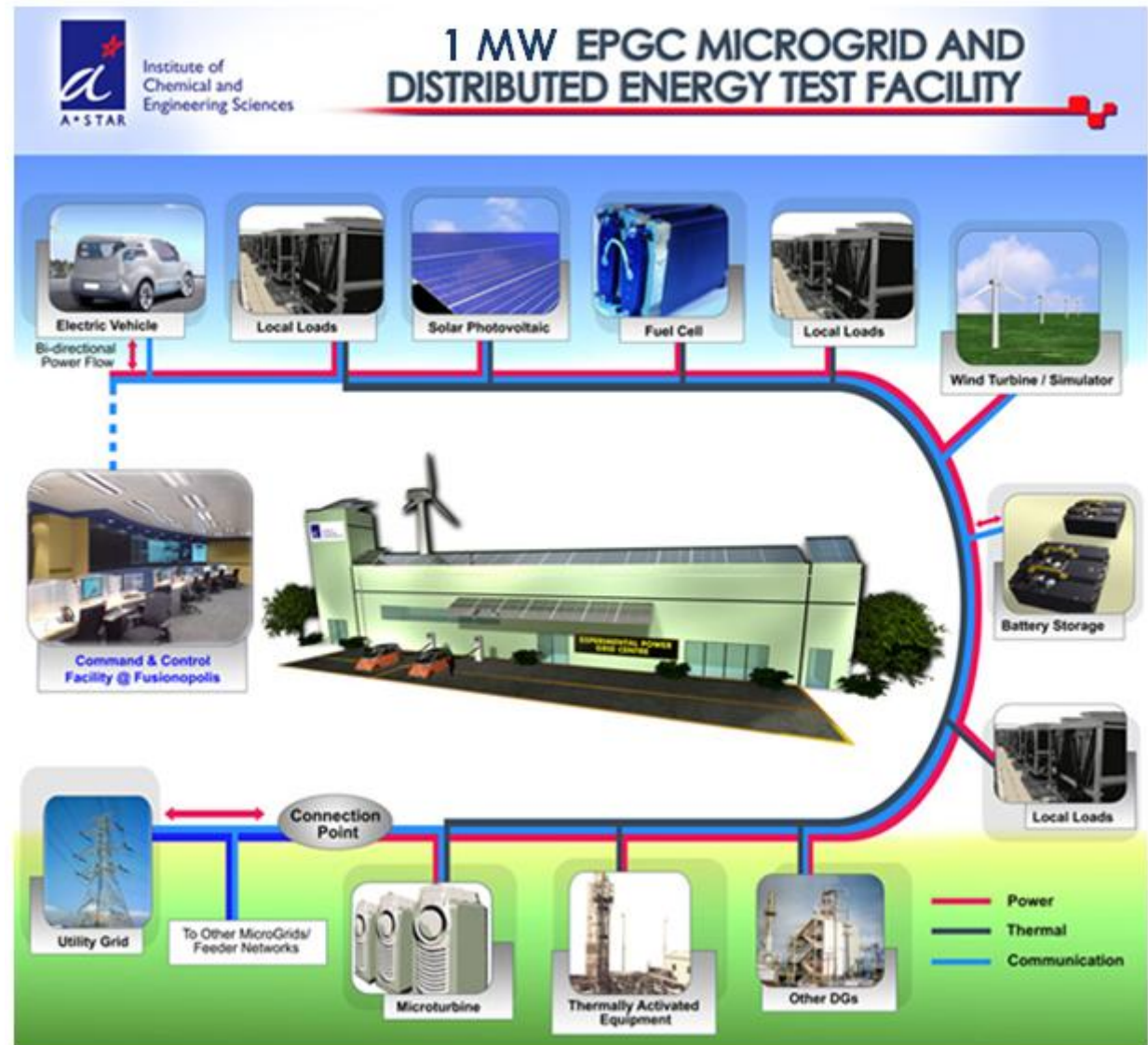
Cleantech Park @ Jalan Bahar



Singapore

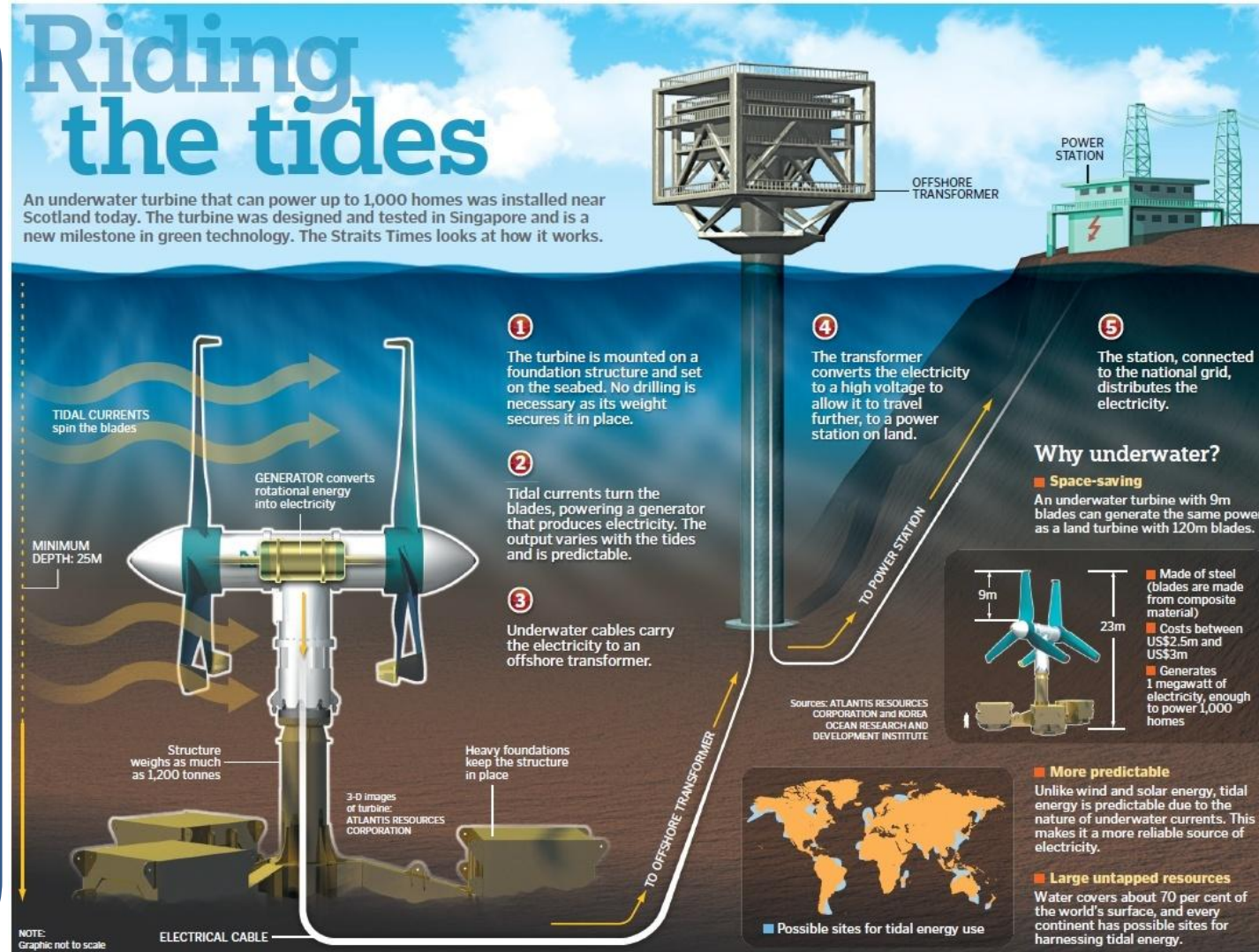
Test-bedding and Living Laboratory for Energy Grid

- World's largest pilot 1 Megawatt Experimental Power Grid Centre
- S\$38mi (USD27.5m) facility
- Allows electricity from renewable energy sources to be fed into the Grid



- *Atlantis Resources Corporation* (a Singapore-based firm) develops world largest tidal turbine

- Installed at Orkney Islands, the 1MW (US\$3m/S\$4.1m) underground turbine can generate consistent electricity to power up to 1,000 homes





- Zero Energy Building project is a collaborative R&D effort among BCA, NUS, SERIS and partners from the private sector
- Singapore Government target to get **80%** of all buildings on Green Mark certification by 2030



Light pipes



Solar panels



Photovoltaic systems

Singapore

Nuclear Security & Nuclear Power Option



“Nuclear Power not ruled out”

In Washington, at the Nuclear Security Summit, Prime Minister Lee Hsien Loong said, “*the Government was just beginning to study the long-term feasibility of nuclear power for Singapore*”.

Straits Times, April 15, 2008



U.S. President Barak Obama (R) and Prime Minister Lee Hsien Loong pose for photographs at the start of the Nuclear Security Summit at the Washington Convention Center April 12, 2010 in Washington, DC. Forty-seven delegations from around the world have converged on the United States' capital to discuss nuclear security. (Source: www.life.com)

Technology
to reduce
carbon
emissions

- Conversion from Oil-fired to Gas-fired Combined Cycle Plant
- Recycling Energy – Power-and-Steam Co-Gen Plant



Senoko Power Plant
Since conversion -
Achieved Reduction
of 2.5 mi ton of
CO₂ emission per
year

Singapore

Greener Urban Mobility Research – Collaborations & Joint Research



4 Research Clusters

Transport Optimization

- Travel Pattern Analytics
- Sensors & Robotics
- Open Source Road Traffic Simulator

Transport Telematics

- Traffic Modeling & Predictive Analytics
- Collaborative Location Based Services

Integrated User Experience

- Personal Travel Advisor
- Unified Travel Information
- Mashups Geospatial Transport Information

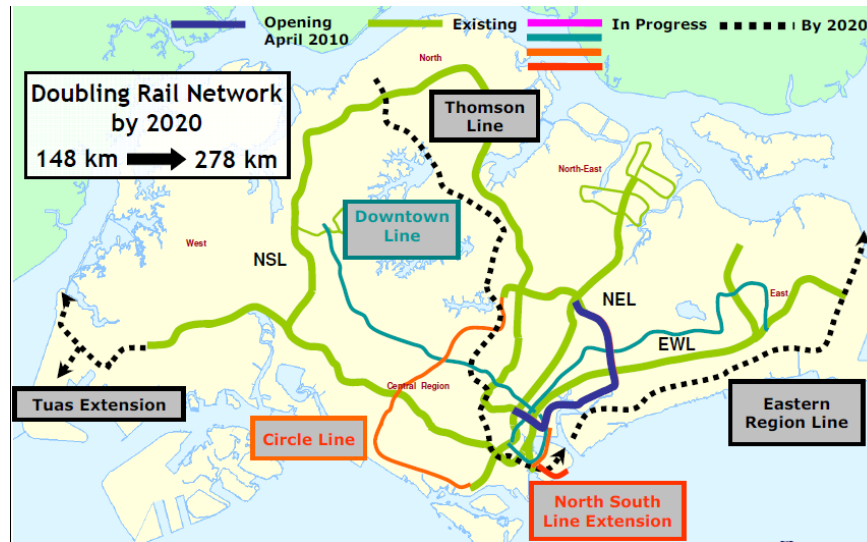
Environment & Energy

- Green IT
- Green Vehicles



Singapore

Greener Urban Mobility



- Test-bedding new technologies - **electric vehicles** and **diesel-hybrid buses**
- **Low Carbon Technology Transport**

Improve the design and engineering of Rapid Transit System to achieve greater **energy efficiency**

Low Carbon Vehicle



Urban Mobility ~ 13% of Singapore Energy Consumption is in Transport Sector

Green
Building
Target of
80% of all
building
certified by
2030



Solar panels on
rooftops of HDB apts.

- by 2011 -3,000 residential units will have solar panels installed
- Housing Development Board (HDB) invested S\$2.3 million for this sustainable housing initiative

Sustainable Public Housing



Singapore

Waste Minimisation and Recycling



To attain 70% recycling rate by 2030



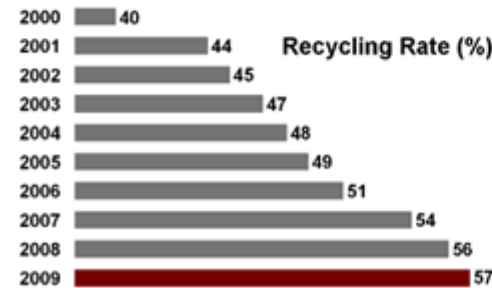
SINGAPORE 2009 WASTE STATISTICS

1,230 kg generated by each person in 2009

6,114,100 tonnes Generated by everyone in 2009

57% Recycled

43% Disposed



41% Incinerated at Four Waste-To-Energy Plants

2% Landfilled at Semakau Landfill

Singapore

- From dependence on imported water to self-sustaining



Reclaimed Water for Industrial & Potable Use



Marina Barrage



Urban Reservoir will store 10% of Singapore's Demand

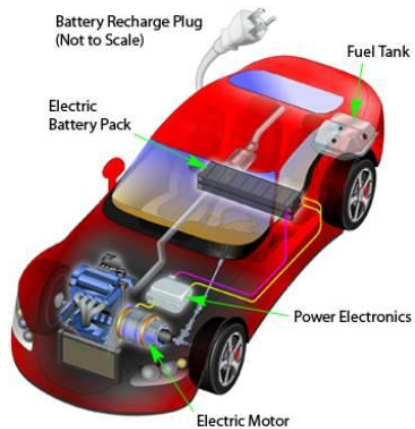


Singapore DTSS
Routing all wastewater through large deep tunnel system by gravity to 2 new water reclamation plants



Growing Singapore to be a Global Hydro-Hub

Electric Vehicles



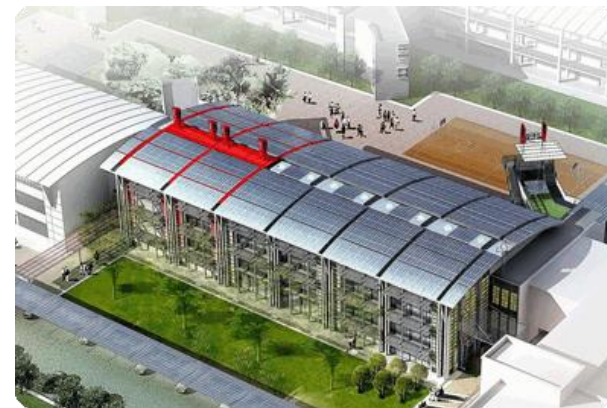
Carbon Services



Smart Grids

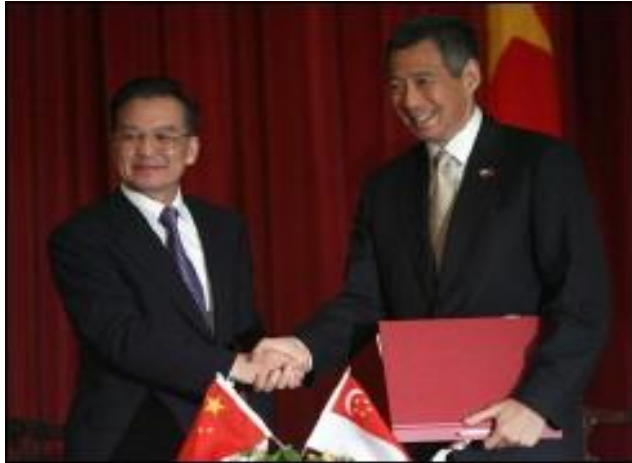


Green Buildings



Singapore

Exporting Sustainable Solutions: Developing Eco-Cities Overseas



THE STRAITS TIMES

Tianjin: Singapore-China ties hit new heights with eco-city pact

19-November-2007

Guangzhou: Keppel studying feasibility of developing the eco-friendly Knowledge City.

24-March-2009



Vietnam: Vietnam-Singapore Industrial Park breaks ground.

13-Jan-2010



ASEAN

- ASEAN Energy Resources



Singapore

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- Challenges and Drivers for Change
- National Strategy and Policy



NUS

- Collaborations
- New Opportunities
- Contributions

Summary

Regional and International
Collaboration is the key success factor

**Exploratory
Science**

**Future
Technology**

**Policy /
Implementation**

**Energy
Sustainability**

SOLAR ENERGY RESEARCH
INSTITUTE OF SINGAPORE
(SERIS)



**Singapore's national institute for
Applied Solar Energy research**

NUSNNI /
Sustainable Energy
Materials and Systems



**Research in areas of Solar Energy,
Li-ion Batteries, Hydrogen
Production & Storage and Fuel
Cells**

Centre for Total Building
Performance (CTBP)
A BCA-NUS Centre for
Tropical Building Research



**Research in tropical Building
Design, Construction, Maintenance
and Management**

NUS Environmental
Research
Institute (NERI)



**Interdisciplinary research,
education and expertise in the
environment affecting Singapore
and Asia**

Singapore Institute of
Nuclear Science
& Engineering Research
(SINSER)



**An initiative on nuclear science
and engineering program**

**Exploratory
Science**

**Future
Technology**

**Policy /
Implementation**

**Energy
Sustainability**

NUS Global Asia Institute
(GAI)



NUS President's initiative on Research and Scholarship directed at topics pivotal to Asia's future

Energy @ NUS website



One-stop portal on Energy Research, Energy Directions and Energy Education in NUS

Energy Studies Institute
(ESI)



A national policy-research institute in energy policies (economics, security and the environment)

Lee Kuan Yew School of
Public Policy (LKYSPP)



Areas of focus include Asian Energy Security and Energy Governance

Energy Sustainability Unit
(ESU)



To develop course structure & training syllabus for the Singapore Certified Energy Manager Training Programme

Office of Environmental
Sustainability (OES)



To effect a total shift to environmental sustainability in all aspects of campus life

Major survey of companies (refining, petrochemicals, pharmaceuticals) on their programs & commitment to energy efficiency

Analysis of impact of Singapore's land transport policies on balancing private and public transportation, and on CO₂ emissions

Works with Ministries to monitor:

Global developments & trends in energy/environment/sustainability systems and technologies

The economics of new innovations

The geo-politics of fossil and emerging energy sources.

Solar Energy Research Institute of Singapore (**SERIS**)



Set up jointly by



R&D Clusters

- Silicon Photovoltaics
- Nano-structured Solar Cells
- Solar & Energy Efficient Building including PV System Technology

Service Unit

- PV Module Performance Analysis
- S\$130 mi over 5 years
- 90 Researchers over 5 year of operations
- Solar module testing & certification centre with VDE & Fraunhofer

International Research Luminaries



Prof Joachim Luther
• CEO of SERIS
• Former Director of Fraunhofer ISE from 1993 to 2006



Prof Armin Aberle
• Deputy CEO of SERIS
• Ex-Dy Director of PV Centre of Excellence in UNSW



Dr. Bram Hoex
• 2008 SolarWorld Junior Einstein Award Winner

- New Opportunities for NUS to contribute towards the national agenda on Nuclear Energy

Nuclear Security & Nuclear Power Option

Subject to Government support, NUS is prepared to undertake the following high impact research in areas:

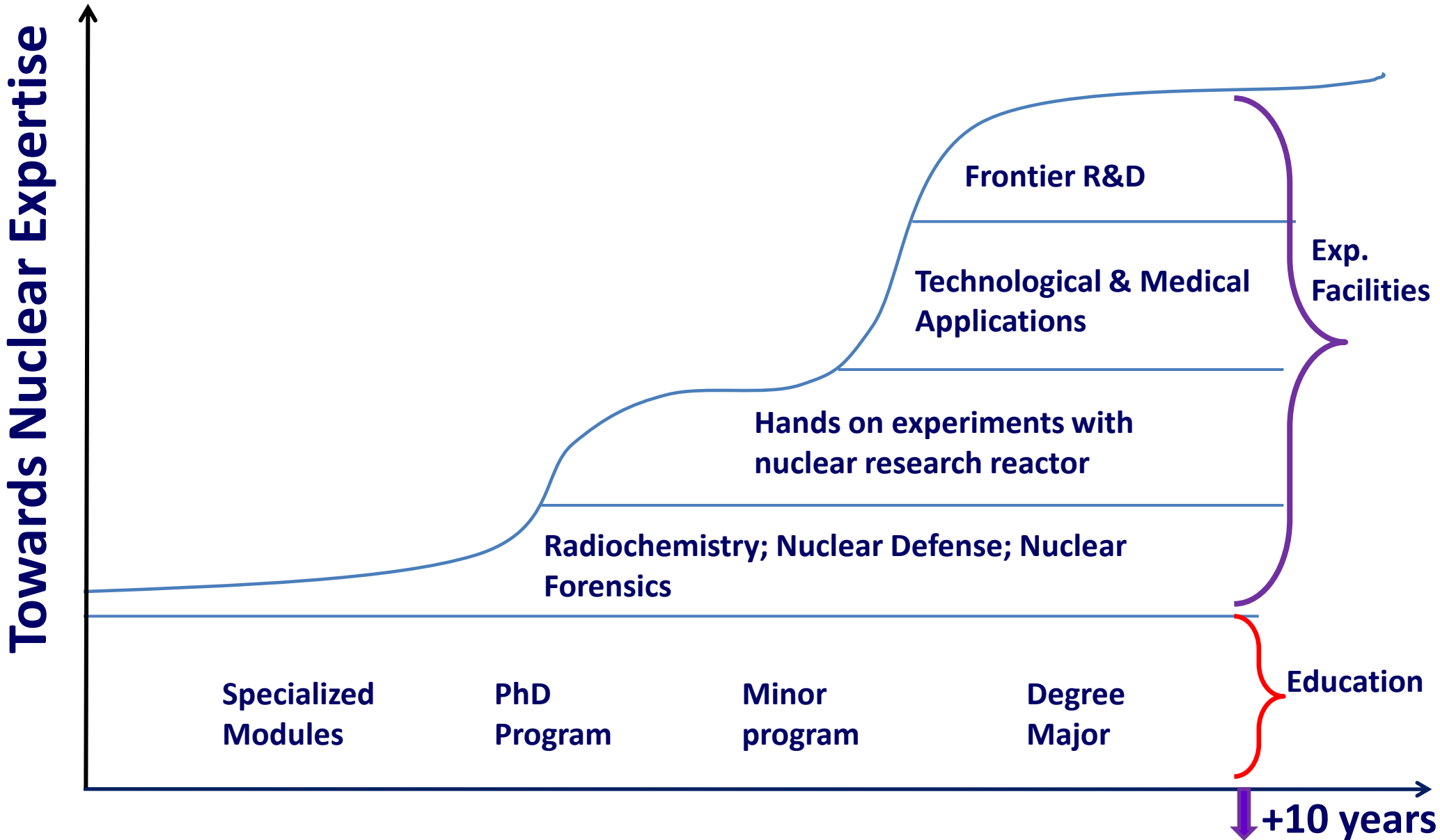
- ✓ nuclear forensics & detection
- ✓ radio chemistry & nuclear defense
- ✓ reactor engineering
- ✓ nuclear medicine
- ✓ material sciences
- ✓ environmental sciences
- ✓ life sciences



**Nuclear Science & Engineering
Education – Undergrad Attachment with
University of Texas @ Austin**

NUS

- New Opportunities for NUS to contribute towards the national agenda on Nuclear Energy



Platinum Award



UNIVERSITY TOWN: Received the Green Mark for Districts Award (Gold Plus). In addition, University Town's Education Resource Centre received the Green Mark for Buildings Award (Platinum)

MOCHTAR RIADY BUILDING: Received the Green Mark for Buildings Award (Gold) →



Gold Award



BCA GREEN MARK

- Platinum Award
- Gold Plus Award
- Gold Award
- Certified Award



← **T-LAB:** Received the Green Mark for Buildings Award (Certified)

Certified Award

Institution of Higher Learning



Solar Energy Research Institute of Singapore



Centre for Sustainable Energy Research

Public Sector



Agency for Science, Technology and Research

14 Research Institutes including:
 • Experimental Power Grid (@ICES)

• Sustainable Manufacturing Centre (@SIMTech)

• Institute of Materials Research & Engineering

• Institute of Microelectronics



HOUSING & DEVELOPMENT BOARD

Building and Construction Authority

Private Sector



Global Wind Energy R&D Centre



GRENZONE

Contribute to a Greener Earth

Solar System Integration Development Centre



Organic PV R&D



Solar R&D



ATLANTIS RESOURCES CORPORATION

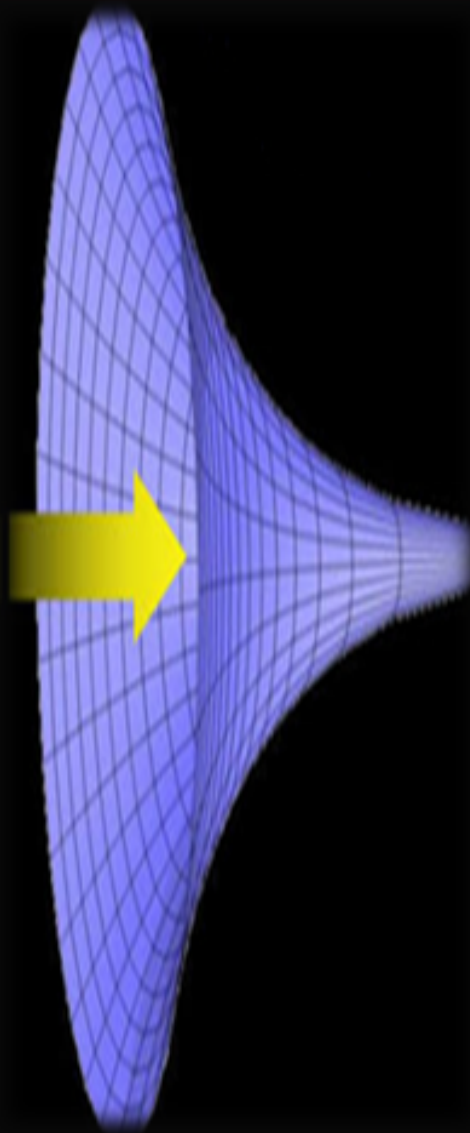
Global Tidal R&D Site



Fuel Cell R&D



Fuel Cell R&D



- **Energy Security Options:**
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Summary

Zero-Carbon Energy Kyoto 2010



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Summary

Regional and International
Collaboration is the key success factor

- ASEAN population ~9% of the World's Population
- ASEAN Natural Energy Resources are limited
- Singapore - no natural energy resources
- Singapore - an International Energy Hub
- Singapore's strong commitment to invest and engage institutes of higher learning, public and private collaborations for advances in energy and environment solutions
- NUS is plugged into the system to contribute

Summary

Zero-Carbon Energy Kyoto 2010



Vision

Singapore – One of the best livable cities on earth

Strategic Thrust

Energy and Sustainability Education and Research

Research Thrust

Energy Efficiencies/Waste to Energy/Solar Fuels/Smart Grid /Bioenergy/ Nuclear Energy

Opportunities for Collaboration

- Energy and Environment Sustainability are global societal challenges
- The next step is for us to work together cross culturally and adopting multidisciplinary education and research to enable new solutions

THANK YOU

seeram@nus.edu.sg