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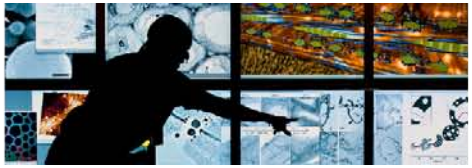
Renewable Energy and Climate Change



Symposium in Honor of 2009 and 2010 ACS Fellows in the Industrial and Engineering Chemistry Division

Helena Chum, NREL Research Fellow

244th ACS
National Meeting
Philadelphia, PA

August 20, 2012

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

1. Industrial and Engineering Chemistry -- Cellulose and Renewable Materials, Chemicals, Fuels, and Energy -- important in the past, present and future.
2. Framing renewable energy technologies and integrated efficient systems
3. Framing energy systems and climate change - Key recent global scenarios
4. Renewable energy sources and climate change – the IPCC Special Report (SRREN)

National Renewable Energy Lab
of the U.S. DOE
Energy Efficiency and
Renewable Energy Office
35 years old
NREL, 2/2012, Golden, Colorado
An Energy System Integration
Experimentation Laboratory

NREL
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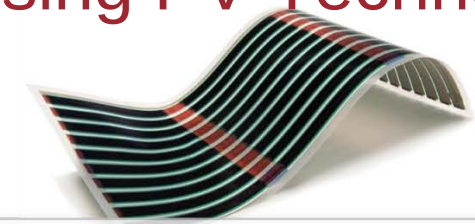
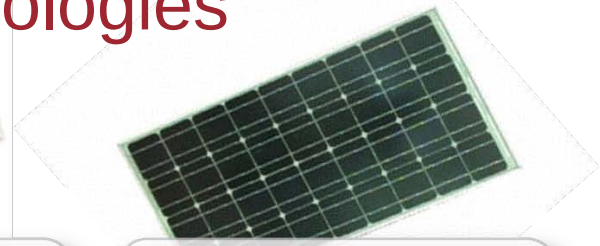
Multiple Promising PV Technologies





CPV

MARKET

- Ground Mounted
- Rooftop Mounted

Thin Films

MATERIAL

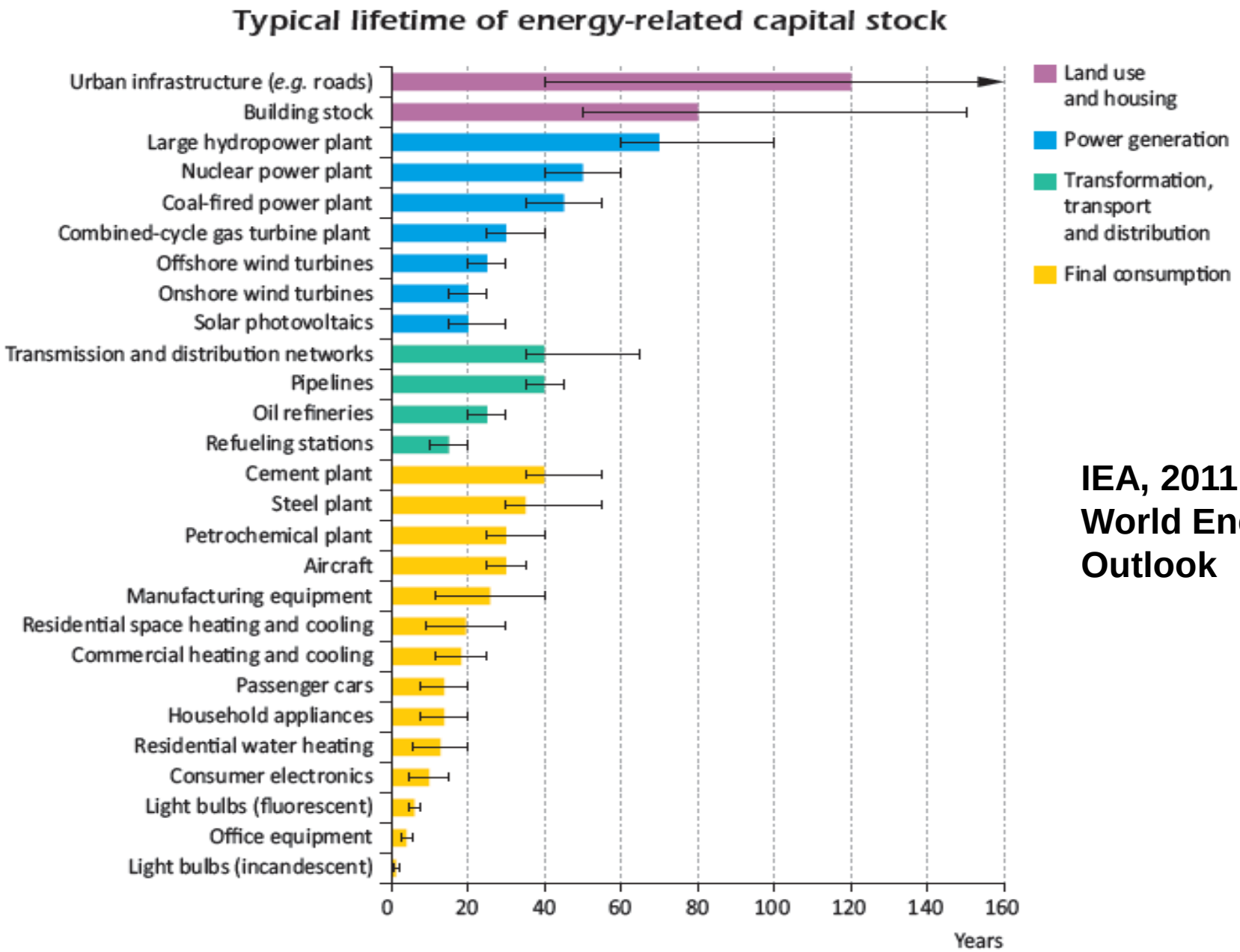
- Amorphous Silicon
- CdTe / CIGS
- Organic

Crystalline Silicon

STRUCTURE

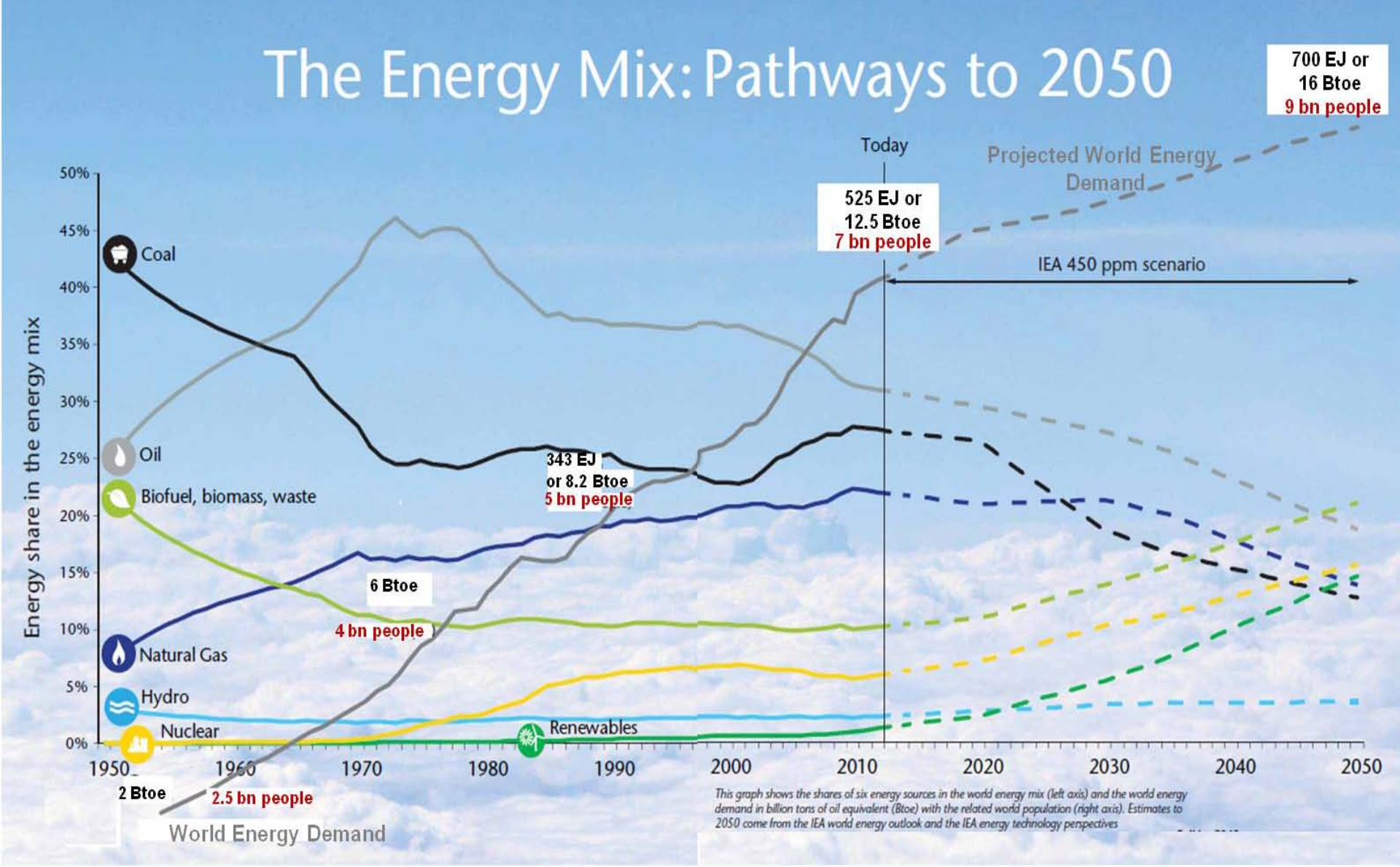
- Multi-Crystalline
- Mono-Crystalline

2. Framing Energy Systems



Note: The solid bars show average lifetimes while the range lines show typical variations.

IEA, 2011 World Energy Outlook



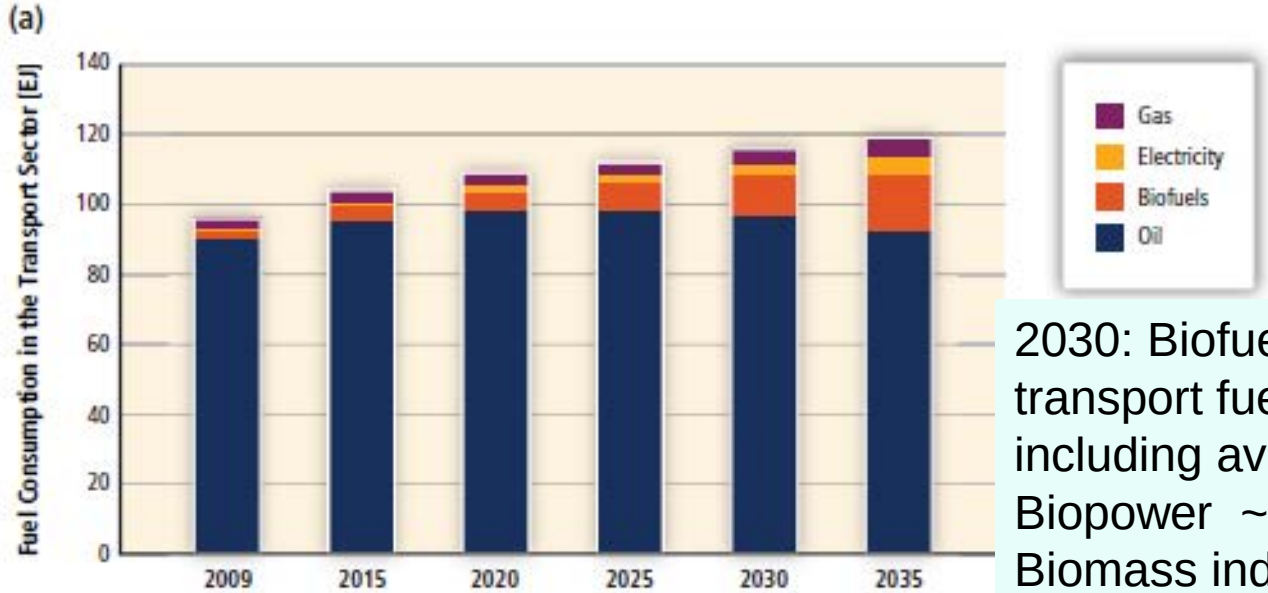
wbcsd energy & climate

Business solutions for a sustainable world

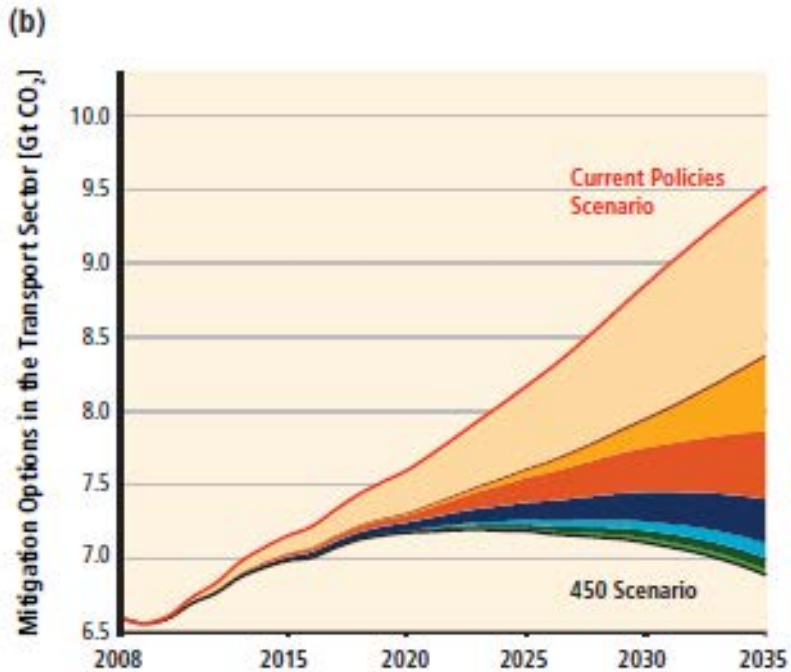
The Energy Mix: Low-carbon pathways to 2050

http://energyinnovation.org/wp-content/uploads/2012/05/WBCSD-The-Energy-Mix.pdf

Higher Resolution Scenario:
2010 IEA-WEO

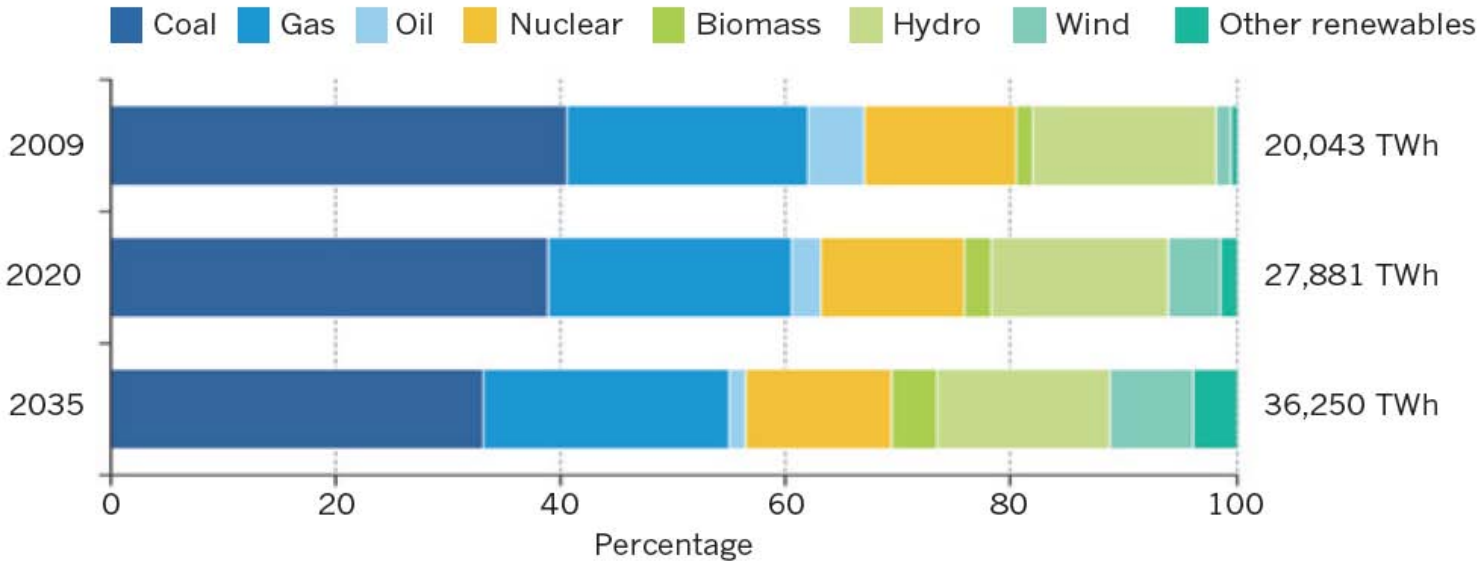


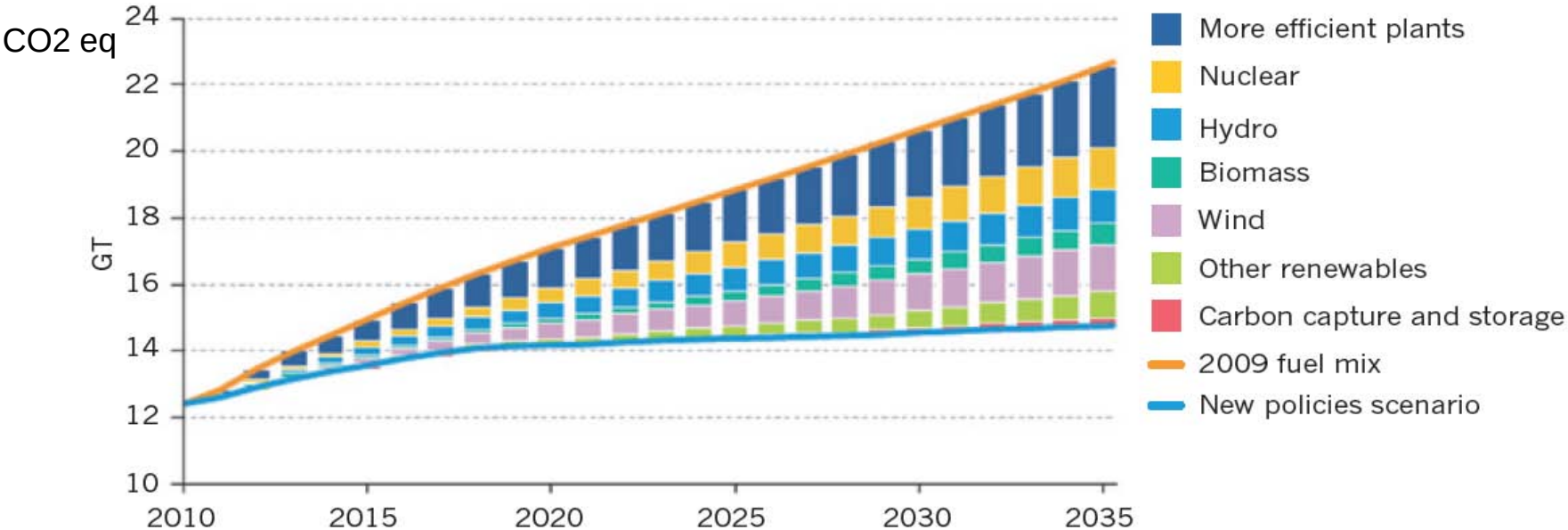
2030: Biofuels ~11% global transport fuels (~60% advanced) including aviation biofuels
Biopower ~5% global electricity
Biomass industrial heating and building double each relative to 2008



	Abatement 2020	2030	2035
Road	83%	80%	80%
Increased Efficiency	67%	51%	43%
Switch to Gas	3%	1%	1%
Switch to Electricity	2%	11%	19%
Switch to Biofuels	11%	17%	17%
Aviation	14%	15%	15%
Increase Efficiency	14%	12%	11%
Switch to Biofuels	0%	3%	4%
Navigation	2%	3%	3%
Other Transport	2%	2%	1%
Total [Gt CO_2]	0.4	1.7	2.6

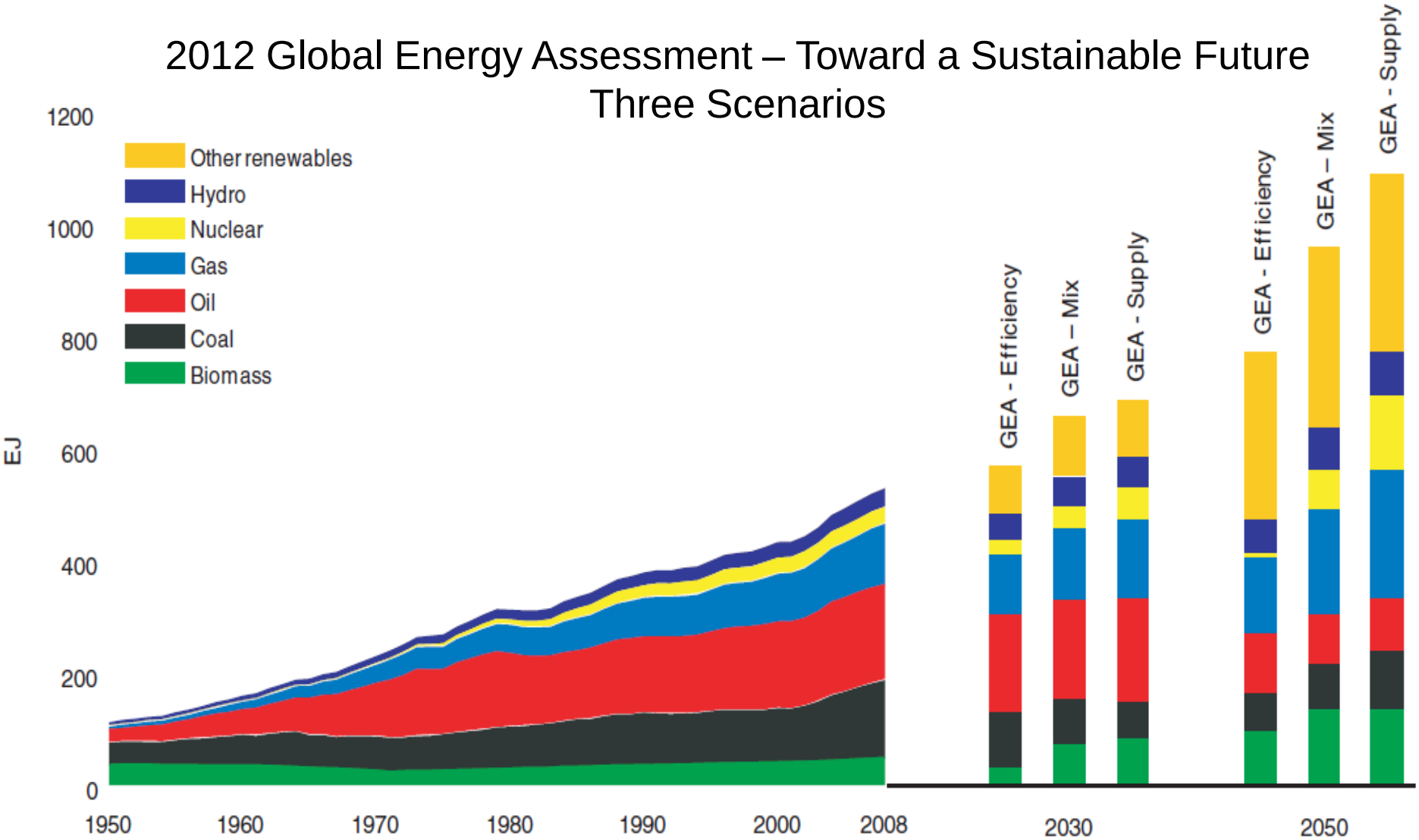
Figure 2.24 | (a) Evolution of fuel consumption in the transport sector including biofuels (*World Energy Outlook 2010*, © OECD/IEA, figure 14.12, page 429 in IEA (2010b)) and (b) shares of carbon mitigation by various technologies including biofuels for road and aviation transport from current policies baseline (upper red line) to the 450 ppm bottom curve of the mitigation scenario. (*World Energy Outlook 2010*, © OECD/IEA, figure 14.14, page 432 in IEA (2010b))





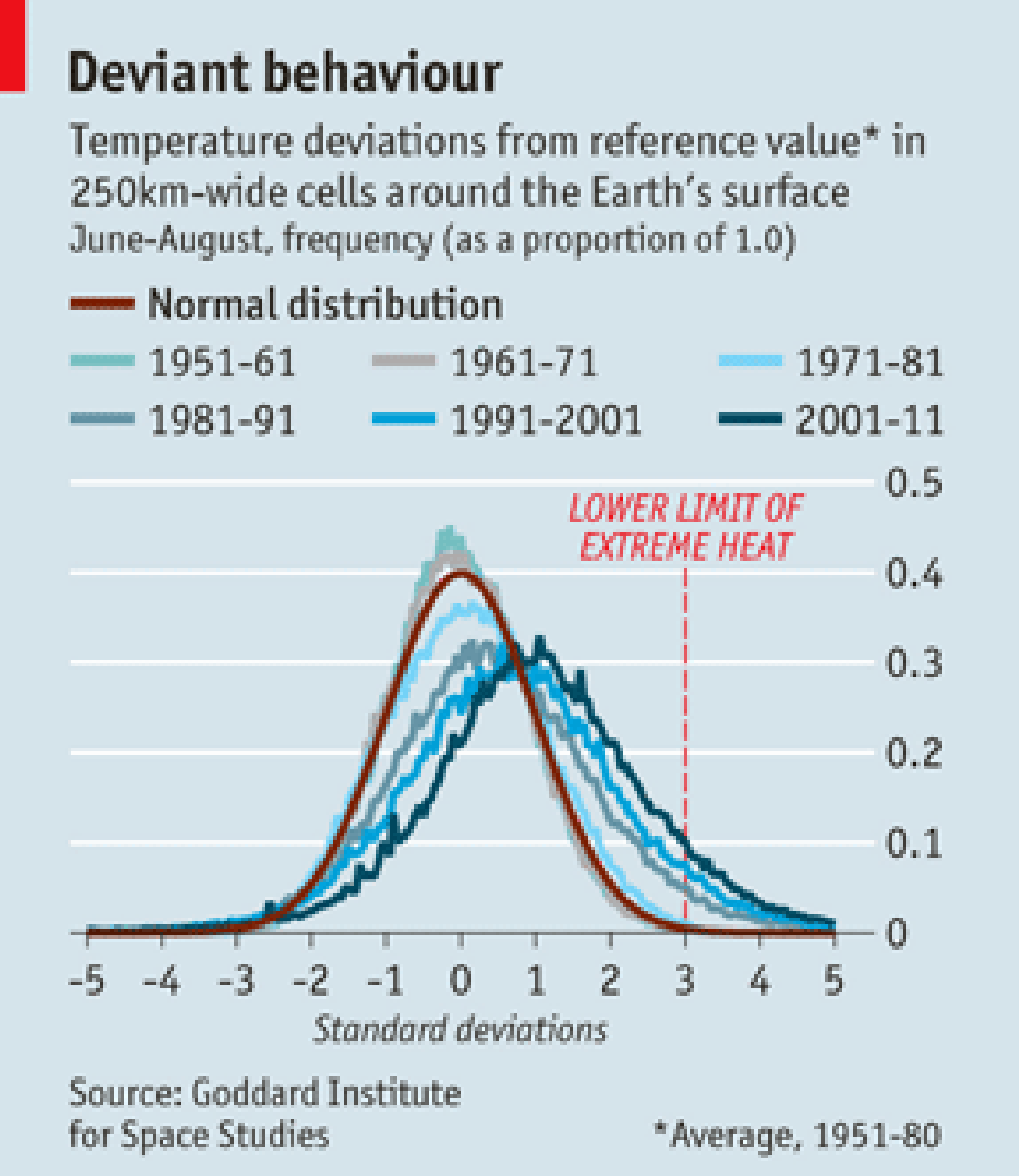
Chu and Majumdar, Opportunities and challenges for a sustainable energy future, Nature , 2012, 488, 294-303. **doi:10.1038/nature11475**

2012 Global Energy Assessment – Toward a Sustainable Future
Three Scenarios



GEA, 2012: Global Energy Assessment – Toward a Sustainable Future, Cambridge University Press, Cambridge UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.

GEA pathways see the interactive web-based GEA scenario database hosted by IIASA:
www.iiasa.ac.at/web-apps/ene/geadb



Climate change
Bell weather
A statistical analysis s
Shows how things really are heating up

The Economist, Aug 11th 2012

Adaptation and Mitigation Needed

Based on J. Hansen et al., Perception of climate change, PNAS Early edition www.pnas.org/cgi/doi/10.1073/pnas.1205276109

Oil and Gas Sector Impacts

Impacts on…

Exploration

- Subsidence
- Increased wave loading
- Loss of surface water access
- Sound impacts on sea mammals

Production

- Early season delays
- Pad damage
- Loss of surface water access
- Increased production interruptions

Transport & Terminals

- Increased ice-load variation
- Damage to shore-line facilities
- Increased shipment interruptions
- Reduced shipping lanes or seasons

Refining

- Loss of access to water
- Increased flooding
- Loss of peak cooling capacity

Pipelines

- Thaw subsidence and frost jacking
- Increased setbacks
- Loss of capacity in existing pipelines.

Neighboring Communities

- Weather-related mortality
- Infectious diseases
- Air-quality respiratory illnesses
- Loss of species and habitat

CLIMATE CHANGE AND ENERGY SUPPLY AND USE : Technical Report for the U.S. Department of Energy in Support of the National Climate Assessment, 2/2012
http://www.esd.ornl.gov/eess/EnergySupplyUse.pdf

The IPCC Special Report on Renewable Energy Sources and Climate Change (CC) Mitigation

1070 pages

122 Countries supplied **Authors**
- 122 Lead
- 132 Contributing
- 35 Review Editors

350 peer reviewers
~25,000 comments

Summary by Helena Chum, NREL
Coordinating Lead Author of Bioenergy Chapter
Based on Contributions from all Authors

http://www.ipcc.ch/

WMO UNEP

SRREN

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Coordinating Lead Authors Meeting with IPCC WGIII cochairs and TSU – Potsdam, Germany, Jan. 2011

ipcc
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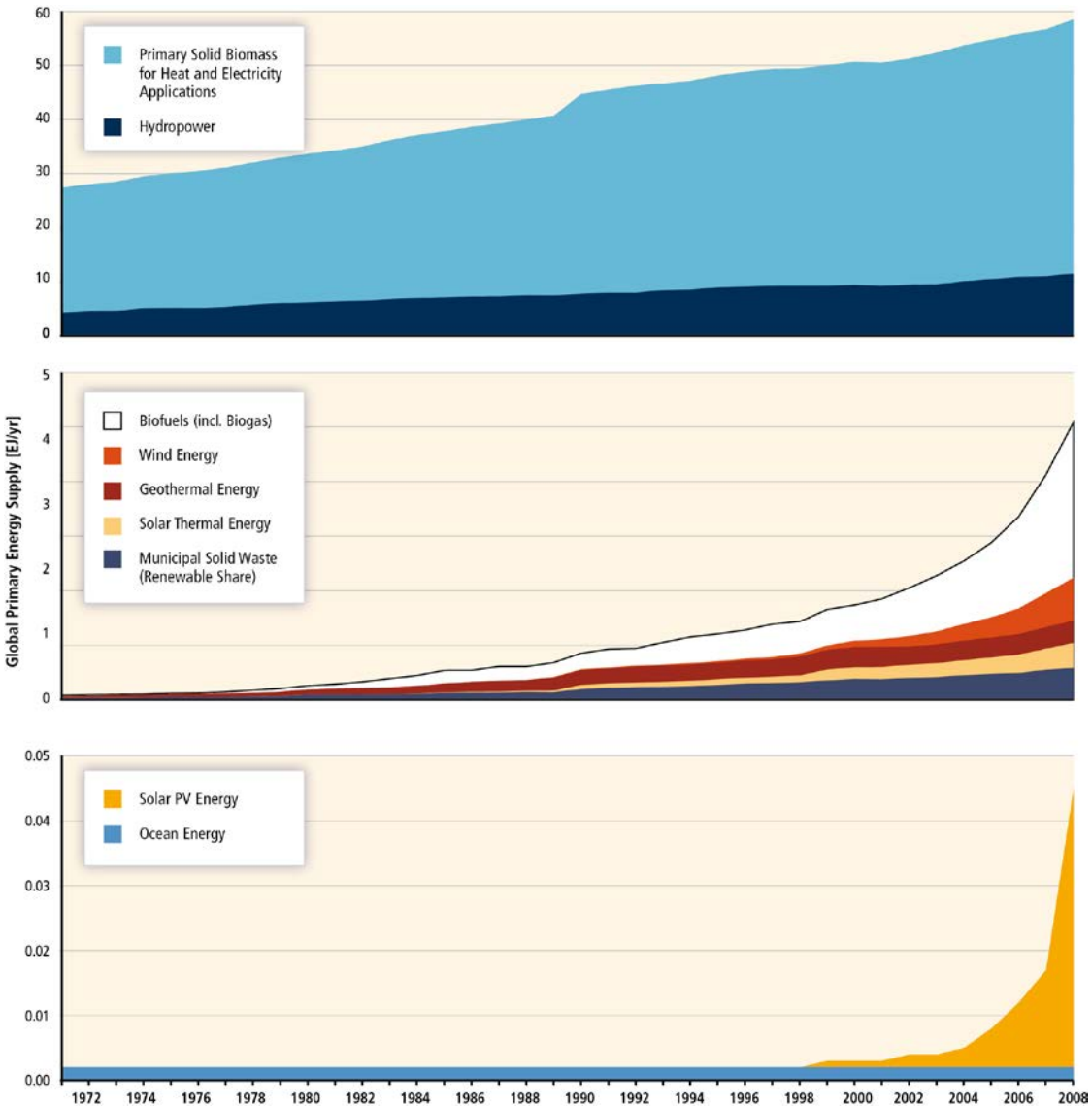
RE growth has been increasing rapidly in recent years.



140 GW of new RE power plant capacity was built in 2008-2009

This equals 47% of all power plants built during that period

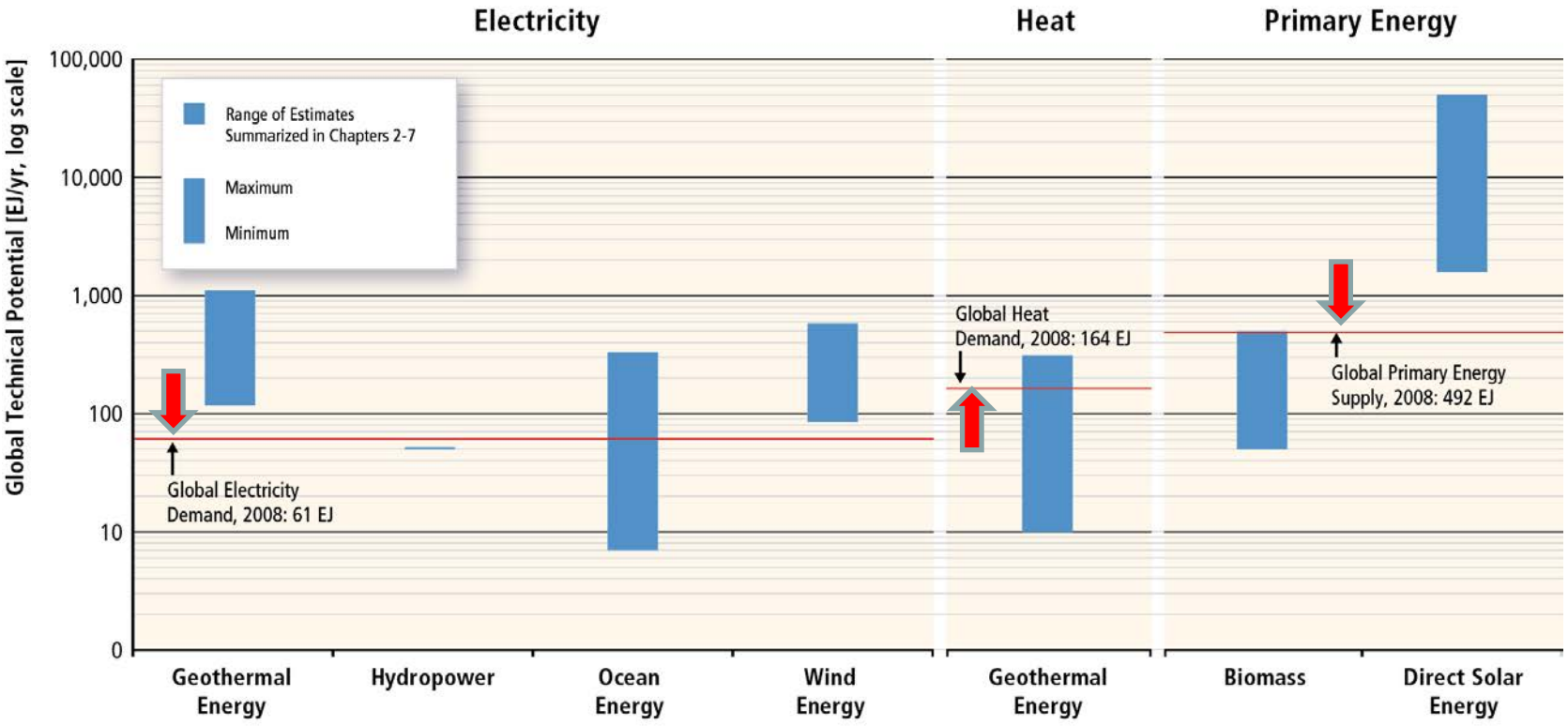
• In 2009 RE capacity additions
- Wind power 32%, 38 GW
- Hydropower 3%, 31 GW
- Grid-connected PV 53%, 7 GW
- Geothermal power 4%, 0.4 GW

-Solar hot water/heating 21%, 31 GWth

• Biofuels 2009
• 3% global road transport or
• 2% of total transport fuels

2009 additions
- Ethanol 10%, 7 billion liters
- Biodiesel 9%, 2 billion liters

The technical potential of renewable energy technologies to supply energy services exceeds current demands.



Range of Estimates of Global Technical Potentials

	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Geothermal Energy	Biomass	Direct Solar Energy
Max (in EJ/yr)	1109	52	331	580	312	500	49837
Min (in EJ/yr)	118	50	7	85	10	50	1575

RESOURCE NOT LIMITING

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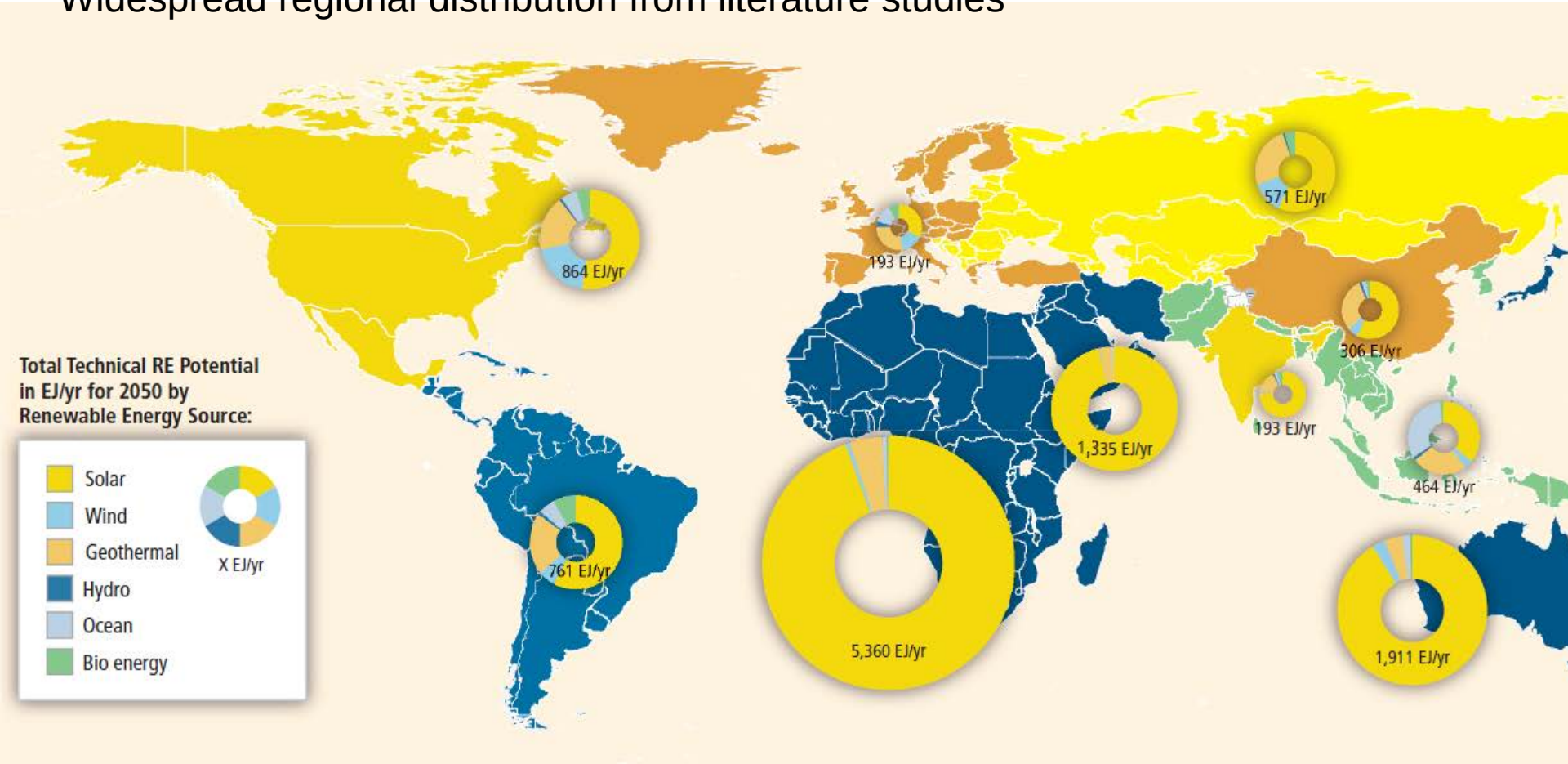
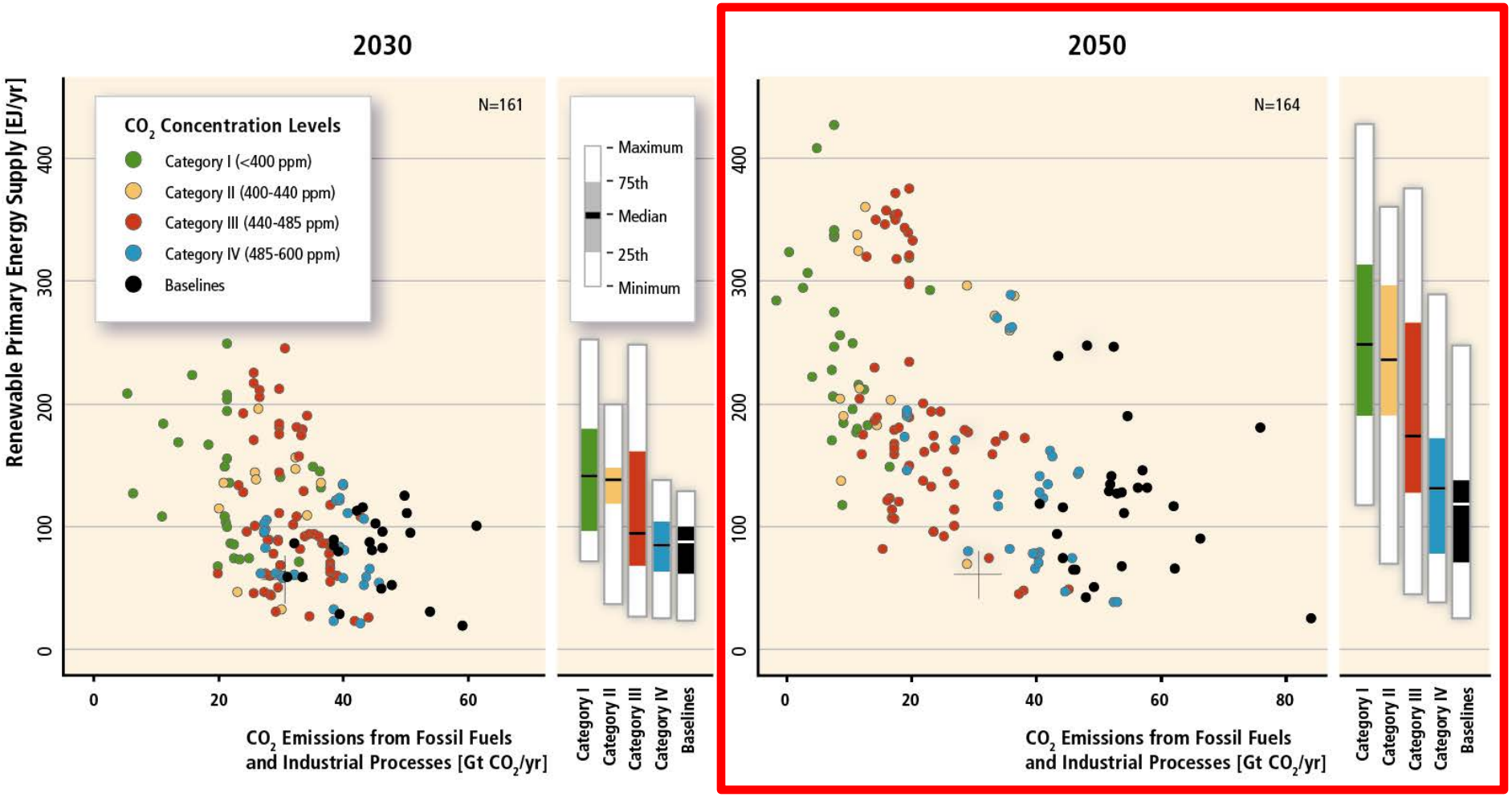
Widespread regional distribution from literature studies



Review of literature studies for regional potentials published by 2009 (not fully comparable to the IPCC study but a visual comparison)

SRREN Figure 10.19

Global RE primary energy supply from 164 long-term scenarios versus fossil and industrial CO_2 emissions.

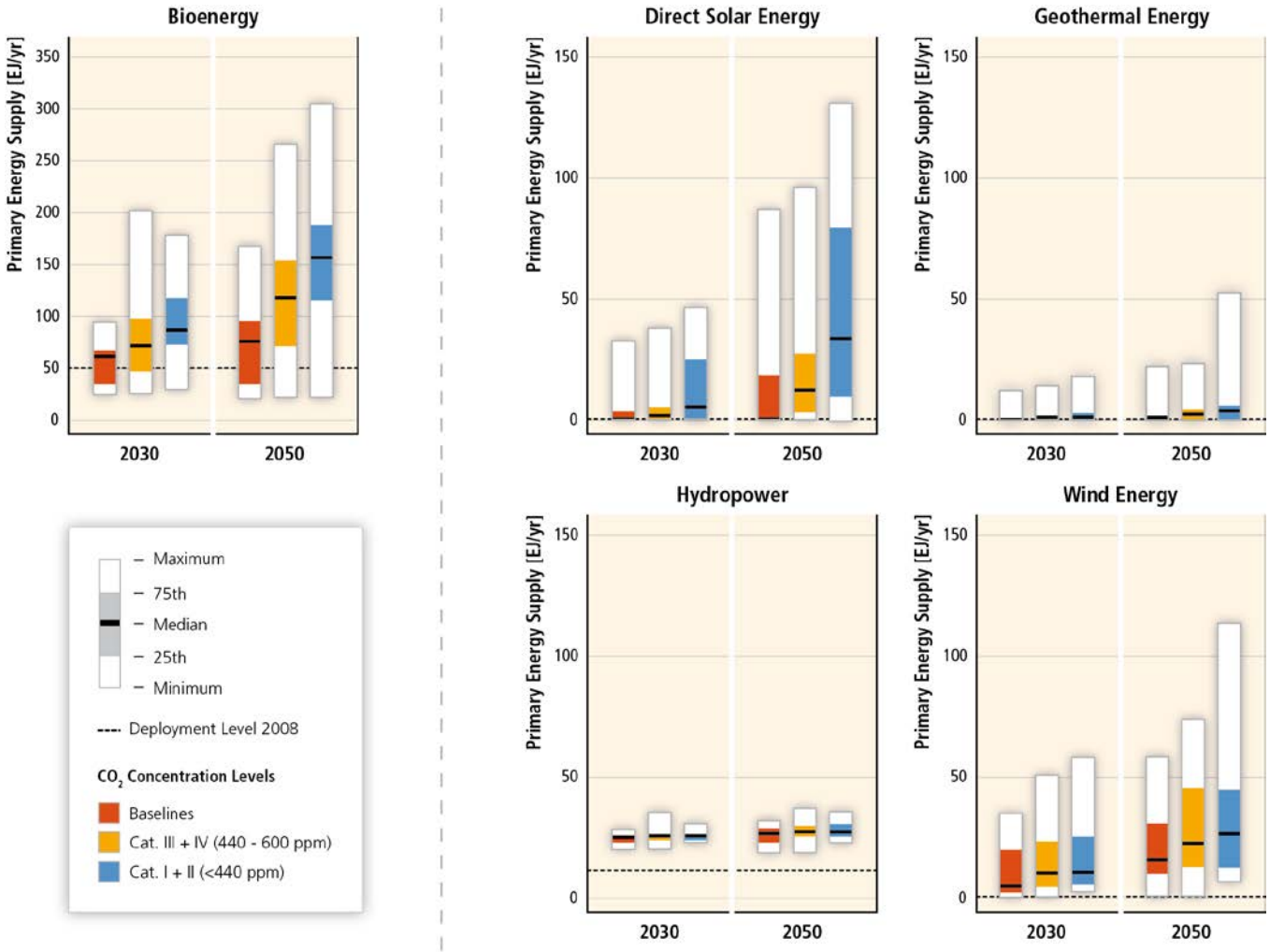


How much RE could be used in the future?
What do current models say? Compared to baseline trajectories.

Source: SRREN SPM, Figure SPM.9

INTERGOVERNMENTAL PANEL ON climate change

RE deployment increases in scenarios with lower greenhouse gas concentration stabilization levels.



Bioenergy Supply is Accounted for Prior to Conversion

Primary Energy Supply is Accounted for Based on Secondary Energy Produced

Many renewable sources could supply low carbon footprint energy

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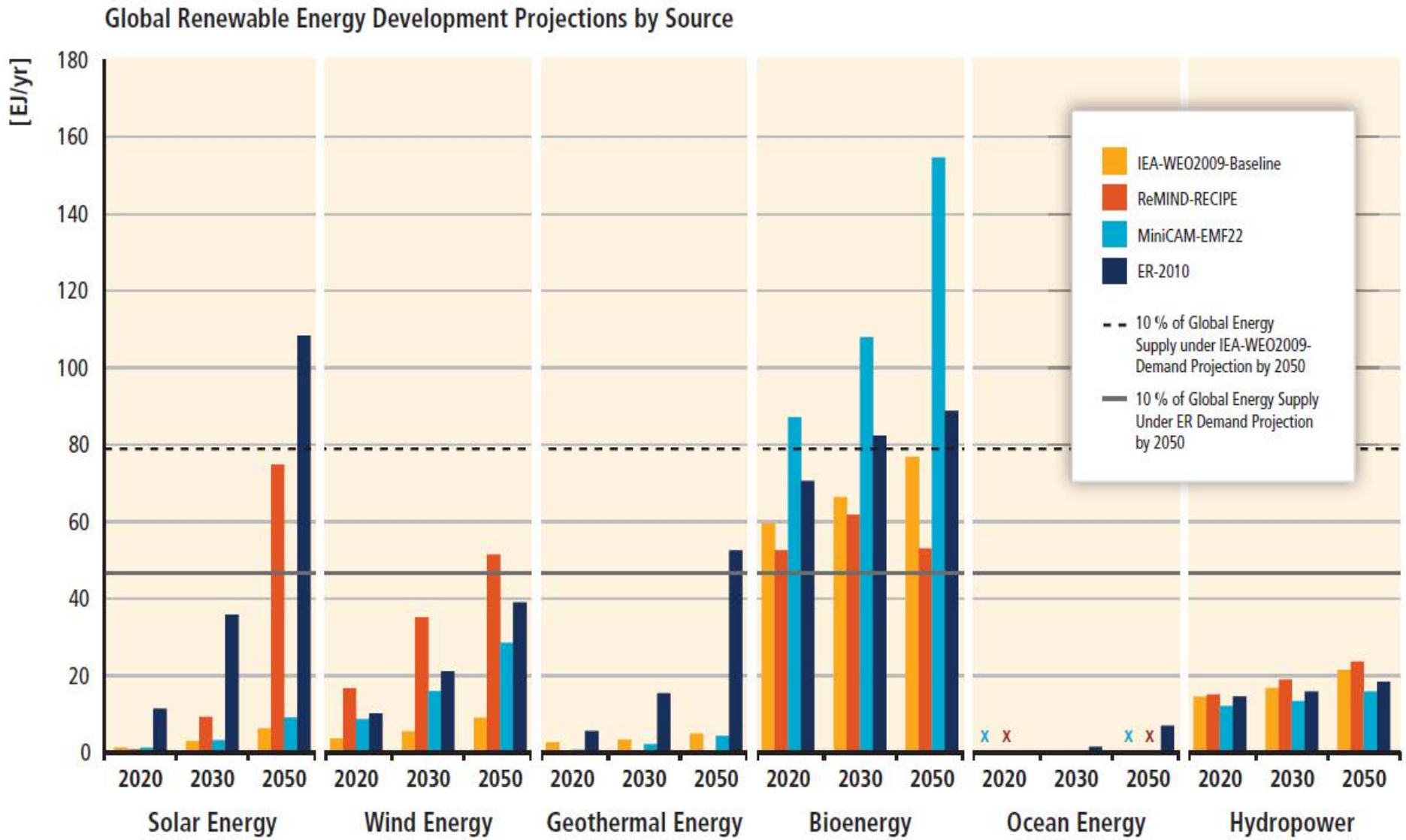

Figure TS.10.8 | Global RE development projections by source and global primary RE shares by source for a set of four illustrative scenarios. [Figure 10.14]

RE costs expressed as Levelized Cost of Energy (LCOE)

LCOE represents the cost of an energy generating system over its lifetime; it is calculated as the per-unit price at which energy must be generated from a specific source over its lifetime to break even. It usually includes all private costs that accrue upstream in the value chain, but does not include the down-stream cost of delivery to the final customer; the cost of integration, or external environmental or other costs. Subsidies and tax credits are also not included.

Notes: Medium values are shown for the following subcategories, sorted in the order as they appear in the respective ranges (from left to right):

Electricity	Heat	Transport Fuels
Biomass: 1. Cofiring 2. Small scale combined heat and power, CHP (Gasification internal combustion engine) 3. Direct dedicated stoker & CHP 4. Small scale CHP (steam turbine) 5. Small scale CHP (organic Rankine cycle)	**Biomass Heat:** 1. Municipal solid waste based CHP 2. Anaerobic digestion based CHP 3. Steam turbine CHP 4. Domestic pellet heating system	**Biofuels:** 1. Corn ethanol 2. Soy biodiesel 3. Wheat ethanol 4. Sugarcane ethanol 5. Palm oil biodiesel
Solar Electricity: 1. Concentrating solar power 2. Utility-scale PV (1-axis and fixed tilt) 3. Commercial rooftop PV 4. Residential rooftop PV	**Solar Thermal Heat:** 1. Domestic hot water systems in China 2. Water and space heating	
Geothermal Electricity: 1. Condensing flash plant 2. Binary cycle plant	**Geothermal Heat:** 1. Greenhouses 2. Uncovered aquaculture ponds 3. District heating 4. Geothermal heat pumps 5. Geothermal building heating	
Hydropower: 1. All types		
Ocean Electricity: 1. Tidal barrage		
Wind Electricity: 1. Onshore 2. Offshore		

The lower range of the levelized cost of energy for each RE technology is based on a combination of the most favourable input-values, whereas the upper range is based on a combination of the least favourable input values. Reference ranges in the figure background for non-renewable electricity options are indicative of the levelized cost of centralized non-renewable electricity generation. Reference ranges for heat are indicative of recent costs for oil and gas based heat supply options. Reference ranges for transport fuels are based on recent crude oil spot prices of USD 40 to 130/barrel and corresponding diesel and gasoline costs, excluding taxes.

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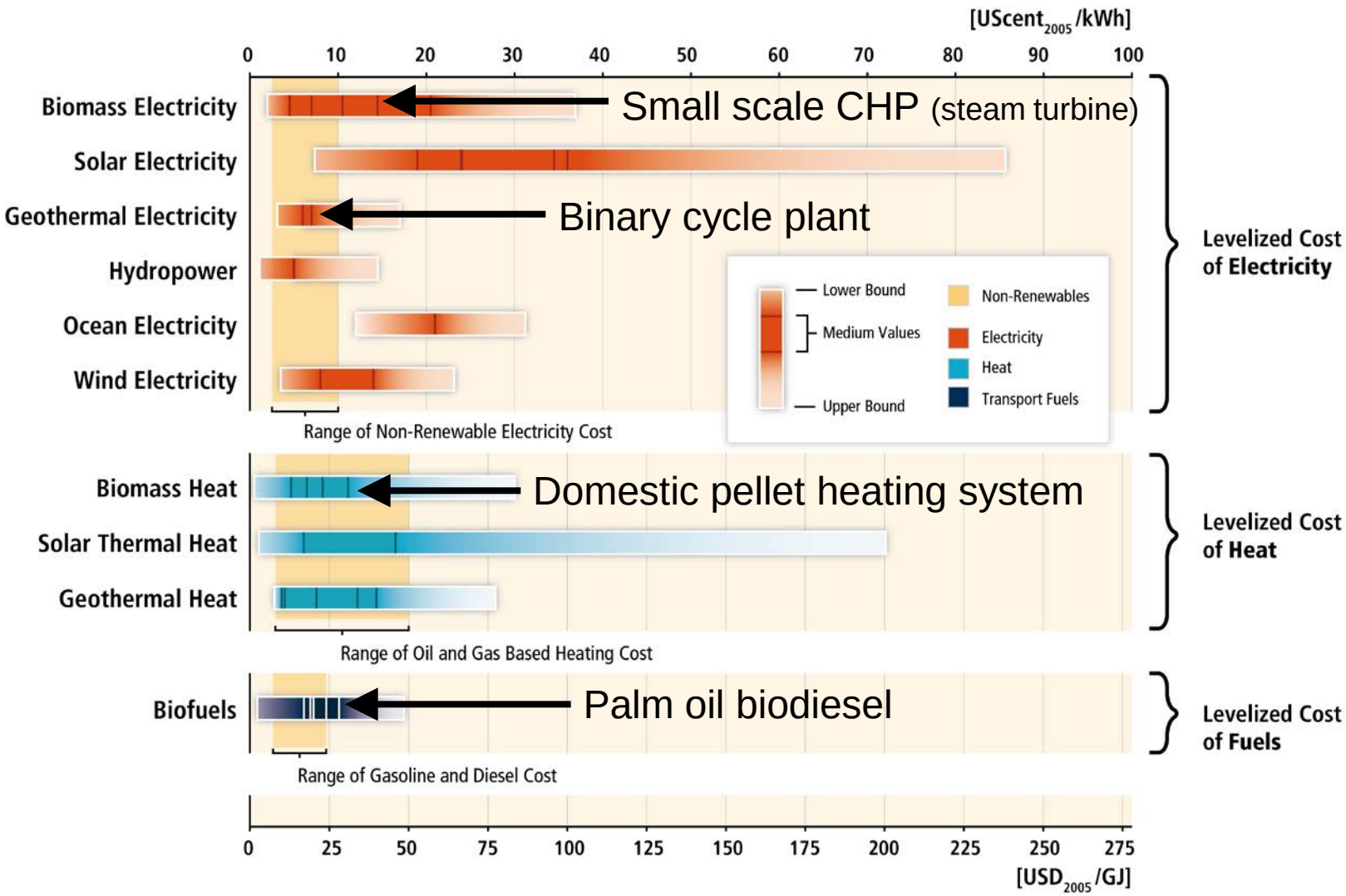
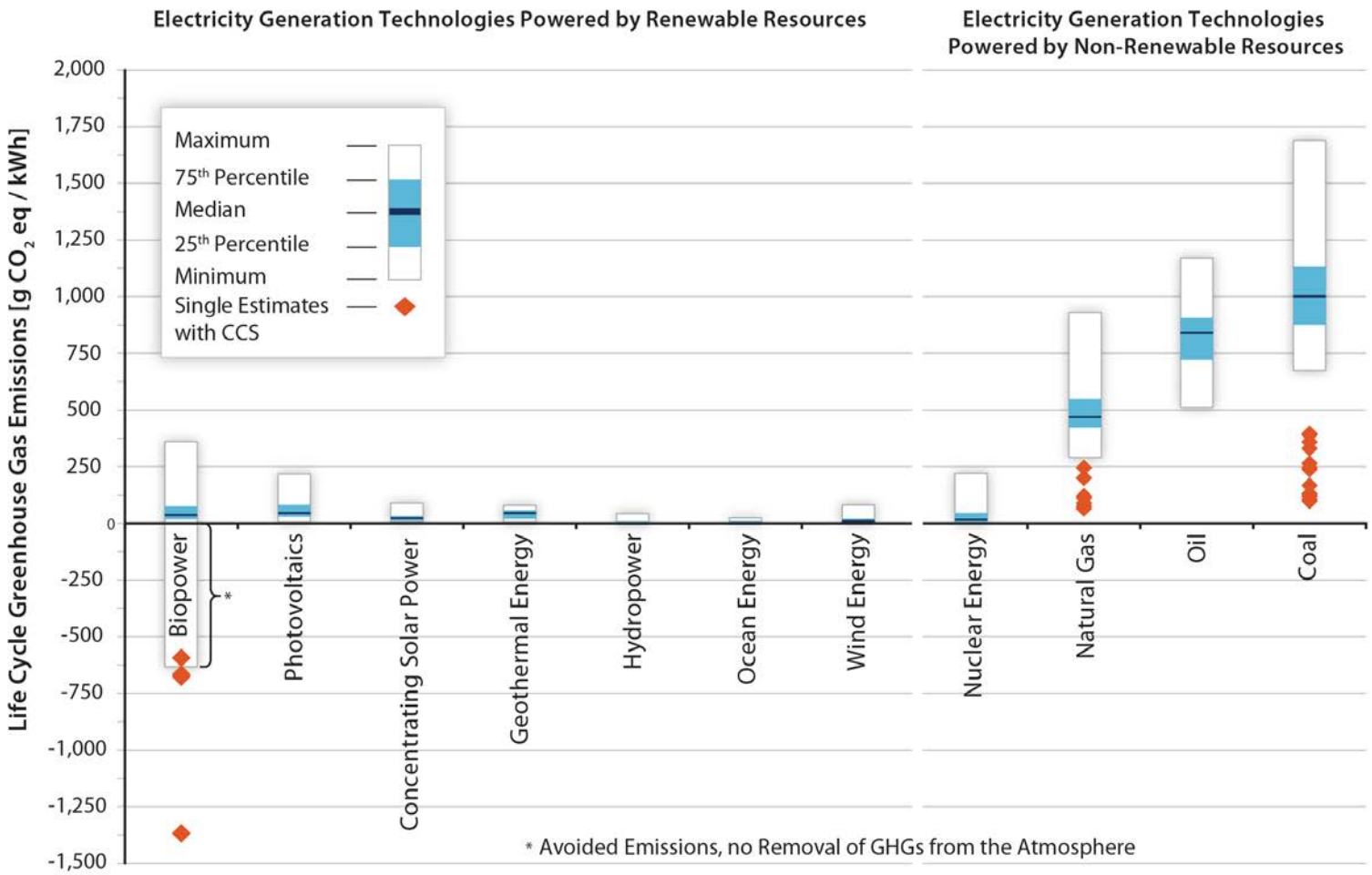
RE costs are still higher than existing energy prices, but in various settings RE is already competitive.



Lifecycle GHG emissions of RE technologies are, in general, considerably lower than those of fossil fuel options.



	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

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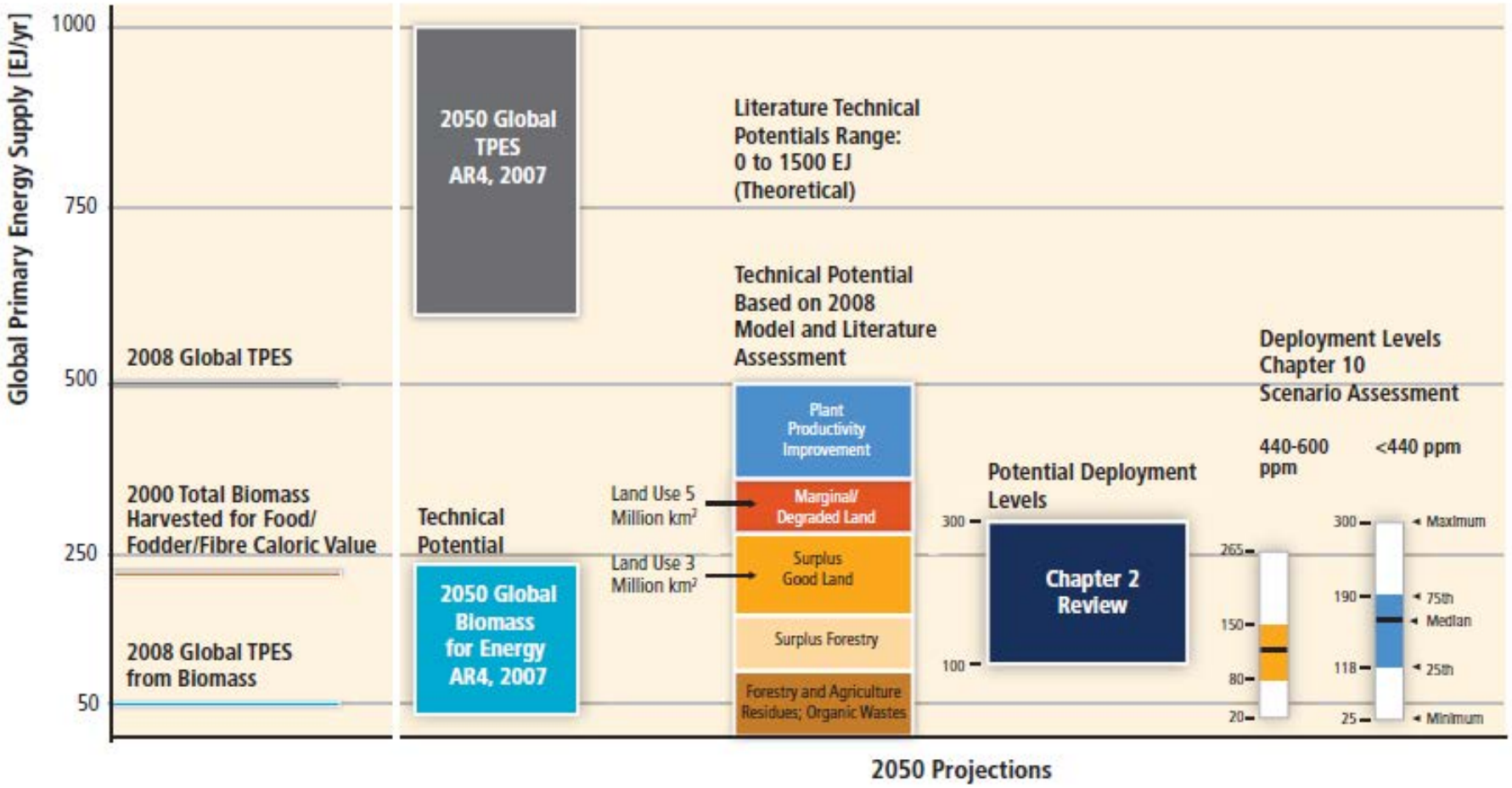
Ranges of terrestrial biomass for energy uses are broad. Complex systems with multiple uses and location resources and markets dependence



- Intensification of agricultural practices, e.g. grazing for pasture could release land in rain fed agriculture (~100 EJ)
- Significant penetration of bioenergy would require substantial (~x2) global agricultural yield increases
- Terrestrial resource potential assessments lack geo-hydrological modeling
- Aquatic biomass potential may be substantial compared conventional terrestrial energy crops but very uncertain
- Yield potential of cultivated of microalgae production can be several fold that of palm oil

INTERGOVERNMENTAL PANEL ON climate change

Biofuels Sustainability

A Maze

Regional Initiatives

EU RED - Renewable Energy Directive

European Committee for Standardization (CEN TC383)

National Initiatives *

The Netherlands Cramer Commission

NTA 8080

U.K. Low Carbon Vehicle Partnership Fuels

U.K. Renewable Transport Fuel Obligation (RTFO)

Stockholm Environmental Institute (SEI)

Sweden-Brazil and private sector; SEKAB Verified Sustainable Ethanol (VSE)

U.S. Renewable Fuel Standard (RFS)

California (US) Low Carbon Fuel Standard (LCFS)

U.S. Council on Sustainable Biomass Production (CSBP) Multistakeholder

German Biofuel Quota Law-Ordinance for Sustainability Requirements

International Sustainability and Carbon Certification System (ISCC)

Implementing Organization

International Bodies' Initiatives

FAO* * OECD* IDB IEA* IFC UNEP*

IDB Biofuels Sustainability Balanced Scorecard

2012 IFC Sustainability Framework

ISO TC248/13065 under development

Multistakeholder Voluntary Schemes

Many comply with ISEAL Alliance; Many NGOs: Rainforest Alliance, WWF, others are founders

Global

BonSucro (prior Better Sugarcane Initiative)

Greenergy

Biomass Biofuels voluntary scheme (2BSvs)

Roundtable on Responsible Soy (RTRS)

Roundtable on Sustainable Palm Oil (RSPO)

Roundtable on Sustainable Biofuels (RSB)

RSB Services Foundation

Intersystem acceptance for RED

***Enabling entities**

IEA Bioenergy tasks (multiple countries) LCA methodologies and sustainability expertise

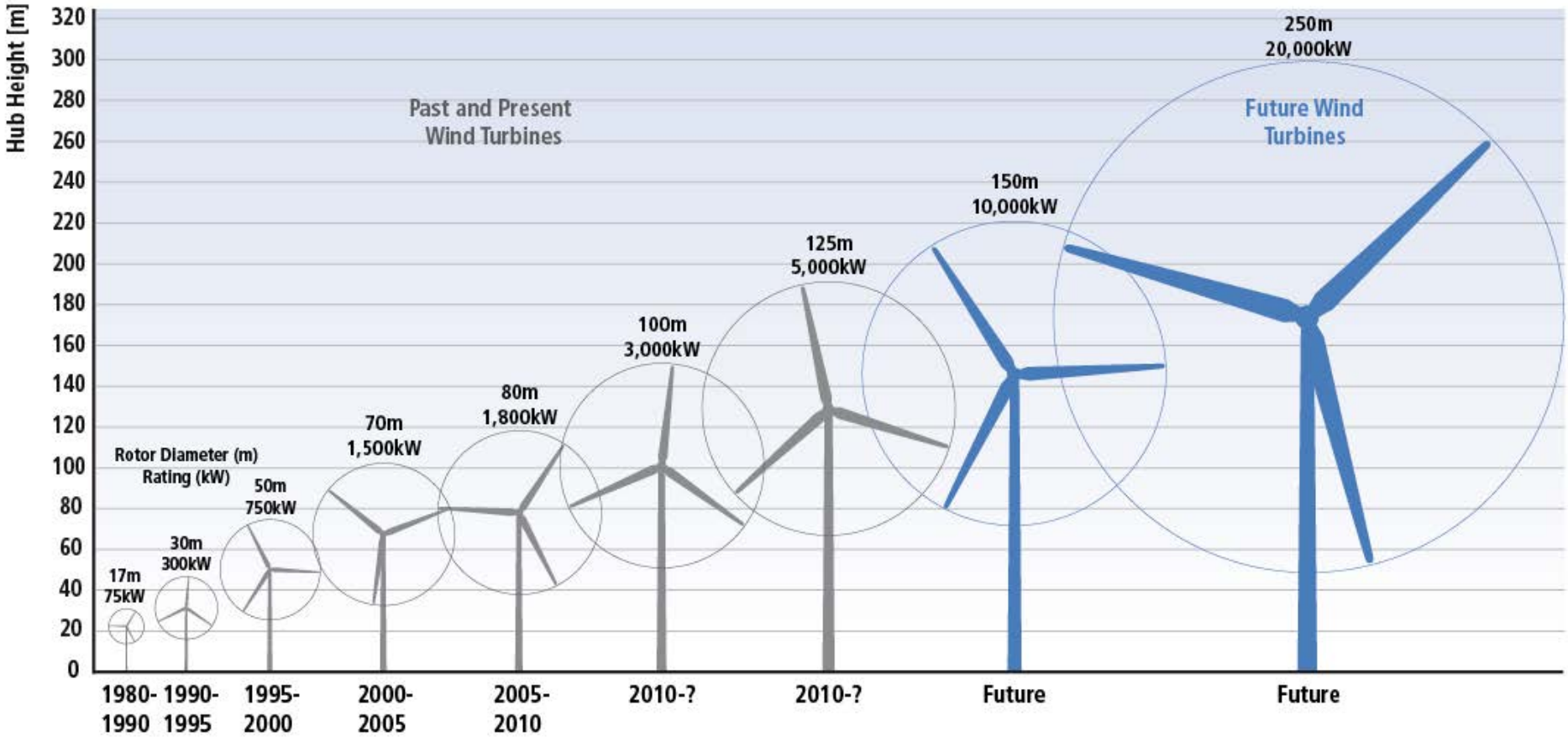
Global Bioenergy Partnership (GBEP) 2011: Sustainability themes and indicators

FAO- Germany: 2012 Bioenergy and Food Security Criteria and Indicators (BEFSCI) tools

* Australia has a Subnational, NSW

Source: NREL (Chum, Warner), UNICA

Technical Advancements: For instance growth in size of typical commercial wind turbines.



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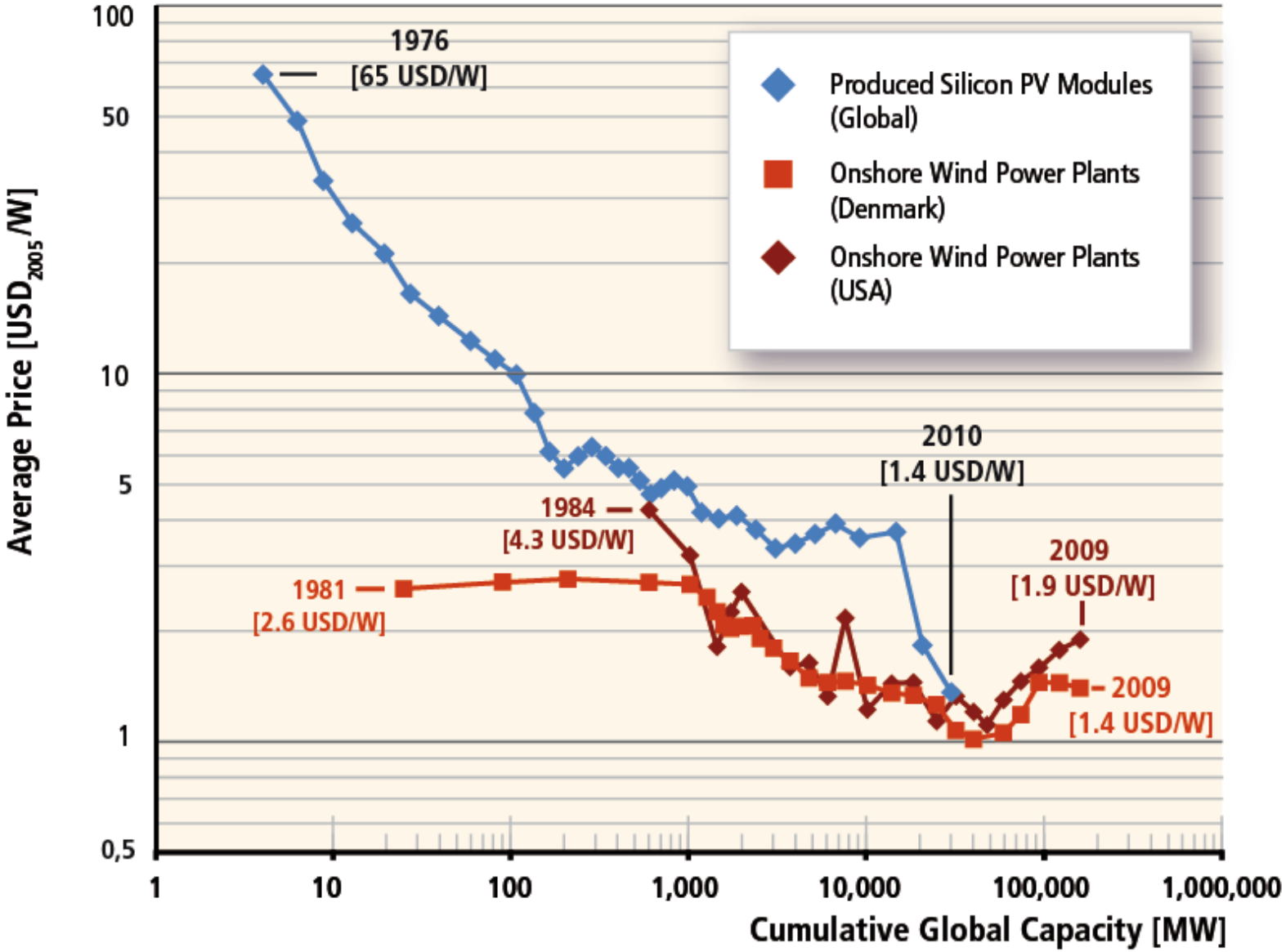
RE costs have declined in the past and further declines can be expected in the future.



Biofuel feedstock and fuel costs have declined for sugarcane (and corn) and ethanol from both sources

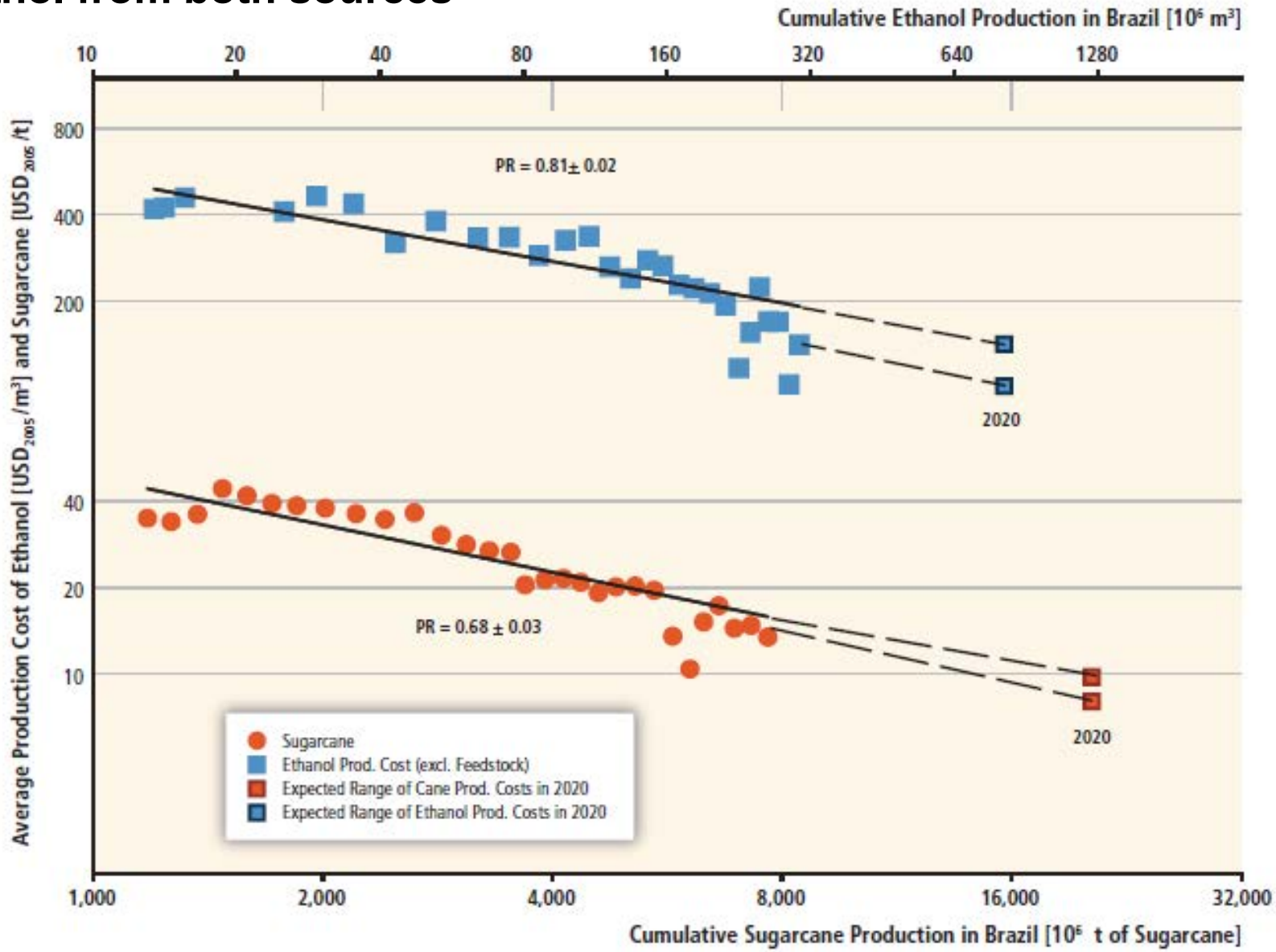
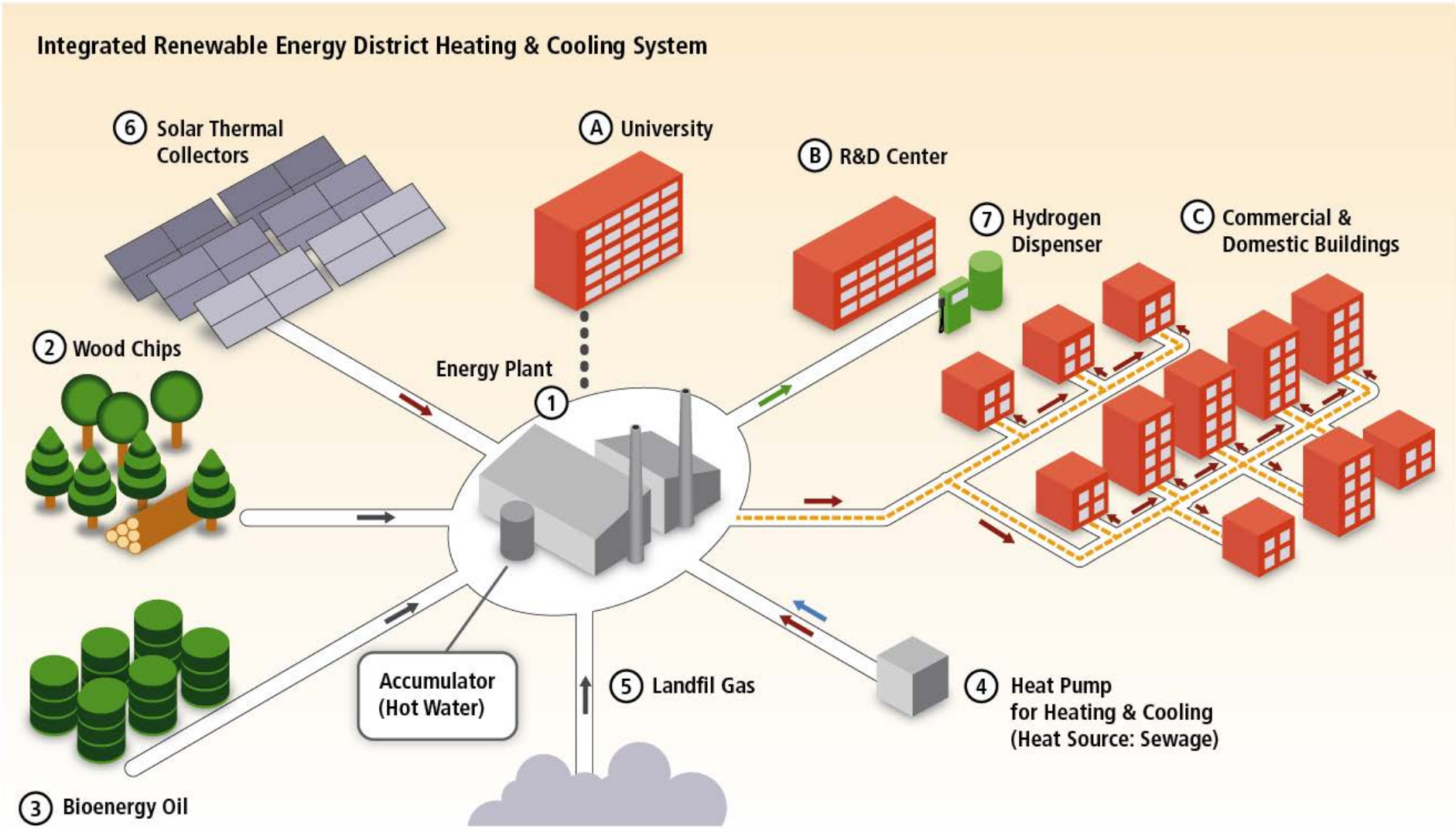


Figure 2.21 | Brazilian sugarcane and ethanol production cost learning curves for between 1975 and 2005 and extrapolated to 2020 (in USD_{2005}). Progress ratio (PR=1-LR) is obtained by best fit to data (van den Wall Bake et al., 2009; reproduced with permission from Elsevier B.V.).

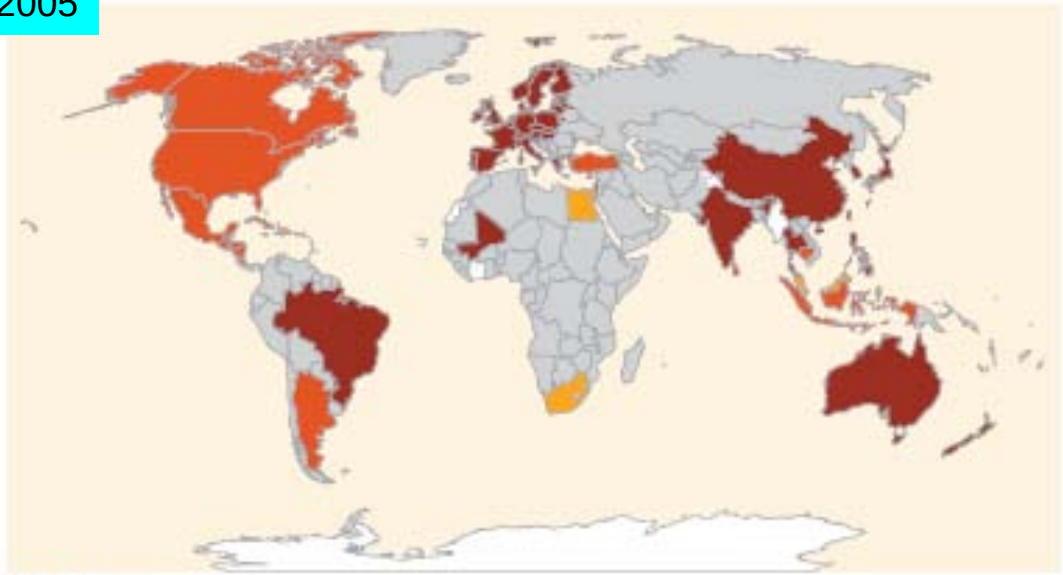
An integrated RE-based energy plant in Lillestrøm, Norway, supplying commercial and domestic buildings



Few, if any, fundamental technical limits exist to the integration of a majority share of RE, but advancements in several areas are needed.

- Transmission and distribution infrastructure
- Generation flexibility
- Energy storage technologies
- Demand side management
- Improved forecasting and operational planning methods

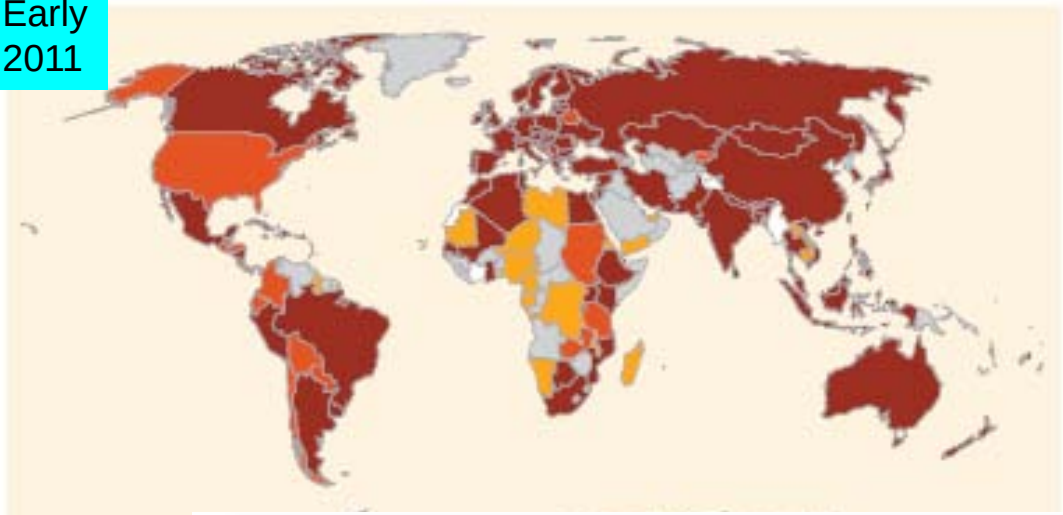
2005



Enabling Policies
Major Progress Drivers

Check the disappearing gray color: countries no RE-specific policy -- from top to bottom figures

Early 2011



Check the increase in orange to dark red: countries with RE-specific policies, targets or both from top to bottom figures

- Countries with at least one RE-specific Policy and at least one RE Target
- Countries with at least one RE-specific Policy
- Countries with at least one RE Target
- Countries with neither RE-specific Policies nor RE Targets

Figure 11.1 | Countries with at least one RE-specific deployment target and/or at least one RE-specific deployment policy in mid-2005 and in early 2011. This figure includes only national-level targets and policies (not municipal or state/provincial) and is not necessarily all-inclusive (RECIPES, 2005; REN21, 2005, 2010, 2011; CIPORE, 2011; Austrian Energy Agency, 2011; IEA, 2011; REEGLE, 2011; DSIRE, 2011).

Conclusion (I)

- High deployment rates are consistent with increasing energy access for the world‘s poor population, improved security for energy supply and human well-being
- Renewables have exhibited technological progress which led to decreasing costs
- The costs of integration in an existing energy system are not quantified yet.
- Climate and renewable energy policies can be designed in a consistent way.

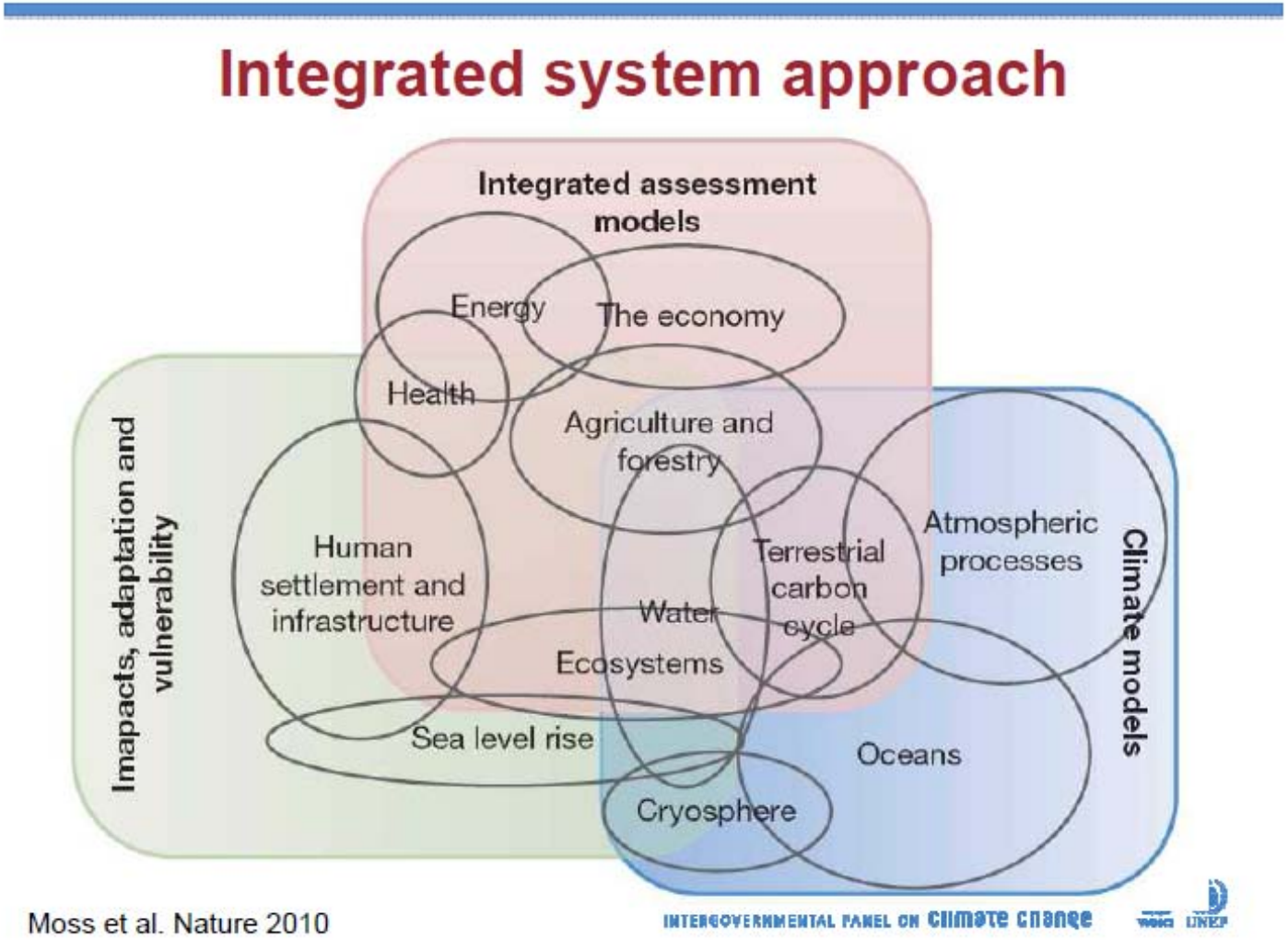
Conclusion (II): Dealing with unknown unknowns

- The existing scientific knowledge is significant and can already facilitate the decision-making process.
- The report has identified the most important known unknowns (e.g. future cost and timing).
- However, the unknown unknowns require the flexibility to learn from experience and to adapt to inconvenient and convenient experiences.

Report posted at: http://www.ipcc-wg3.de/publications/special-reports/

Analysis continues

- 5th IPCC Assessment Report



Thanks

- SERI/NREL Directors and mentors, staff of many areas I worked with: Hub Hubbard, Duane Sunderman, Robert Stokes, Dan Arvizu, Dale Gardner and many others
- DOE/EERE Alison Goss Eng and many others
- ACS – I&EC and Cellulose Divisions over time since 1980, ACS Council, CEI, Nina McClellan, and many others
- Hydrogen Technical Advisory Panel members, and NAS/NAC bilateral US-China members
- IPCC – SRREN colleagues and WGIII dozens
- IEA Bioenergy Agreement and colleagues
- University of Sao Paulo, State University of Campinas, Brazilian government biofuels, S&T…
- Professor P. Krumholz, Thesis Professor and successful industrialist in Brazil for teching me to love the basic, applied, industrial, and global aspects of chemistry.