Training Module on Renewable Energy Technology, Policy & Integration

Caspian Energy Policy Dialogue and Training
Astana, Kazakhstan
3 – 5 July 2012

Hugo Chandler, M.Sc.
For the International Energy Agency

Programme for July 5th

- Morning sessions
  1. RE technologies in the three end-use sectors
     - Electricity
     - Heat
     - Transport
  2. Policy design to support deployment

- Afternoon sessions
  3. System integration: challenges and solutions

  4. Best practice in selected countries

Session 1: Introduction to Renewable Energy

Technology, markets and economics

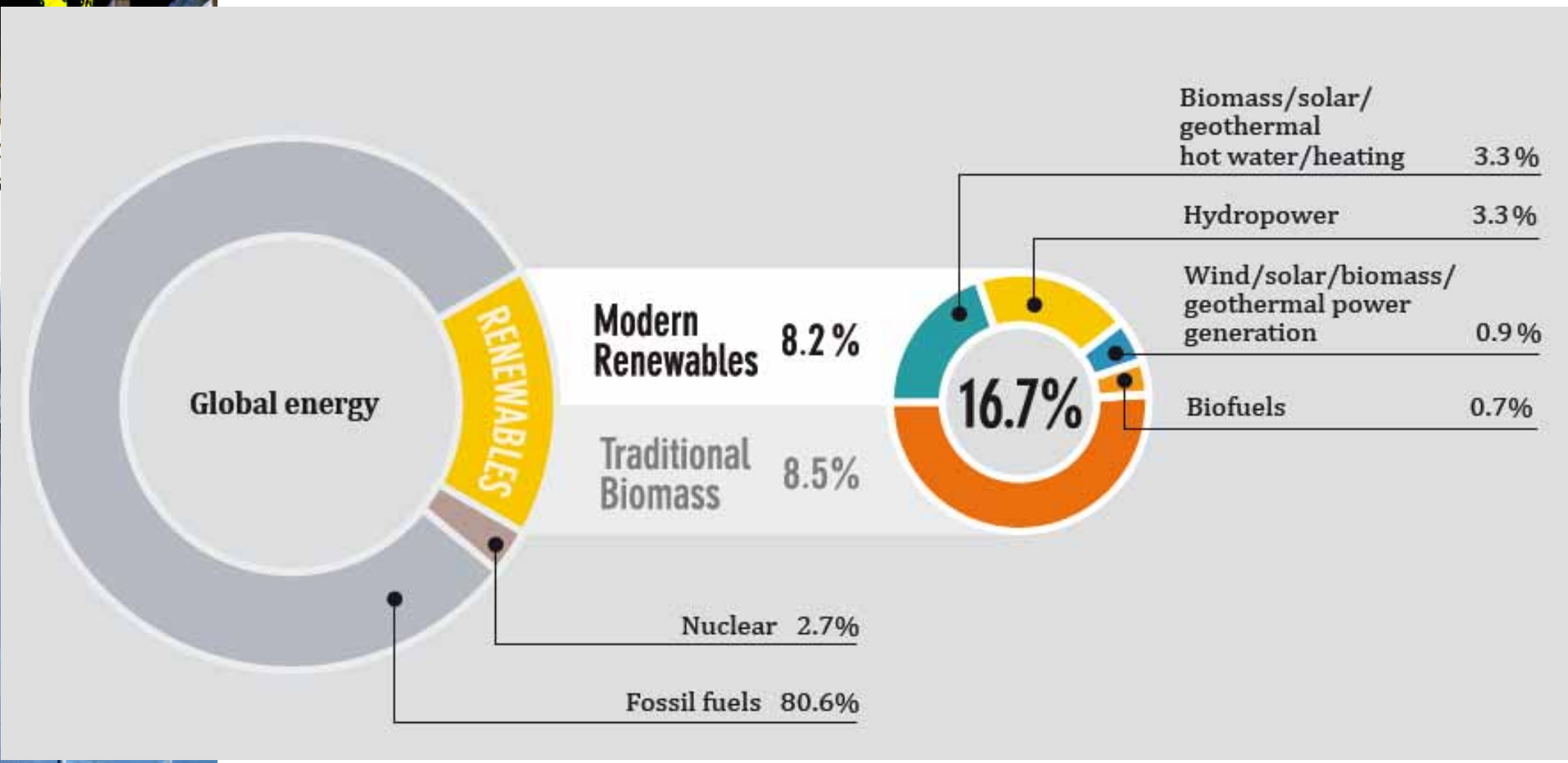
Why should we care about renewable energy?

- Economic development
  - Promise of least cost energy
  - Optimisation of hydrocarbons use
    - What is the opportunity cost of burning hydrocarbons
  - Access to energy
- Energy security, instead dependence
- Environmental protection
  - Reducing emissions of greenhouse gases
  - Local environment: air, soil, water

How much so far?

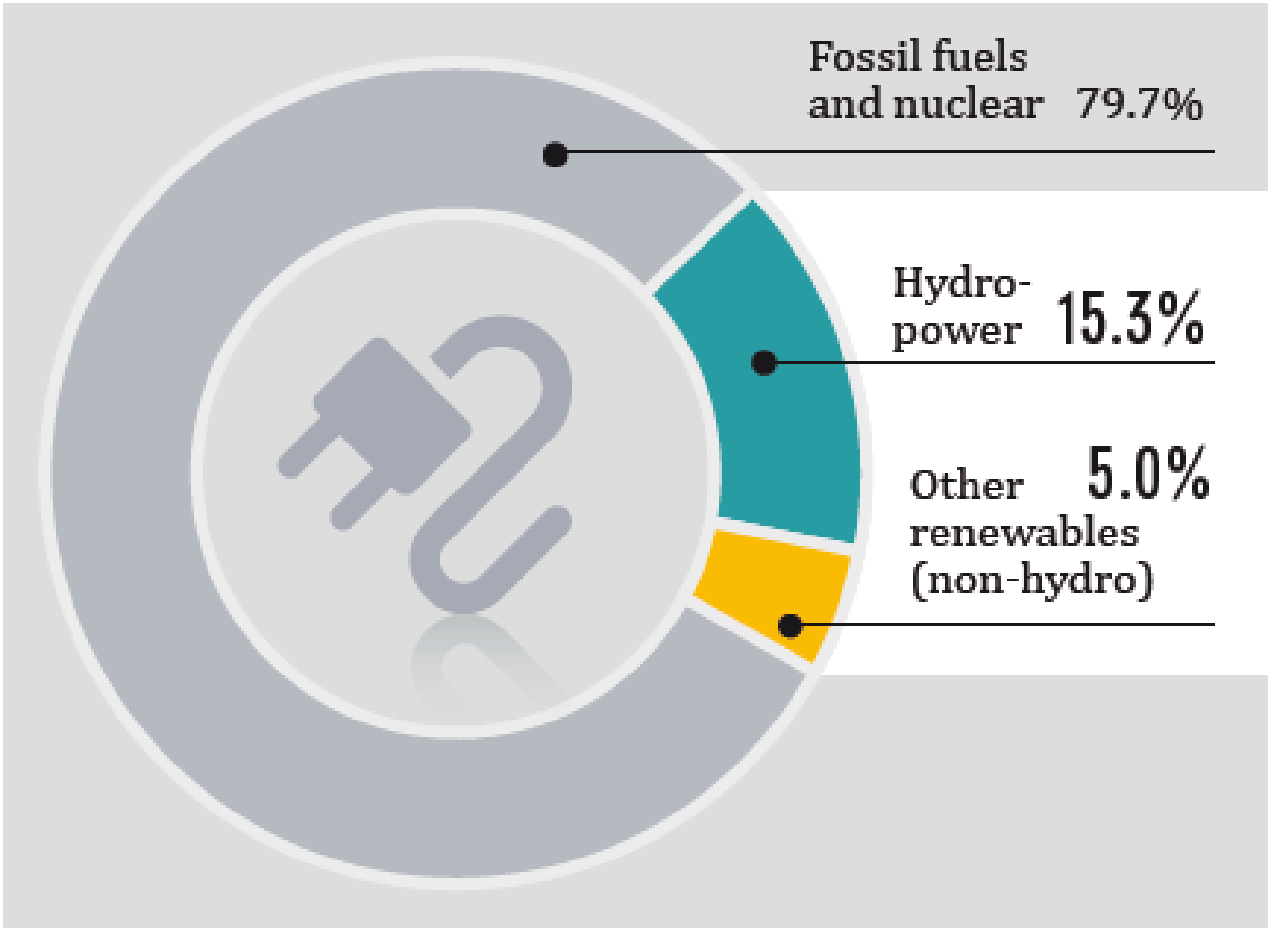
Market shares and growth

RE share of ALL ENERGY consumed (2010)



REN21 Renewable Energy Global Status Report 2012

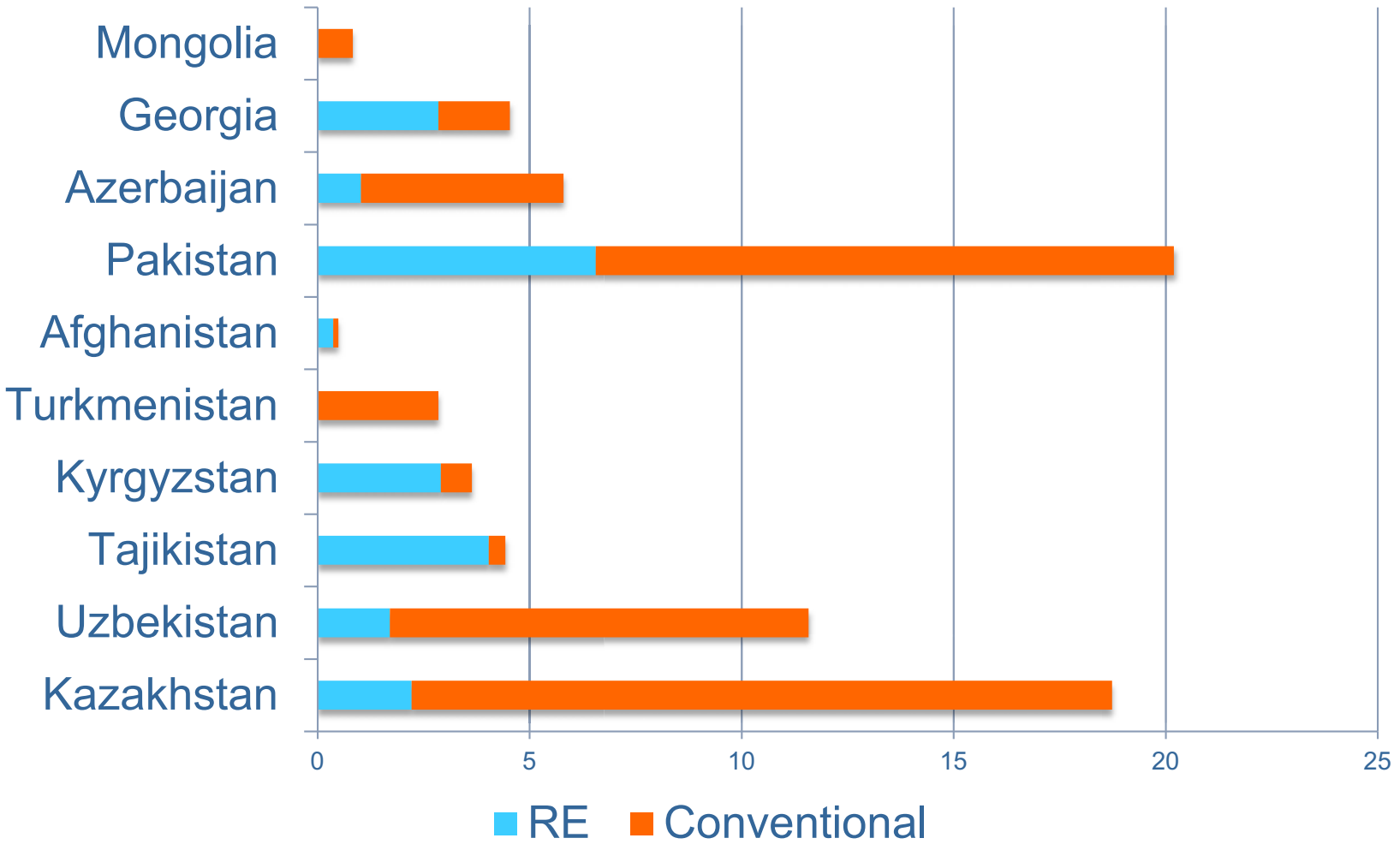
Renewable share of global ELECTRICITY



REN21 Renewable Energy Global Status Report 2012

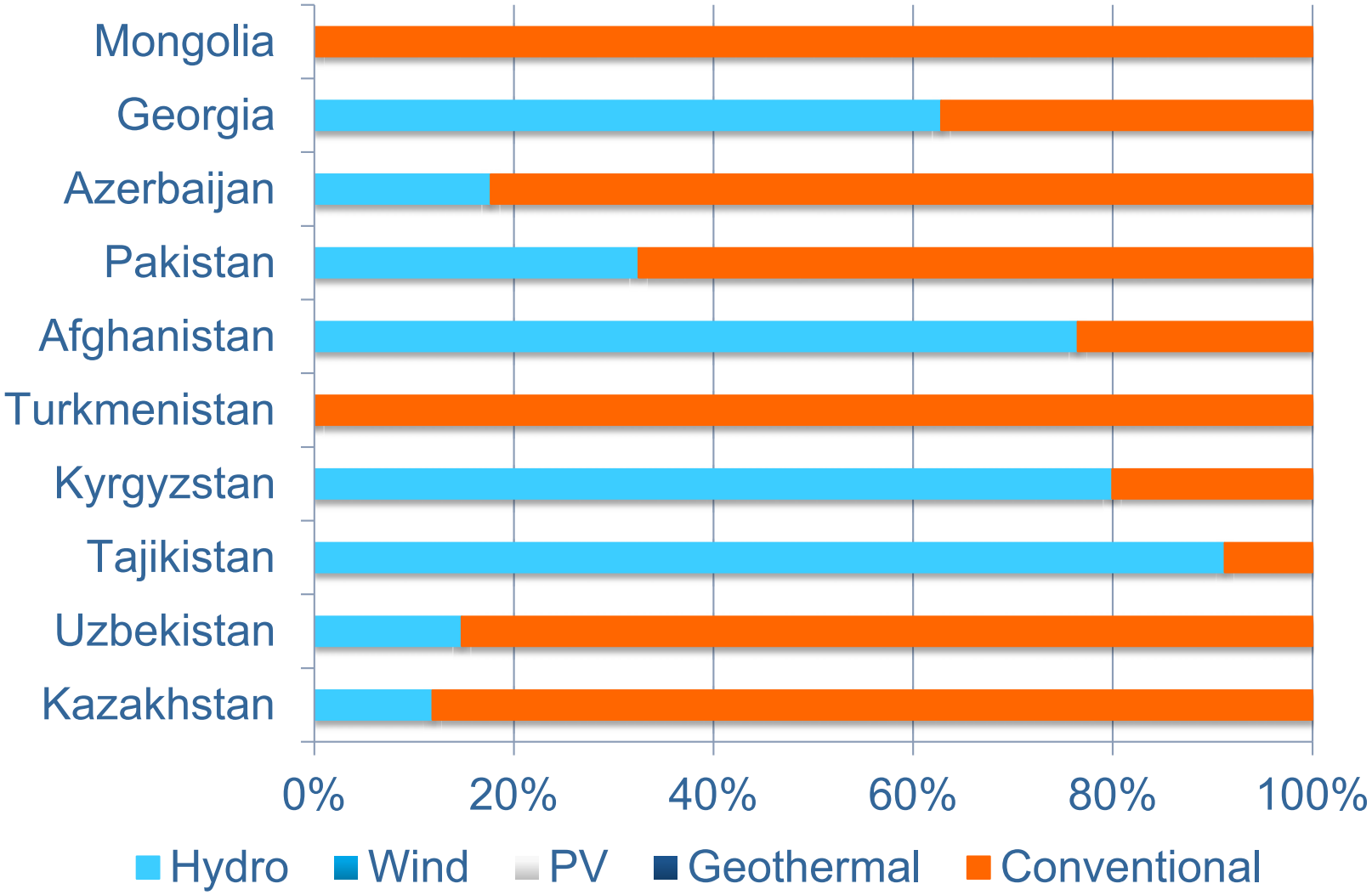
Nearly half of all capacity installed in 2011 is renewable!

Installed capacity: Central & West Asia

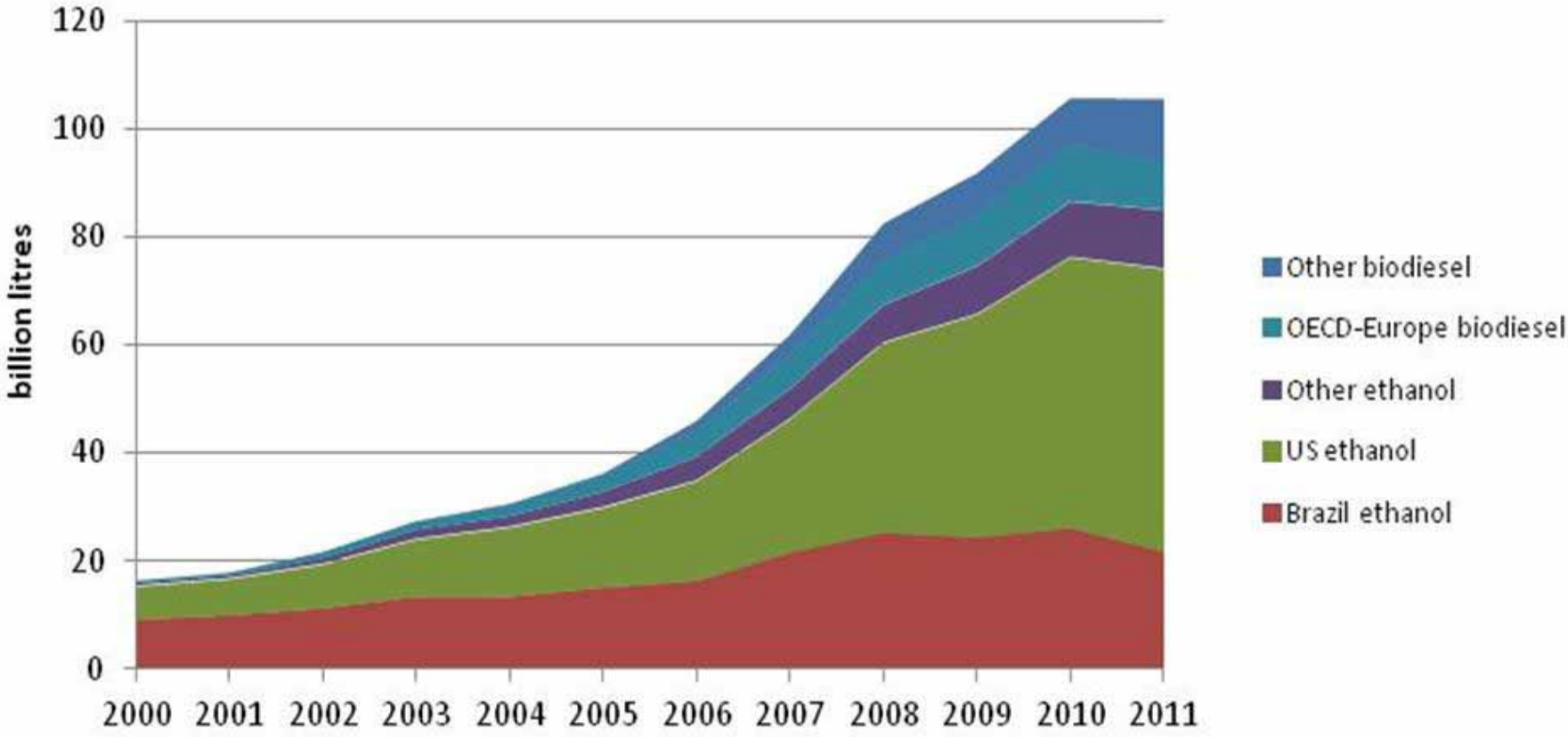


Data: 2009 DoE

Shares of renewables and conventionals

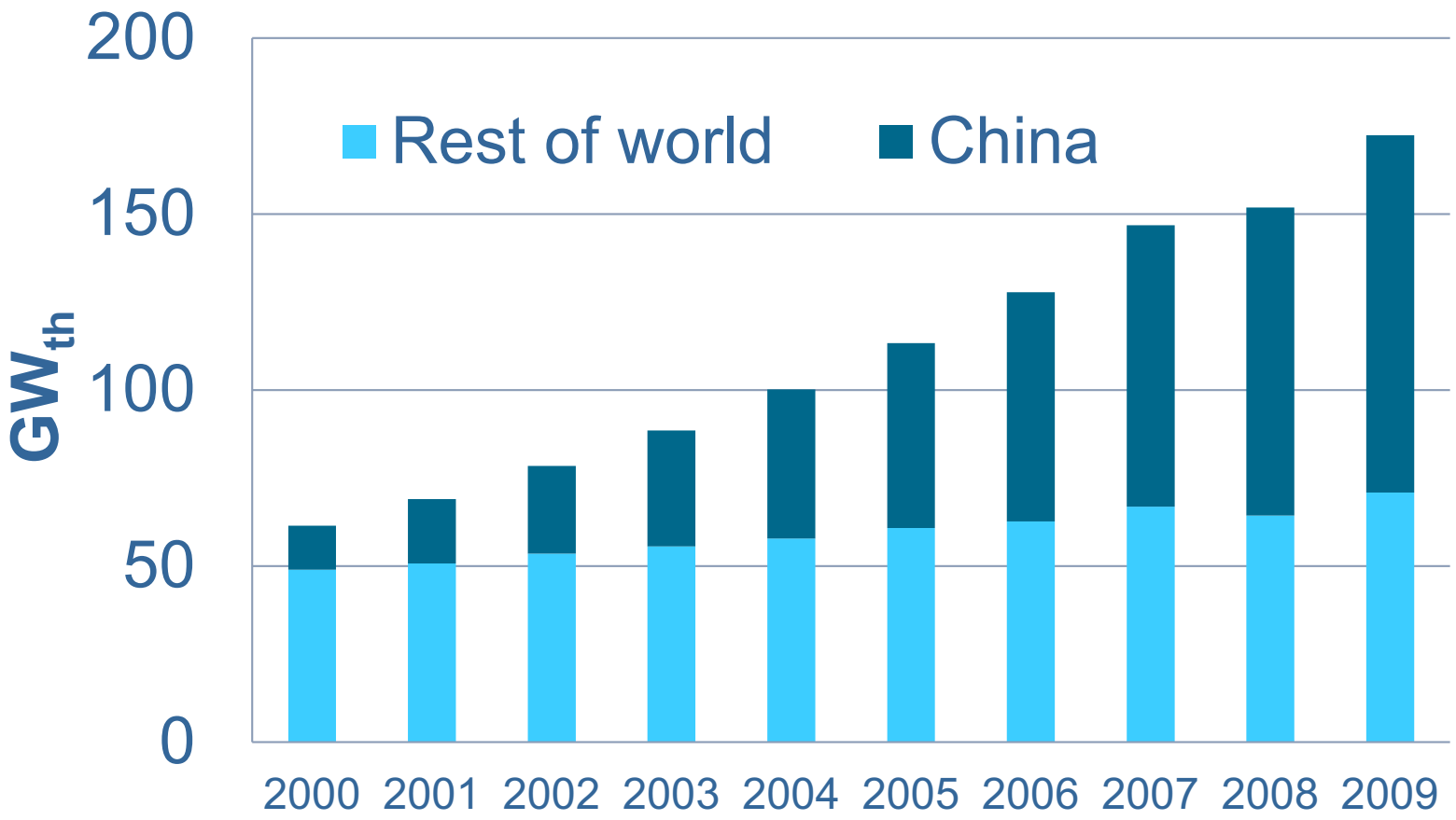


Renewable TRANSPORT



- 3% share of road transport in 2011
- Average annual growth of 26%
- Focused in Brazil, US, EU

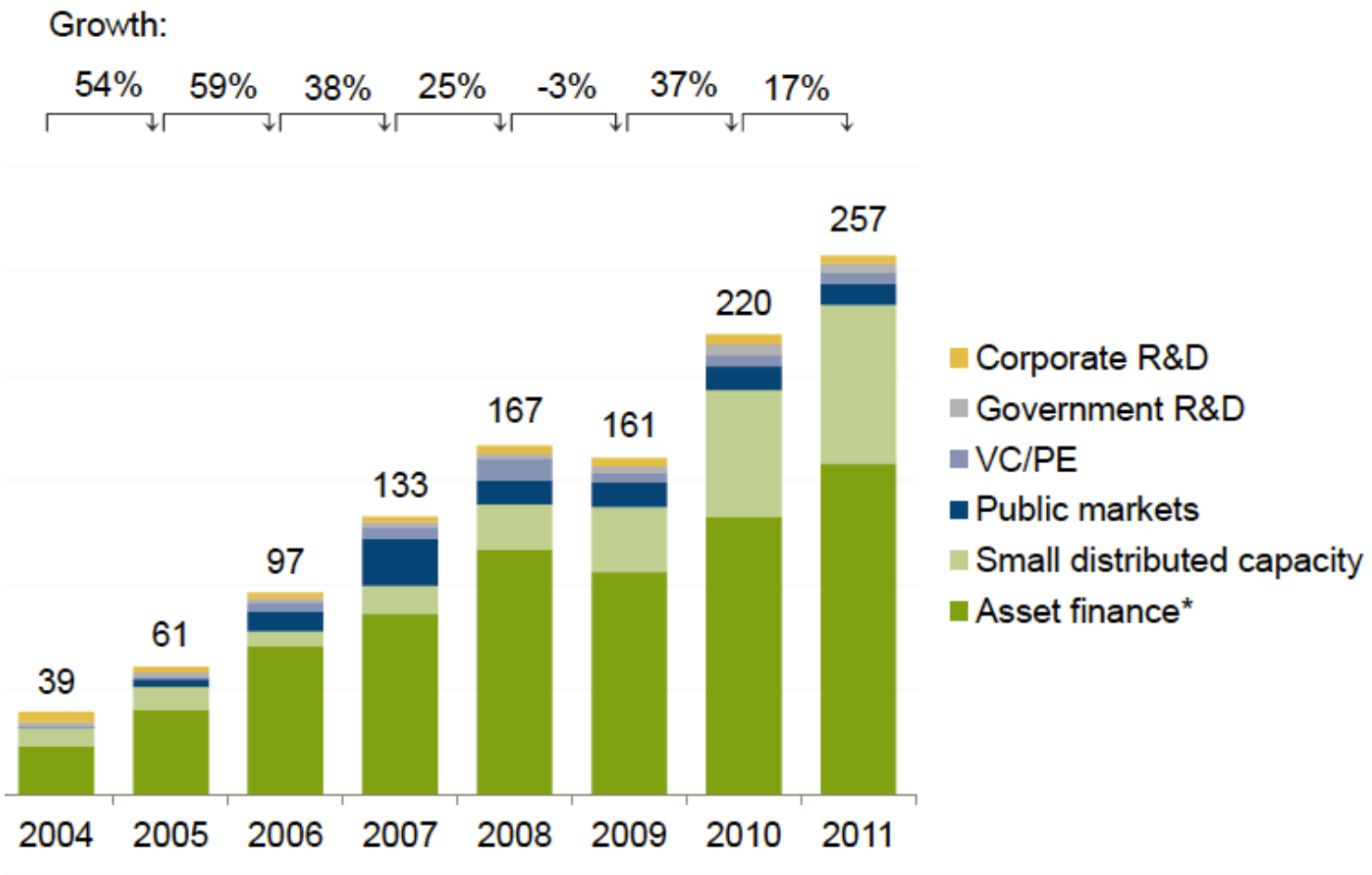
Renewable HEAT



- Rapid growth in solar water heating
- Mainly in China

Investment

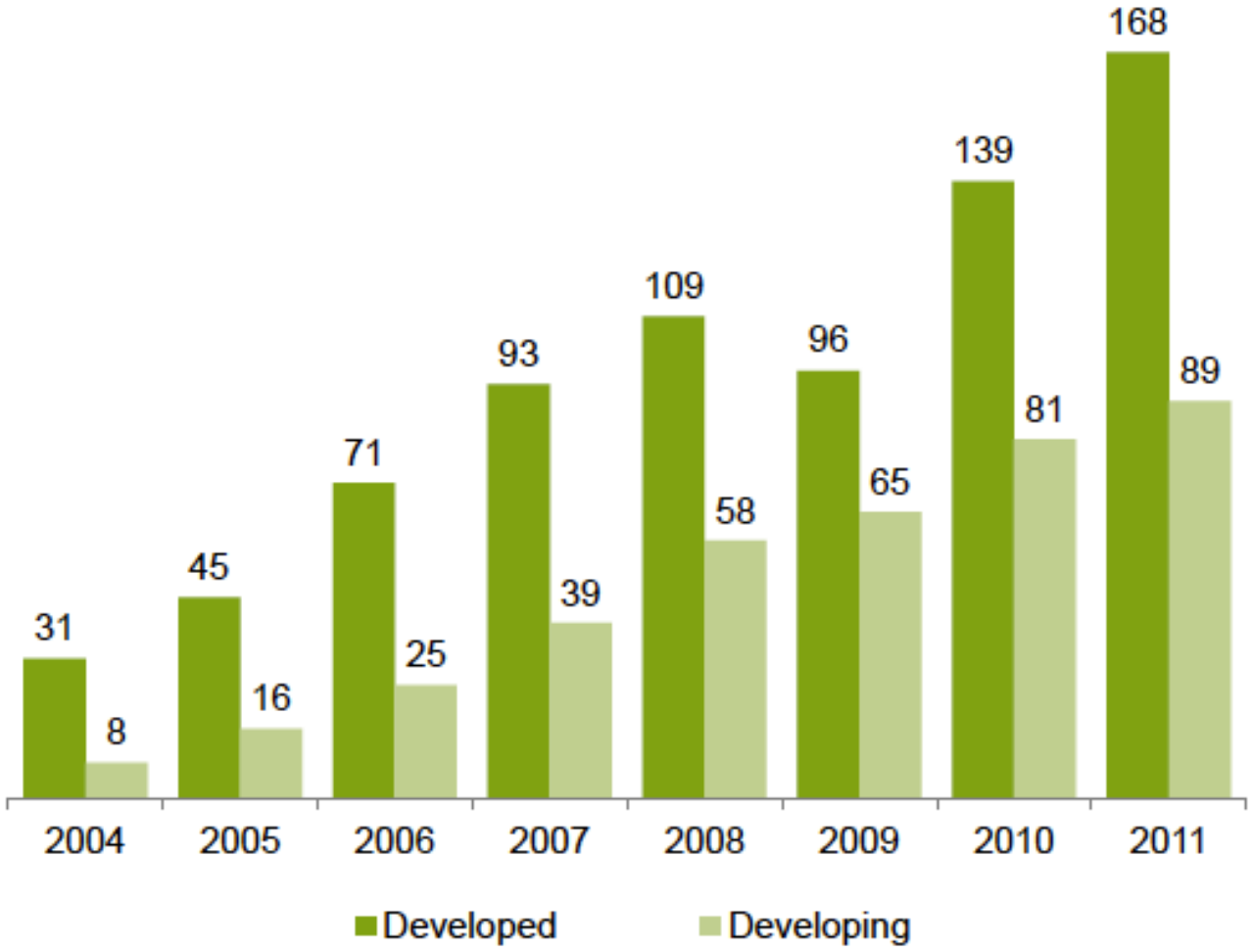
Annual new investment in RE



Market six times bigger than 7 years ago!

UNEP/ BNEF Global Trends in Renewable Energy Investment 2012

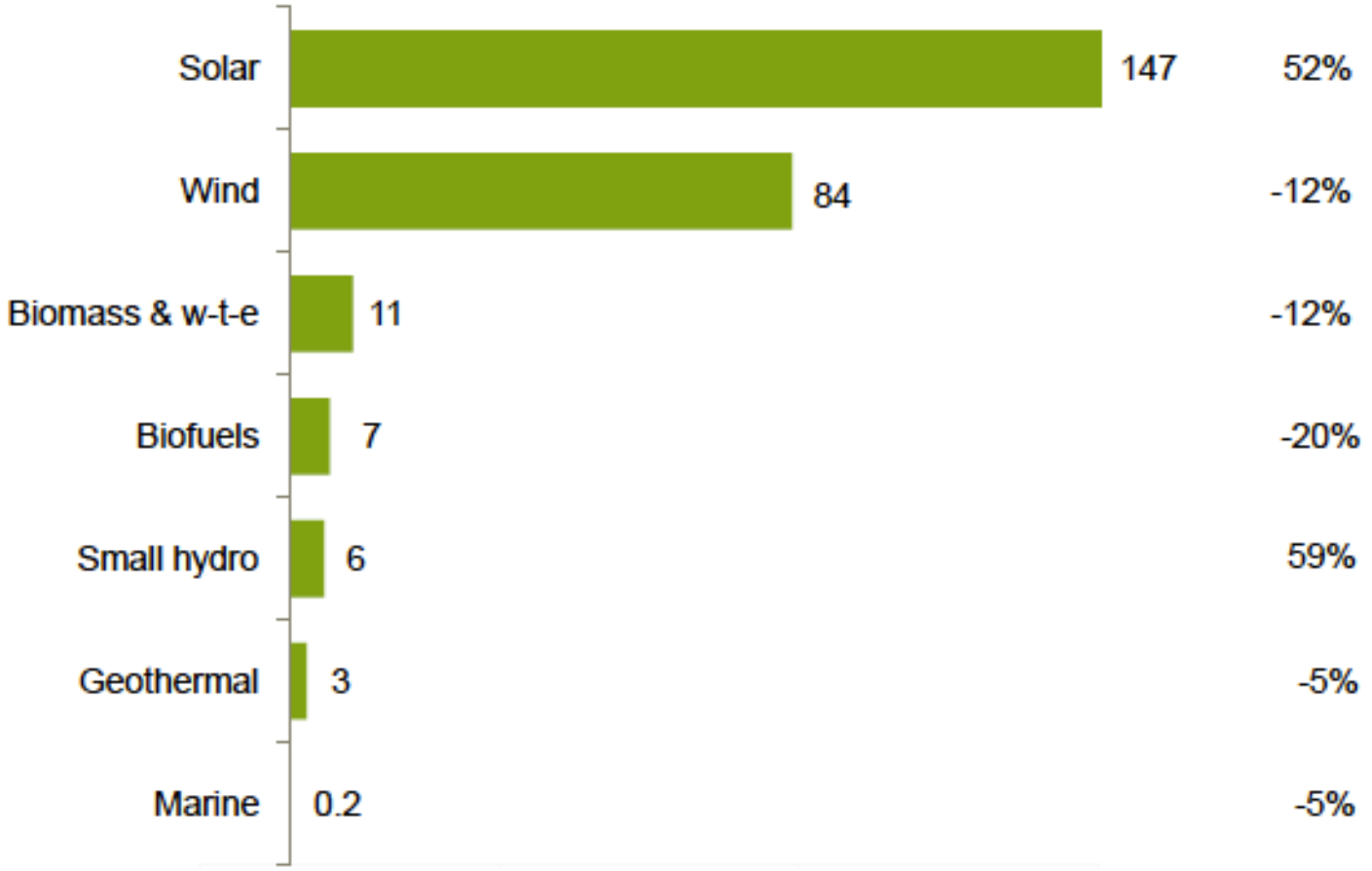
Developed & developing spend 2011



Developing countries are accelerating faster

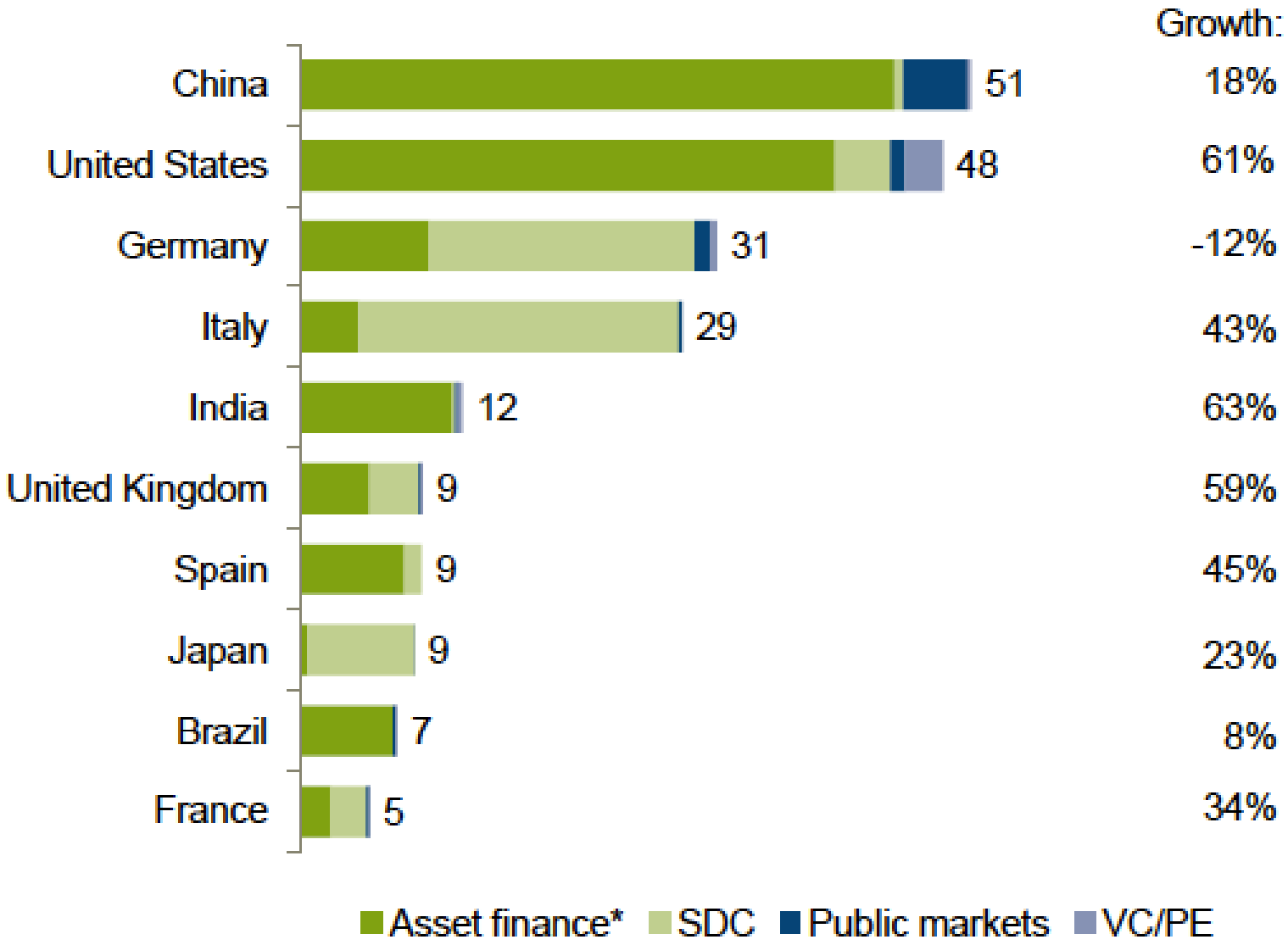
UNEP/ BNEF Global Trends in Renewable Energy Investment 2012

New investment by tech 2011



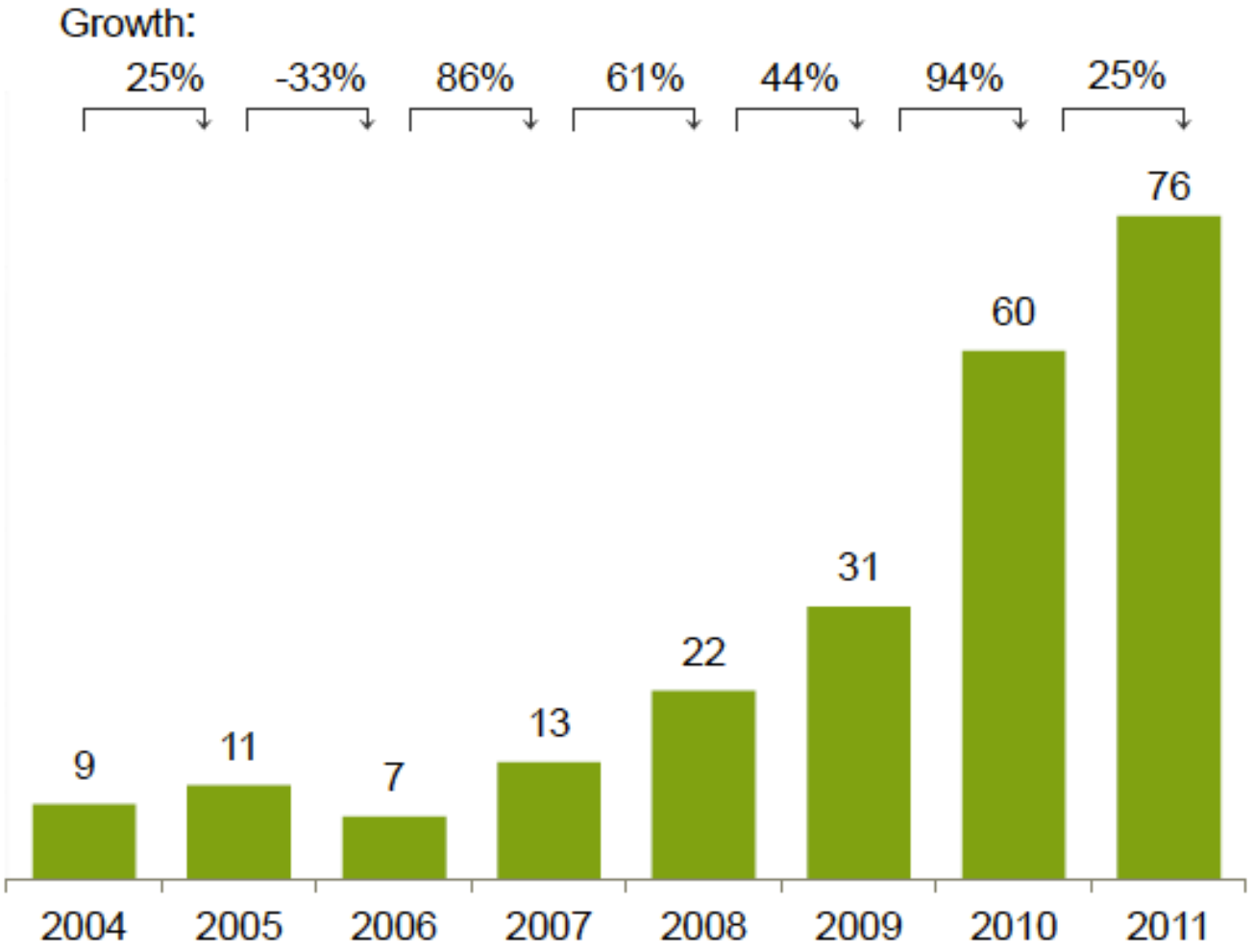
UNEP/ BNEF Global Trends in Renewable Energy Investment 2012

New investment by country 2011



UNEP/ BNEF Global Trends in Renewable Energy Investment 2012

New investment distributed tech



UNEP / BNEF Global Trends in Renewable Energy Investment 2012

The renewable energy technology family

Renewable energy technologies

- Bioenergy
  - Bioenergy for electricity and heat
  - Biofuels
- Geothermal energy
- Hydro energy
- Marine energy
- Solar energy
  - Solar PV
  - Concentrating solar power
  - Solar heating
- Wind energy
  - Onshore
  - Offshore


Renewable electricity technologies
© OECD/IEA 2011

Hydropower

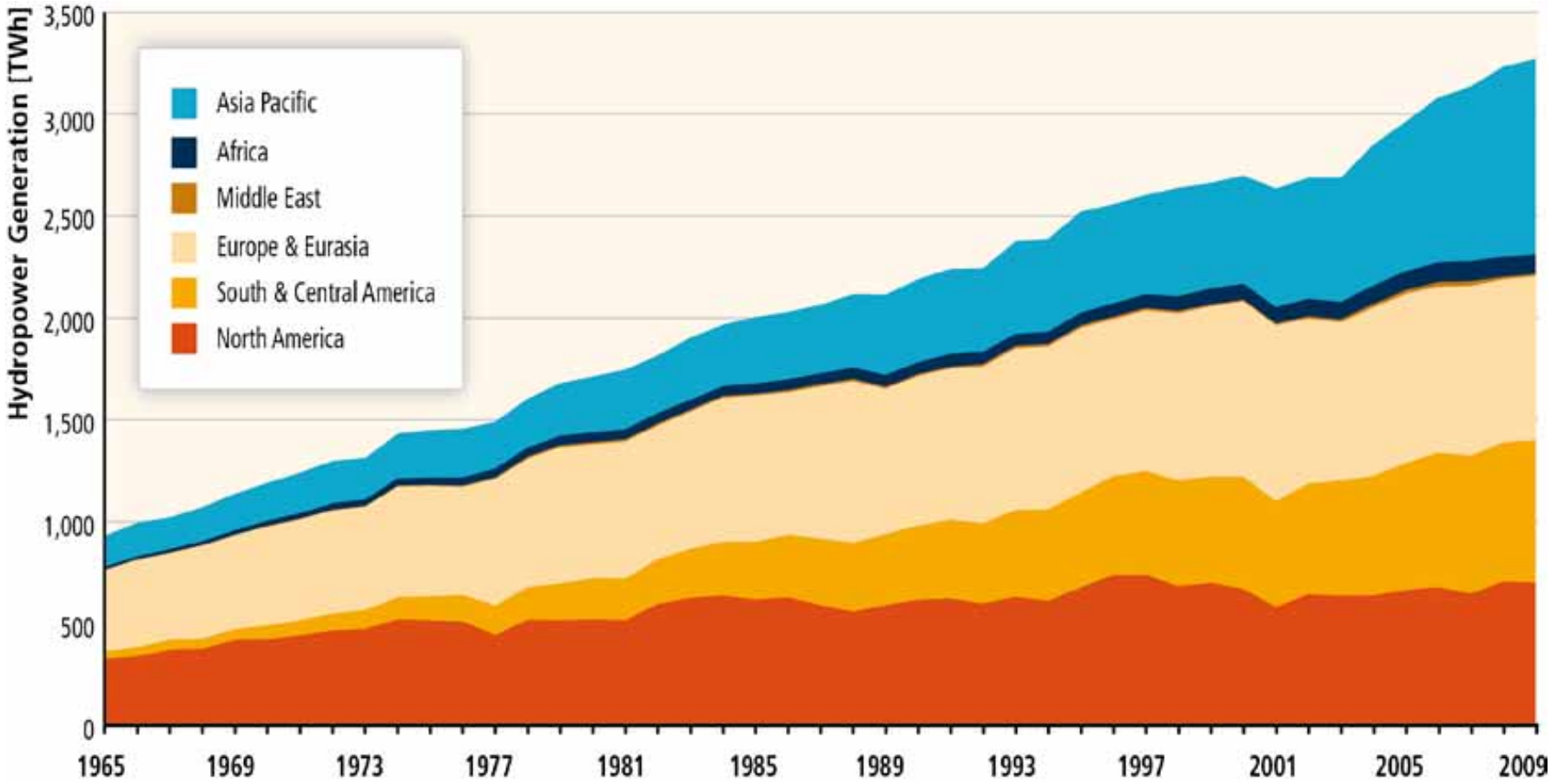
Hydropower

- Run-of-river plants
- Reservoir plants
- Pumped-hydro plants

Hydropower drivers and challenges

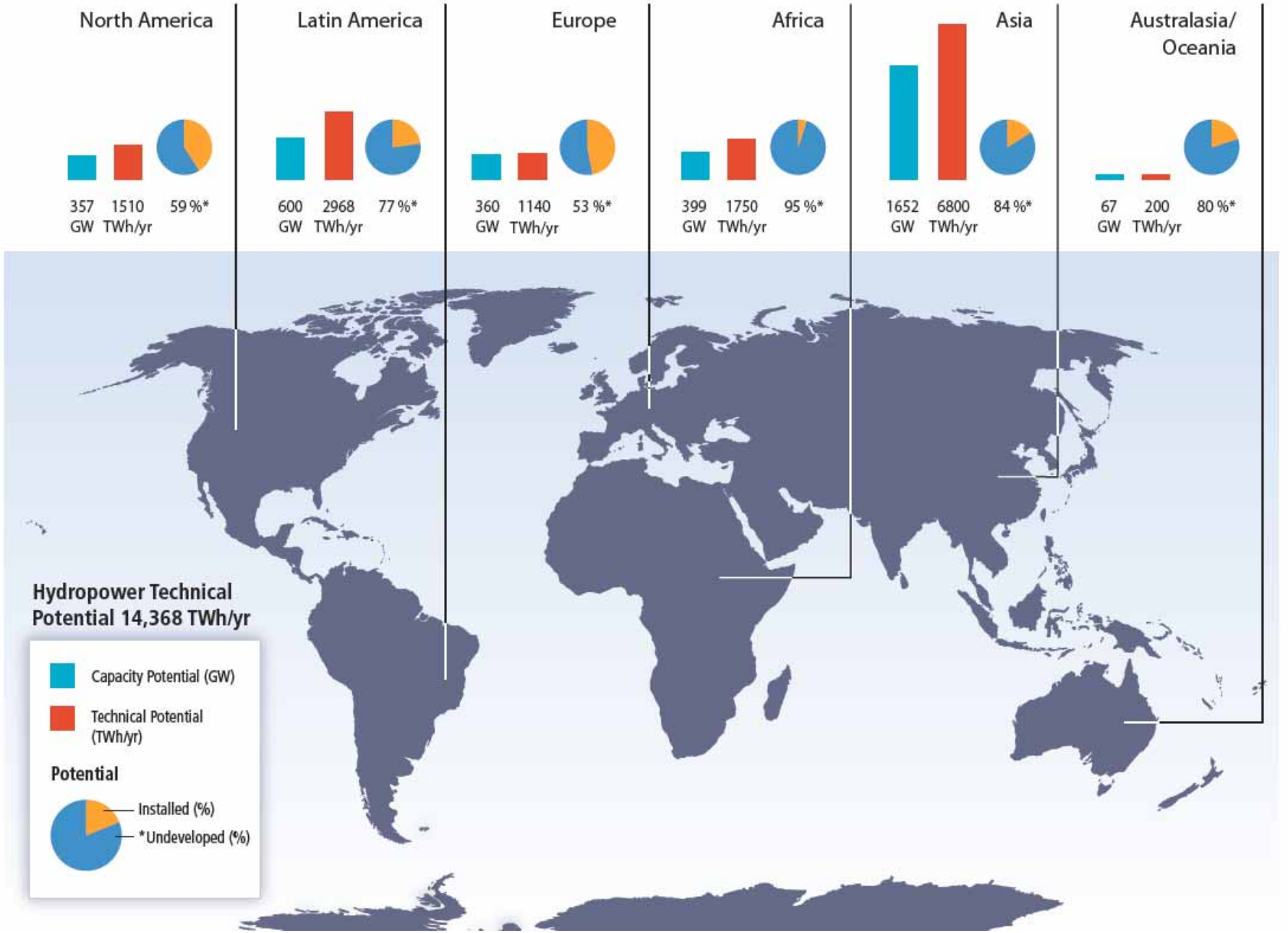
- Specific drivers
  - Multipurpose water resource management
    - Irrigation, flood protection, electricity generation
  - Affordability
  - Energy security
  - Balancing wind / solar PV output
- Challenges
  - Population resettlement and acceptance
  - Environmental impact

Hydropower is well known and fully mature



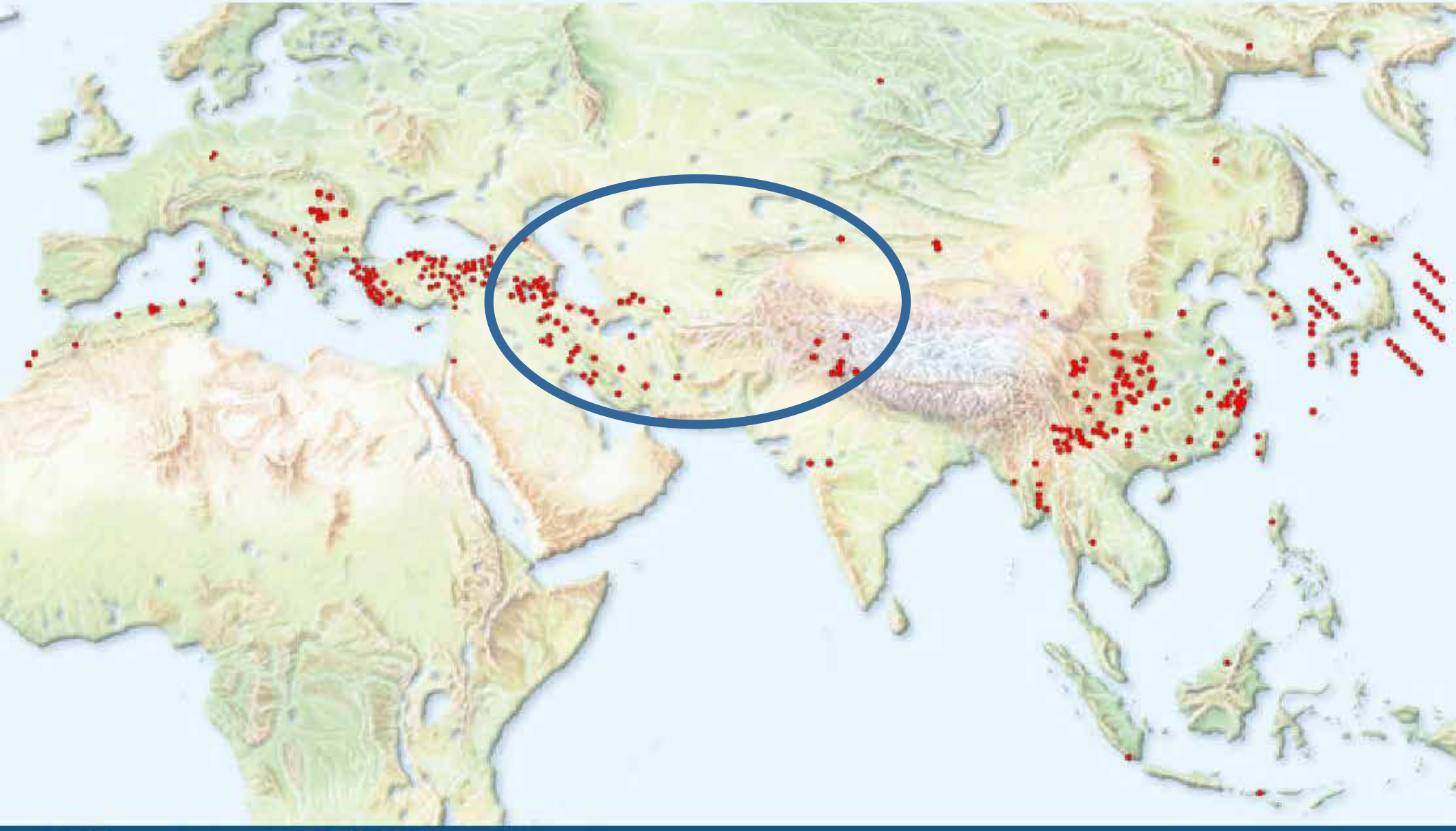
15% of global electricity

But only a quarter of potential tapped to date



Nearly 400 major dams (>60m high) under construction worldwide

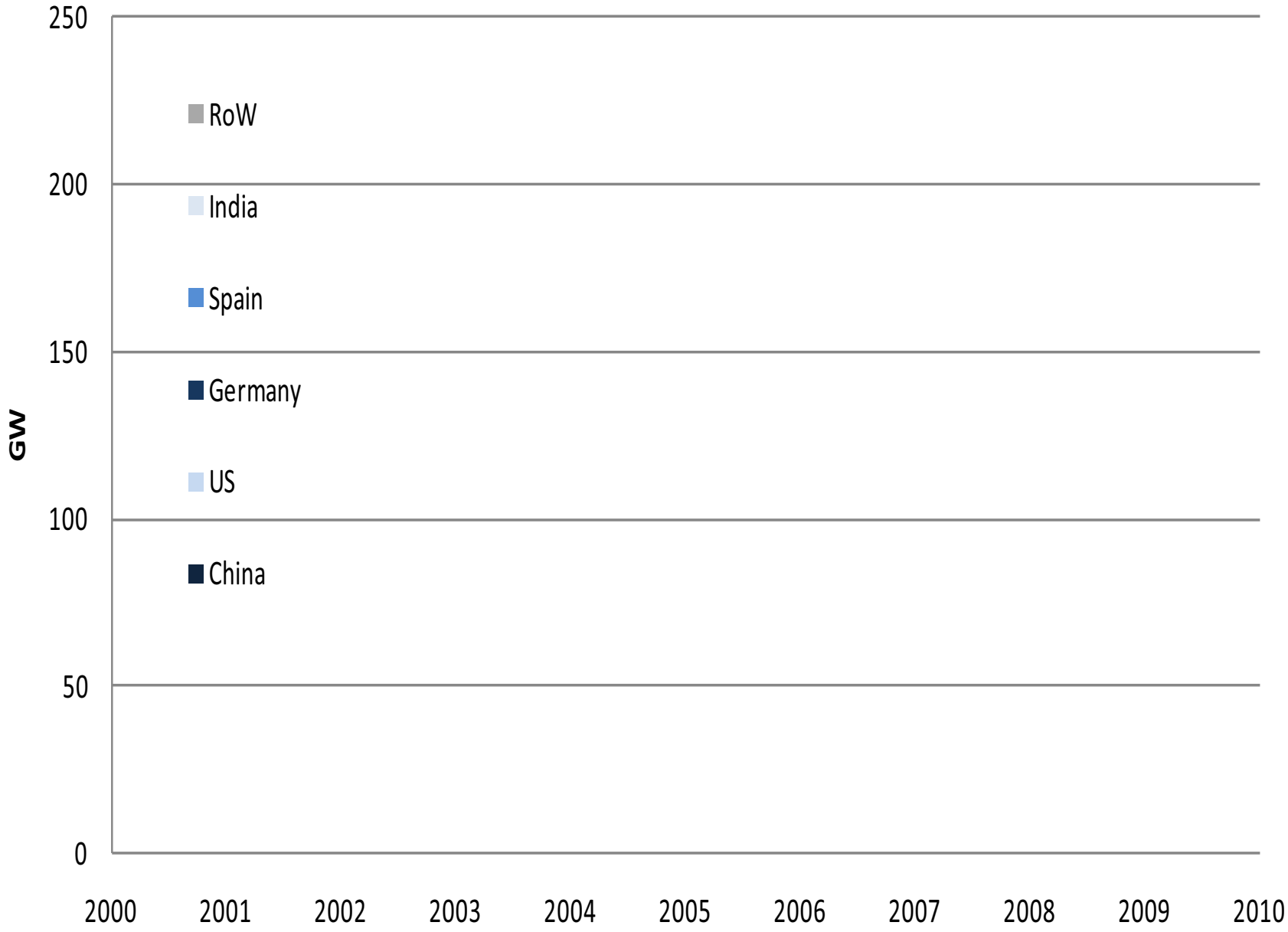
More than 60 per cent are multipurpose



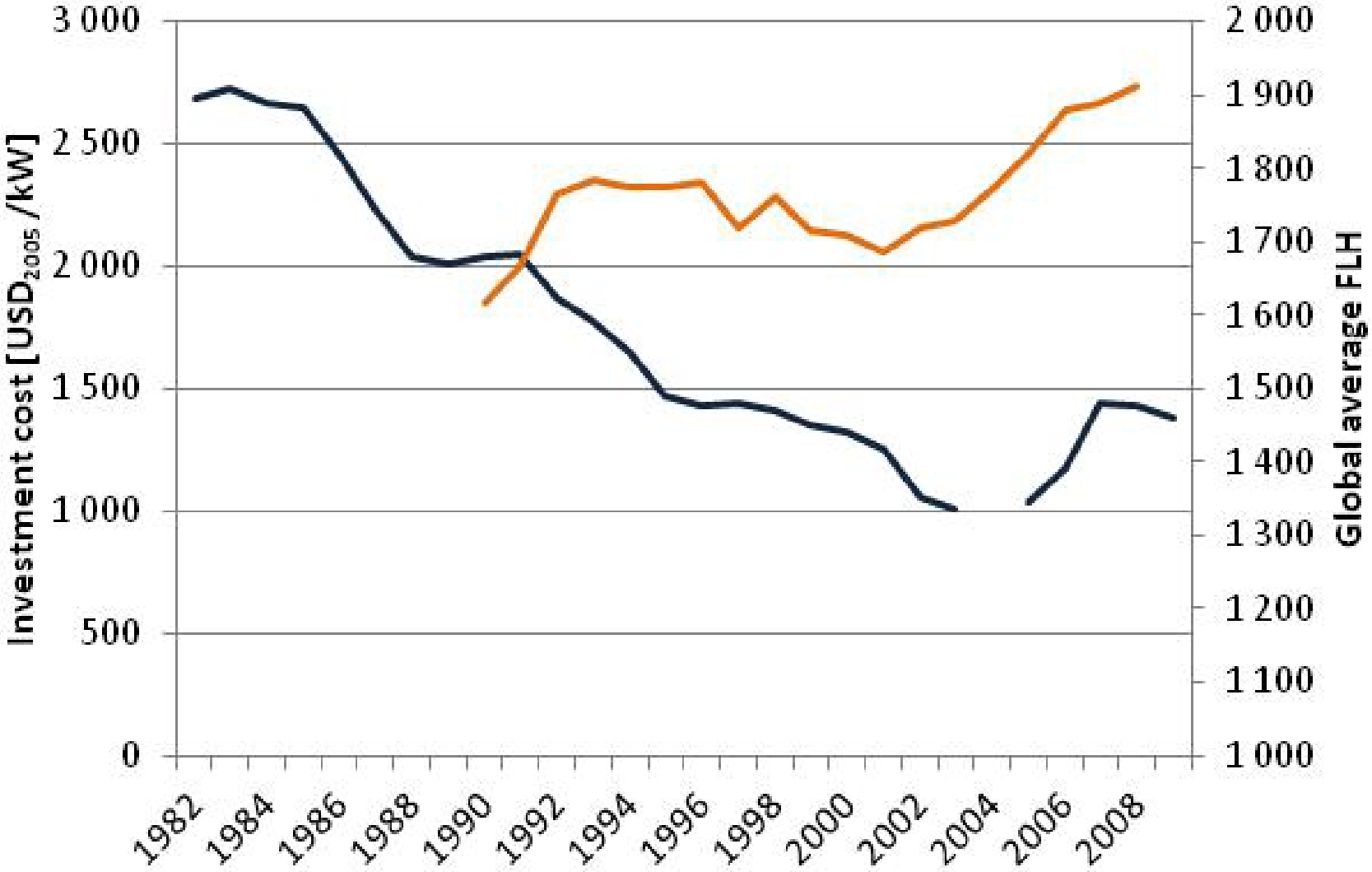
CIGB ICOLD
80 ans years
THE INTERNATIONAL JOURNAL ON HYDROPOWER & DAMS

Wind

Wind capacity to 2010



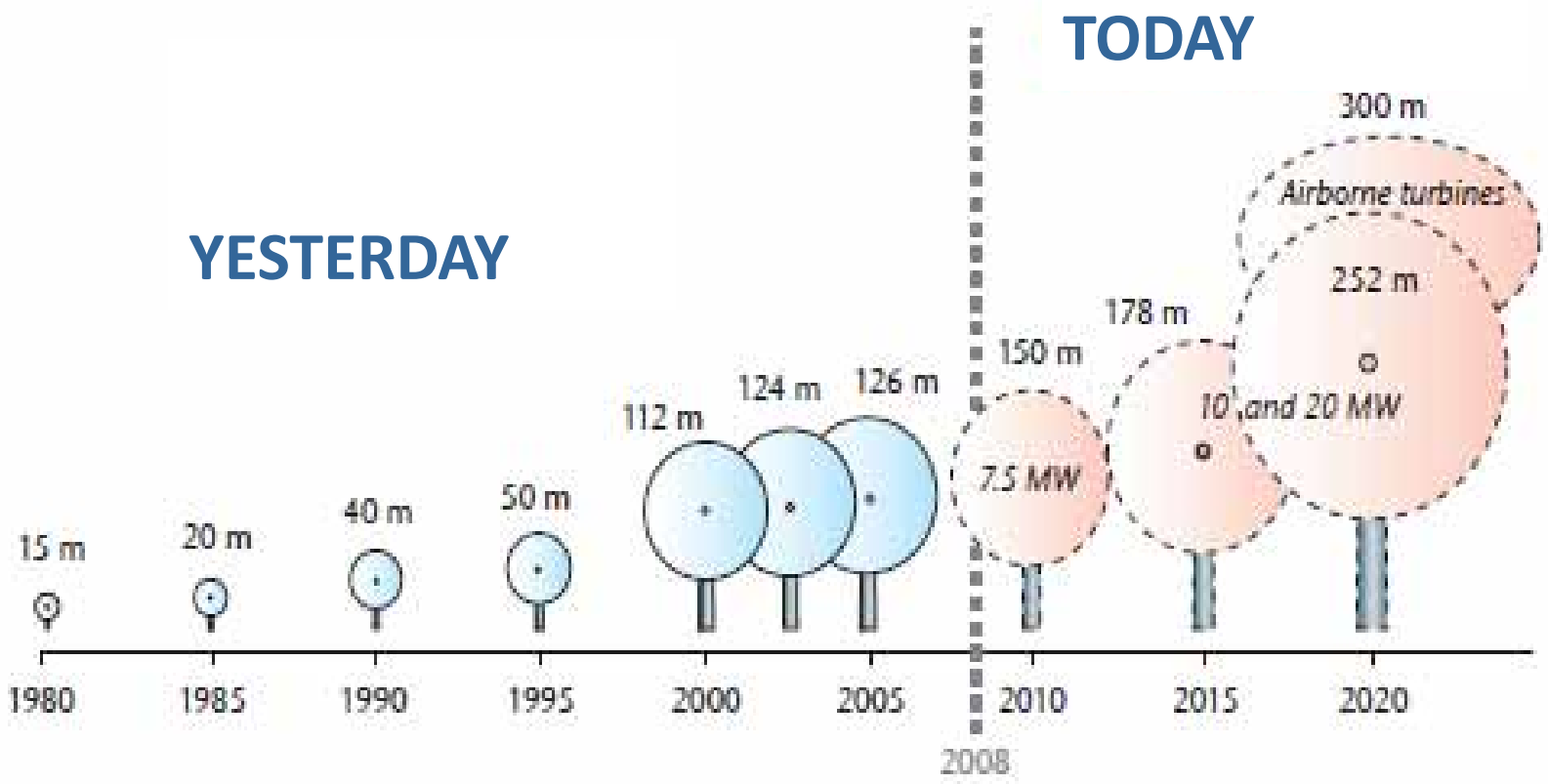
Why? Cheaper hardware and more output!



Onshore wind drivers and challenges

- Specific drivers
  - Technically and commercially established
  - Cost competitive in favourable circumstances
- Challenges
  - Siting (public support)
  - System integration (at high shares)

Growing up

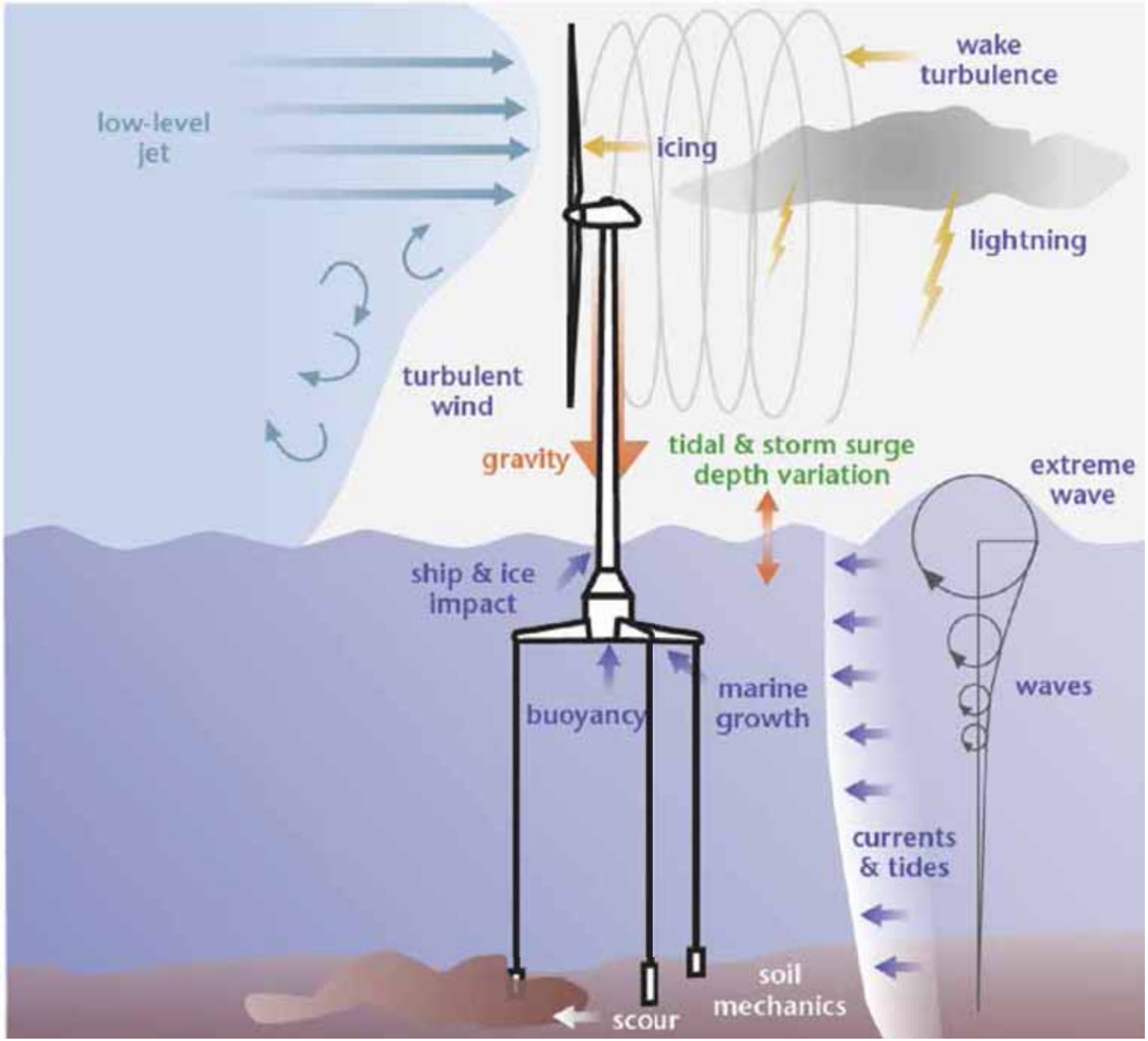


Source: Adapted from EWEA (2009).

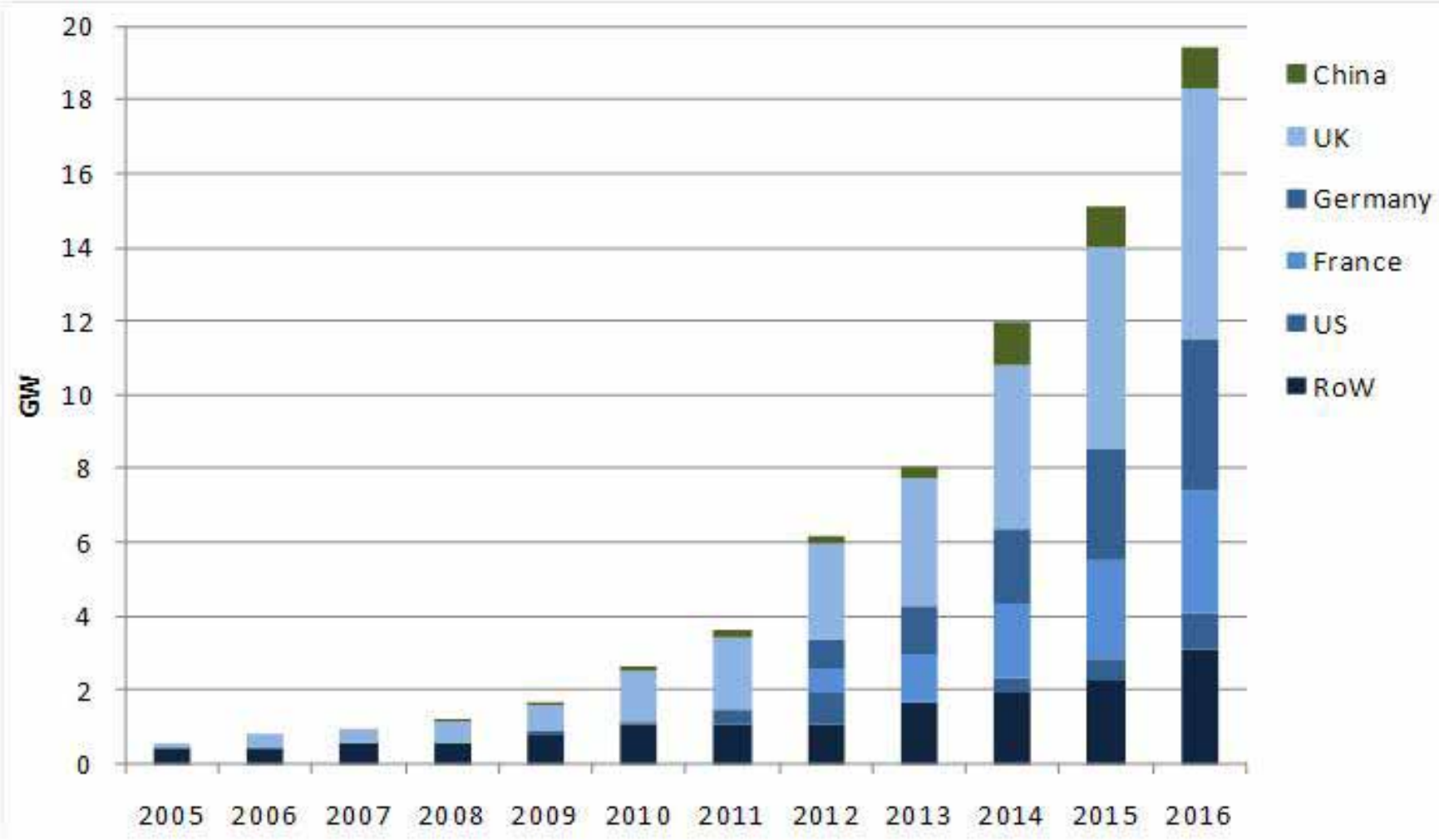
And going to sea

- Narrow installation and O&M windows
- Marinisation
- Bigger, increasingly different turbines
- Commercial demonstration

Offshore challenges

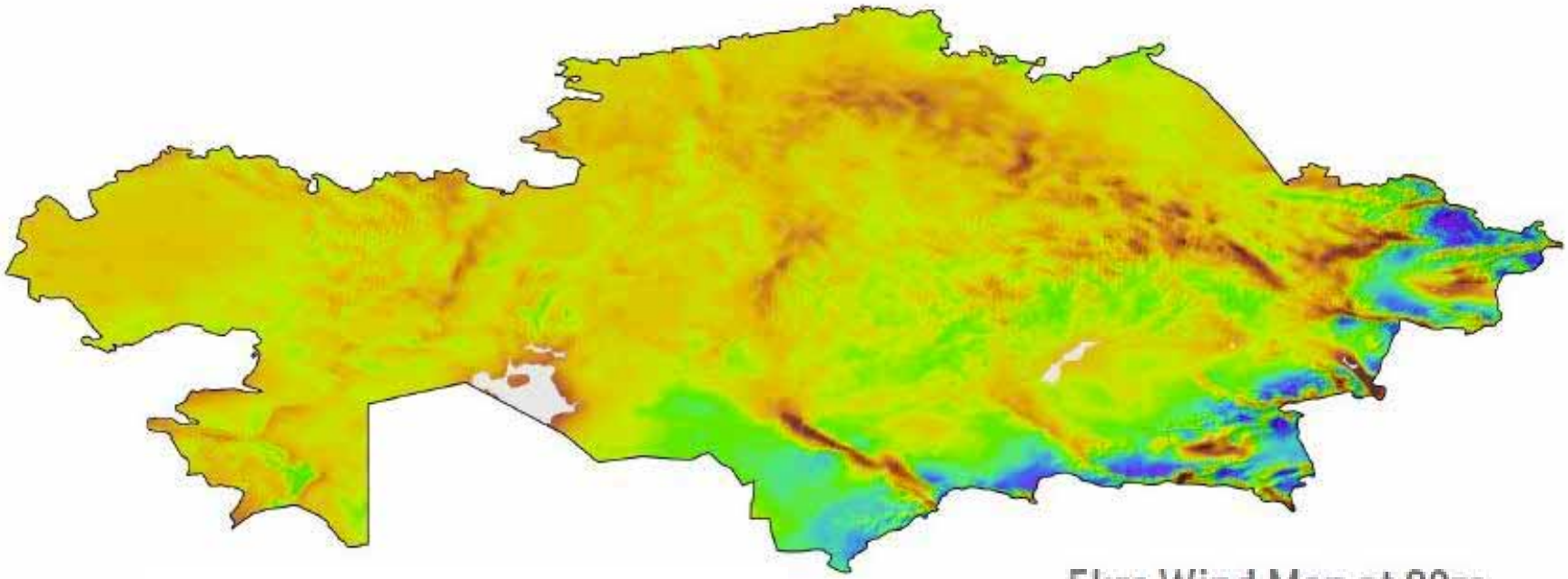


Forecast installed capacity offshore to 2016



Wind in Kazakhstan?

Wind in Kazakhstan?



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Enormous resource. 500 kW to date

Important drivers for Kazakhstan

- **Limit need to import electricity** as economy grows
- **Extend access** to electricity to the country's remote and nomadic populations
- Protect **ecosystems**
- **Reduce line losses** and improve **reliability**
  - End-of-line power plants to support grid
- Resources near **existing transmission**
- Some **correlation** between seasonal wind and demand
- **1999 legislation**: "Electricity Development Programme until 2030" targets 500 MW wind

Bioenergy

Biomass resources

WOODY:

- **Forest residues**: thinnings, leftover plant material after cutting
- **Fuelwood**: logs or any other form to be used in small stoves
- **Industrial wood-processing waste**: sawdust, black liquor
- **Woodlands / urban**: tree trimmings, garden waste
- **Short rotation forestry**: willow, hazel, eucalyptus

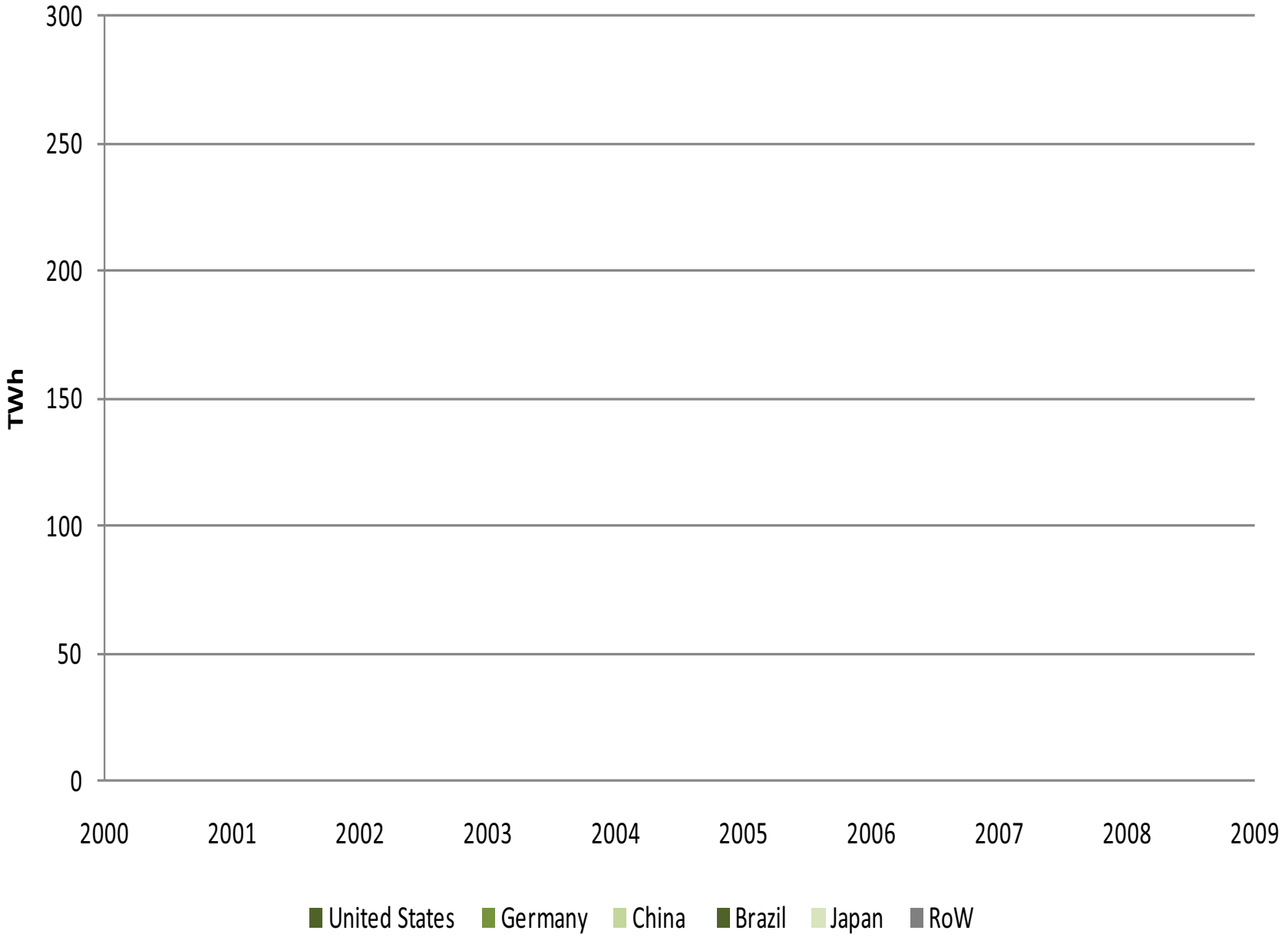
AGRICULTURAL:

- **Agricultural crops**: dedicated and traditional agricultural crops: maize, rapeseed, sunflowers
- **Crop residues**: rice / coconuts husks, maize cobs, cereal straw, cotton
- **Processing residues**: sugar cane bagasse

ORGANIC WASTE:

- **Animal waste**: manure from pigs, chickens and cattle
- **Sewage sludge**: domestic and municipal sewage

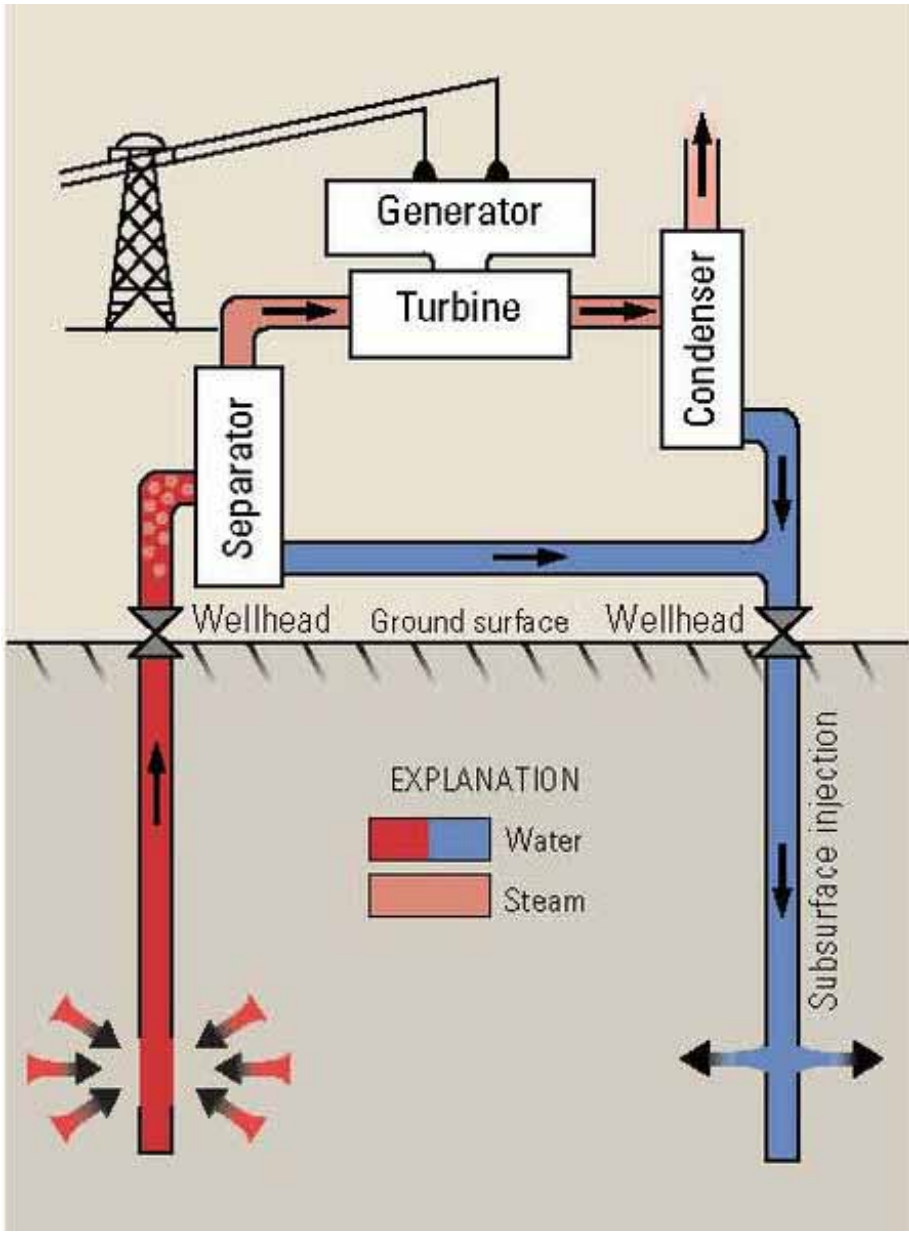
Regional trends in bioelectricity production




Geothermal

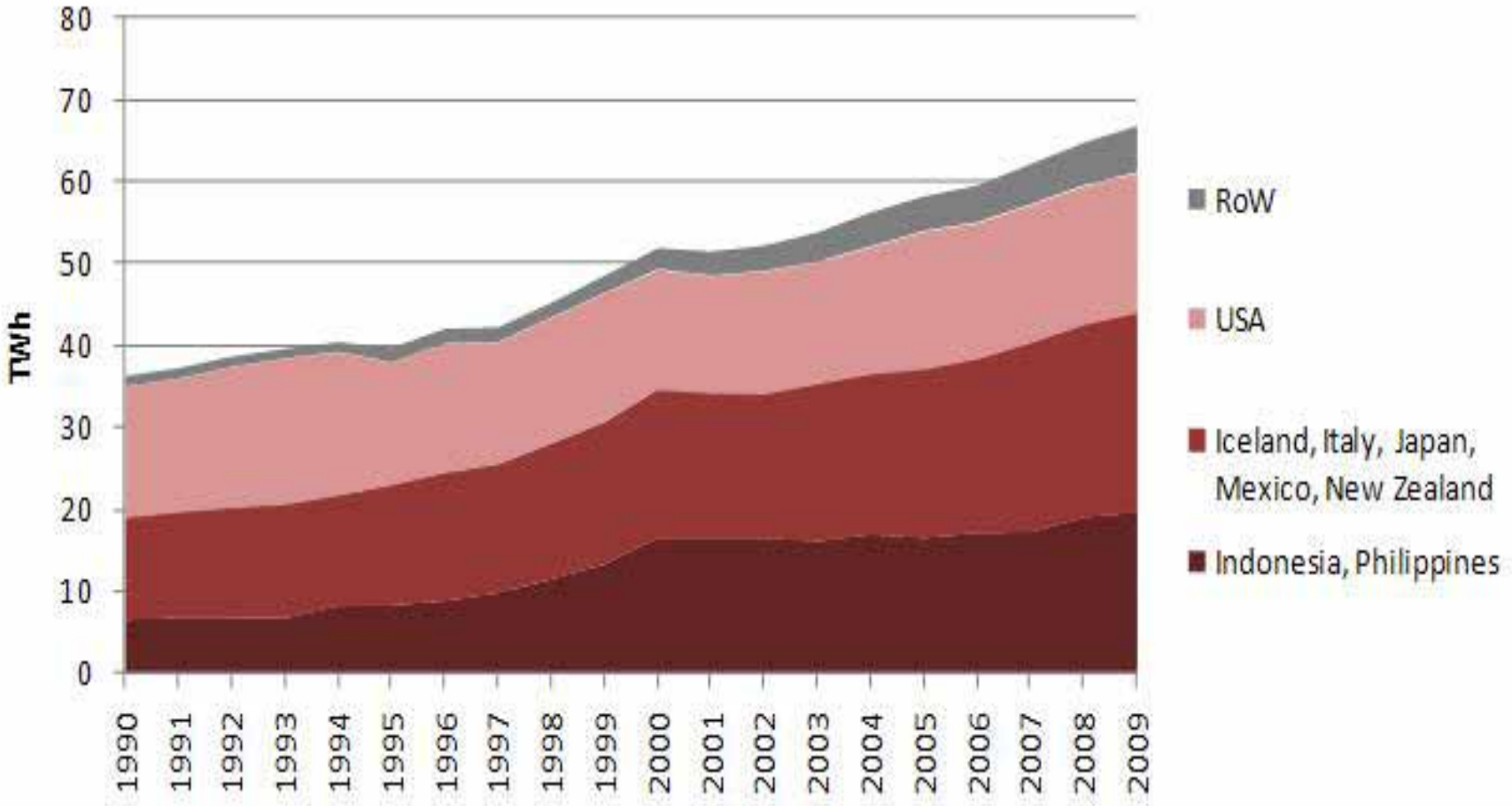
Geothermal electricity

- 66 TWh in 2009
  - 0.33% of global electricity
- Flash
  - Scale: 10 – 250 MW
  - USD 50 – 80 / MWh
  - USD 2 - 4 million / MW
- Binary
  - Scale: 12 MW – 20 MW
  - USD 60 – 200 / MWh
  - USD 2.5 - 6 million / MW



Flash geothermal plant

Regional geothermal electricity generation

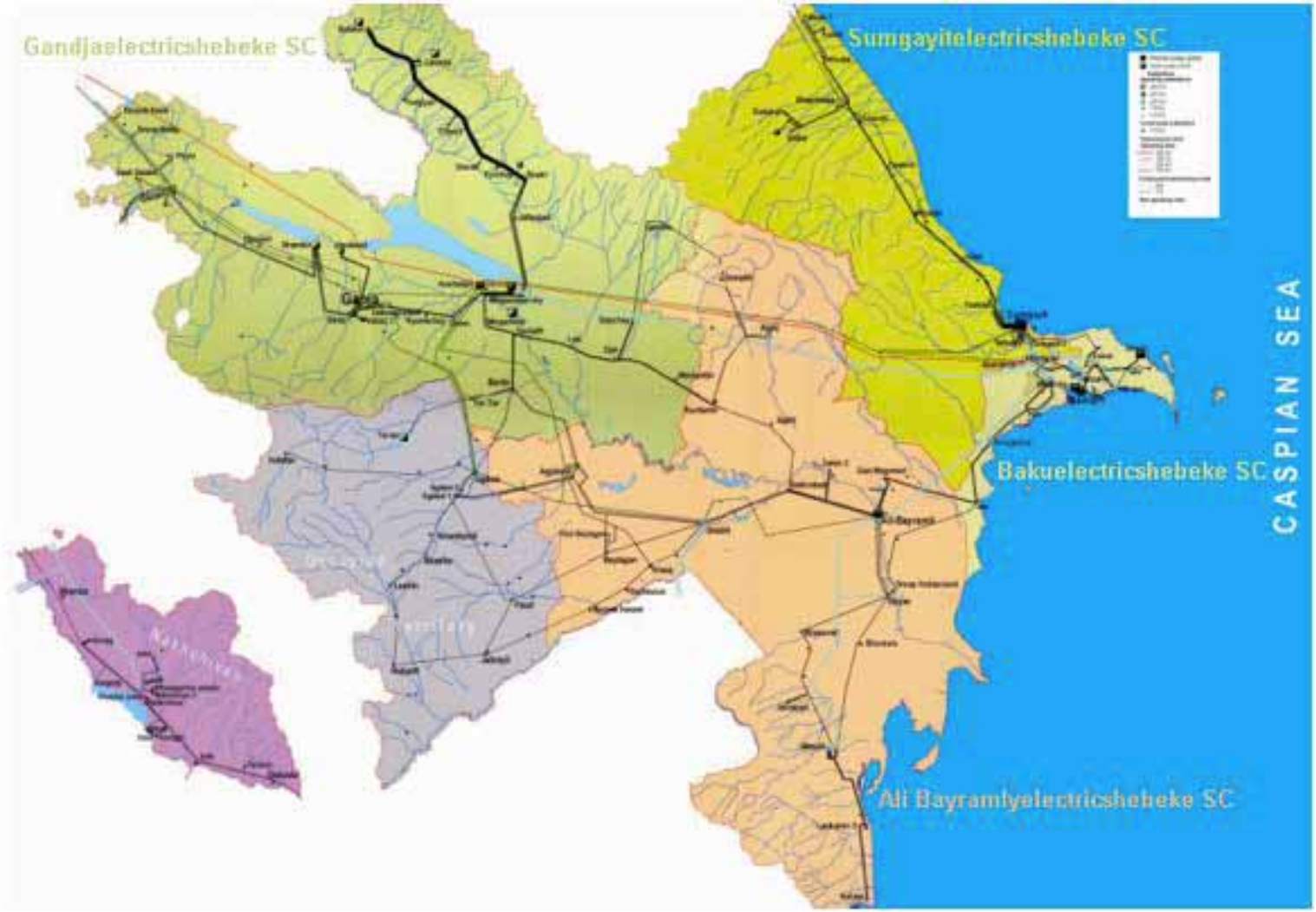


Renewables in Azerbaijan?

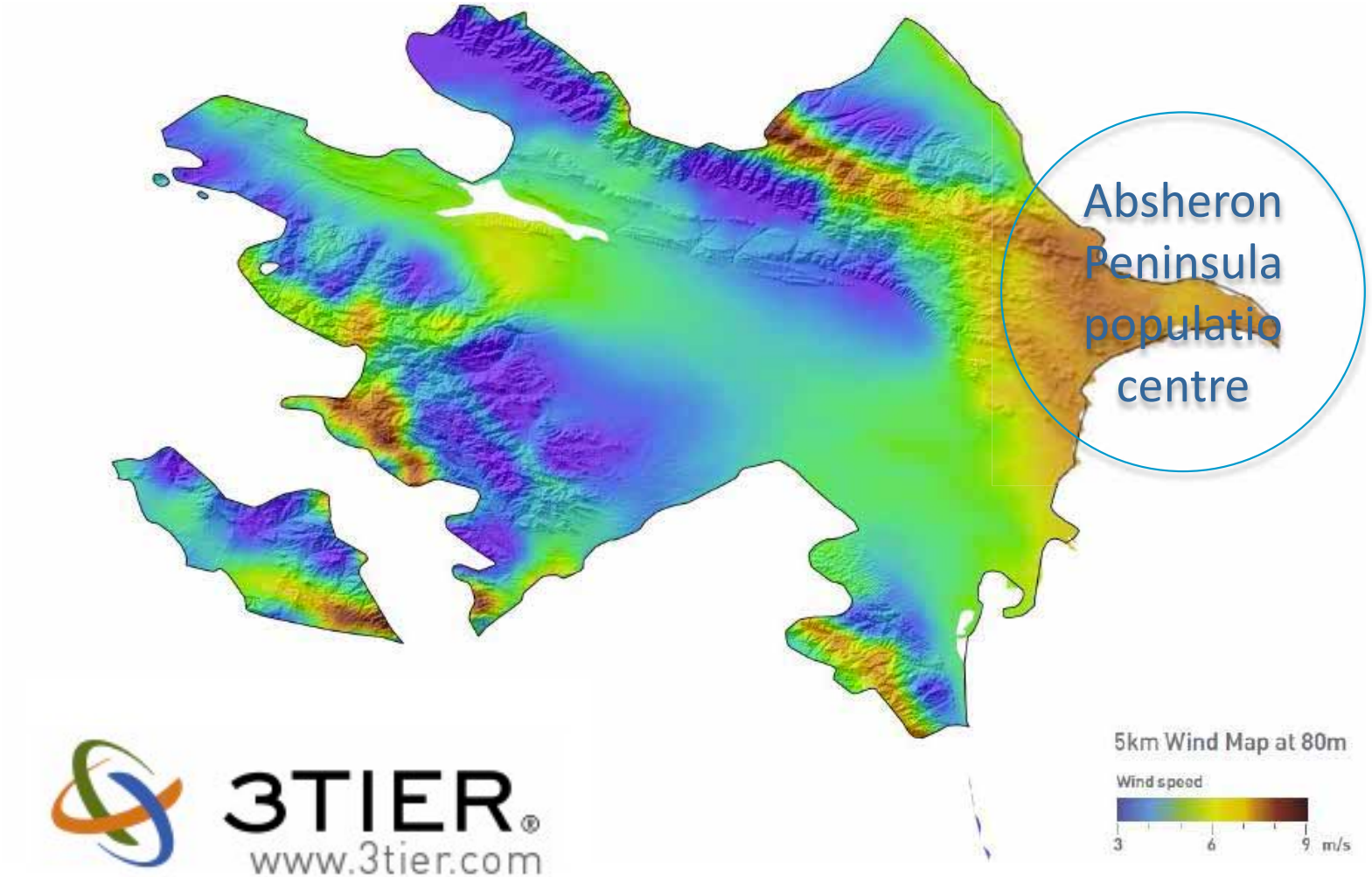
Renewables in Azerbaijan?

- Large **transmission losses**
  - 80% power generation in the west but 70% consumption and fuel in the east
  - 2008 rehabilitation of East/ West lines financed by ADB
- Renewable resources are **available locally**
  - Strong solar resource at Absheron Peninsula
  - Good geothermal resource at Absheron Peninsula
    - At present only for heat
- **Cotton waste** potential for bioenergy

Azerbaijan’s grid



Azerbaijan's wind resource



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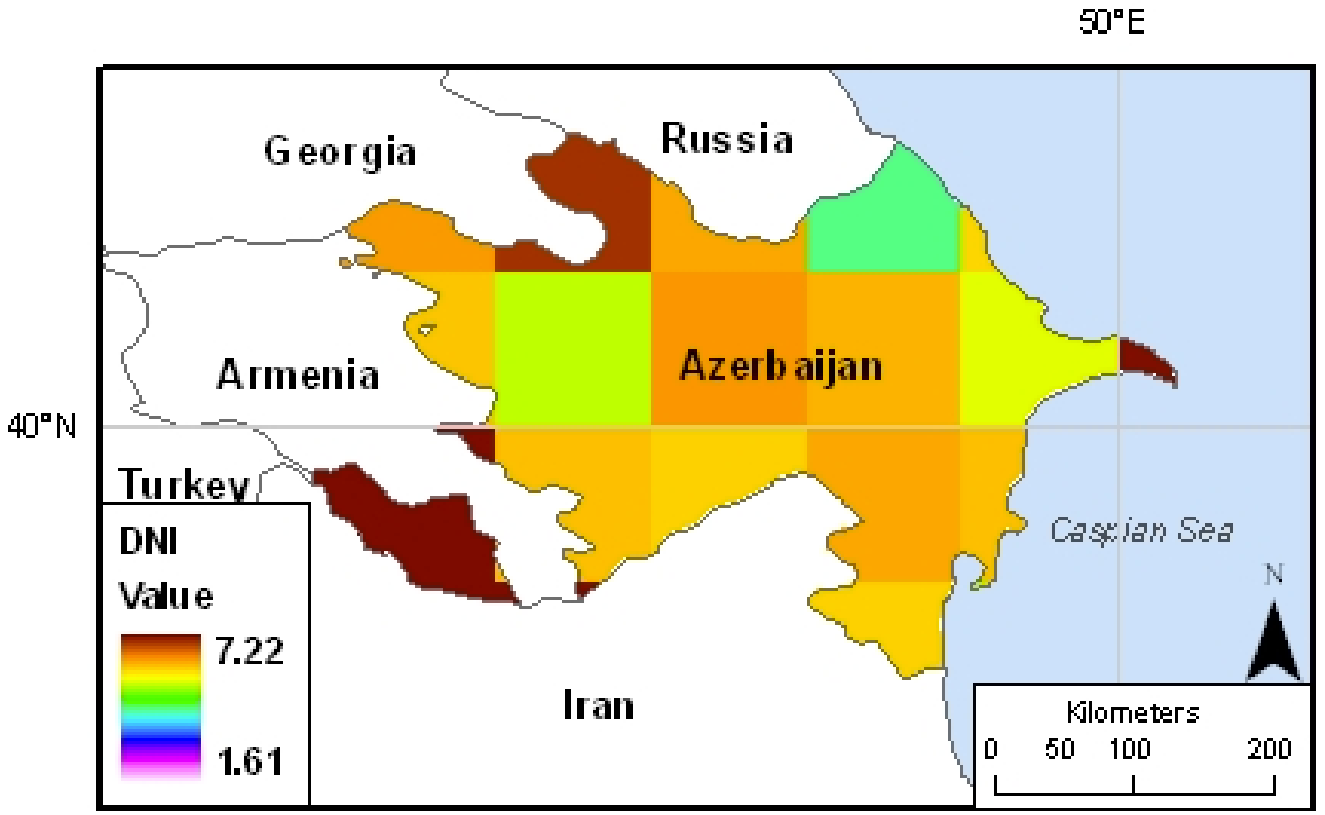
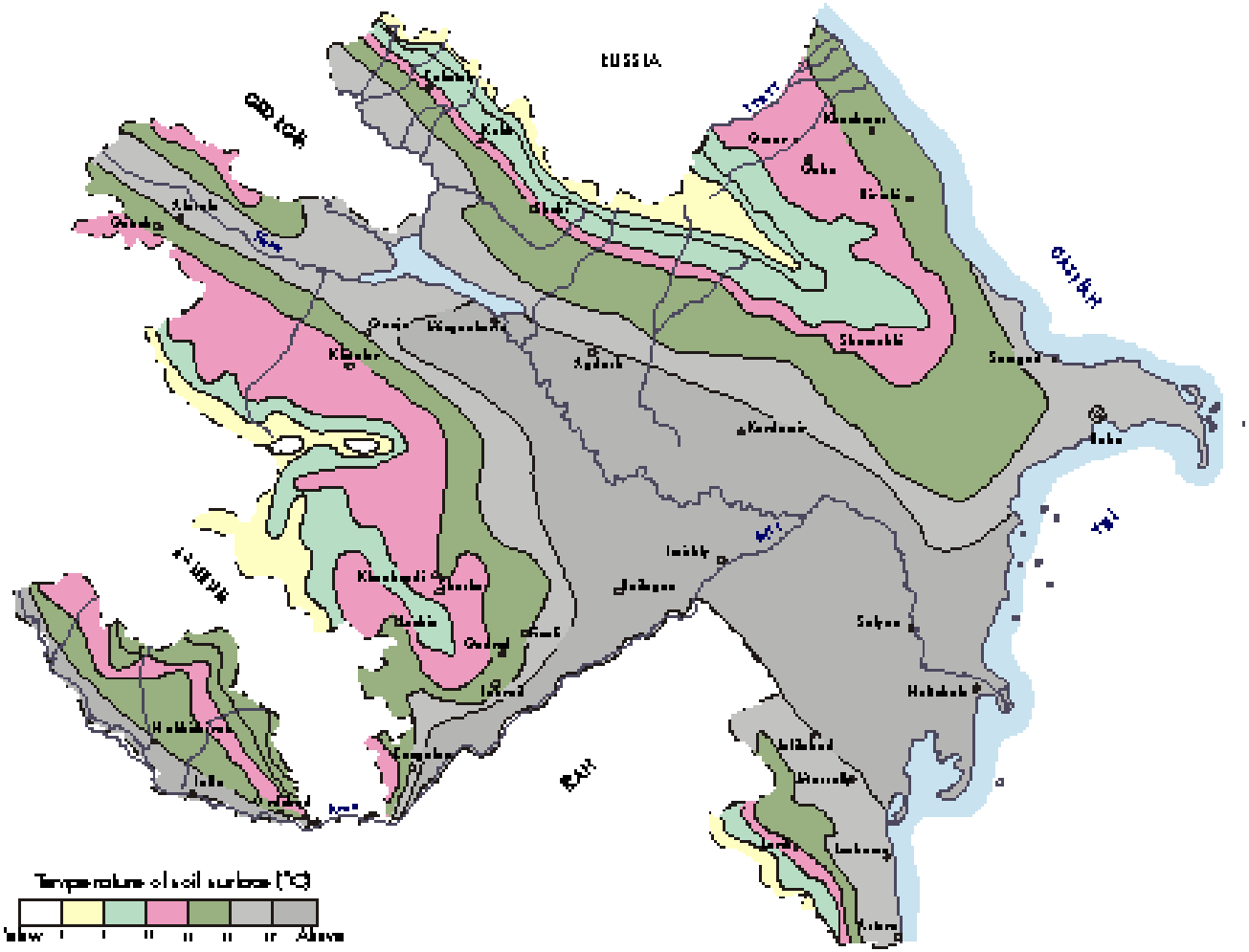
…solar resource

Azerbaijan Solar Direct Normal Insolation (Source: NASA)



…and geothermal resource



Source: GENI

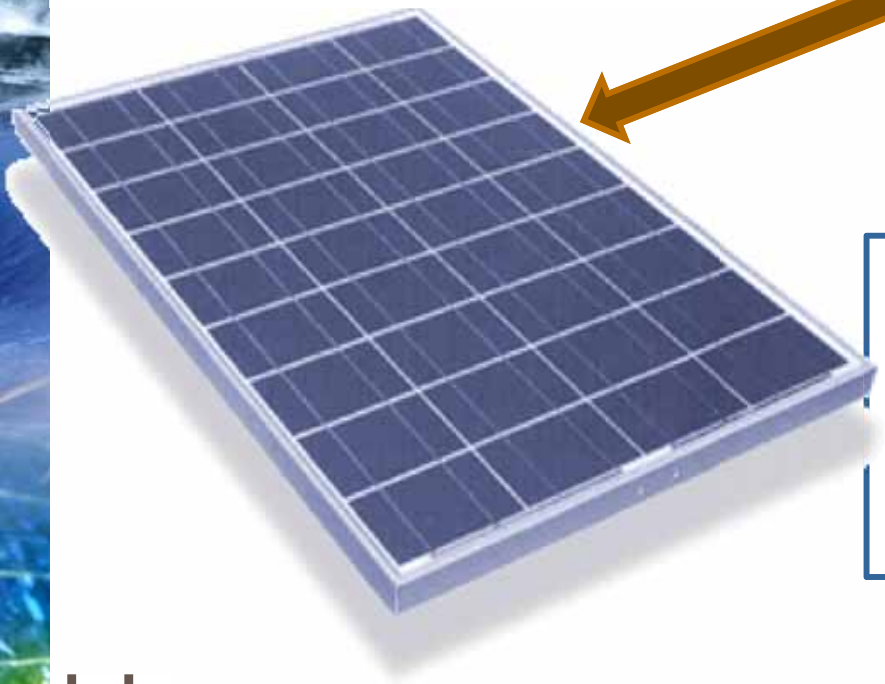
Solar PV

PV technology

Photovoltaic directly converts sunlight into electricity.

The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, silicon

Solar Cell



PV-Module

Multiple cells electrically connected and mounted in a frame is a ‘photovoltaic module’. The electricity produced is directly dependent on the intensity of light reaching the module

PV technology 2

Modules can be connected in an array

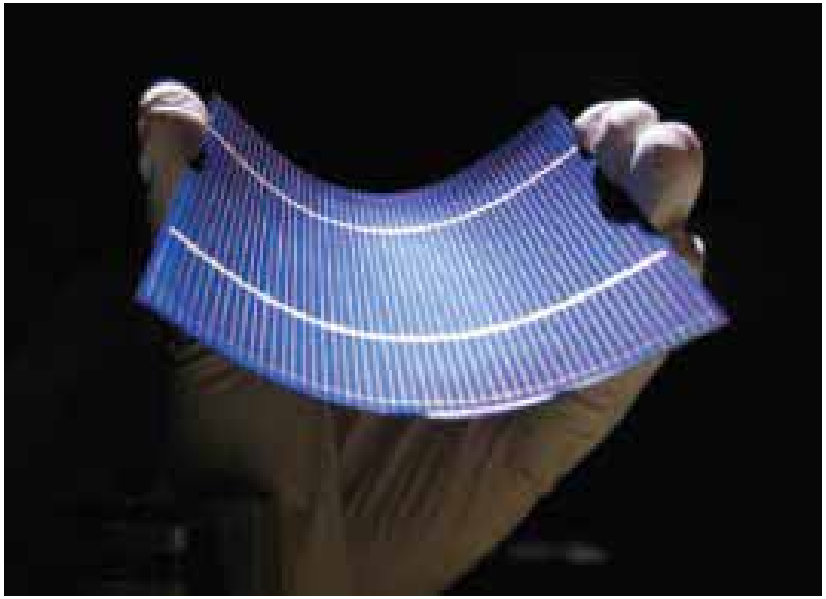
Arrays can be connected to in a power plant generating electricity at any voltage required

PV technology 3

Another important family of solar cells is based on “thin-film” technology, requiring significantly less semiconducting material

These are cheaper to make, hence market share will likely increase

However, they typically have lower efficiencies than wafer-based cells → greater surface area needed.

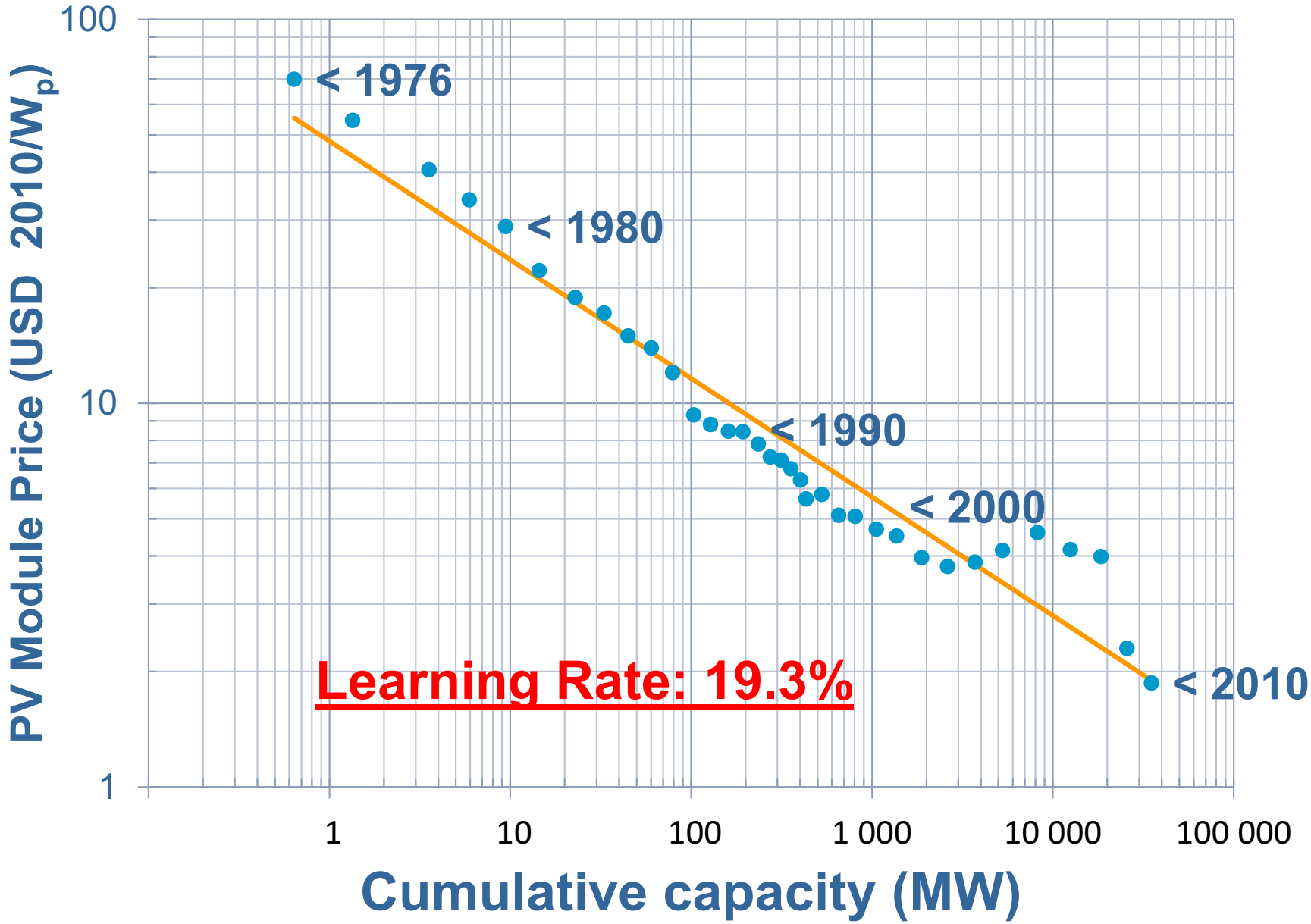


Source: European Commission

PV key points

- PV can use all light (direct and indirect)
- Resource exists almost everywhere
- Installed mainly at the end-user (to date)
- Variable output
- Peak & mid-peak
- Grid parity by 2020

Solar PV cost reductions

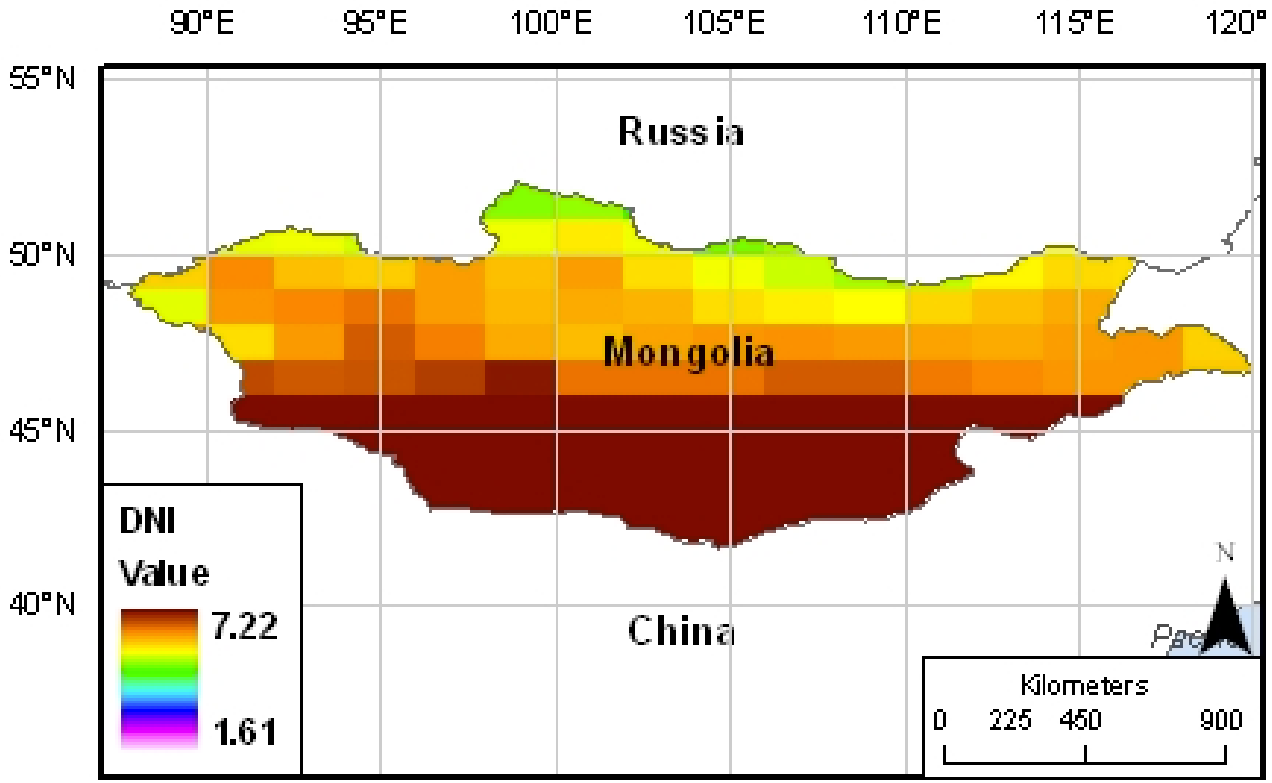


Data from Breyer and Gerlach, 2010

Distributed renewables in Mongolia?

Mongolia

Mongolia Solar Direct Normal Insolation (Source: NASA)



Solar drivers in Mongolia

- Few population centres → distributed wind and PV may be cheapest option
- National **Renewable Energy Program** (2005-2020), June 2005.
  - 20-25% RE penetration of energy for 2020
- **2007 Renewable Energy Law**
  - Electricity price support (FIT); fund for wind hydro solar
- **National 100,000 Solar Gers** program
- New renewables **deployment has begun**:
  - 4% of TPES (2009 EBRD)
  - 8 MW wind operating
  - Multi MW scale wind plants planned (2009)
  - 4000 micro wind turbines in use (5 – 150W).
  - 206 kW PV operating, plus 60 000 micro PV systems for herders (EBRD 2009).


Concentrating Solar Power

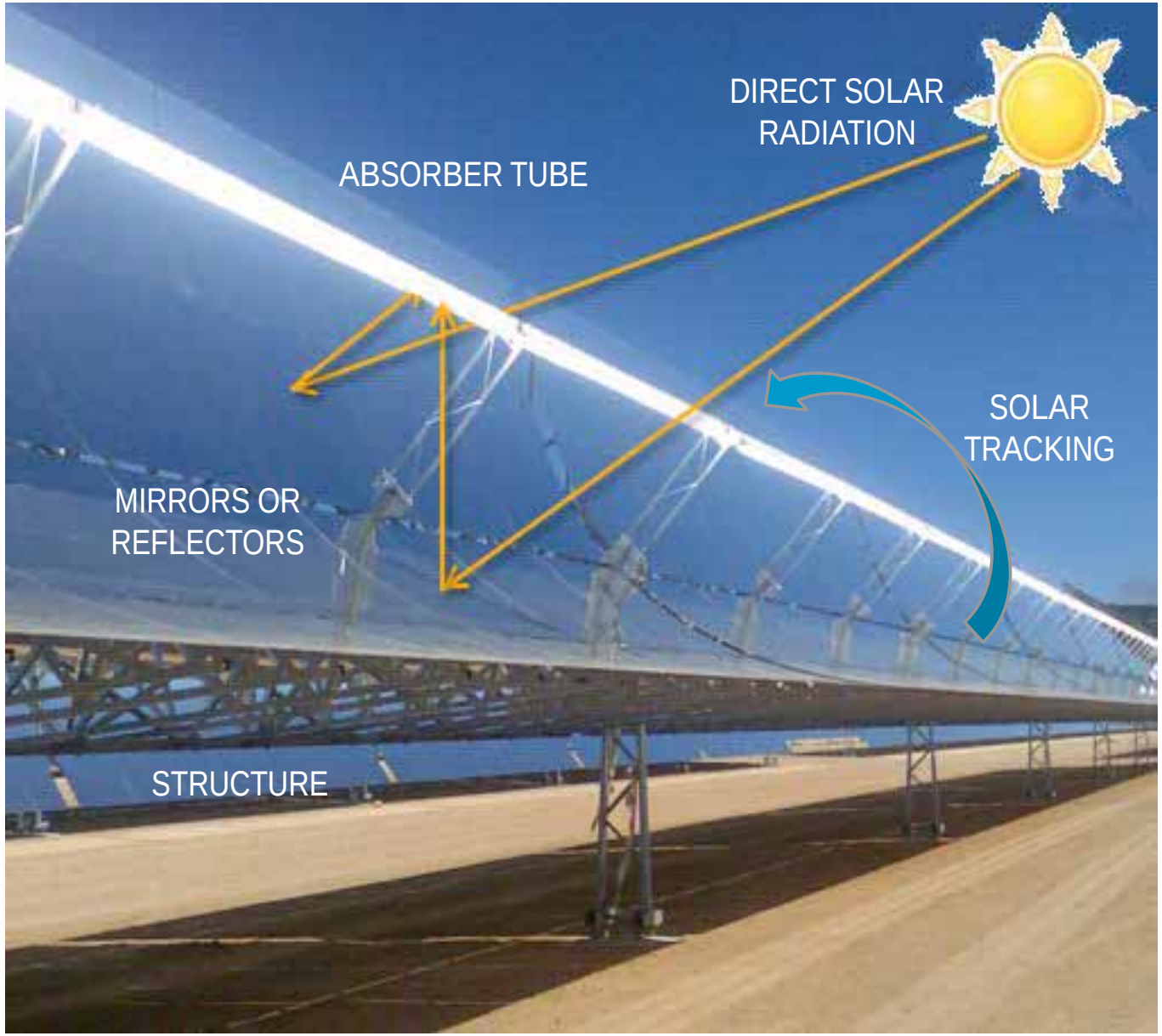
Concentrating solar power 1

Plants convert produce electric power by converting the sun's energy into high-temperature heat using various mirror configurations. The heat is then channeled through a conventional generator.

Source: Torresol Energy

Central tower receiver

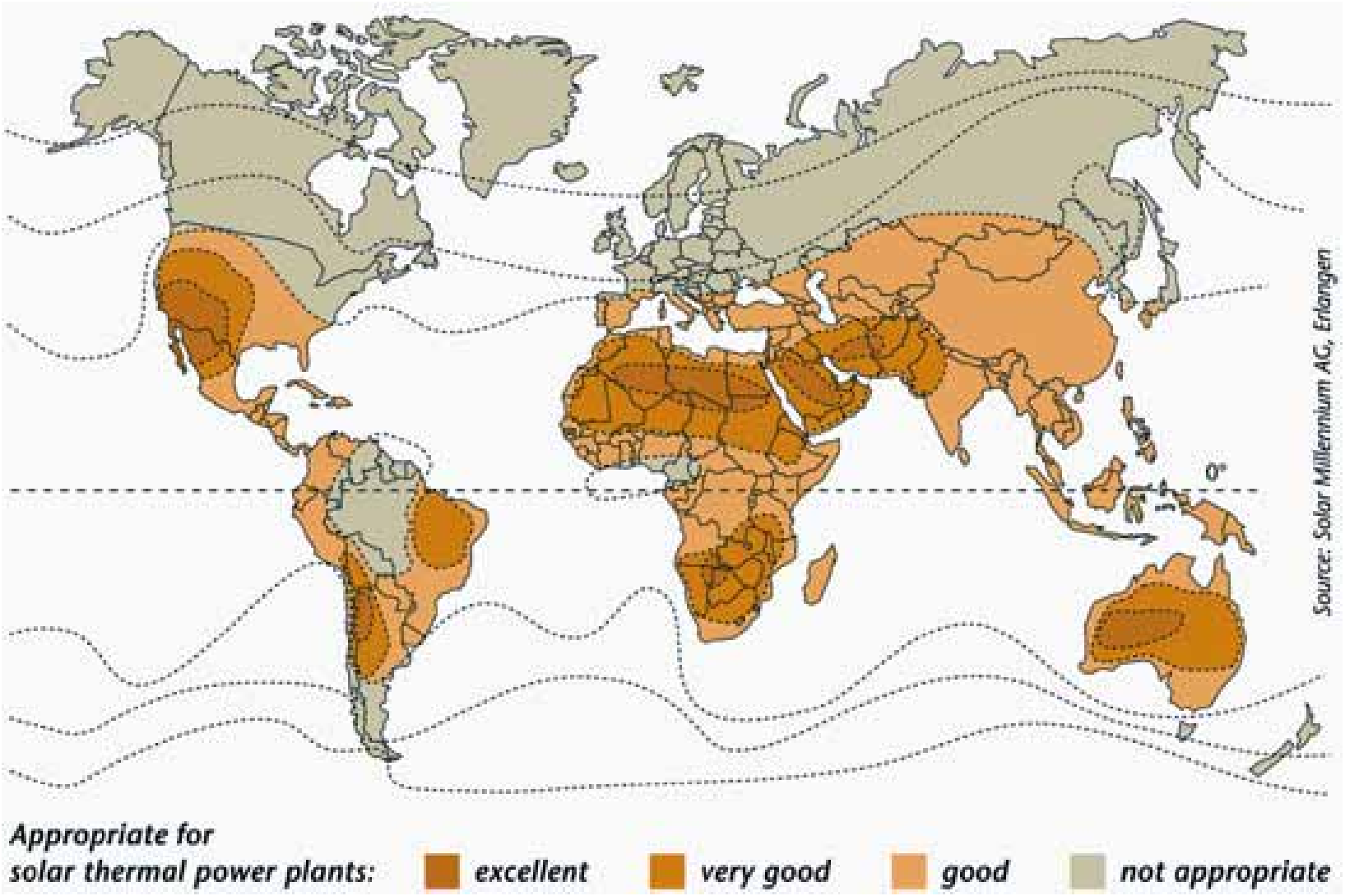
Concentrating solar power 2



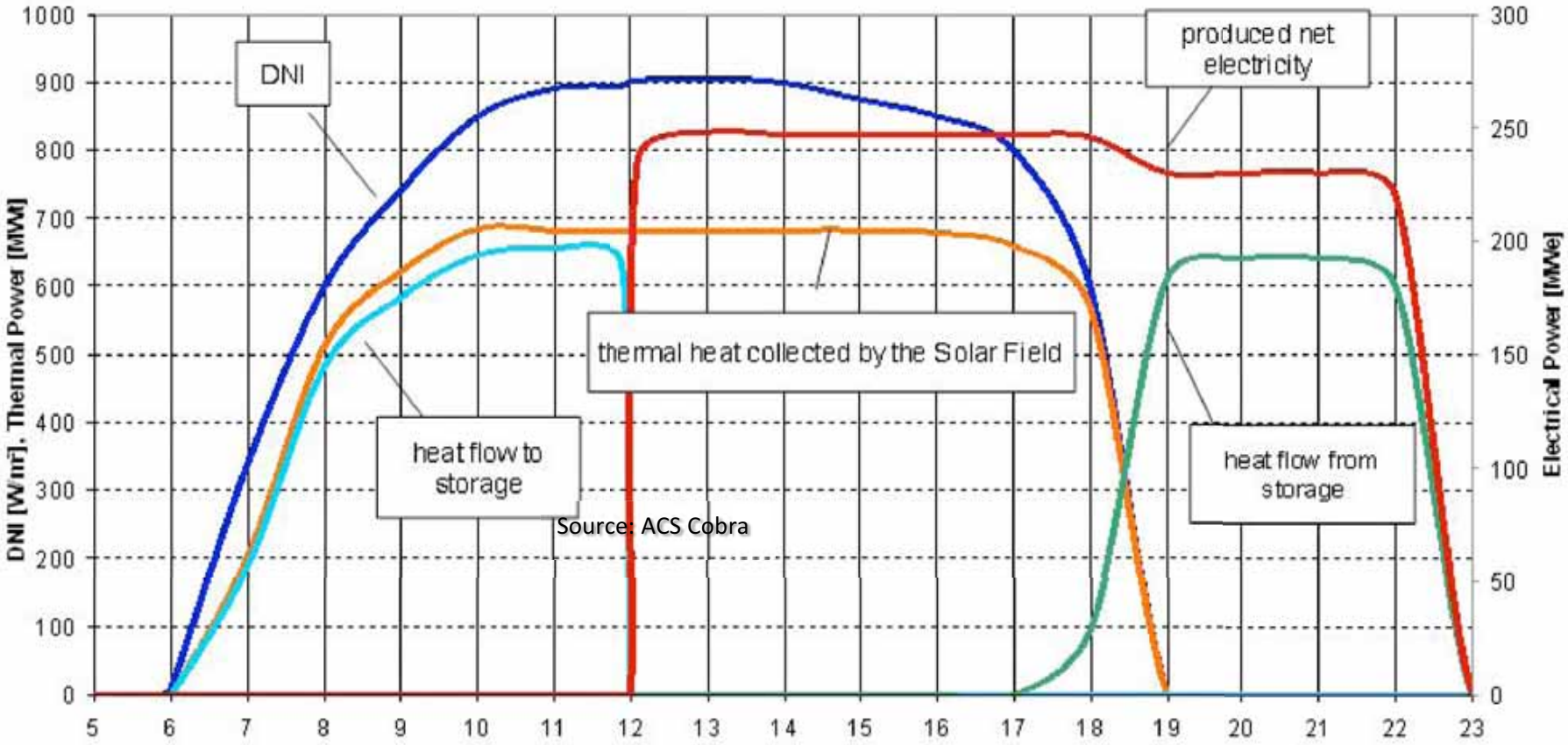
Parabolic trough

Solar resource (CSP)

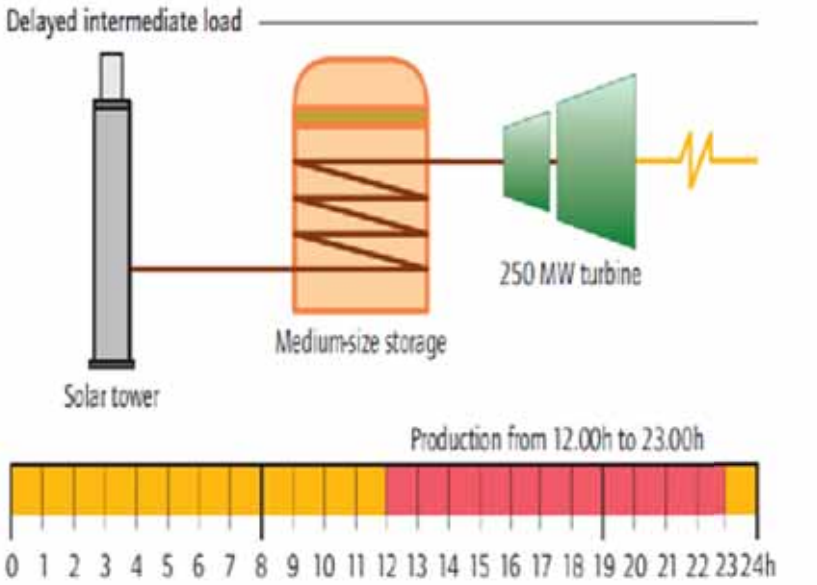
The World's "Sun Belt" (35° north to 35° south), receives several thousand times global energy demand

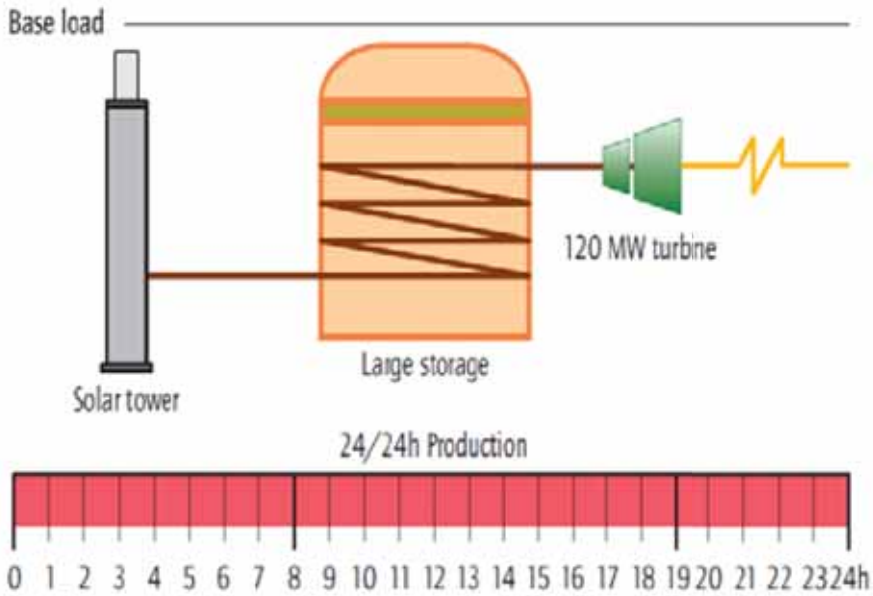


Role of storage in solar thermal

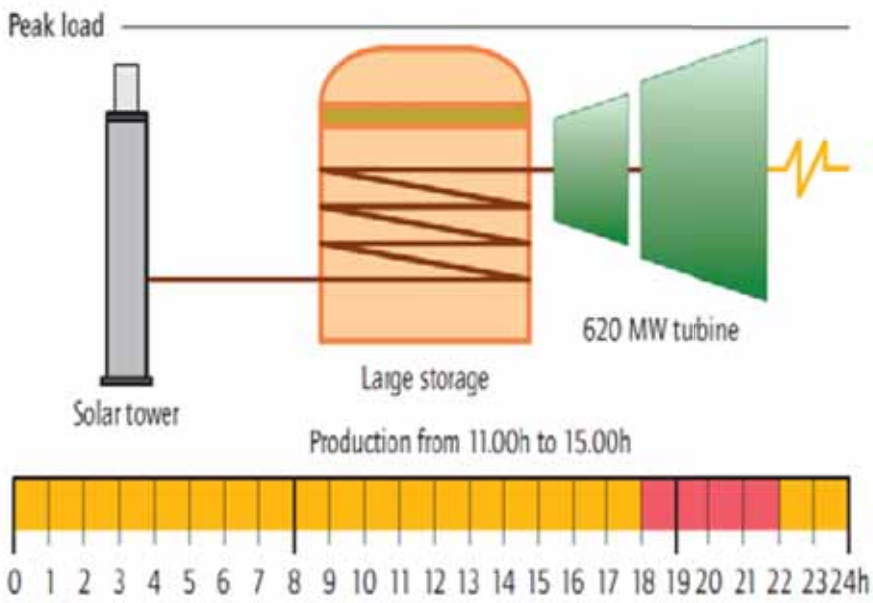


Baseload to peak load with the right configuration





Thermal storage can be used to shift production, to extend it to base load or to concentrate it to super peak load



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CSP key points

- CSP requires direct sunlight
- Resource strongest in semi-arid countries
- Mostly utility scale
- Firm, dispatchable power
- Peak to base-load capability with storage
- Competitive peak power by 2020
- HVDC lines are needed for transport

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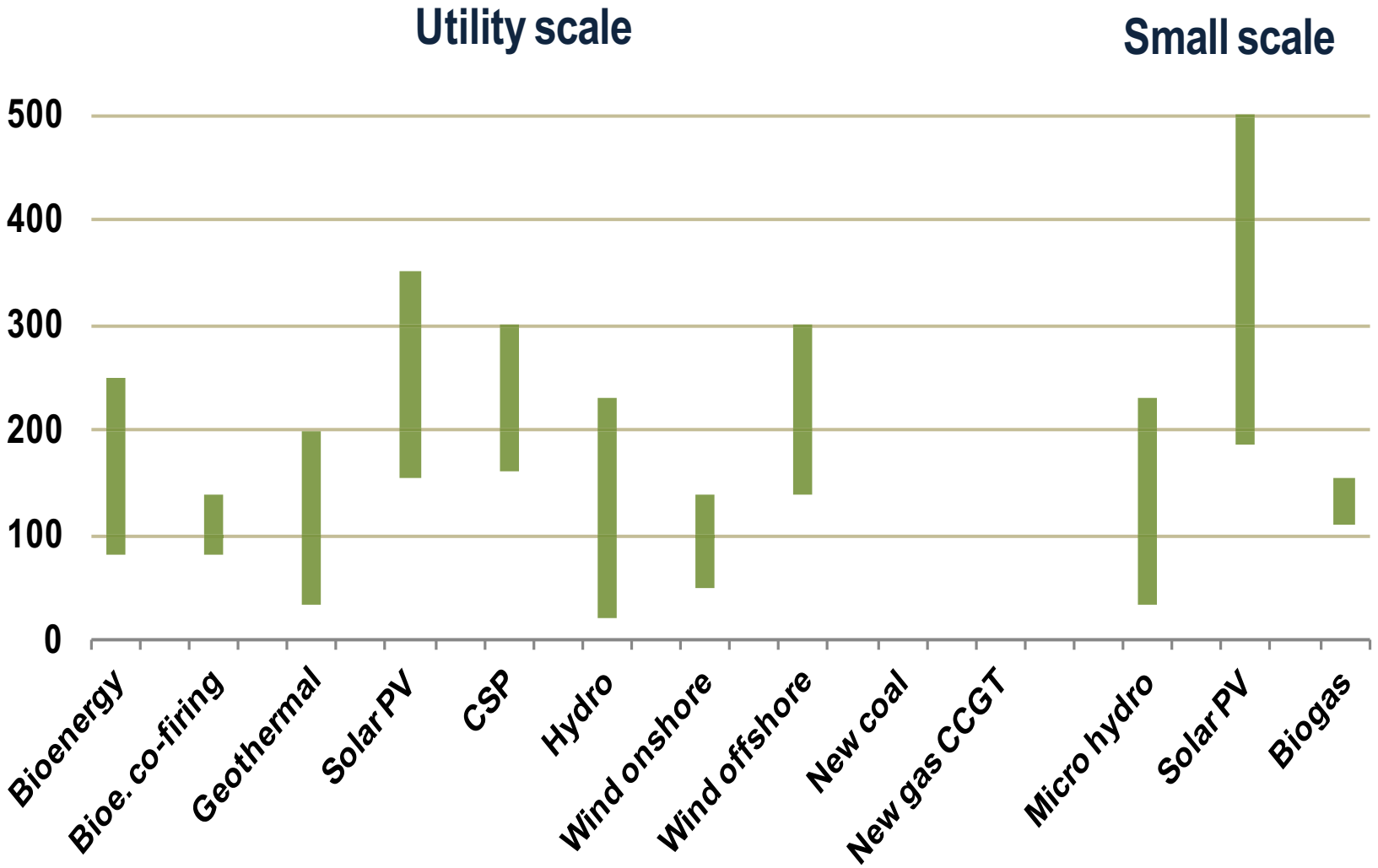
Marine

SUMMARY STATS

TECHNOLOGY	STATUS	SCALE	PRODUCTION
ELECTRICITY			**TWh/y**
Biomass	Commercial	100kW – 300 MW	267
Geothermal	Commercial	1 – 250 MW	67
Solar **PV**	Commercial	1kW – 50 MW	19
Solar **CSP**	Demonstration	1 – 250 MW	0.9
Hydro	Commercial	100kW - 10,000 MW	3288
Wind On Shore	Commercial	1kW – 500 MW	340
Wind **Off Shore**	Demonstration	100 – 1000 MW	
Wave / tidal	R&D,D	100kW - 2 MW	0.5
HEAT & COOL			**PJ**
Solar Water Heating	Commercial	$1kW_{th}$ – $1 MW_{th}$	319
Geothermal	Commercial	0.5 – $10 MW_{th}$	440
Traditional Biomass	Commercial	0-5 kW_{th}	34000
Modern Biomass	Commercial	$5kW_{th}$ – $30 MW_{th}$	9000
TRANSPORT			**PJ**
Bioethanol from sugar and starch	Commercial		2100
Biodiesel from oil crops	Commercial		
New Technologies for transport fuels	R&D,D		

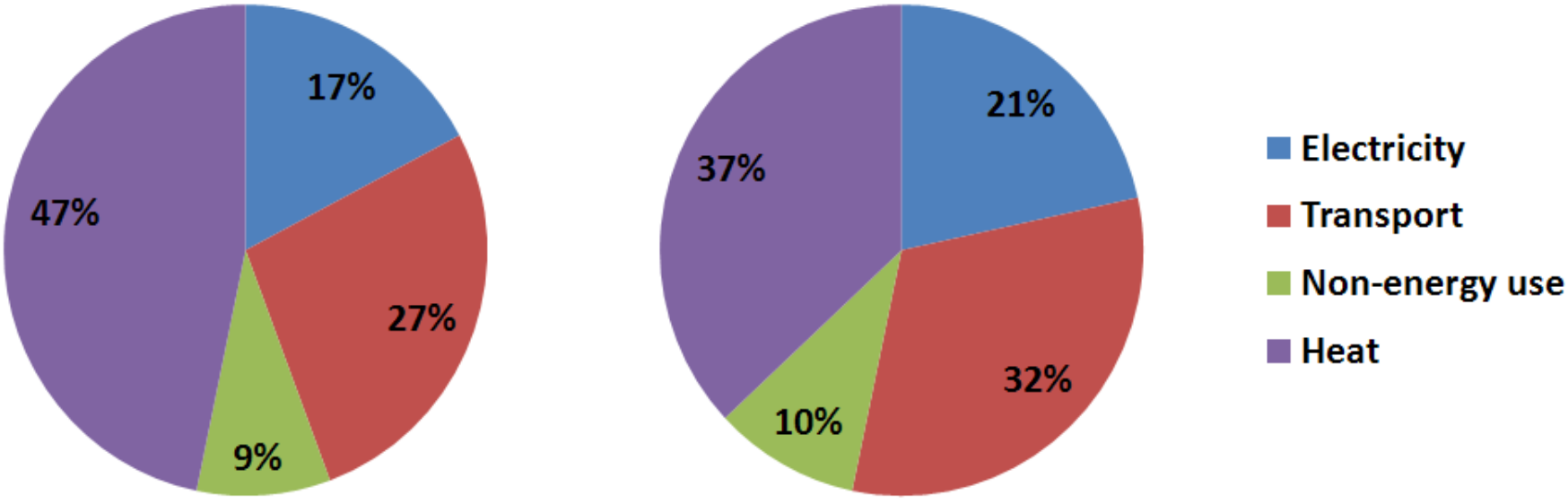
Renewable electricity costs



- **Large ranges** depending on technology and resource
- Competitiveness with new fossil power plants depending on local conditions, but getting **competitive in more circumstances**

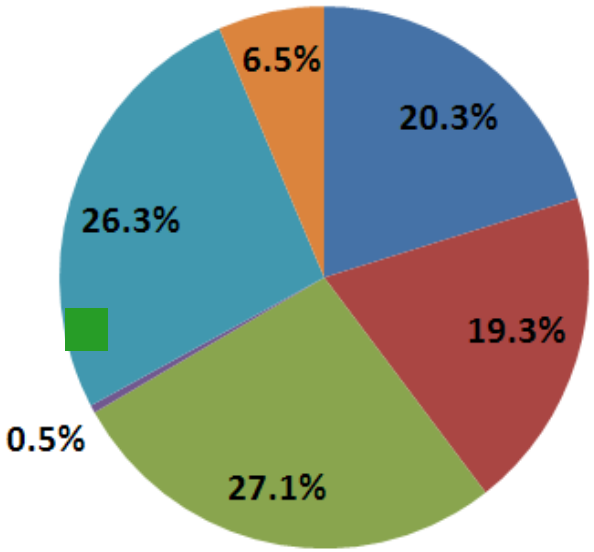
Heat – the "elephant in the room"

- Share of heat in energy use (2009)

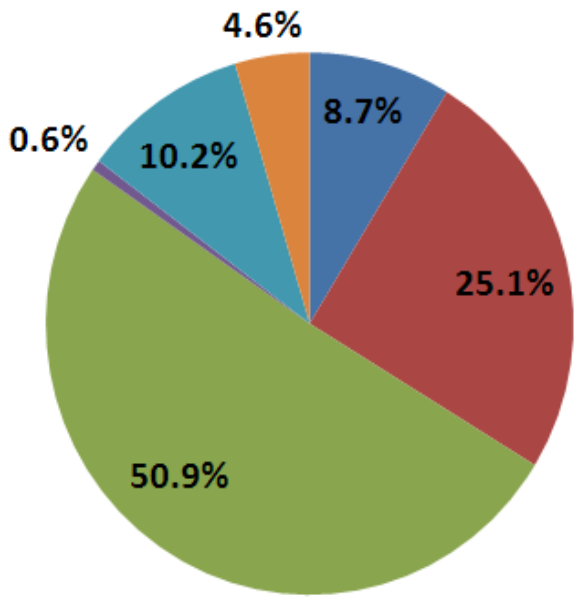


- Basic needs: space heating, cooking
  - In colder regions, heat share can be (much) higher
- Industrial processes
- Inefficient traditional uses (<15%)

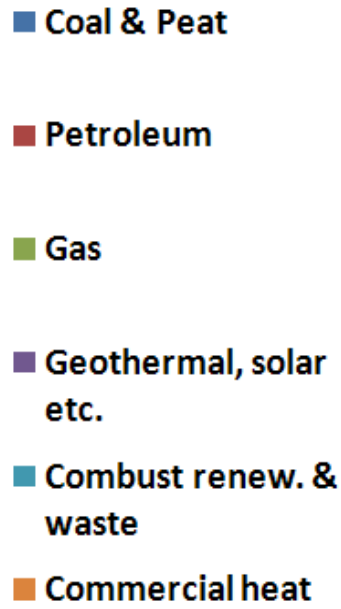
Fuels used to produce heat (2009)



World



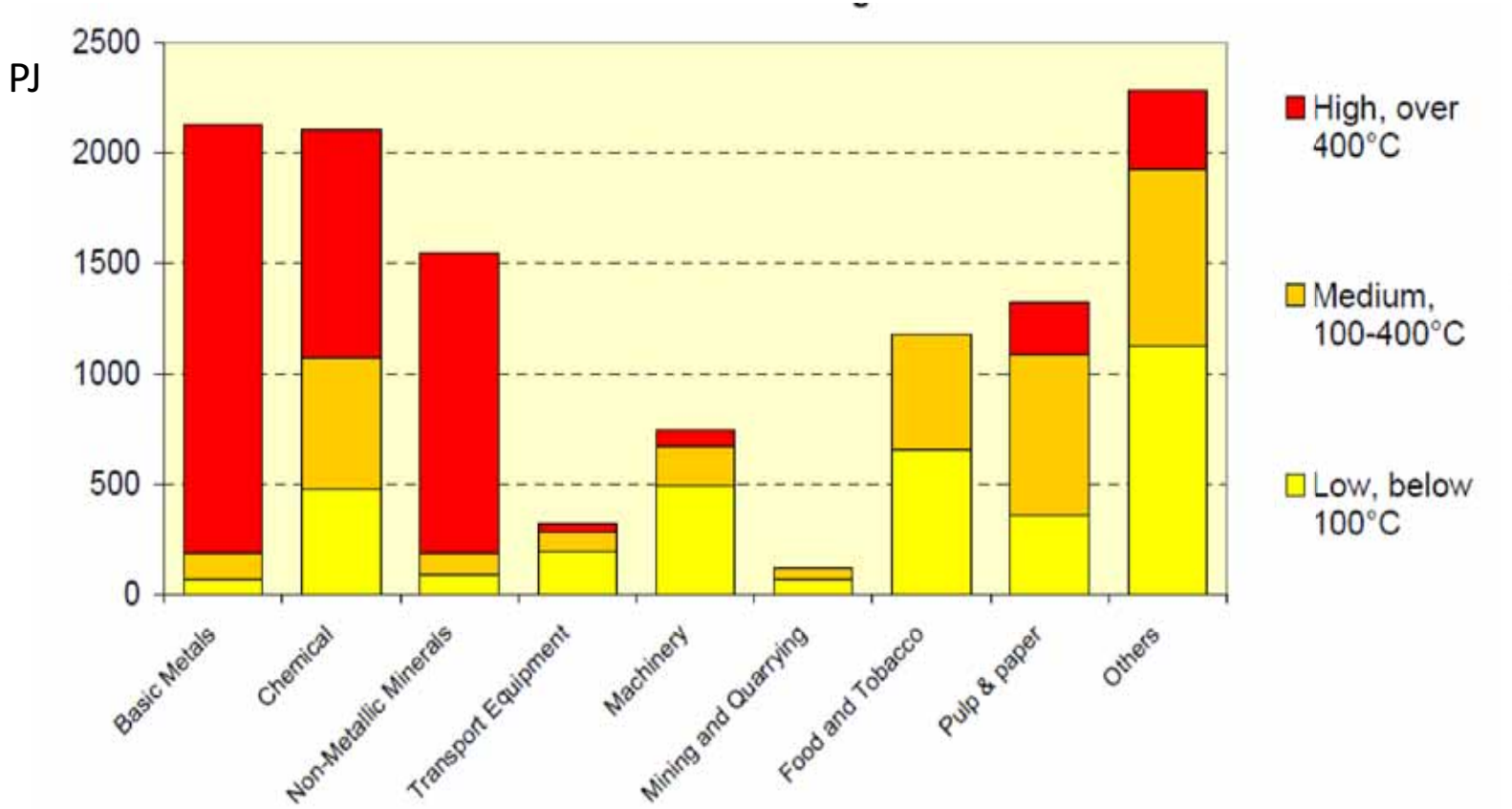
OECD



- RES-heat makes up 10% of all energy used for heat.
  - 89% is from solid biomass, particularly traditional uses in LDCs
  - May see a shift towards (more efficient) fossil fuels
  - Traditional uses may convert to modern CHP

Providing for industrial heat needs

Estimated industrial heat demand by temperature range in Europe, 2003



Source: Werner, 2005-2006

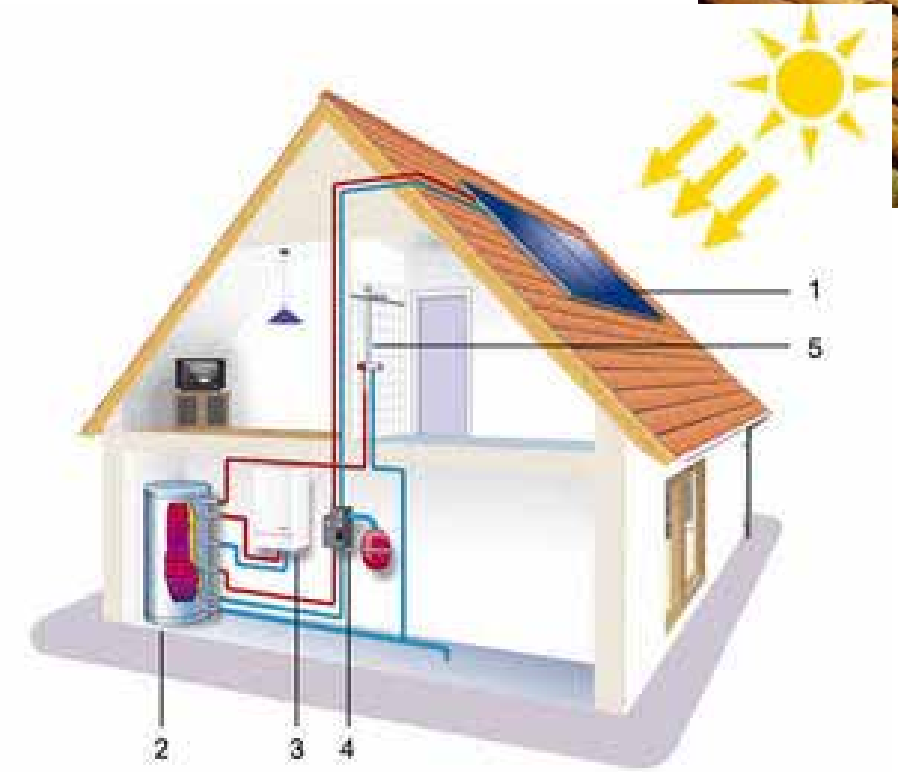
- Large heat needs at various temperature levels
  - Demand all year round
- Low-temp. solar heat available everywhere
- High-temp. solar heat in hot and dry climates

© OECD/IEA 2011

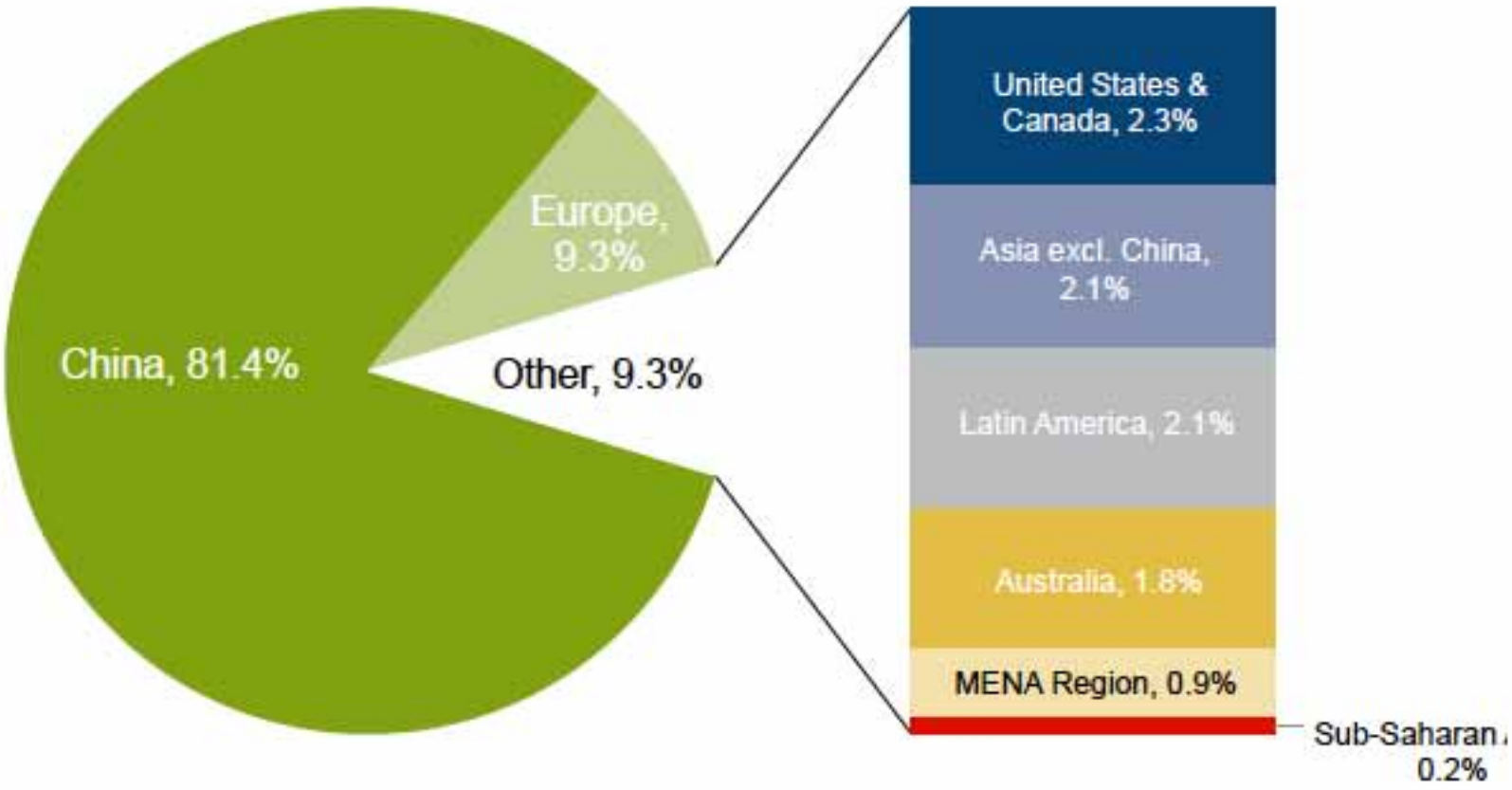
Renewable heat sources

- Solar thermal heat
- Geothermal heat
- Biomass (solid and biogas)
- Heat pumps using a renewable source
- Renewable electricity used for heat

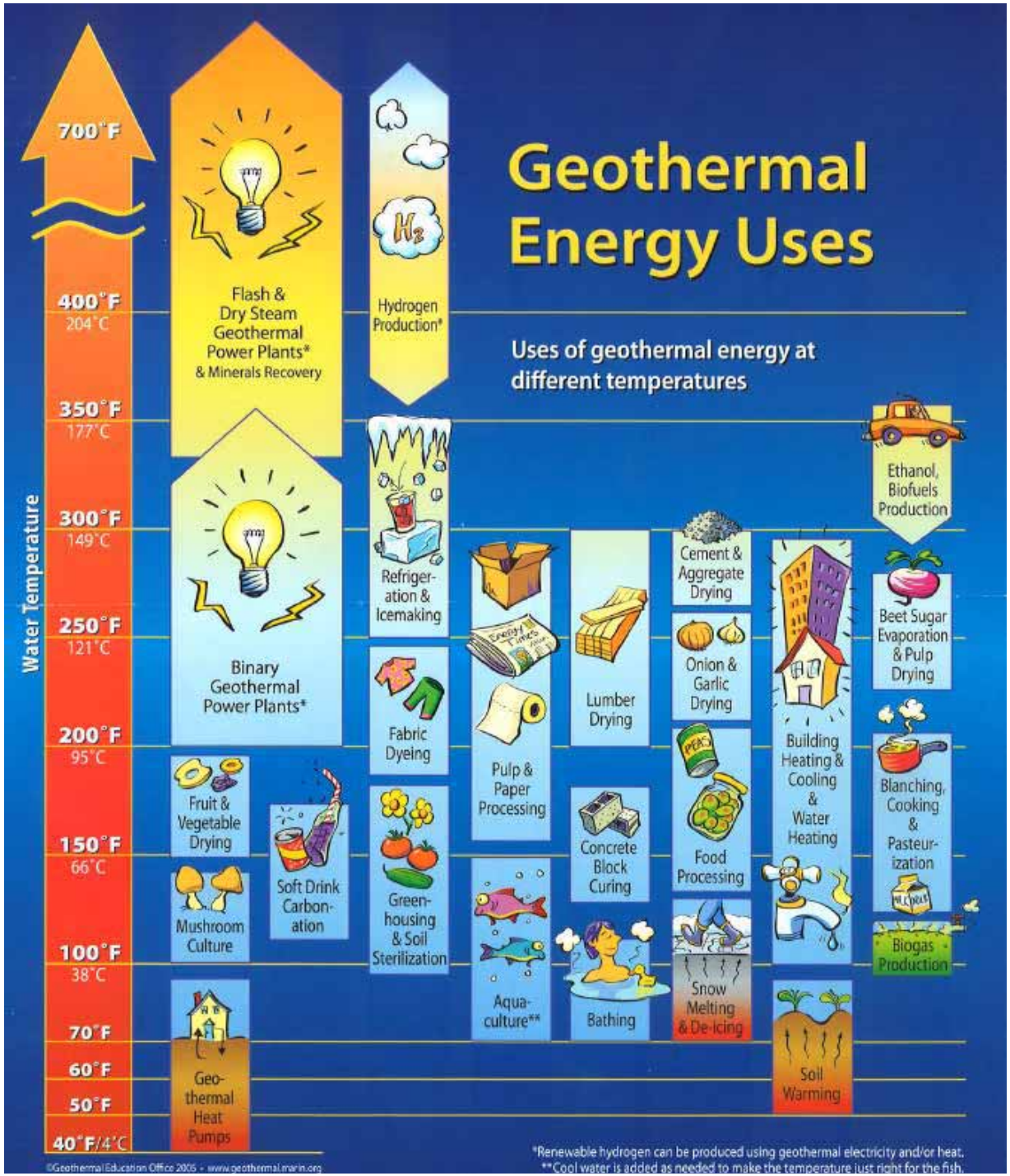
Solar water heating



Solar water heating installations



Geothermal heat



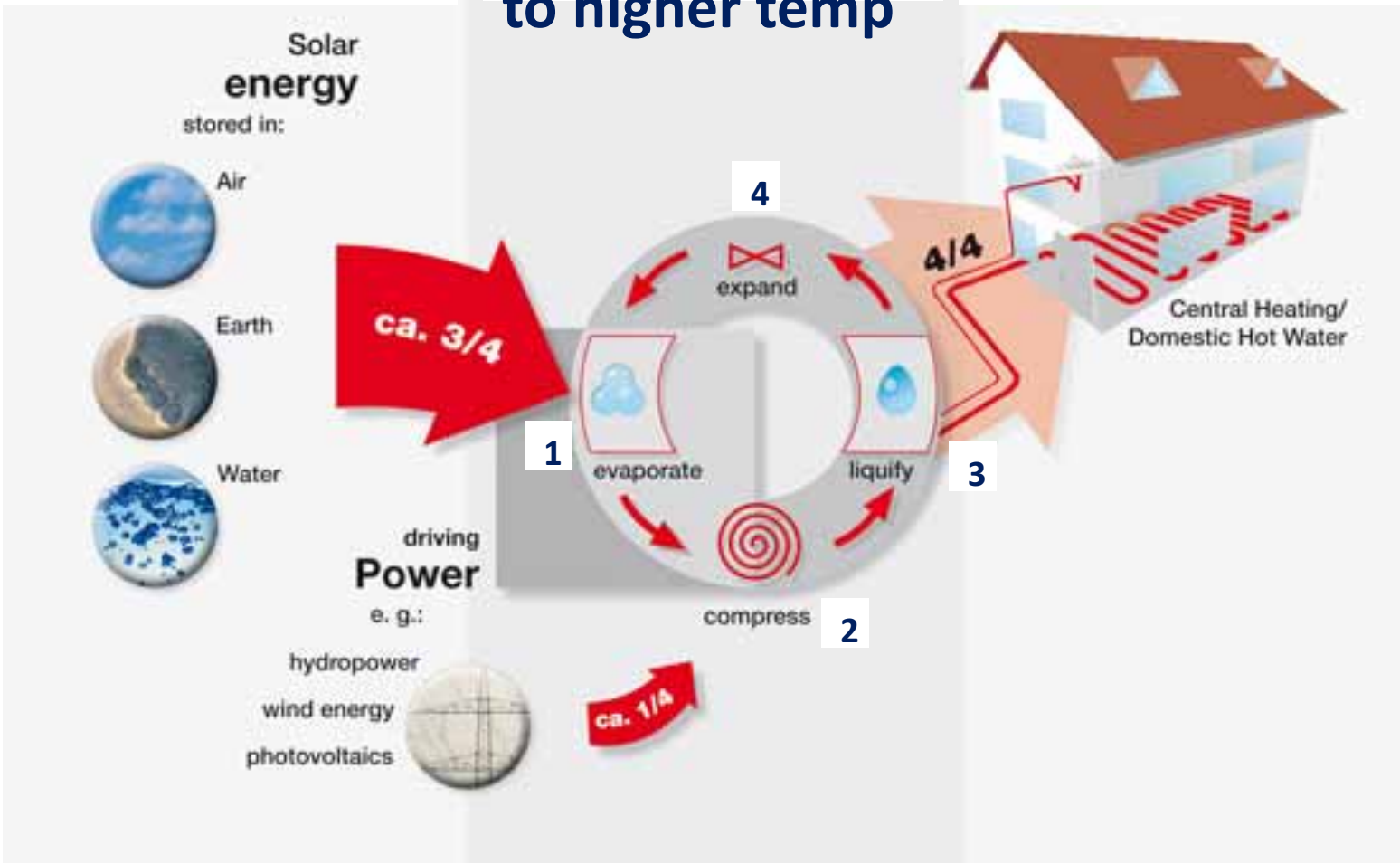
Source: Geothermal Information office, 2005

Heat pumps

Heat extraction

Transformation to higher temp

Distribution



Biomass combustion for heat (and power)

- Mature and competitive
- CHP conversion efficiencies of 70-90%
- Forestry and agricultural wastes
- However, complex pre-treatment, upgrading and conversion processes, and food competition are important

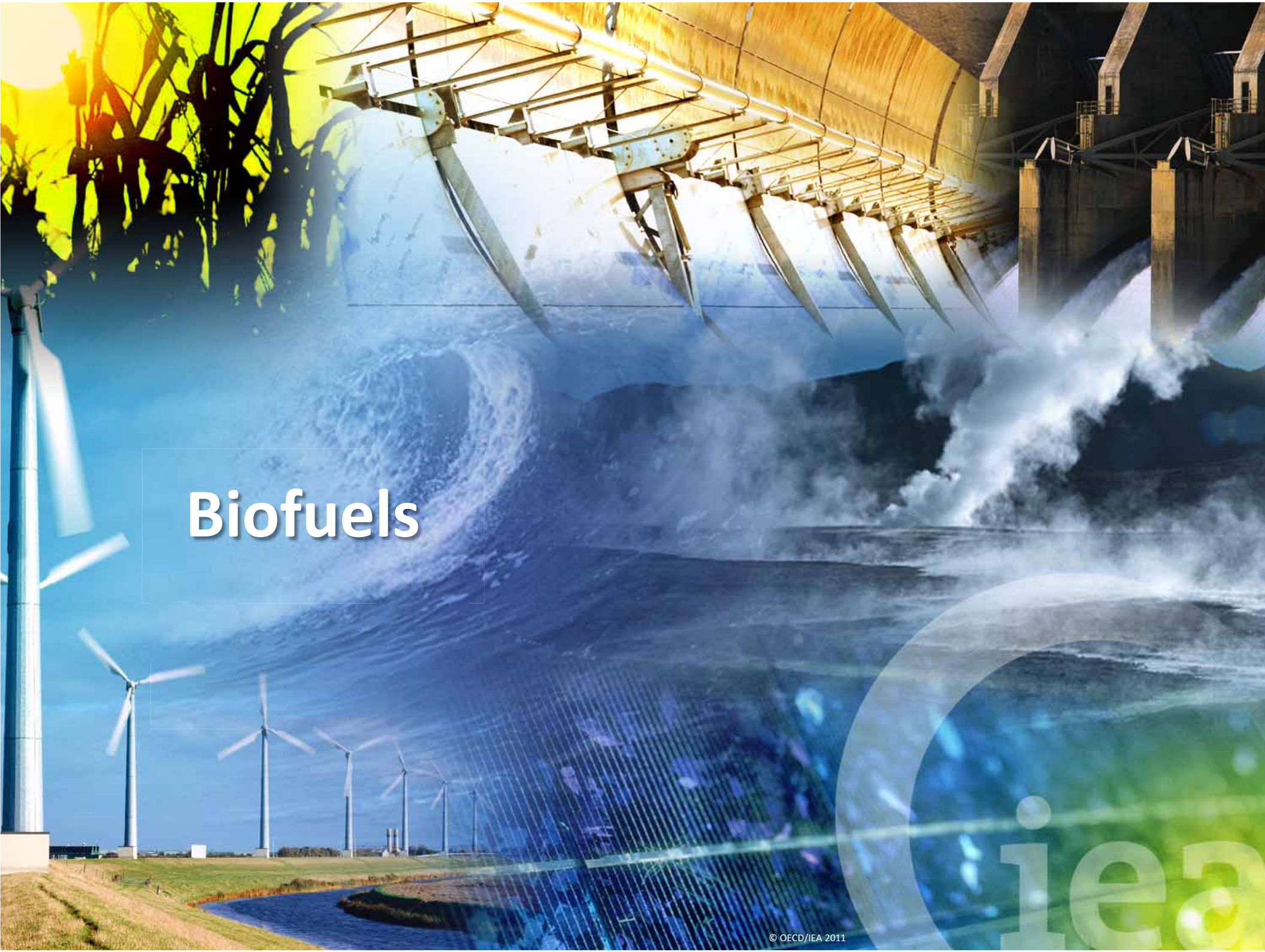
Additional challenges to renewable heat

Aside from barriers common to all renewables (economics, R&D, market, information), deployment of renewable heat has additional barriers

- Fragmented market
- Fragmented finance
- Incumbent infrastructure
- Proximity of resource to heat demand
- Variable output needs to be matched to demand
  - Time and temperature
  - Diurnal and seasonal

Conclusions

- **Heat dominates** final energy use, so expanding renewable heat is important
- **Shares of modern renewable heat are still small,** exceptions just in a few countries
- Apart from common barriers to renewable energy, deployment of renewable heat has **additional barriers**



Biofuel: definitions

- **Bio*mass*:**

  Any organic matter (i.e. it decomposes) that is derived from plants or animals.

- **Bio*fuels*:**

  Liquid and gaseous fuels produced from biomass, used in the transport sector.

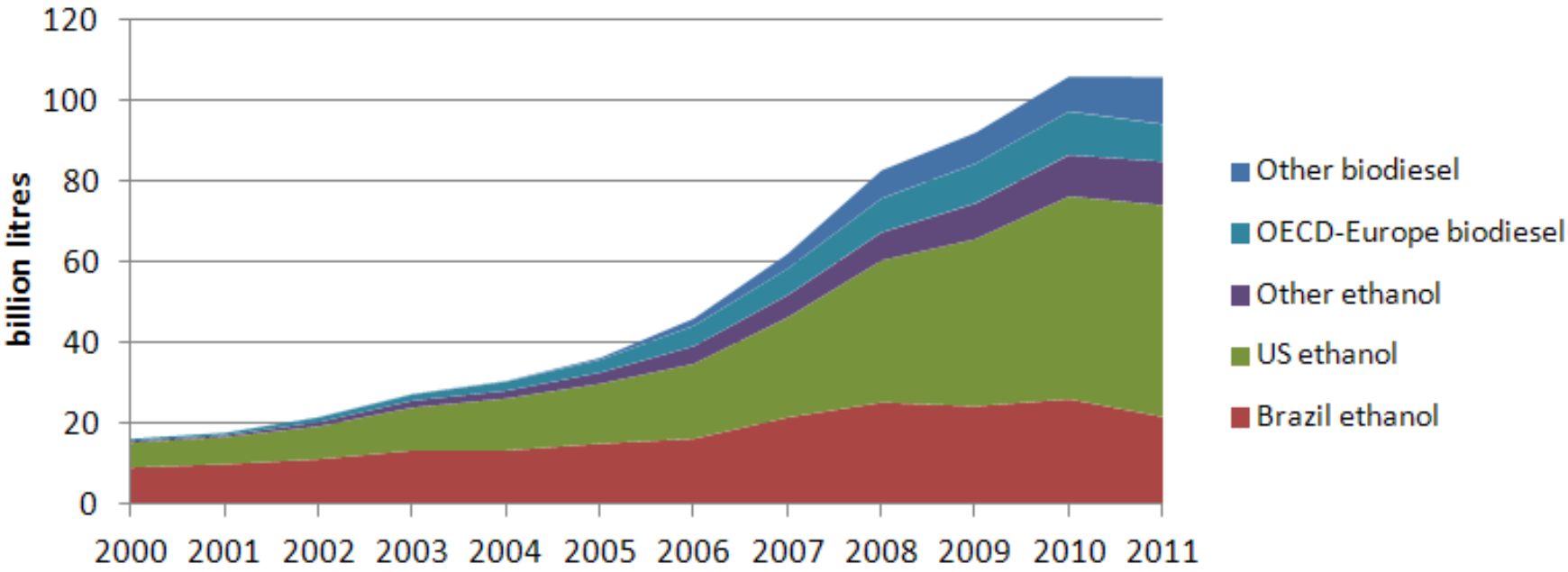
  - **Conventional biofuels (1st generation)**

    Well-established; in commercial production

    - **Ethanol:** sugarcane, sugarbeet, corn, wheat, cassava
    - **Biodiesel:** oil palm, rapeseed, soybean, sunflower
    - **Biogas:** biomethane produced from anaerobic digestion of energy crops (*e.g.* maize silage) and wastes (*e.g.* manure)

Courtesy: www.flashnewstoday.com; www.palmplantations.com.au; soilcrop.tamu.edu; www.reggie.net

Biofuel production 2000-10



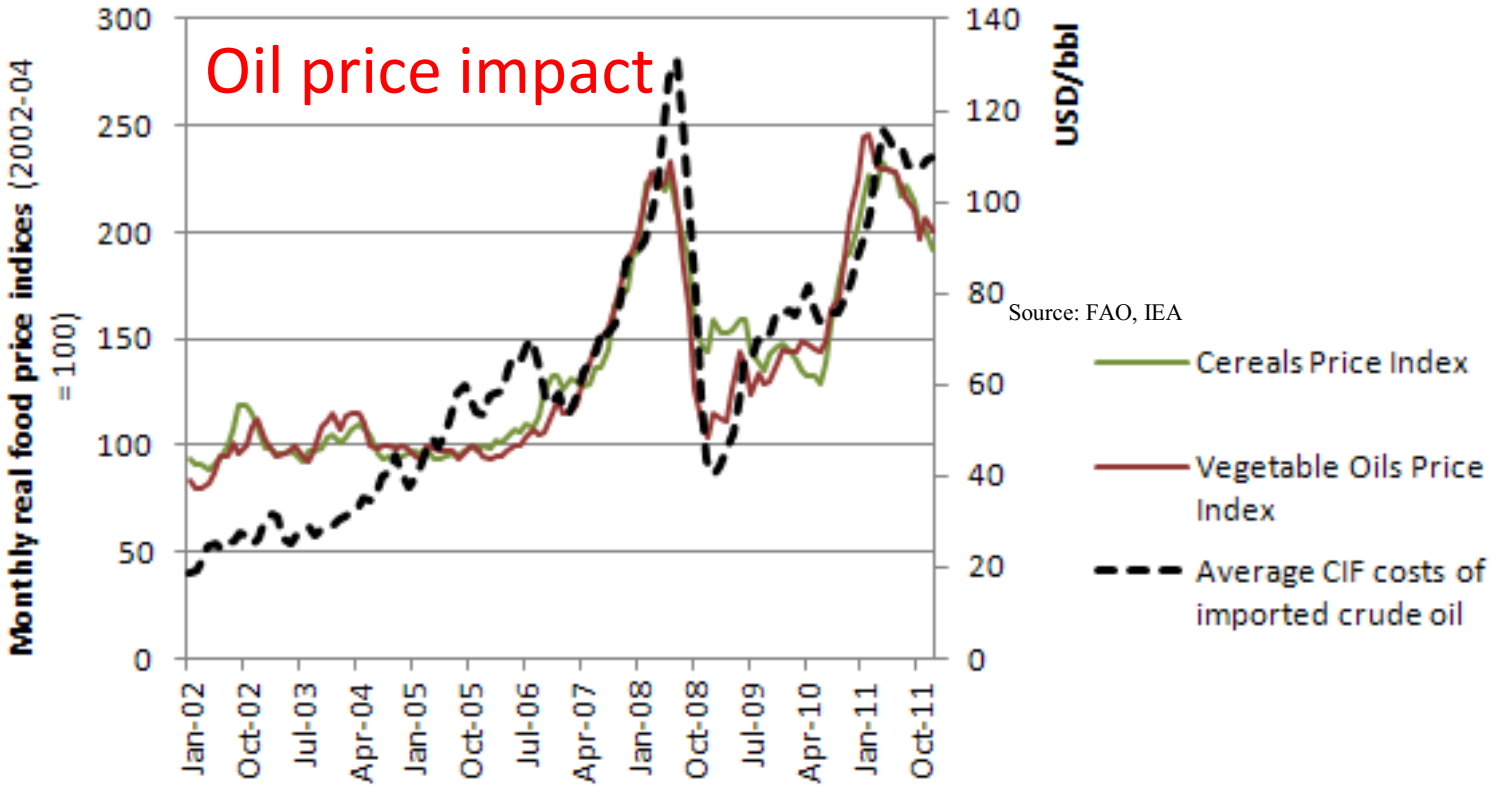
Source: IEA Oil Market Report December 2011

- Rapid increase in global biofuel production in the last 10 years
  - US and Brazil largest producers followed by EU
  - Ethanol production dominates in US and Brazil; biodiesel in Europe
- Biofuels provide around 3% of total road transport fuel today
- Policy is main driver behind biofuel development
  - More than 50 countries have blending mandates and targets

Biofuel sustainability

"Food vs. fuel" debate

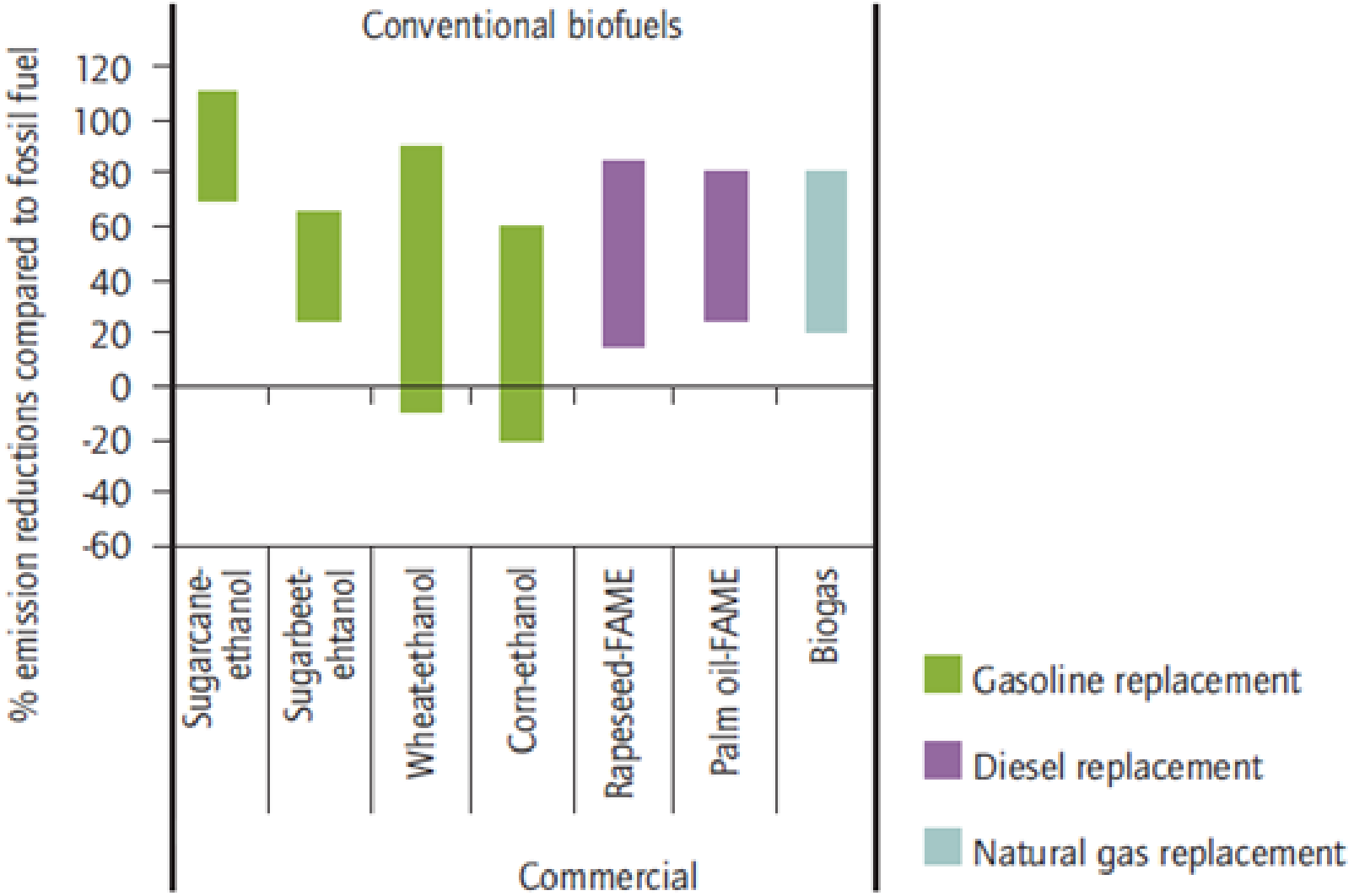
- Latest studies suggest limited impact on food prices
  - Biofuel production occupies <1% of global agricultural area globally
  - Valuable by-products for the fodder market (e.g. dried distiller's grains, soy-meal)



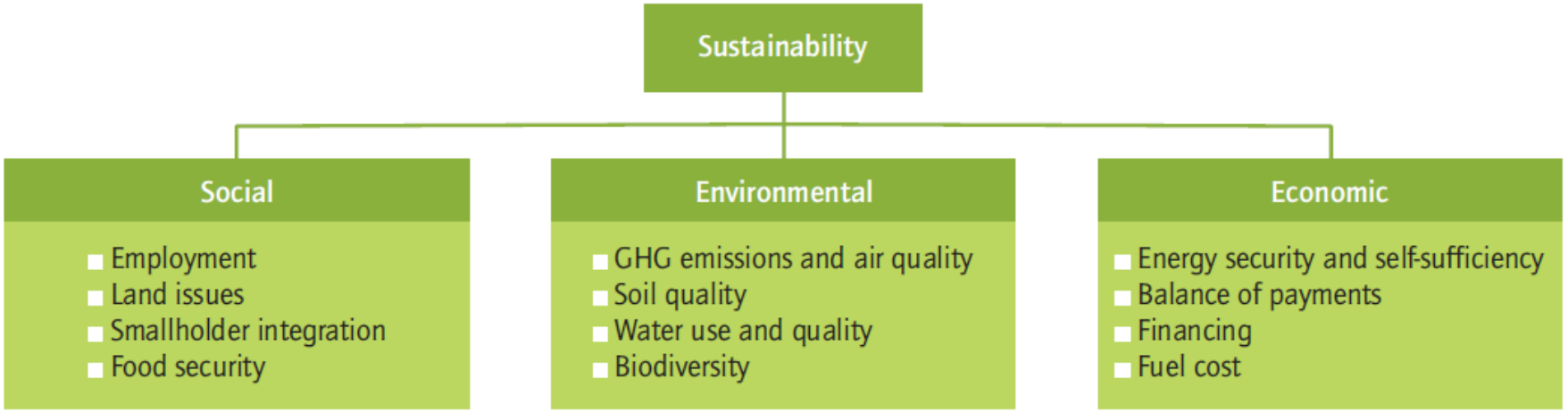
- Other factors with impact on agricultural commodity prices
  - Weather
  - Speculative trading
  - Currency volatility

Biofuel sustainability

- GHG reduction potential of some conventional biofuels low, even negative
  → Advanced biofuels promise higher GHG savings



Three sustainability pillars



Source: IEA Technology Roadmap – Biofuels for Transport (forthcoming)

- All three pillars must be considered **simultaneously** to ensure the sustainability of biofuel production
- Sustainability **certification** first important step in this direction

Money from old rope

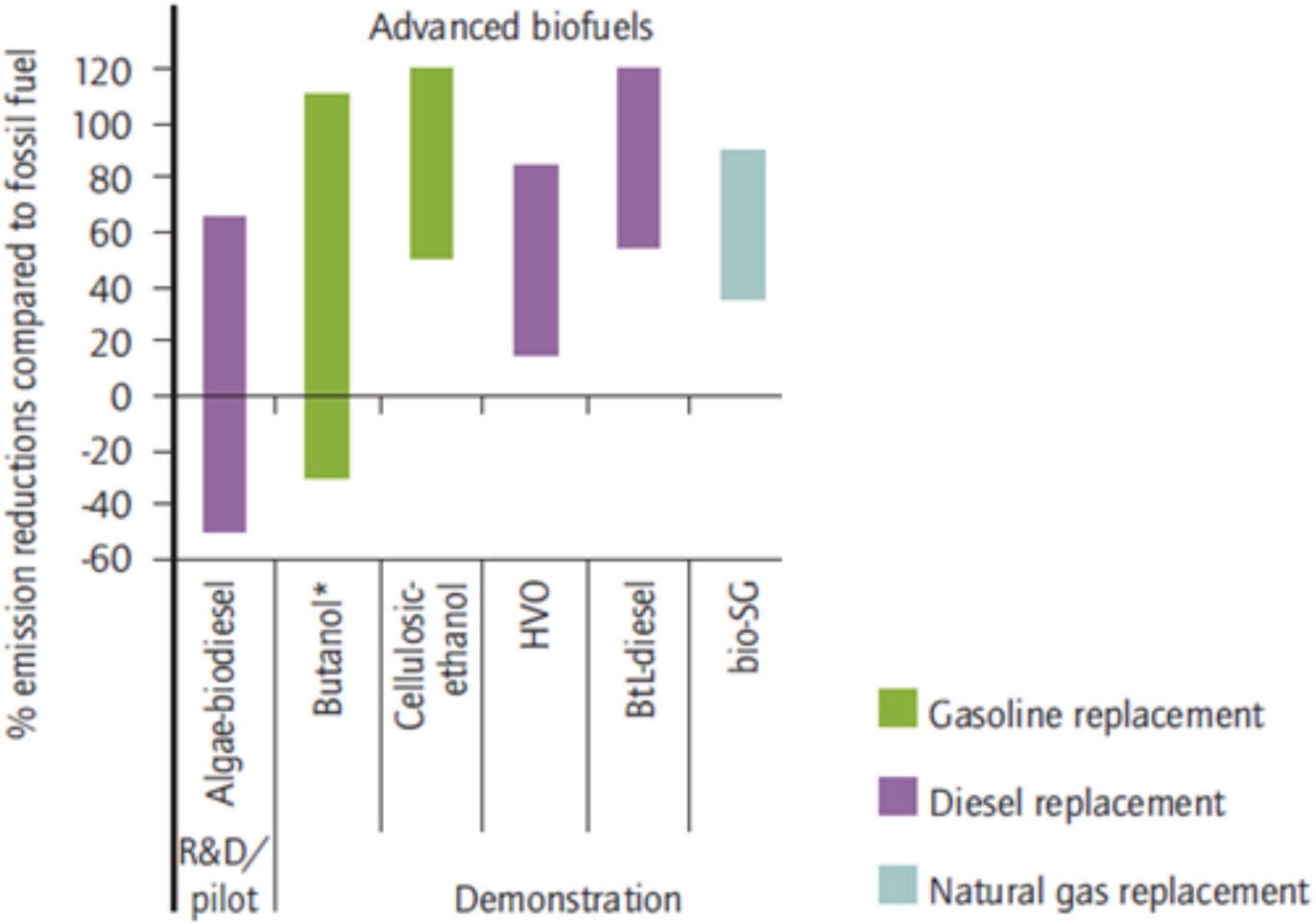
- **Advanced biofuels**
  - Currently in R&D, pilot or demonstration phase
  - **Hydrotreated vegetable oil (HVO):** same feedstocks as conventional biodiesel
  - **Cellulosic-ethanol:** different types of lignocellulosic biomass
  - **Biomass-to-liquids (BtL)-diesel:** different types of lignocellulosic biomass
  - **Bio-synthetic gas (bio-SG):** biomethane produced from different types of biomass
  - **Other novel technologies** in the R&D phase
    - Algae-biofuels
    - Sugar-based hydrocarbons
- **Advanced biofuels promise:**
  - High land-use efficiency
  - Use of non-arable land
  - Reduced fertiliser input through use of perennial crops

Courtesy:
A. Eisentraut; www.biofuelstp.eu;
www.roulonspropre-roulonsnature.com

GHG reduction potential

- GHG saving potential for cellulosic-ethanol and BtL-diesel show quite similar potential GHG savings

  → However, values need to be validated for commercial-scale production

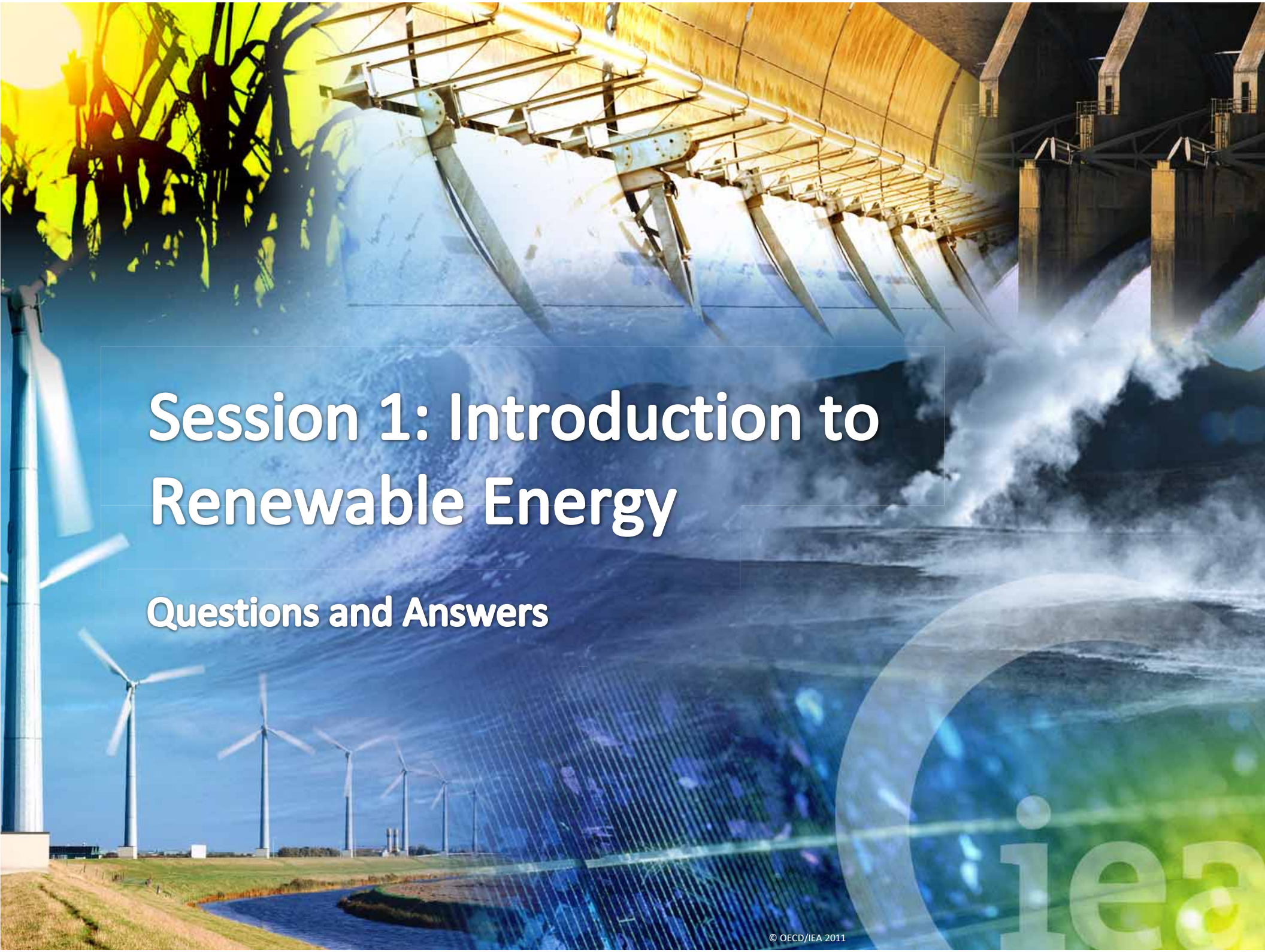


Advanced biofuels pilot and demonstration plants

http://demoplants.bioenergy2020.eu

Session 1 summary

- A **wide range of technologies** canprovide:
  - Electricity
  - Heat
  - Biofuels
- Technologies are at **different stages** of maturity
- **Markets are well established** in some
  - And **growing strongly**
- **Costs are reducing**
  - Renewables are cost competitive in an increasing range of applications where resource is favourable
- Significant resources exist in **central & west Asia**



Session 1: Introduction to Renewable Energy

Questions and Answers