Climate Change Mitigation

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Erasmus+

Agenda

1. **Recap Climate Change Physics**

2. **External Costs of Climate Change**

3. **Mitigation Measures**

   - Introduction

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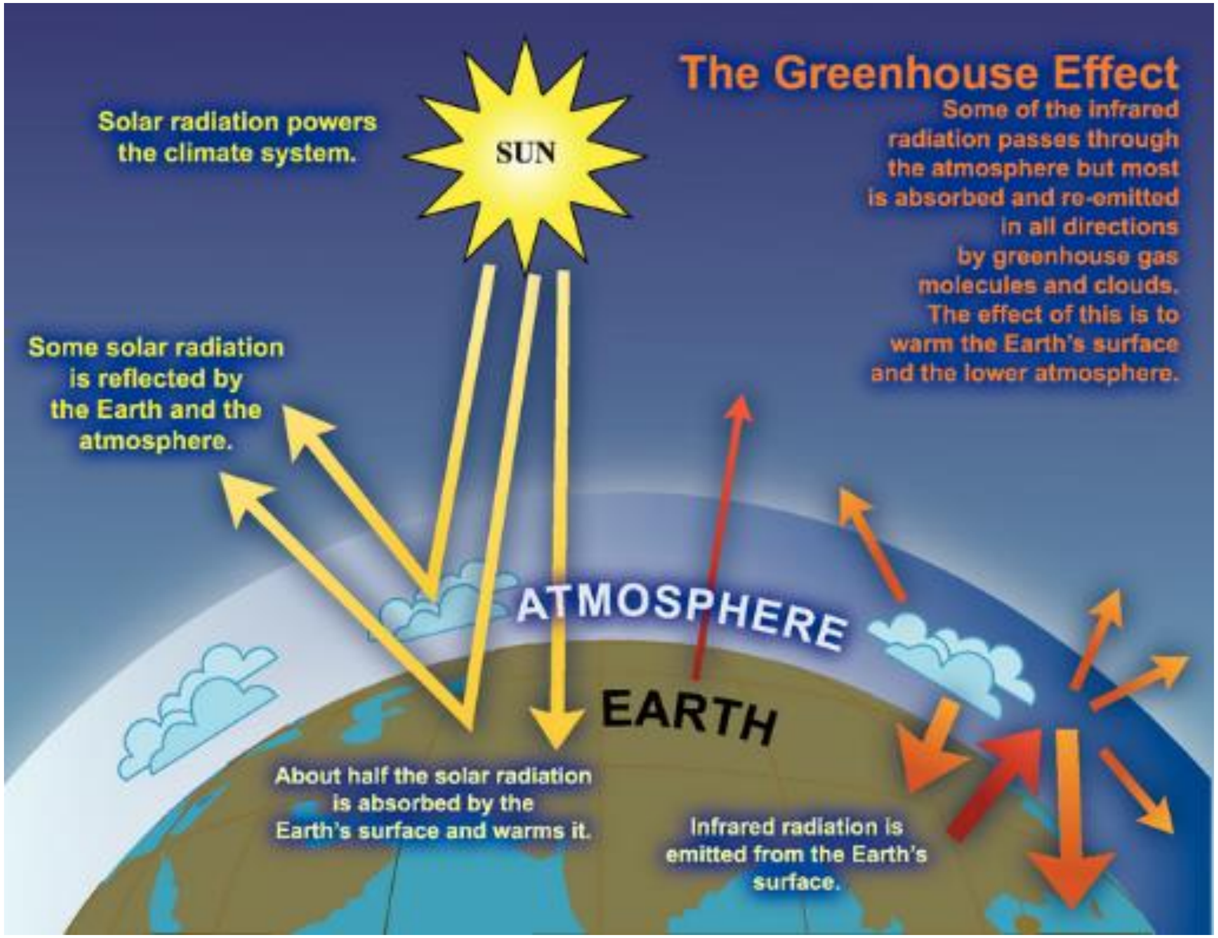
15 min coffee break

   - Energy Efficiency & Sufficiency
   - Renewable Energies & Storage: Potentials, Technologies and Costs
   - Foundations of Sustainable Energy Systems

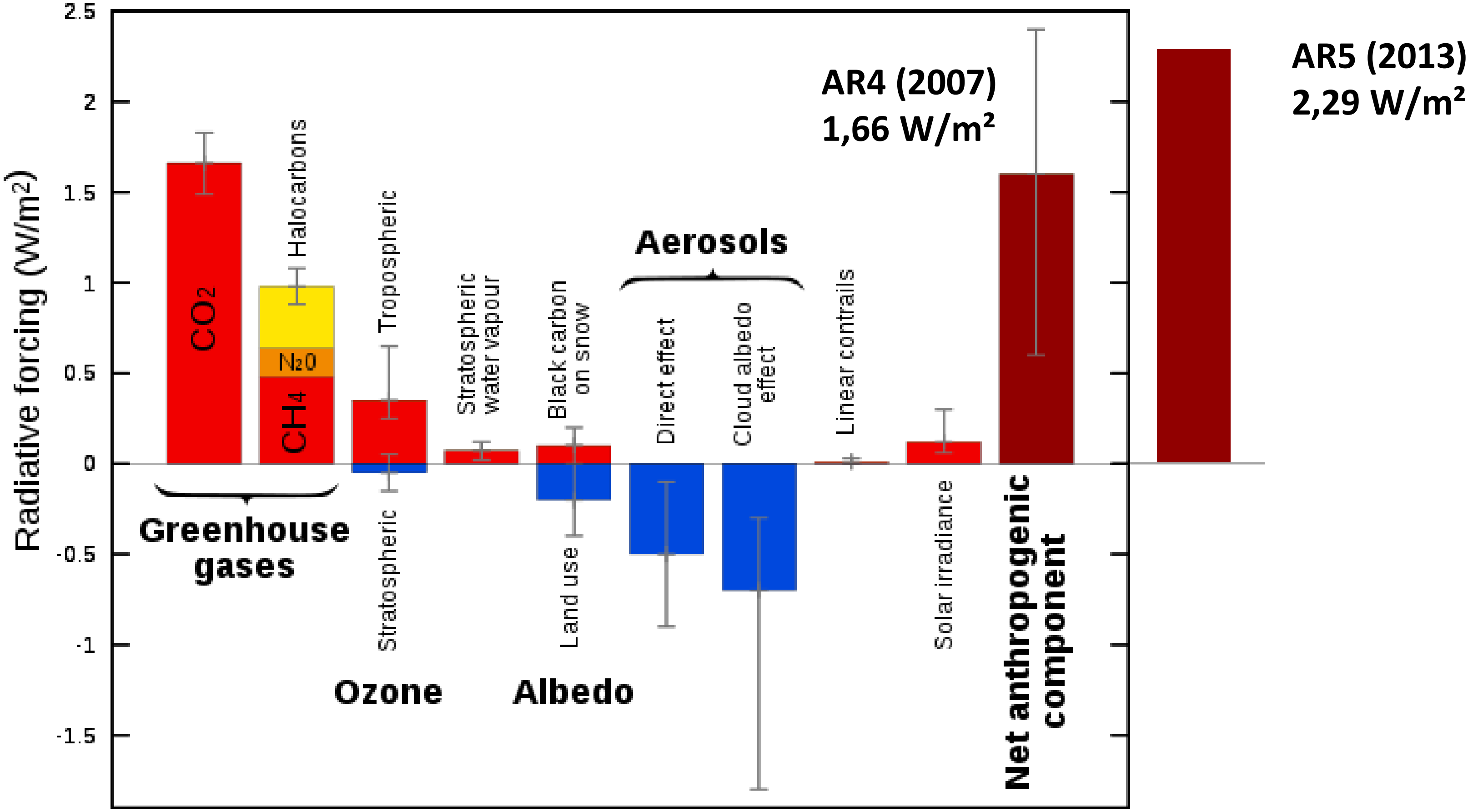
Recap
Climate Change Physics

Greenhouse Gas Effect



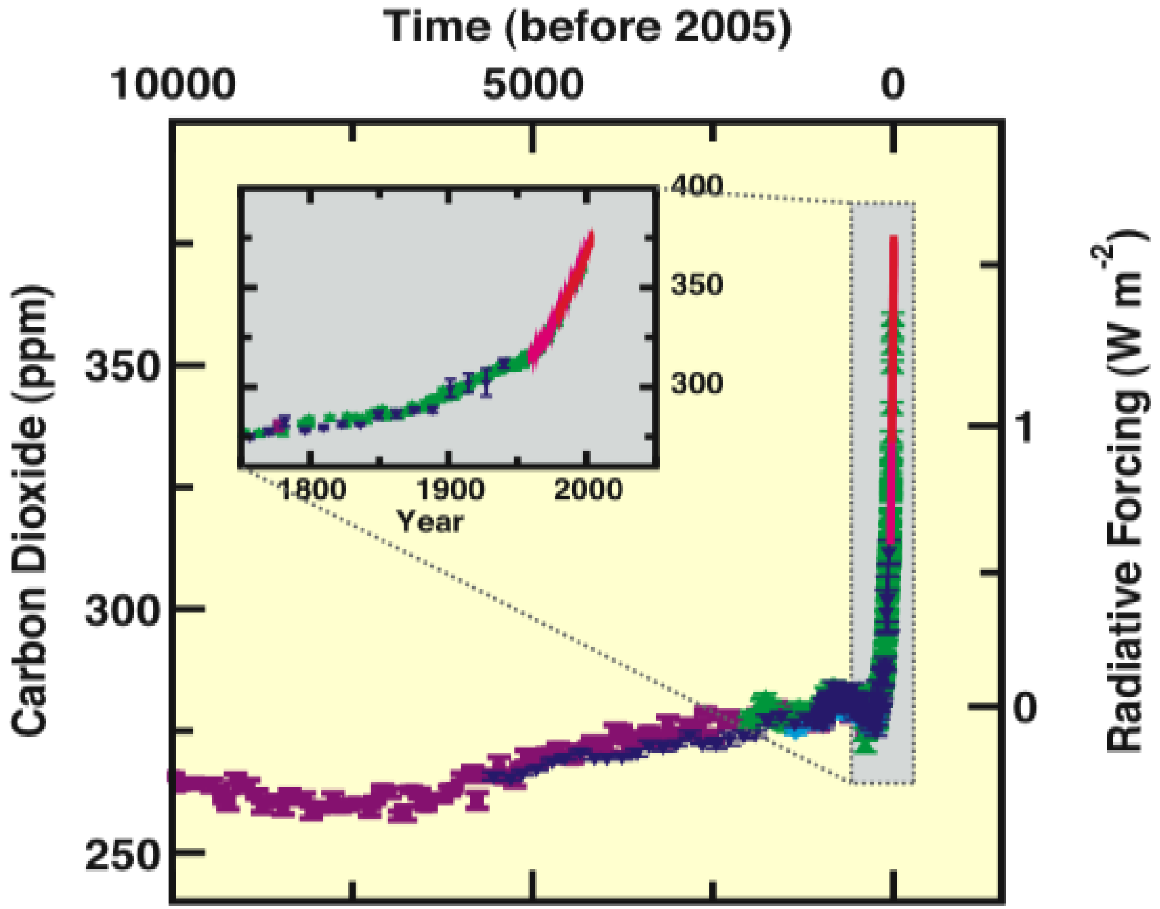
Source: http://www.earthontheedge.com

Radiative Forcing Components



Source: IPCC 2013 (WG I, SPM, p2)

Drivers of Climate Change

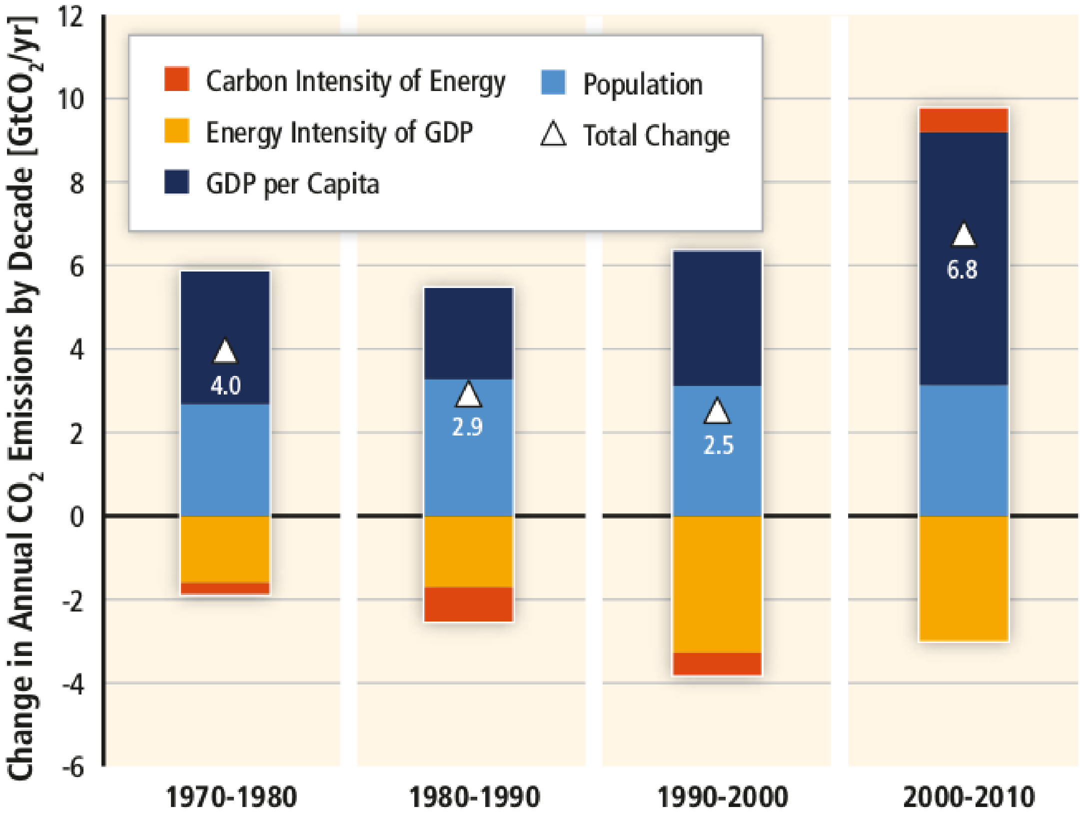


Source: IPCC 2007 (WG I, SPM, p.3)

Drivers of Climate Change

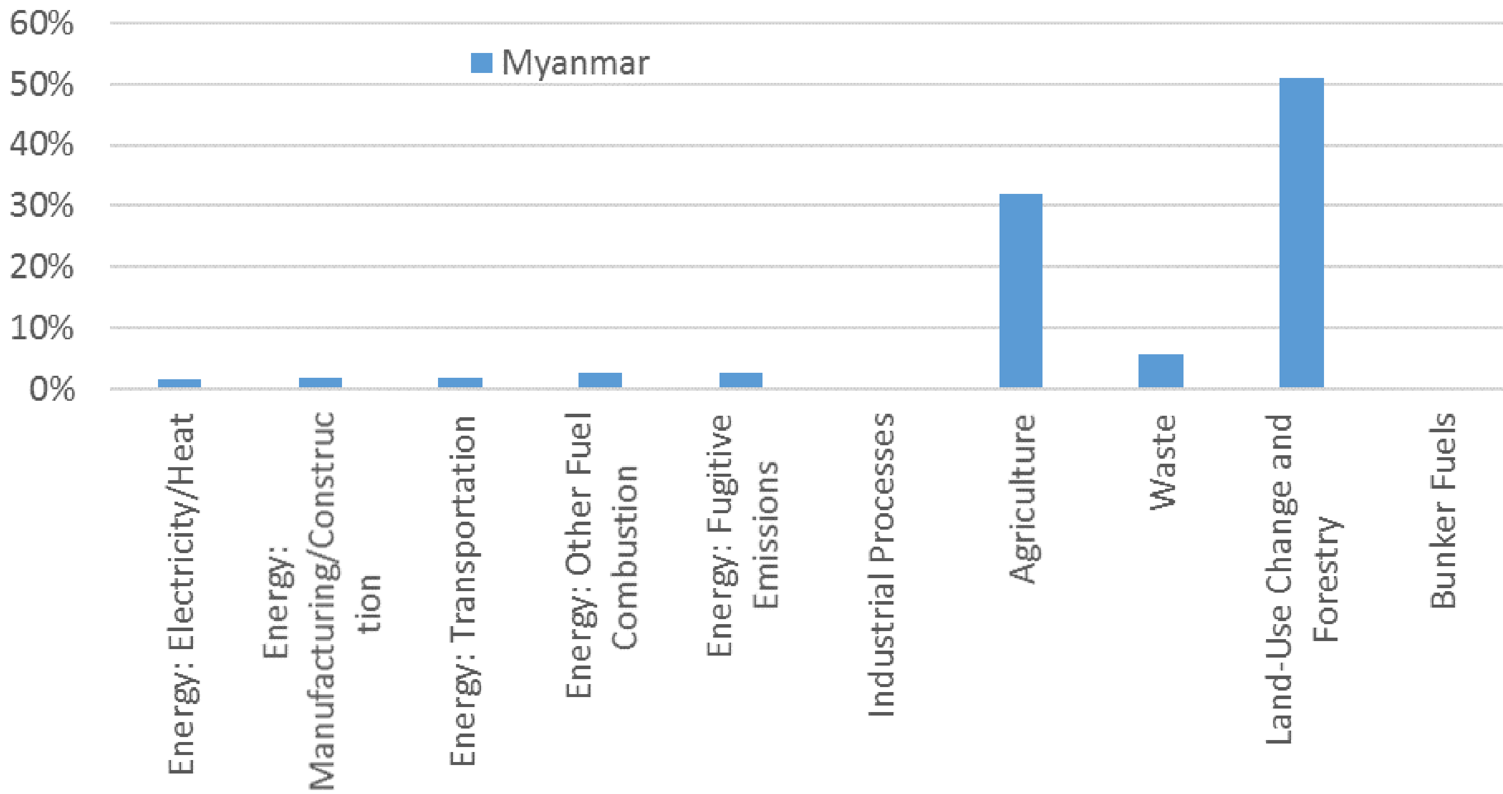
***"Globally, economic and population growth continue to be the most important drivers** of increases in CO_2 emissions from fossil fuel combustion."*

IPCC 2014 (WG III), TS, p.47



Source: IPCC 2014 (WG III), TS, p.48)

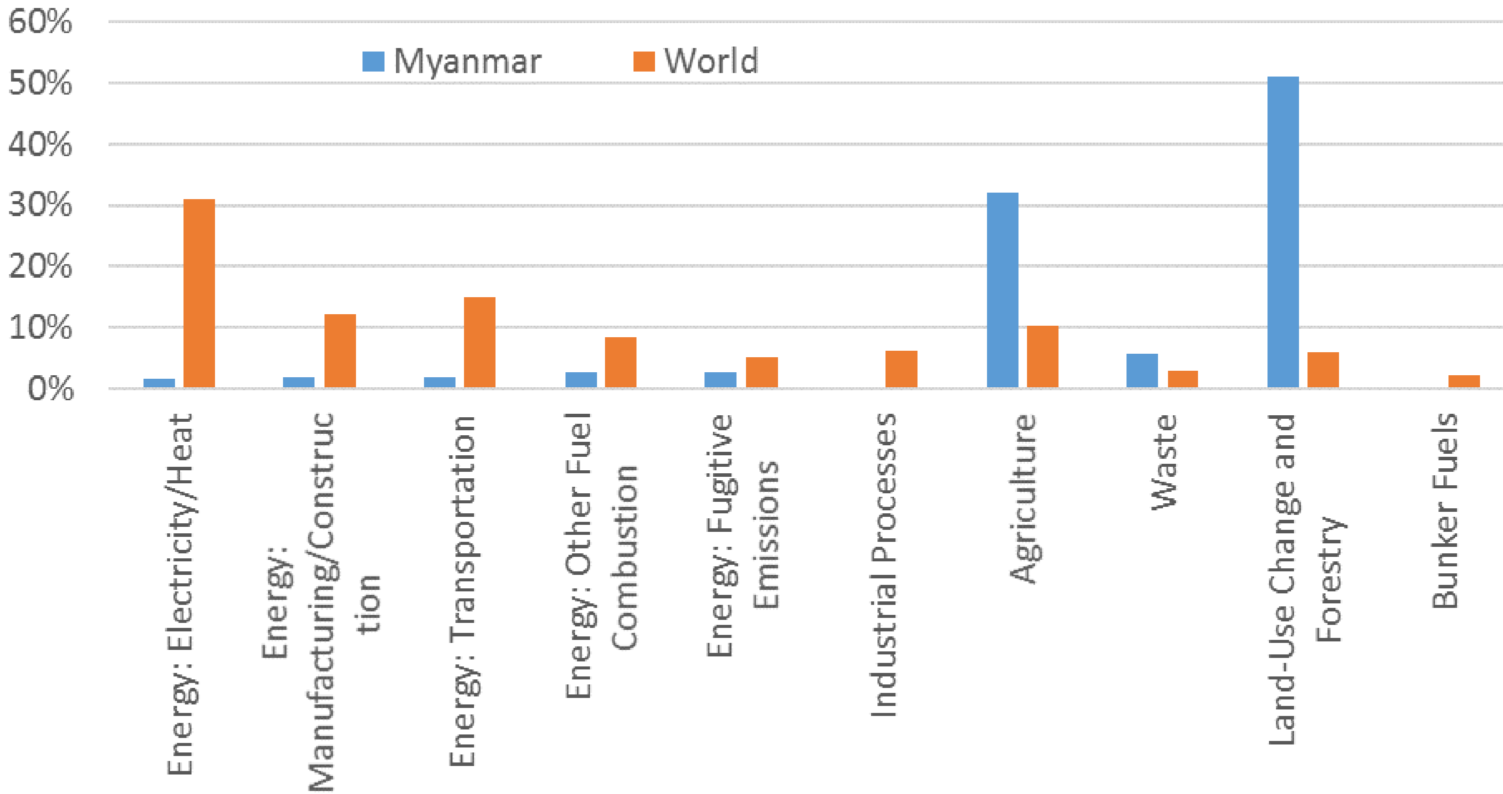
Source of GHG Emissions – Myanmar



Total: 202 Mt CO_2e

Source: World Resources Institute (2013)

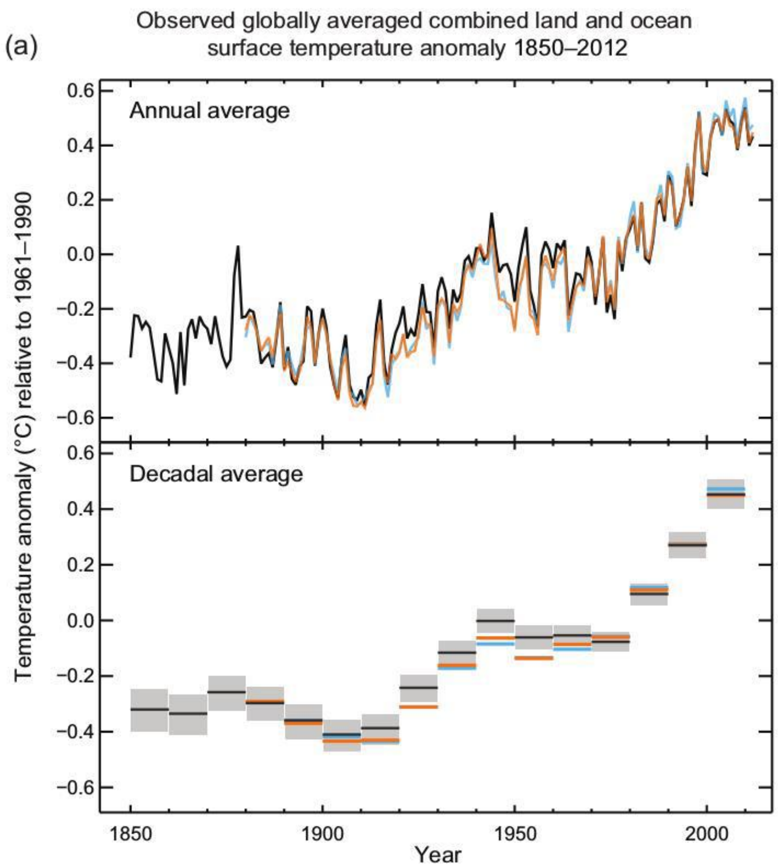
Source of GHG Emissions – Myanmar vs. World

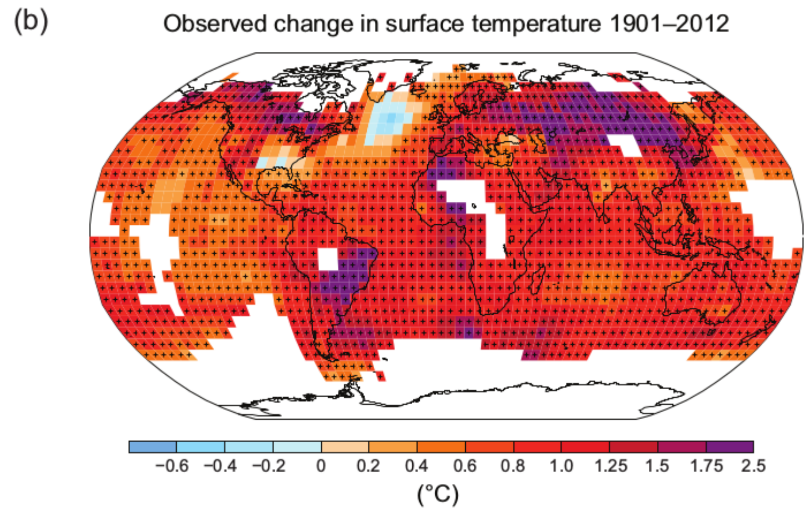


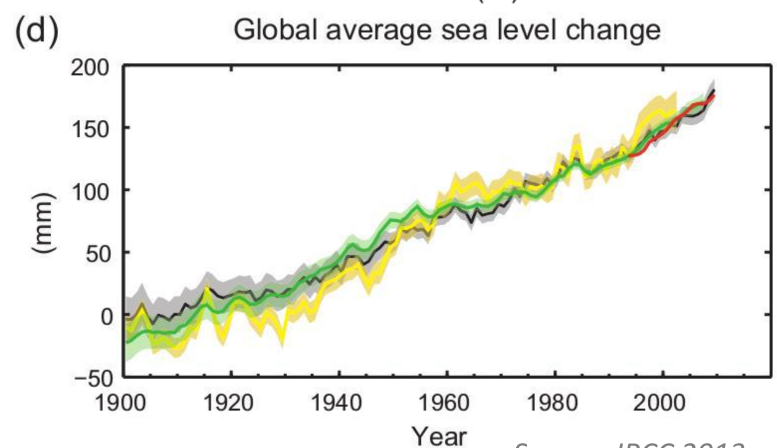
Total: 202 Mt CO_2e (0.4 % worldwide)

Source: World Resources Institute (2013)

Rise of Global Temperatures





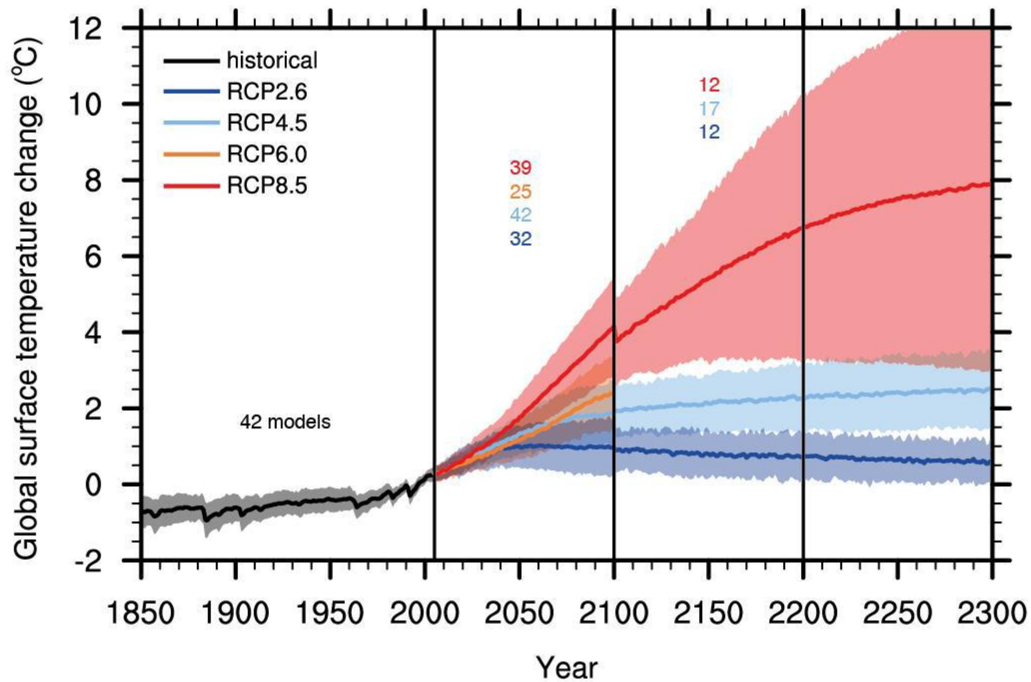


Source: IPCC 2013, p. 6 & 10

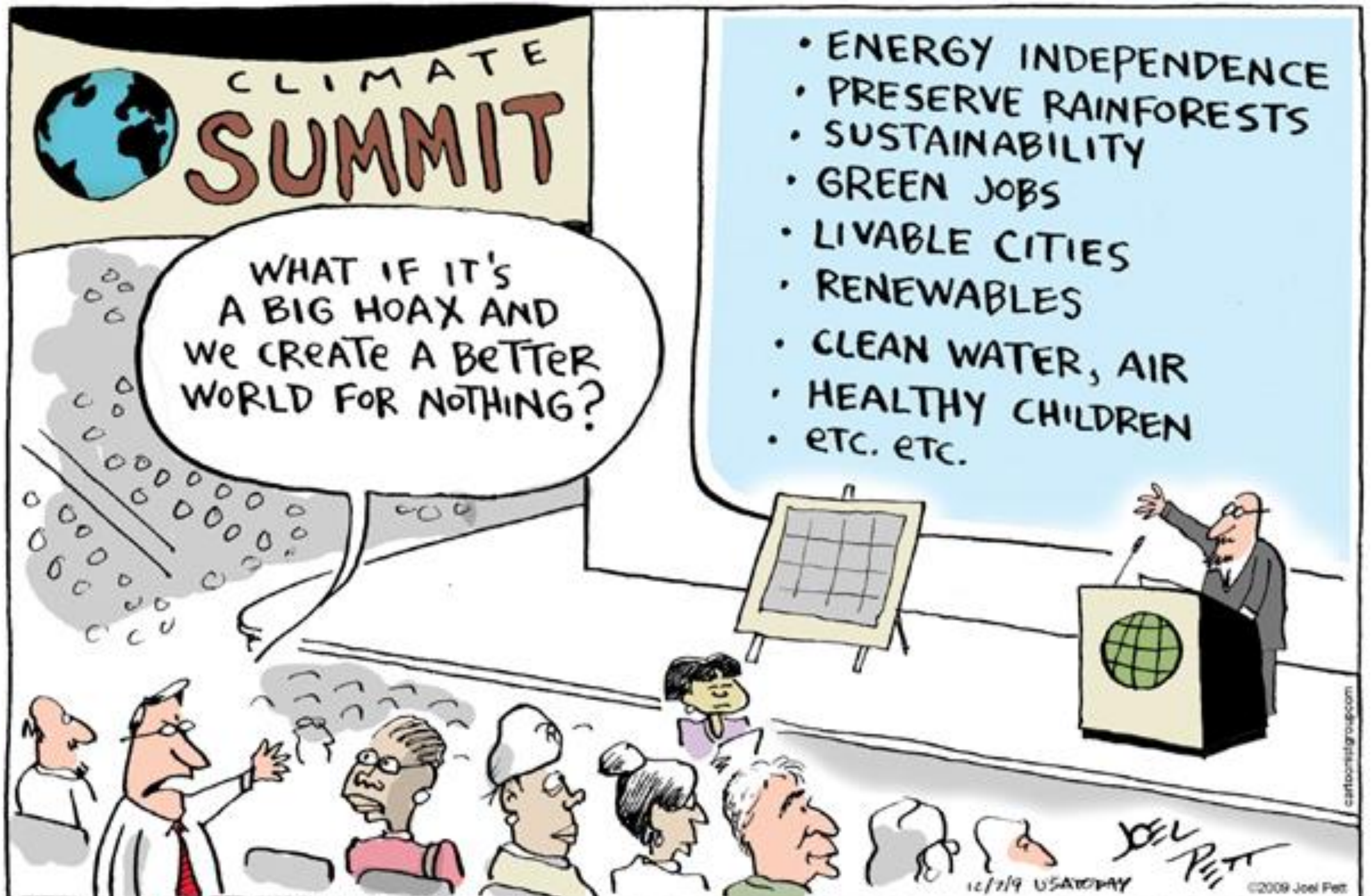
GHG Emission projections

„Continued emissions of greenhouse gases will cause further warming and changes in all compoents of the climate system.

Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.“



Source: IPCC 2013 (WG I), TS, S.89)



CLIMATE SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• ETC. ETC.
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External costs of Climate Change

How much does climate change cost?

Impacts of Climate Change - Myanmar

Observed changes

1. Droughts (1980s, 1990s, 2010)
2. Strong cyclones (Nargis 2008)

Source: Myanmar Climate Change Alliance

Impacts of Climate Change - Myanmar

<u>**Observed changes**</u>

1. Droughts (1980s, 1990s, 2010)
2. Strong cyclones (Nargis 2008)
3. July to October 2011: heavy rain and flooding in the Ayeyarwady, Bago, Mon and Rakhine Regions/States
4. July/August 2015 flooding and landslides displaced 1.6 million people, caused almost 120 deaths, damaged agriculture and infrastructure

Source: Myanmar Climate Change Alliance

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Future Impacts

1. Increase in the prevalence of drought events
2. Increase in intensity and frequency of cyclones
3. Rainfall variability: erratic and intense rainfall events
4. Increase in the occurrence of flooding and storm surge
5. Sea-level rise
6. Increase in extreme high temperatures

Source: Myanmar Climate Change Alliance

How does Climate Change Affect the Economy and Society?

Agriculture:

- Sudden loss of crops
- Mid-term Negative impact on agricultural production (efficiency) and food security
- Long-term soil erosion
- Impact on livestock
- Loss of fishing ressources

Environment, Natural Resources and Biodiversity:

- Vulnerable ecosystems (fires)
- Loss of biodiversity
- Degradation of environment (forest die-back, spread of grasslands/steppes/deserts)

How does Climate Change Affect the Economy and Society?

Transport & Industry

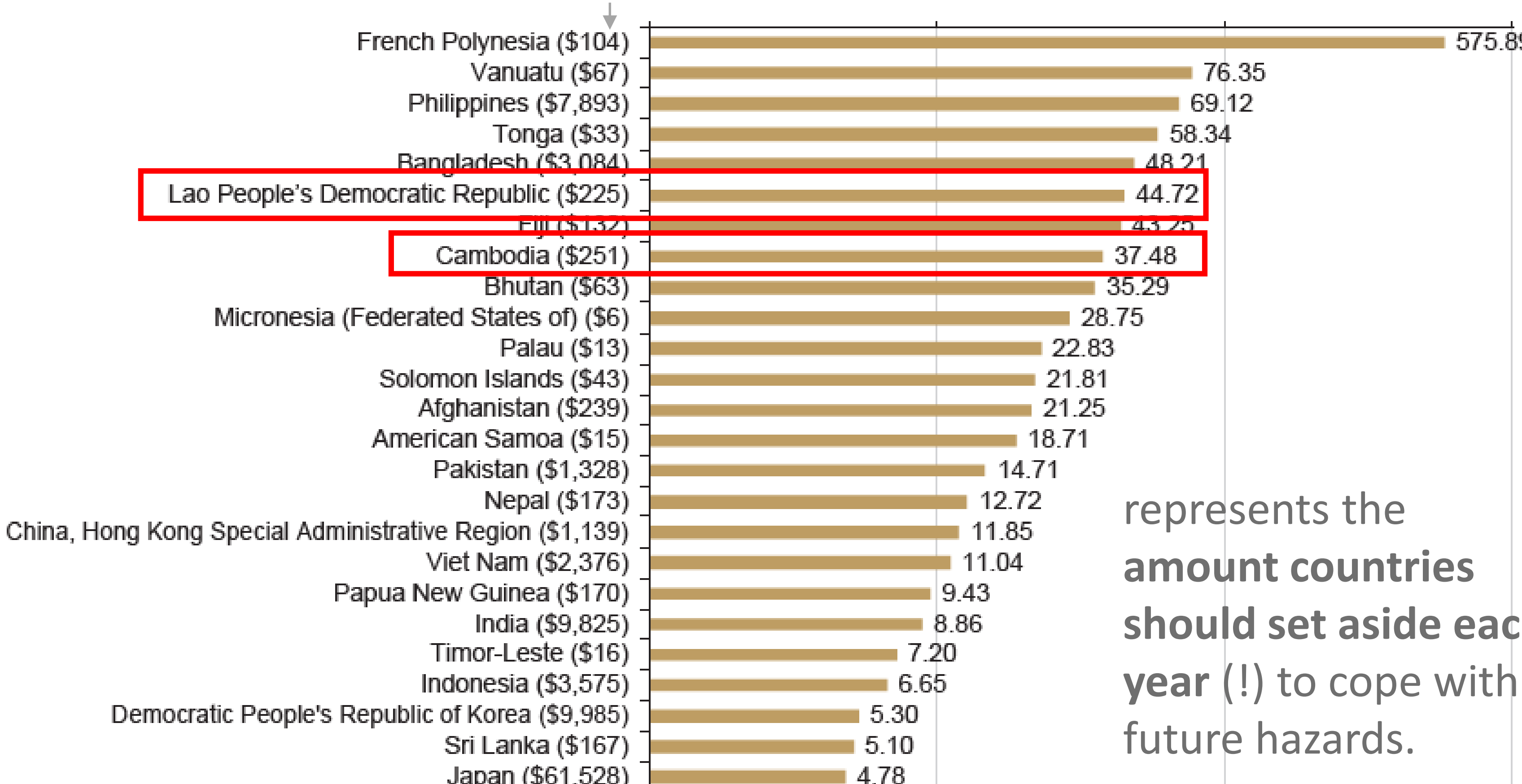
- Loss of infracstructure from extreme weather events
- Resource availability

Human Settlements/Cities and Public Health:

- Increased vulnerability of growing cities (flash floods, infrastructure loss)
- Rising food prices
- Spread of diseases
- Decreased fresh water resources

Financial Loss due to Climate Change

Absolute value (million US$) in % of total social spending



represents the **amount countries should set aside each year** (!) to cope with future hazards.

Source: UNISDR (2015)

What are External Costs?

"… costs that arise from any human activity when the agent responsible for the activity does not take full account of the impacts on others of his or her actions."

An external cost occurs when producing or consuming a good or service imposes a cost upon a third (unrelated) party.

<u>Examples:</u>

- Pollution from a power station affects the health of people in the nearby city → owner does not have to pay for treatment
- Construction of a dam destroys farmland → farmers are not compensated

Total Costs to Society = Private Costs + External Costs

The existence of external costs can lead to market failure because the free market generally ignores the existence of external costs.

Source: IPCC 2014, WG III

What are External Costs?

1. Direct costs of climate change events
   - Damages due to increasing natural disasters
   - changes in production, production loss

2. Broader social and economic costs, lost opportunities for development
   - **Human health:** higher mortality rate, reduction in life expectancy, cancer, health problems
   - **Building material:** quicker aging of sand stone, steel corrosion
   - **Crops:** yield changes
   - **Global warming:** economic impacts due to temperature change
   - **Amenity losses:** air and noise pollution
   - **Ecosystem:** pollution, soil degradation
   - **Tourism:** loss of biodiversity & attractiveness, air pollution

How Do We Measure External Costs?

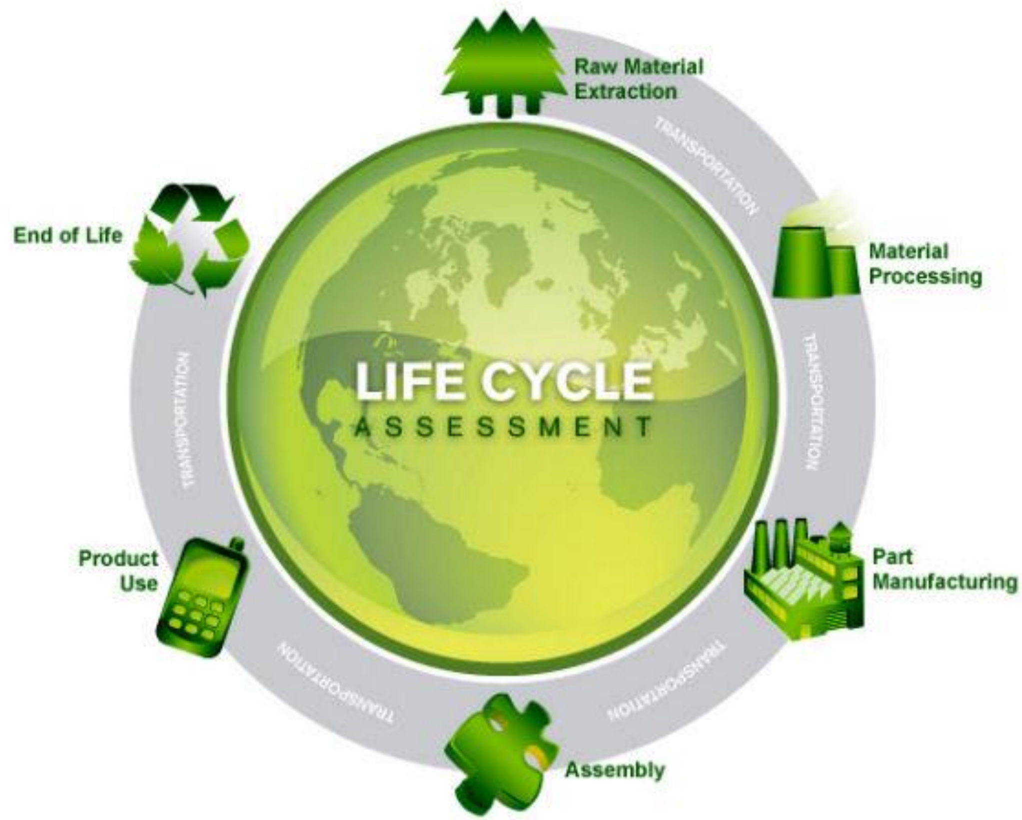
1. Calculations using simplistic assumptions → uncertain cost estimations
2. Concepts:

Life-cycle analysis (LCA)

- „cradle-to-grave analysis“
- assessing environmental impacts associated with all the stages of a product's life

Green accounting

- factor environmental costs into financial calculations



Source: http://www.solidworks.com

How Do We Measure External Costs?

What is the scope?

Burden: Emission and pollution levels

Dispersion: Spread of pollution around the source.

Exposure: Extent of exposure of population at risk.

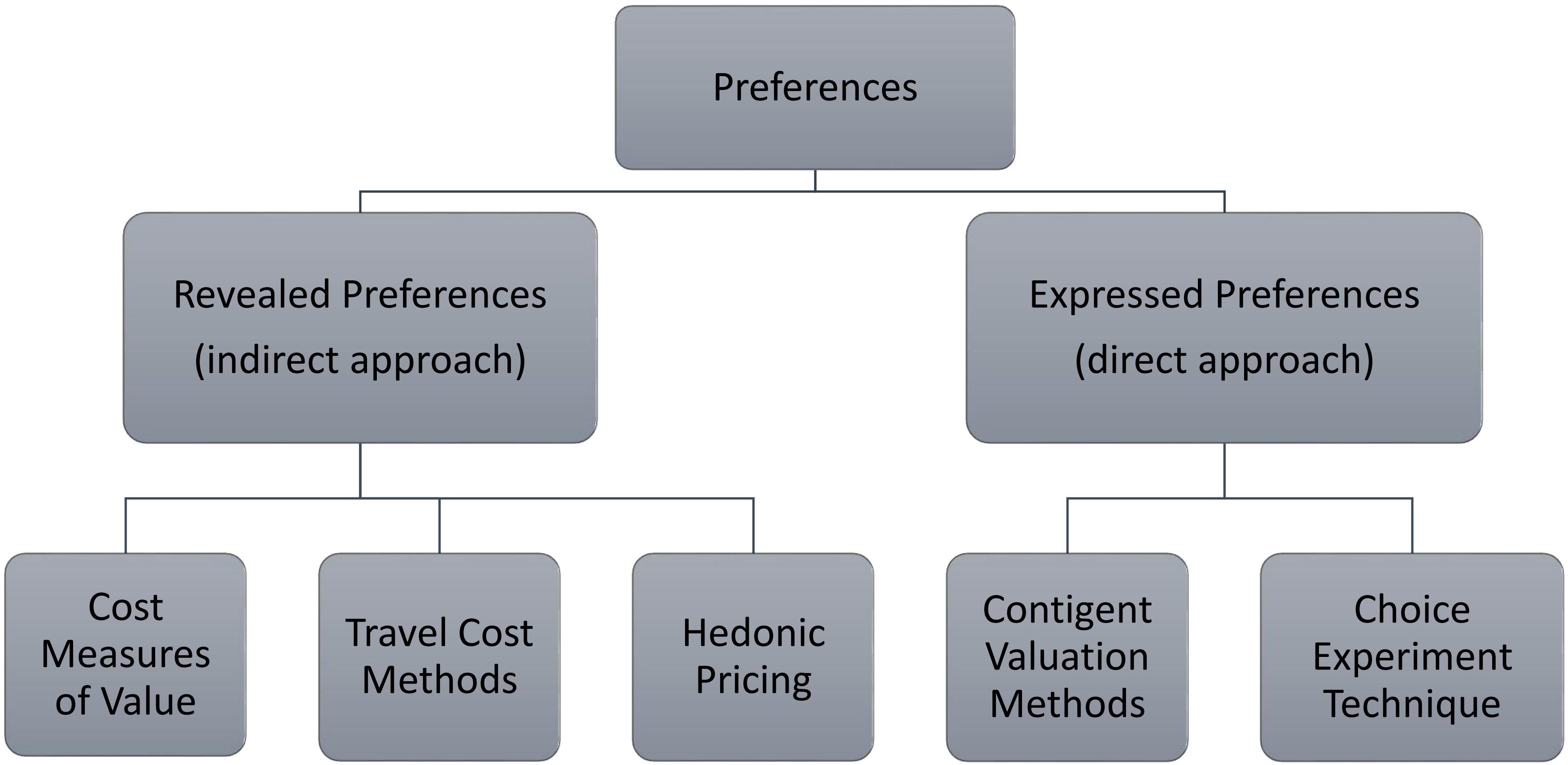
Impact: On premature deaths, ill health, lost crop production, ecological risk etc.

Damage: Monetary equivalent of each impact.

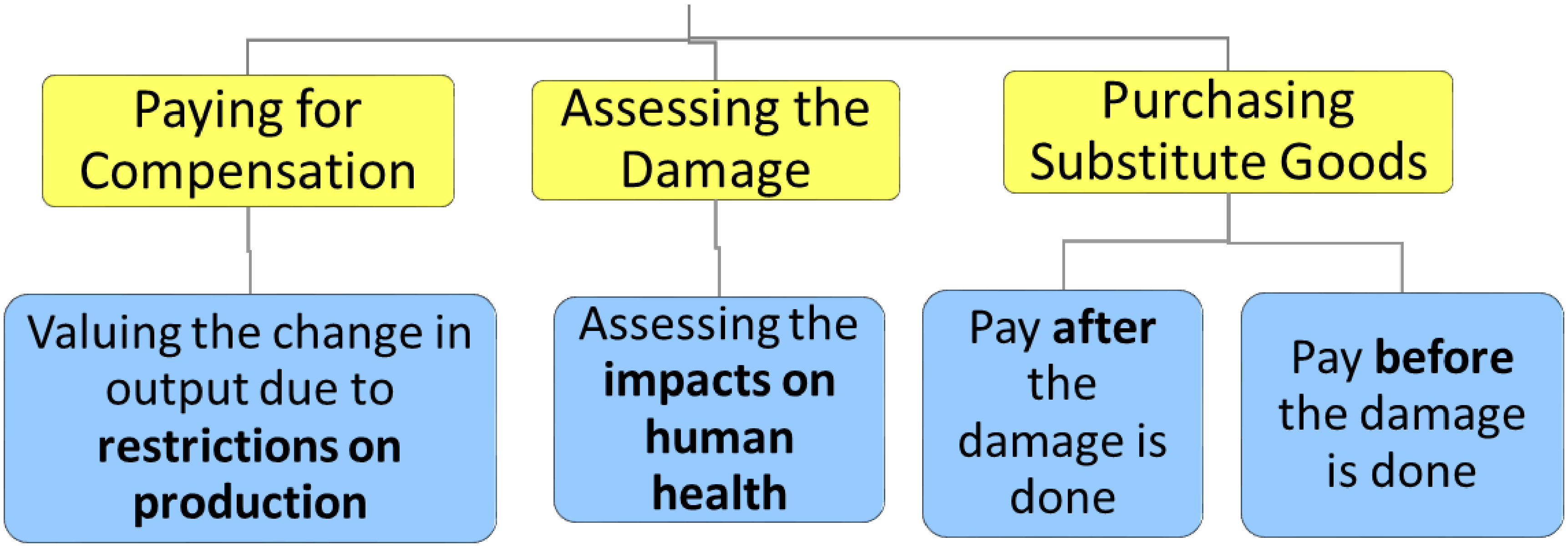
Figure 2. Components of the Impact Pathway Approach

Source: Jankovic, Kamel (2014): Methods for estimation of external costs of transport

How Do We Measure External Costs?



How do we measure External Costs? - Cost Approach

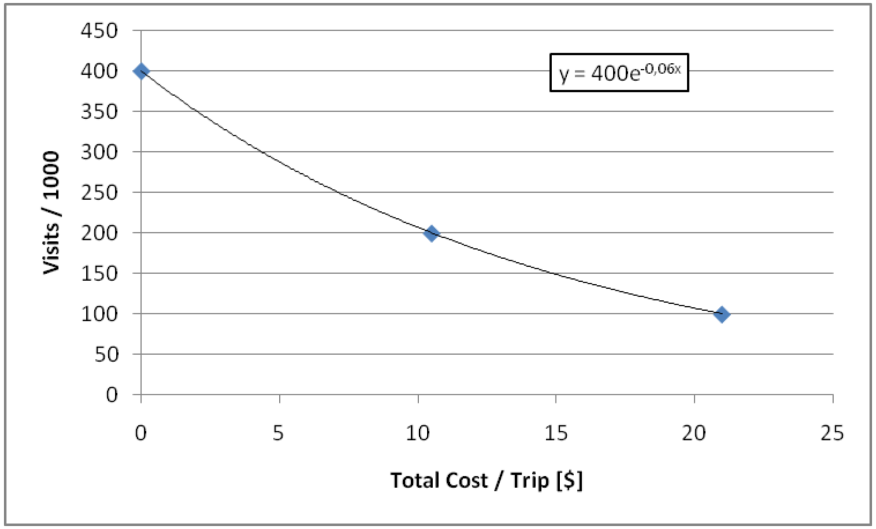


- Determining the costs of a damage
- Depends on a given/known market price…

How Do We Measure External Costs? – Travelling Cost Approach

1. Simplest and least expensive method to determine external costs
2. Used to valuate e.g. recreational sites
3. Example:

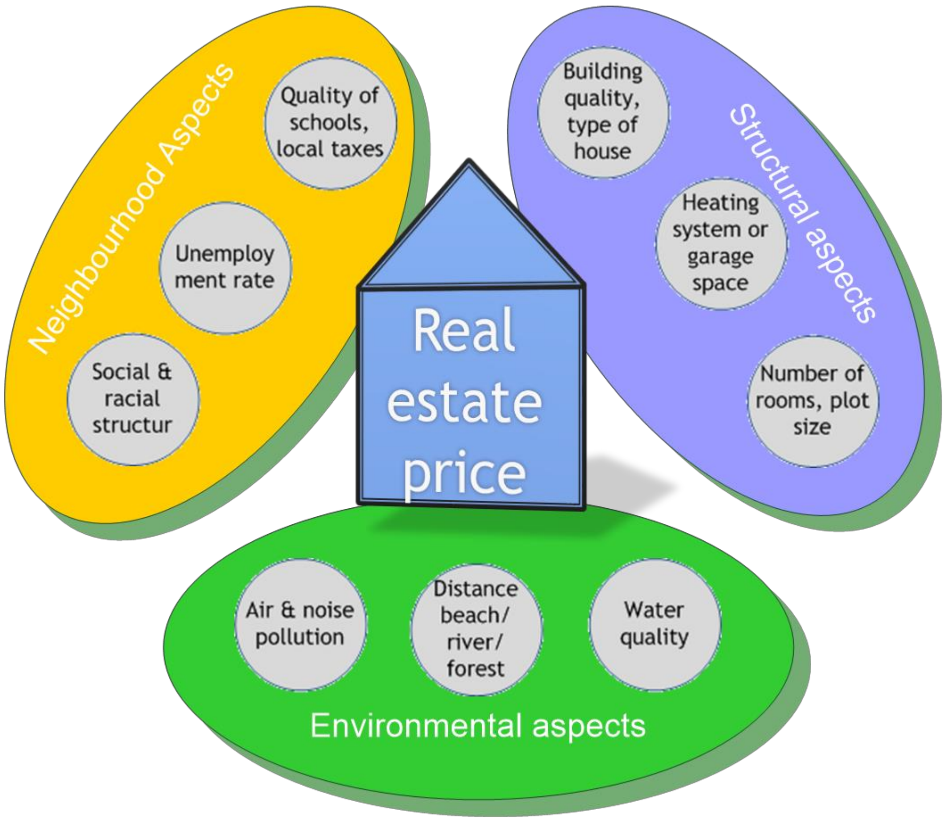
   - National park is threatened by hydro power project
   - Money to finance restoration, reforestation, compensation measures, …
   - ➢ How much money should be spend to preserve this site?
   - ➢ **How much money are visitors willing to spend?** What is their visit worth? (→ more expensive entry fee)



Source: King & Mazzotta, 2000

How Do We Measure External Costs? – Hedonic Pricing

1. Valuating someones willingness to pay for a certain good with preferred attributes
2. Example: buying a house, two similar options
   - one house is directly at a main road
   - the other one at a not busy road
   - → Price difference is the external costs of the noise and the pollution of the cars on that street



Source: Niclausen, 2010

How Do We Measure External Costs? – Contigent Valuation Method

1. Works with surveys
2. Willingness to pay to maintain the existence of (or be compensated for the loss of) an environmental feature, such as biodiversity.
3. What would you willing to pay to avoid…

   - … air pollution from new industrial site?
   - … noise pollution from new road?
   - … loss of cultural heritage due to commercial development?

How Do We Measure External Costs?

Example: traffic jam/congestion

- Damage = time loss
- Means less time to earn a living

- Costs = Average income/hr * time loss in traffic jam * no. of people affected

- Ethical question: How would you measure the value of someones life?
  - Microeconomic view: income per year * expected lifespan
  - Macroeconomic view: share on national GDP
  - Society: value of his experiences/wisdom, ability to educate people, …

Problems with External Costs

1. External costs can be estimated, but…
   - They are incomplete
   - They rely on uncertain data
   - They depend on discounting and aggregation
   - They are highly uncertain, primarily because impacts occur in a distant future
   - They are strongly dependent on ethical assumptions
   - They are strongly dependent on individual preferences

2. Nonetheless, the estimates provide some guidance for policy

The Use of External Costs?

1. **Cost-benefit-analysis:**
   The costs to establish measures to reduce a certain environmental burden are compared with the benefits.
   - E.g. economic benefit of a company vs. its health impact

2. **„Internalization“ of external costs**
   - Goal: fixing market failure that neglects external costs
   - Social costs shall become private costs

Total Costs to Society = Private Costs + External Costs

   - „polluter pays principle“

Internalization of External Costs

Methods:

1. **Negotiations:** when few participants and good/equal information
2. **Emission certificates:** allowances to emit a certain amount of emissions
3. **Pigou-Tax:**
   - tax on pollution (e.g. 5 USD/ton CO_2)
   - = incentive to reduce emissions
   - Useful when tax is higher than costs for reduction
     → reducing emissions is cheaper
4. **Voluntary payments** by consumers/polluters to repair damage (e.g. setting off emissions from flights through compensation payments)
5. **Government regulation** (pollution limits, limits on mining etc.)

Mitigation Measures

>> Introduction

Adaptation vs. Mitigation

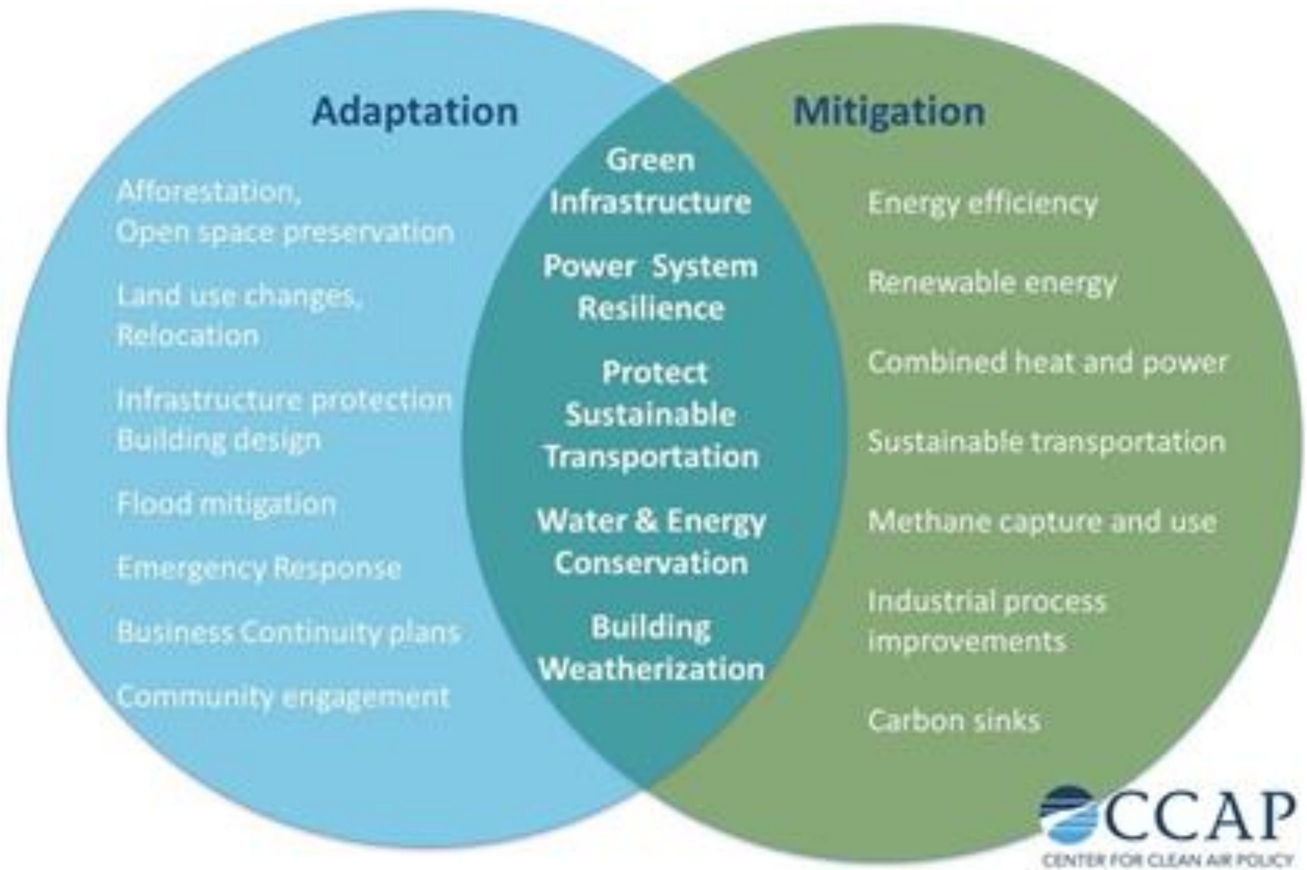
Two means of coping with human-induced climate change and its impact

1. Adaptation
   "The process of ***adjustment to actual or expected climate and its effects****. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and ist effects."*

2. Mitigation
   "Mitigation, in the context of climate change, is ***a human intervention to reduce the sources or enhance the sinks of greenhouse gases*** *(GHGs)"*

Source: IPCC 2013 (WG II), TS, p. 40

Adaptation vs. Mitigation

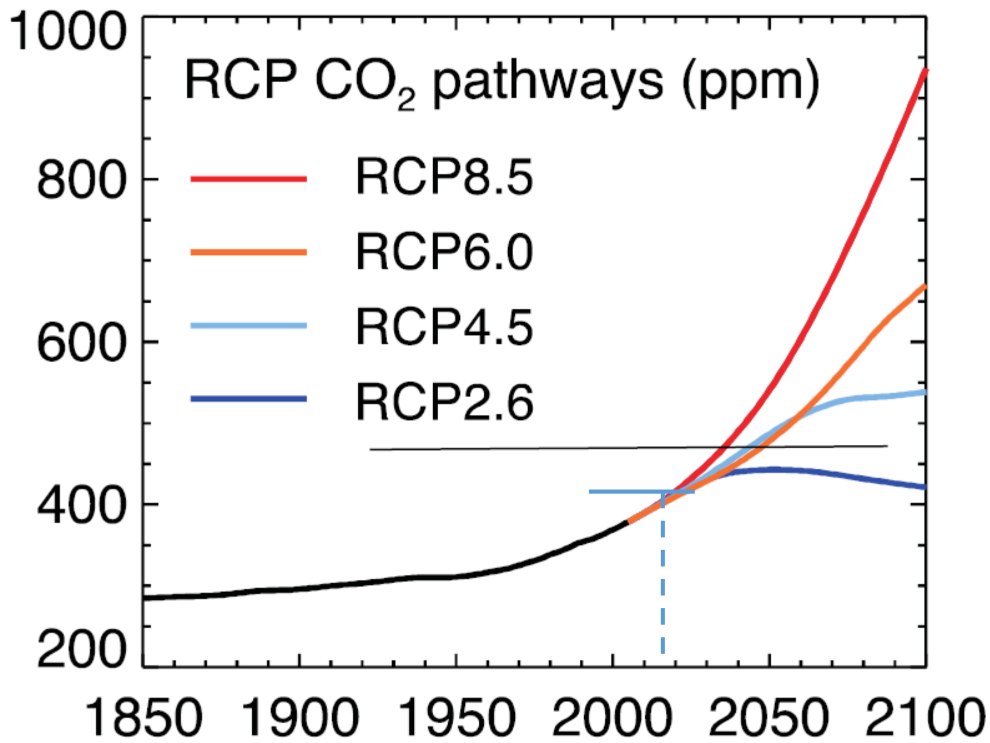


Mitigation ultimately means reducing GHG emissions!

Reaction vs. proaction

Why do we have to cut GHG Emissions?

1. GHG concentration is fast approaching the maximum tolerable level, necessary for a temperature stabilization below the **2°C threshold** **(< 450 ppm CO_2)**
2. Current status: **410 ppm** (+40 ppm since 2000)
3. If we don't reduce our annual emissions we will have passed **450 ppm by 2040**



Source: IPCC 2013 (WG I), TS, p.94)

Climate Change Mitigation

1. "While adaptation is hugely important, the region should also make greater mitigation efforts. Low-carbon growth brings significant co-benefits, and the **costs of inaction far outweigh the costs of action**."

2. Implementation of mitigation measures requires, among other things:
   - development and availability of low-carbon technology
   - development of comprehensive policy frameworks
   - elimination of market distortions
   - incentives for private sector action
   - significant flows of finance

Source: Asian Development Bank, 2009, p. XXIV & 90

Climate Change Mitigation

1. Mitigation measures are often **“win-win” measures** that address climate change and are also good sustainable development practices.
2. **Government has a vital role** to play in providing incentives and an effective policy framework for individuals and companies to adapt to climate change and to enhance their adaptive capacity.
3. It is **always better to proactively** avoid possibly devastating concequences than to react later to the already existing damage!

Source: Asian Development Bank, 2009, p. XXIV & 90

Mitigation Measures

>> Energy Efficiency & Sufficiency

Energy Sufficiency vs. Efficiency (vs. Consistency)

Three pillars of reducing (energy-related) emissions

1. Energy sufficiency
   - Latin: „to be enough“
   - Reduce consumption of raw materials and energy as far as possible by reducing the demand for goods and services, especially those requiring high levels of resource use
   - People’s individual needs should be satisfied → but which level is “appropriate”?
   - New “needs” are constantly created by technological developments and advertising (e.g. car, TV, smartphone)
   - Possibly endless stream of new needs vs. finite resources
   - Is more of a psychological problem, requires change in behavior and consumption habits
   - Difficult to implement…

Source: Konzeptwerk neue Ökonomie: Three Strategies towards Sustainability, 2013

Energy Sufficiency vs. Efficiency (vs. Consistency)

Three pillars of reducing (energy-related) emissions

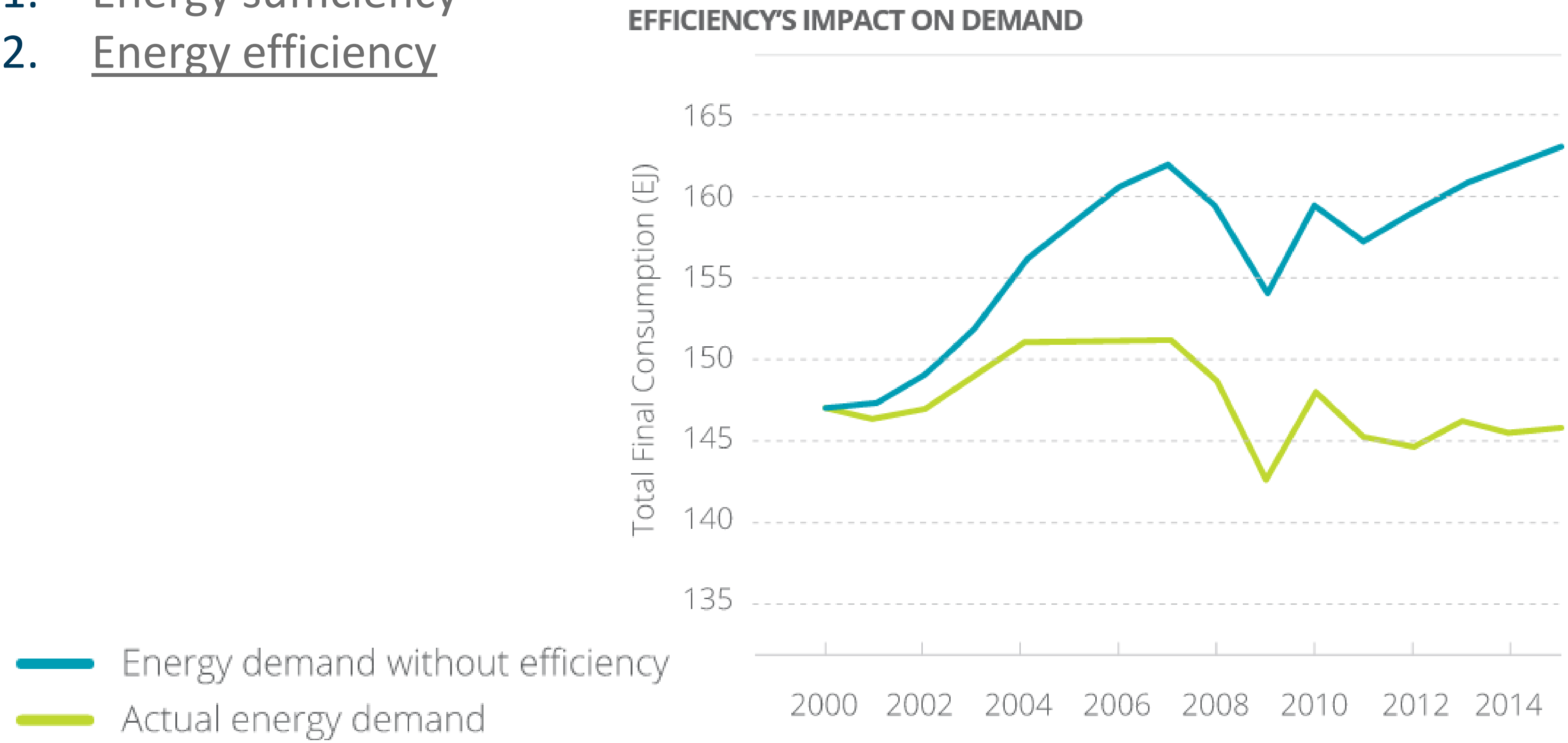
1. Energy sufficiency
2. <u>Energy efficiency</u>
   - Efficient energy use
   - Reduce the amount of energy required to provide products and services
   - achieved by adopting a **more efficient technology** or production process or by application of commonly accepted methods to **reduce energy losses**
   - Technological strategy
   - reduces energy costs
   - "It is the one energy resource that every country possesses in abundance and is the quickest and least costly way of addressing energy security, environmental and economic challenges." (IEA)
   - IEA: improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third
   - **"Energy which we don't consume we don't need to produce in the first place"**

Source: IEA Energy Efficiency Market Report 2016

Energy Sufficiency vs. Efficiency (vs. Consistency)

Three pillars of reducing (energy-related) emissions

1. Energy sufficiency
2. <u>Energy efficiency</u>



Source: IEA Energy Efficiency Market Report 2016

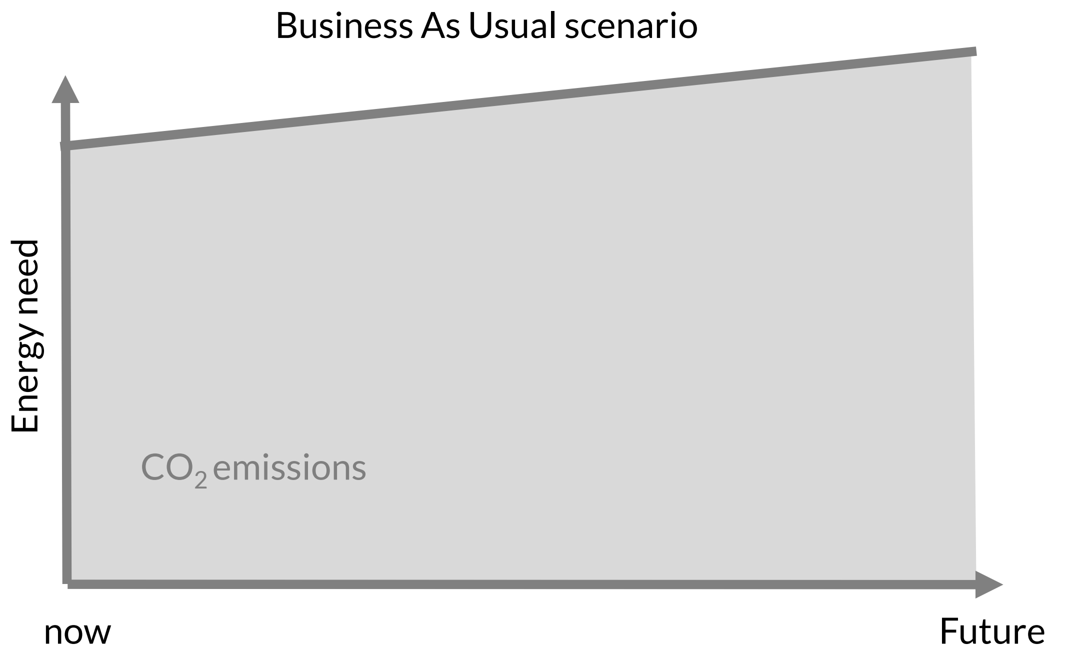
Energy Sufficiency vs. Efficiency (vs. Consistency)

Three pillars of reducing (energy-related) emissions

1. Energy sufficiency
2. Energy efficiency
3. Energy consistency

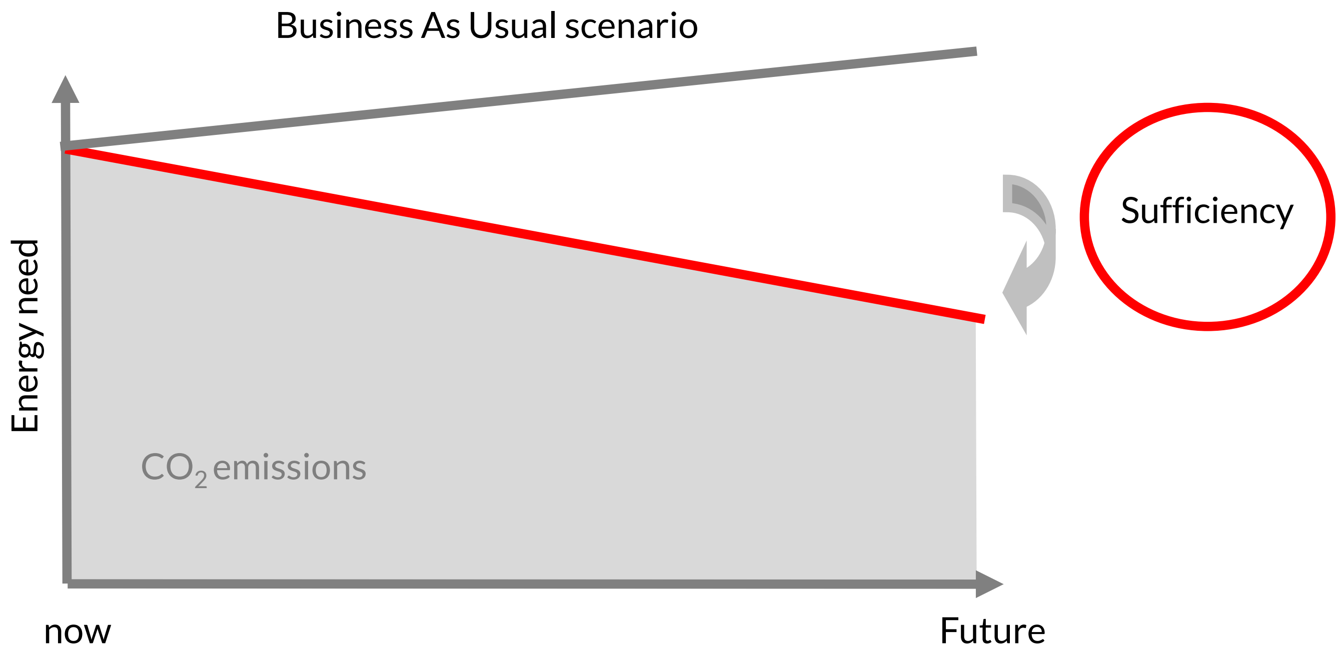
- Providing the needs with climate friendly resources and energies
- Transformation of the current energy system towards a sustainable system based on renewable energies (substitution)
- Also a technological strategy

Energy Sufficiency vs. Efficiency (vs. Consistency)



Source: Hohmeyer et al. 2011

Energy Sufficiency vs. Efficiency (vs. Consistency)



Source: Hohmeyer et al. 2011

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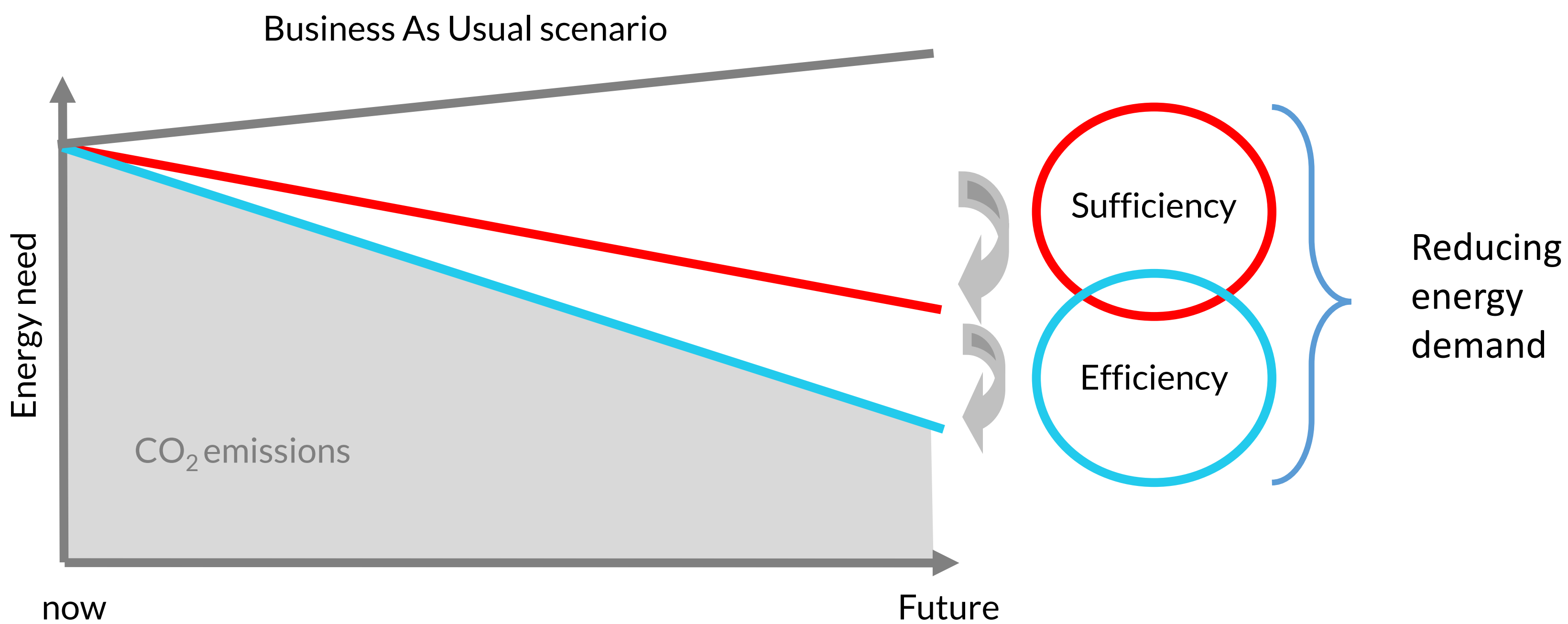
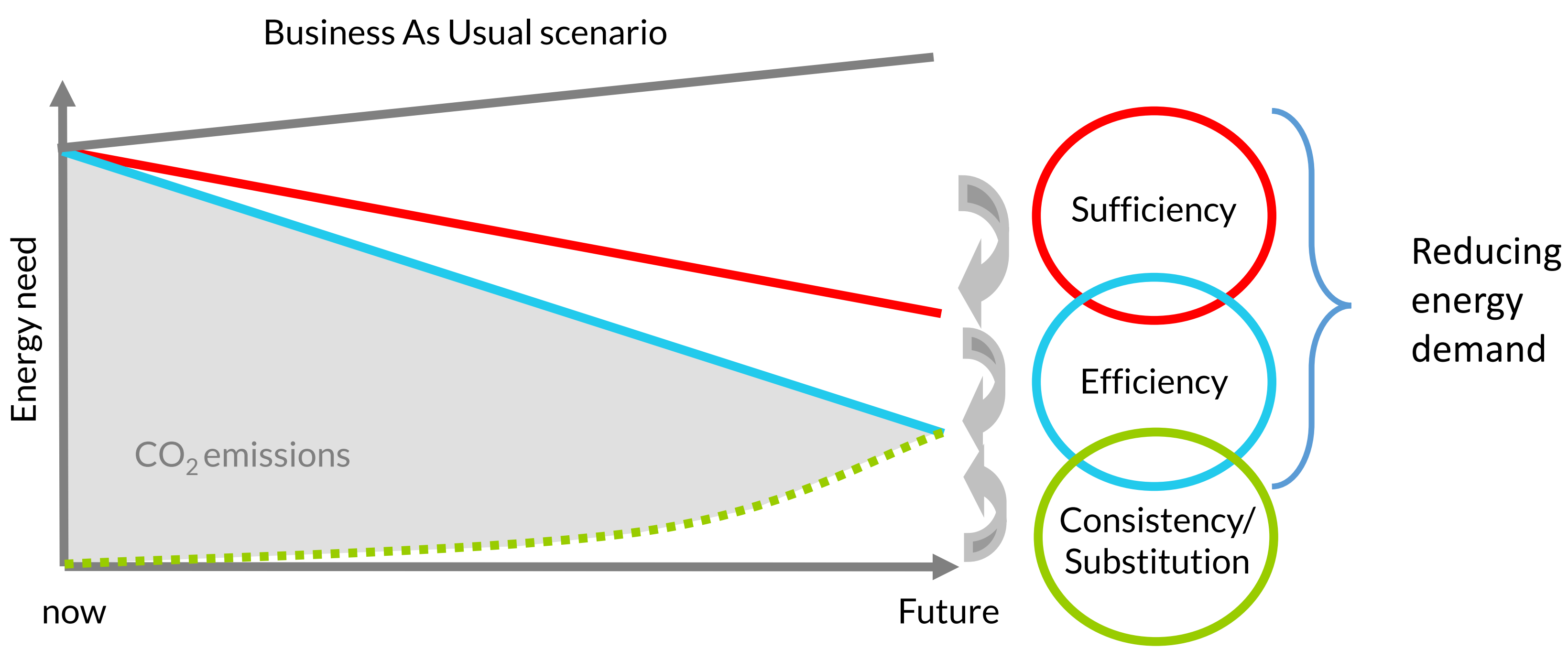


Source: Hohmeyer et al. 2011

Energy Sufficiency vs. Efficiency (vs. Consistency)



Source: Hohmeyer et al. 2011

Summary – Part 1

Climate Change:

- GHG emission problem
- Main emission source: aggriculture and land use
- Worldwide: energy conversion, industry, transport
- Keep global temperature rise below +2°C

External Costs of Climate Change

- Serious effects on Economy, Society and Nature
- External costs occurs when producing/consuming a good/service imposes a cost (damage) upon a third (unrelated) party
- Different methods, difficult to determine
- Use: internalization of external costs

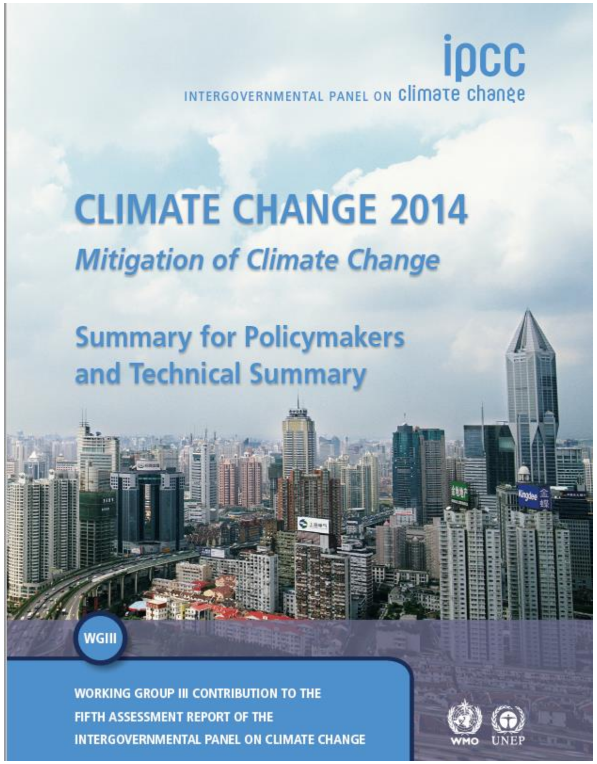
Mitigation measures

- Adaptation vs. Mitigation
- Energy efficiency, sufficiency & consistency

15 min coffee break!

Zettberlin / photocase.de

Sources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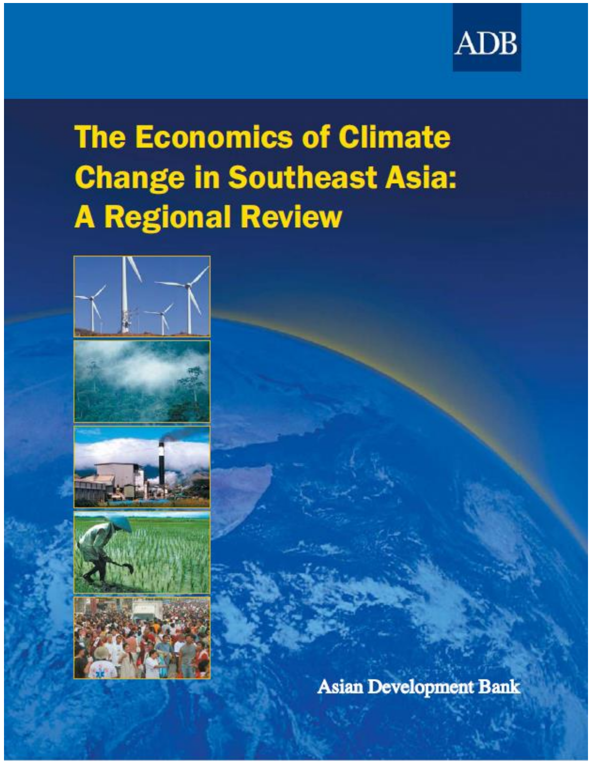
WMO
UNEP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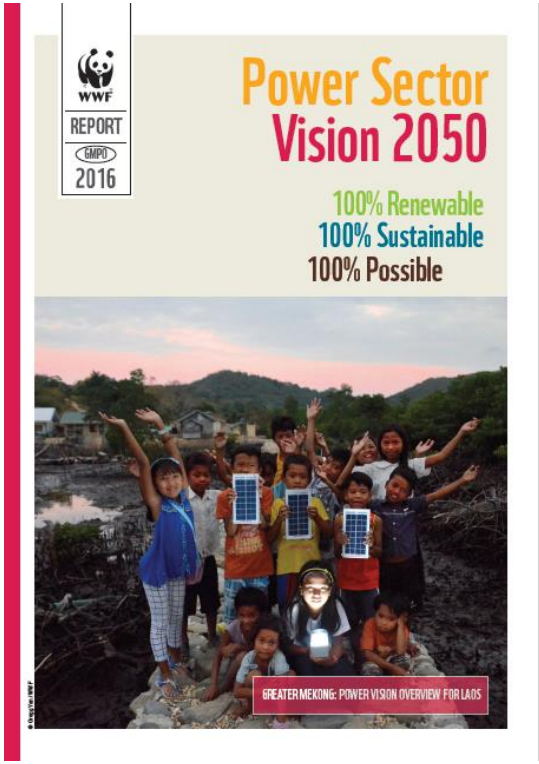
Asian Development Bank


WWF
REPORT
GMPO
2016
Power Sector
Vision 2050
100% Renewable
100% Sustainable
100% Possible
GREATER MEKONG: POWER VISION OVERVIEW FOR LAOS

Housing sector

1. Efficient **lighting** and use of daylight
2. More efficient **electrical appliances** and heating and cooling devices
3. Improved **cooking** stoves/fuel stove efficiency (e.g. electric cooking as a replacement of wood)
4. Improved **insulation** of building
5. Passive and active **solar design** for heating and cooling
6. **Example:** Green Mark Scheme in Singapore
   - Rating system to evaluate a building for its environmental impact and performance
   - Initiative to move Singapore's construction industry towards more environment-friendly buildings
   - promote sustainability and raise environmental awareness among developers/builders

BCA GREEN MARK

Source: Asian Development Bank, 2009, p. 135 f.

Industry & Commercial Sector

1. More efficient end-use electrical equipment
2. Heat and power recovery
3. Material recycling and substitution
4. Control of non-CO_2 gas emissions (industrial processes)
5. Efficient process-specific technologies
6. Use of more efficient boilers, motors, and furnaces,
7. Material recycling and substitution, particularly in energy-intensive sectors (iron/steel, cement, paper/pulp, chemicals)
8. Improved management practices (energy auditing, benchmarking)
9. Periodical energy audits
10. Energy performance standards for industrial equipment

Source: Asian Development Bank, 2009, p. XXIV & 90

Transport Sector

1. Switching to cleaner fuels
2. Use of fuel-efficient vehicles
3. Use of hybrid/electric cars in road transportwith more powerful and reliable batteries
4. Better traffic management & planning
5. Shifts from road transport to rail and public transport systems
6. Promotion of non-motorized transportn(cycling, walking)
7. Higher efficiency aircraft
8. Toyota has recently announced that their fleet would emit nearly zero carbon by 2050 (BBC, 2015)

Source: Asian Development Bank, 2009, p. 134

Non-energy Related Mitigation Measures - Agriculture Sector

1. "Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than of any other region." (ADB)
2. Cropland management (sequester soil carbon, reduce N_2O emissions)
3. Rice Management in flooded rice fields to reduce methane emission
4. Manure & livestock management (methane reduction)
5. Fertilizer and manure management (nitrous oxide reduction)
6. Sequestration: Increasing the size of existing carbon pools, thereby extracting CO_2 from the atmosphere (e.g., afforestation, reforestation, integrated systems, carbon sequestration in soils)

Source: Asian Development Bank, 2009, p. 141 ff.

Non-energy Related Mitigation Measures - Forestry

"As the largest source of emissions, the region's forestry sector holds the key to the success of mitigation efforts, and has great potential to sequester carbon through reduced emissions from deforestation and degradation (REDD), afforestation and reforestation, and forest management."

1. Creation of parks/reserves, protected areas and biodiversity corridors
2. Identification/development of species resistant to climate change
3. Better assessment of the vulnerability of ecosystems
4. Monitoring of species
5. Development and maintenance of seed banks
6. Including socio-economic factors in management policies

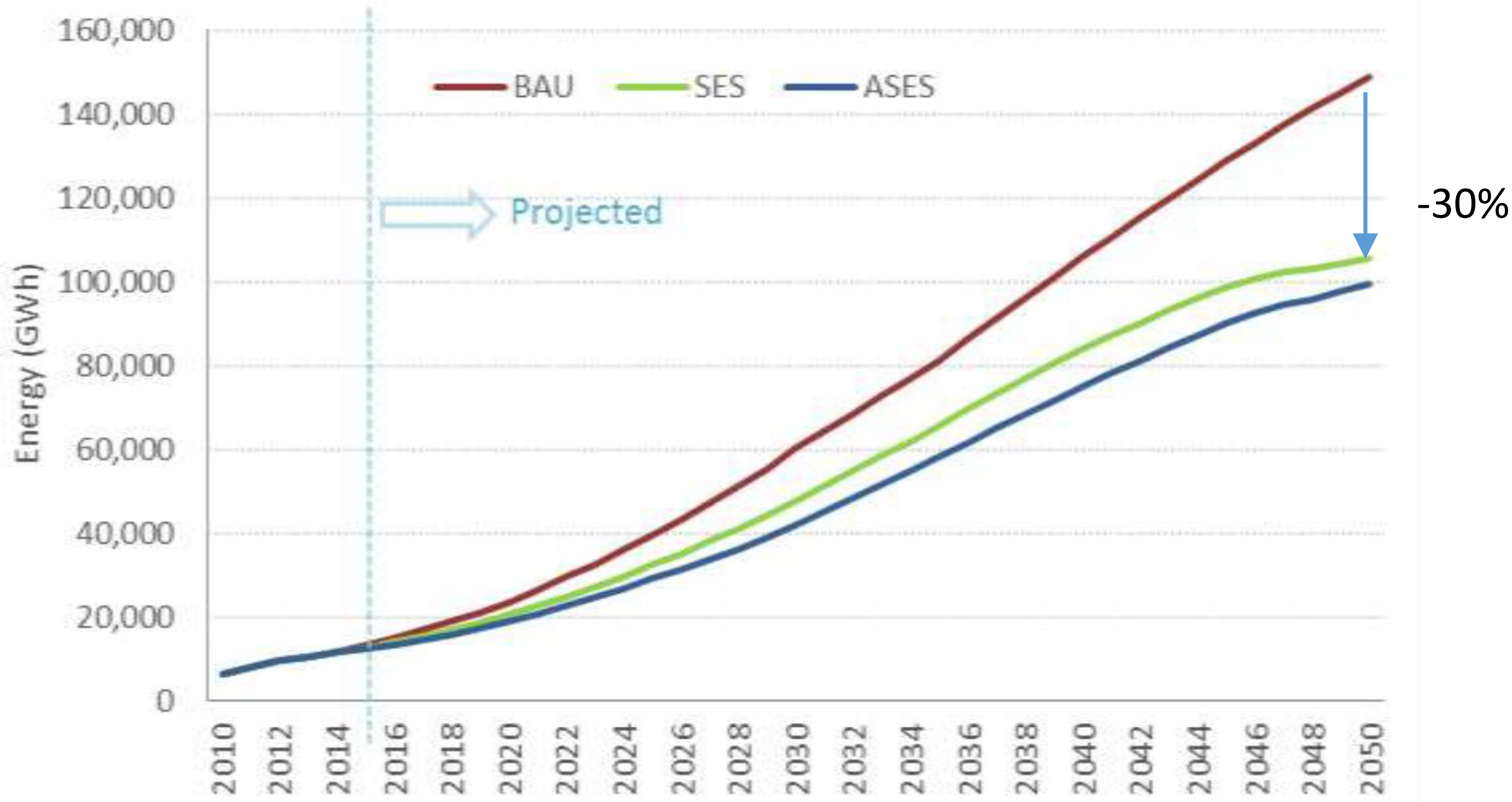
Source: Asian Development Bank, 2009, p. 93 & 123

Additionally: Policy Measures & Instruments

1. **Economic Instruments**
   - Taxes (carbon taxes, fuel taxes)
   - Tradeable allowances (emission trading schemes, vehicle efficiency standards)
   - Subsidies (feed-in tariffs for renewable energies, taxe exemptions for efficiency investments)
2. **Regulatory Instruments**
   - Efficiency or environmental standards, quotas
   - Energy management systems/reporting
   - Nature protection regulations
3. **Information programmes**
   - Labelling of efficient products
   - Benchmarking (e.g. top-runner system)
   - Certification schemes
   - Research
   - Training and education

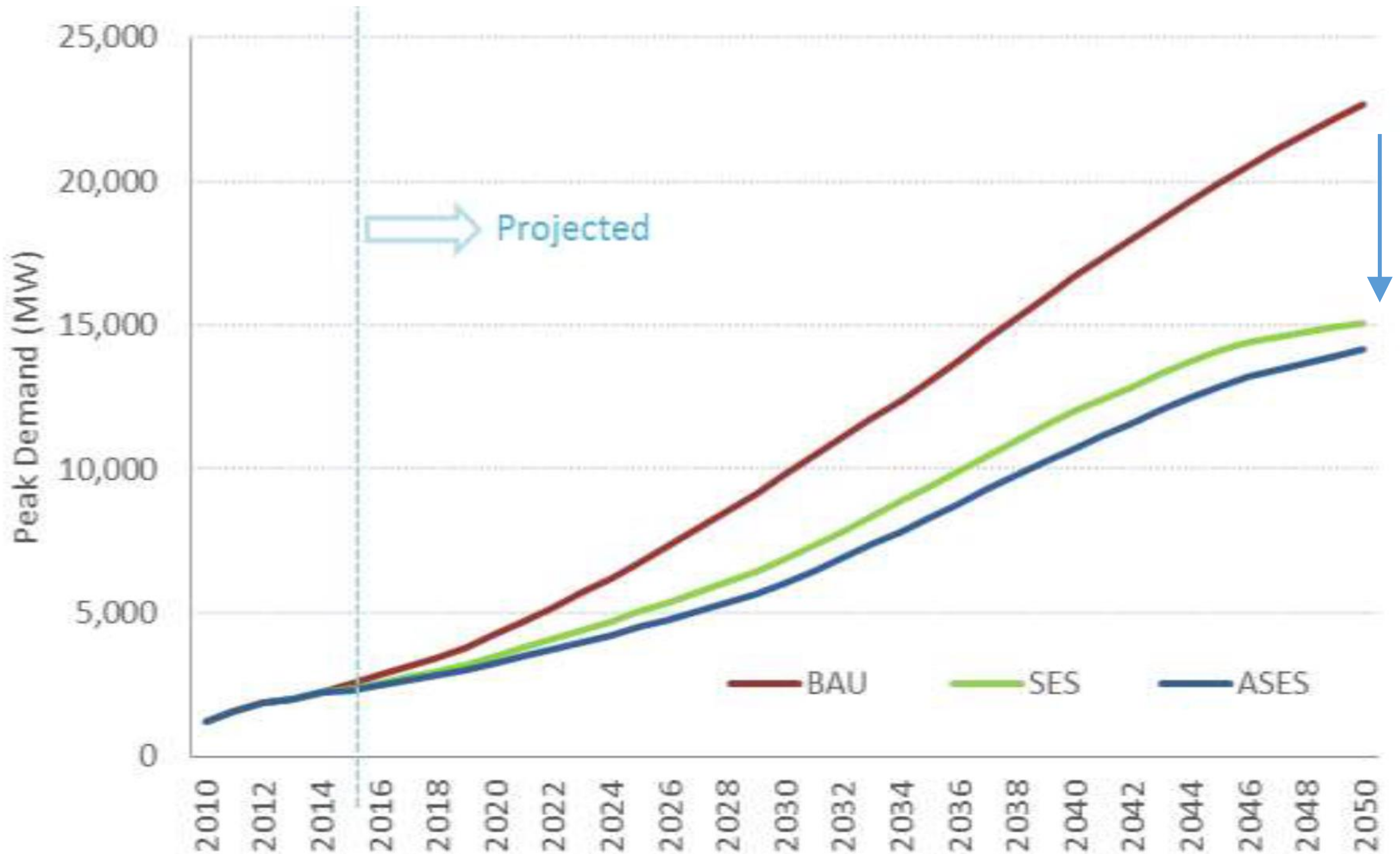
Source: IPCC 2014 (WG III), TS, p.97)

Energy Efficiency Potential Myanmar



Source: WWF 2016, p. 159

Energy Efficiency Potential Myanmar – Peak Demand



7-8 GW less production capacity needed!

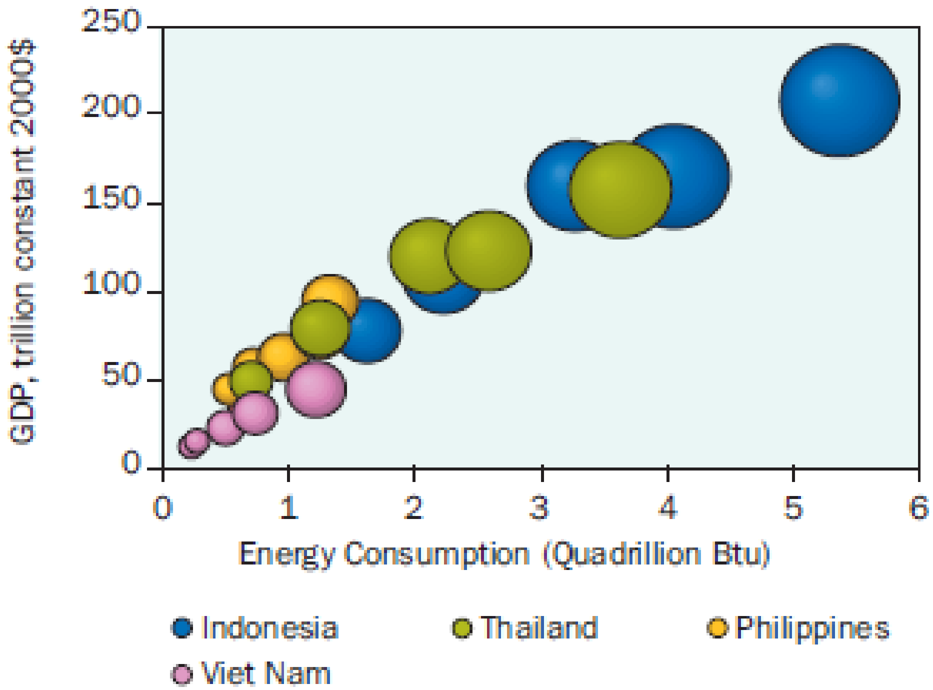
Source: WWF 2016, p. 160

Mitigation Measures

>> Consistency: Renewable Energy Resources, Technologies and Costs

Renewable Energies as Key Mitigation Measure

1. **Transformation** of the current energy system towards a sustainable system based on renewable energies
2. **Substitution** of fossil fuels and their emissions with renewable energies



Energy consumption (x-axis) vs. GDP (y-axis) vs. CO_2 emissions (bubble size)

→ **Goal: providing the needs with climate friendly resources and energies**

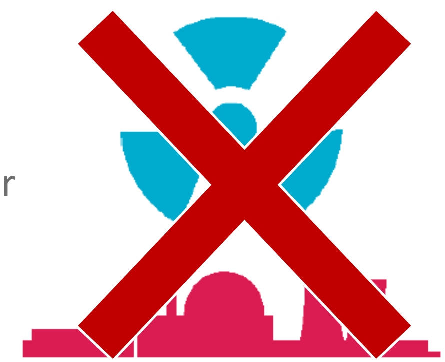
Source: Asian Development Bank, 2009, p. 156

Which Options for a Sustainable (CO_2-free) Energy Supply Do We Have?

1. Coal & Gas

- Resources are unevenly spread in Asia
- Supplies of oil and gas are set to decline
- Variable prices are difficult to predict
- Severe environmental & health impacts and carbon emissions

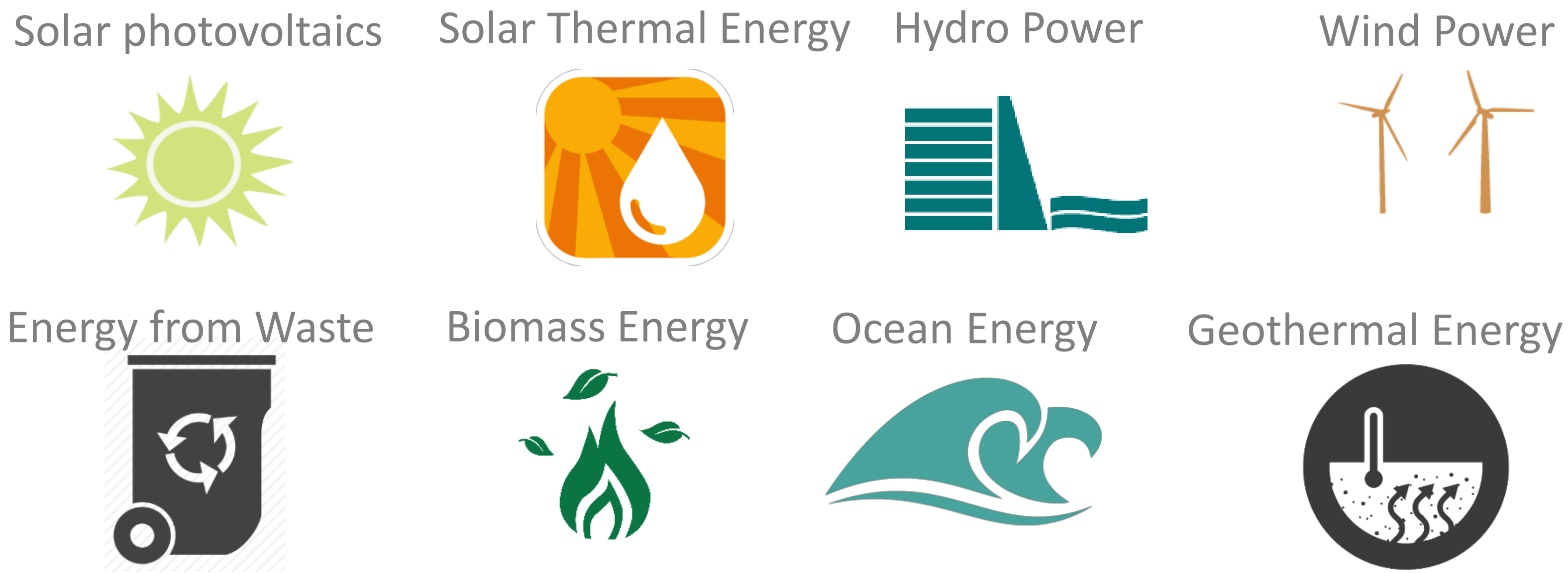
2. Nuclear energy



- Low carbon emissions – although mining and uranium production is very energy intensive and highly polluting (radio-active contamination of villages around uranium mines)
- Nuclear waste will be dangerous for 100,000 years or longer
- Risk of nuclear proliferation: materials and technology needed for nuclear energy can also be used to produce nuclear weapons
- Risky technology: major accidents in history (e.g. Fukushima/Japan)
- Extremely expensive option

Which Options for a Sustainable (CO_2-free) Energy Supply Do We Have?

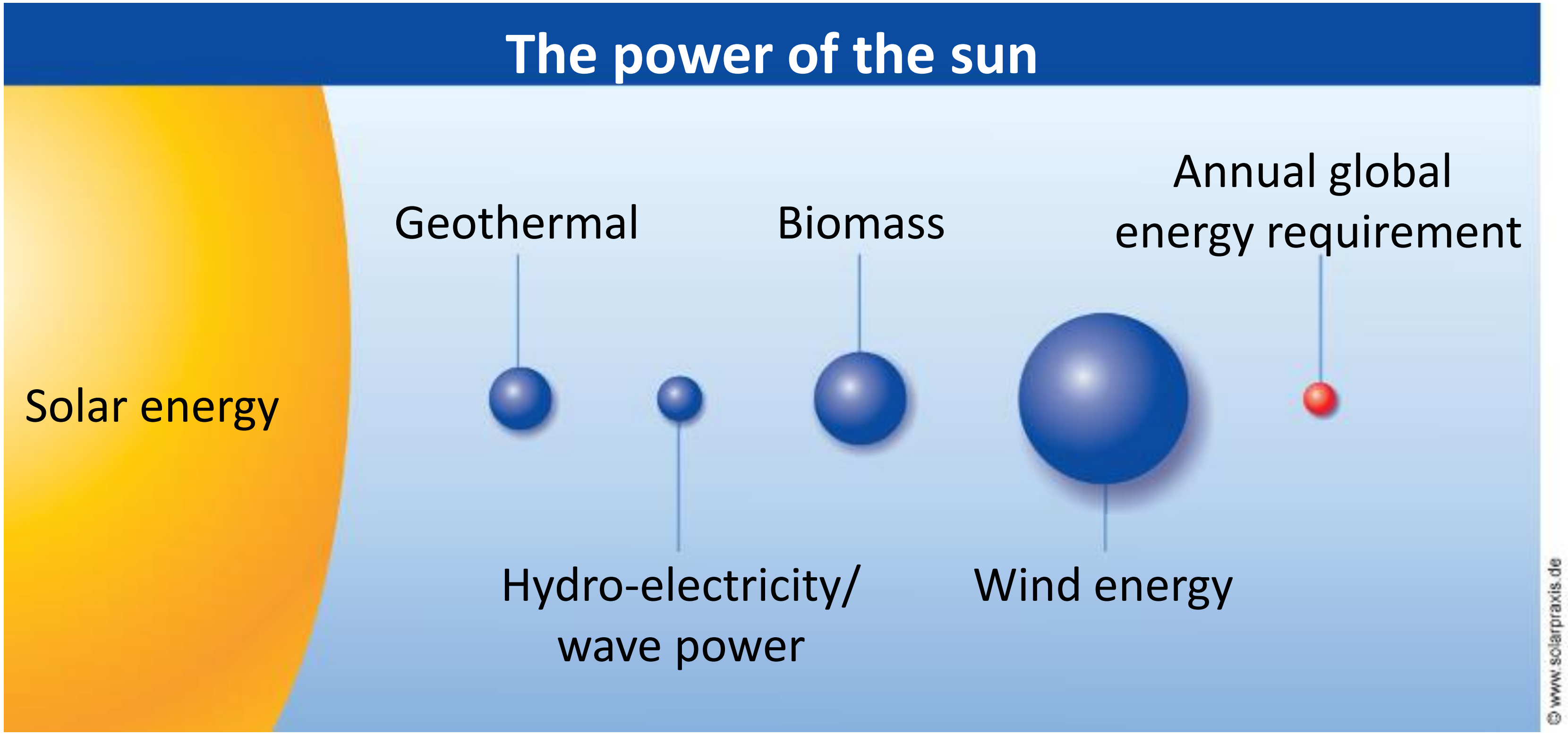
Renewable energies



- Clean/no carbon emissions, environmentally friendly
- Relatively cheap, (almost) no fuel costs
- Reduce import dependancy

Potential of Renewable Energy

Solar energy = 15,000 x world energy demand



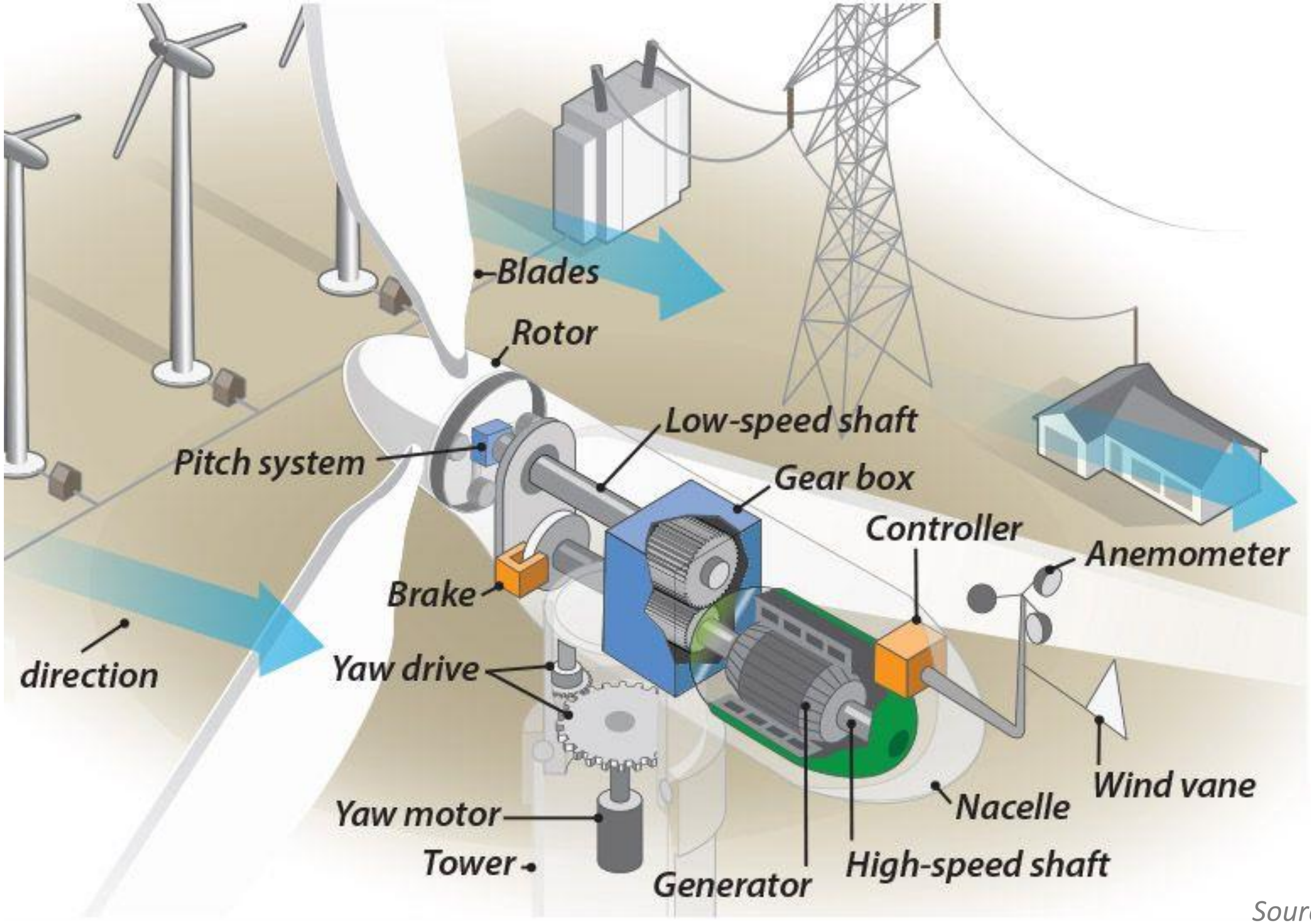
Wind Energy - Technology

1. Wind turbines convert the kinetic energy of the wind into mechanical power and electricity
2. Historically used for grinding mill or water pumps

Onshore wind energy

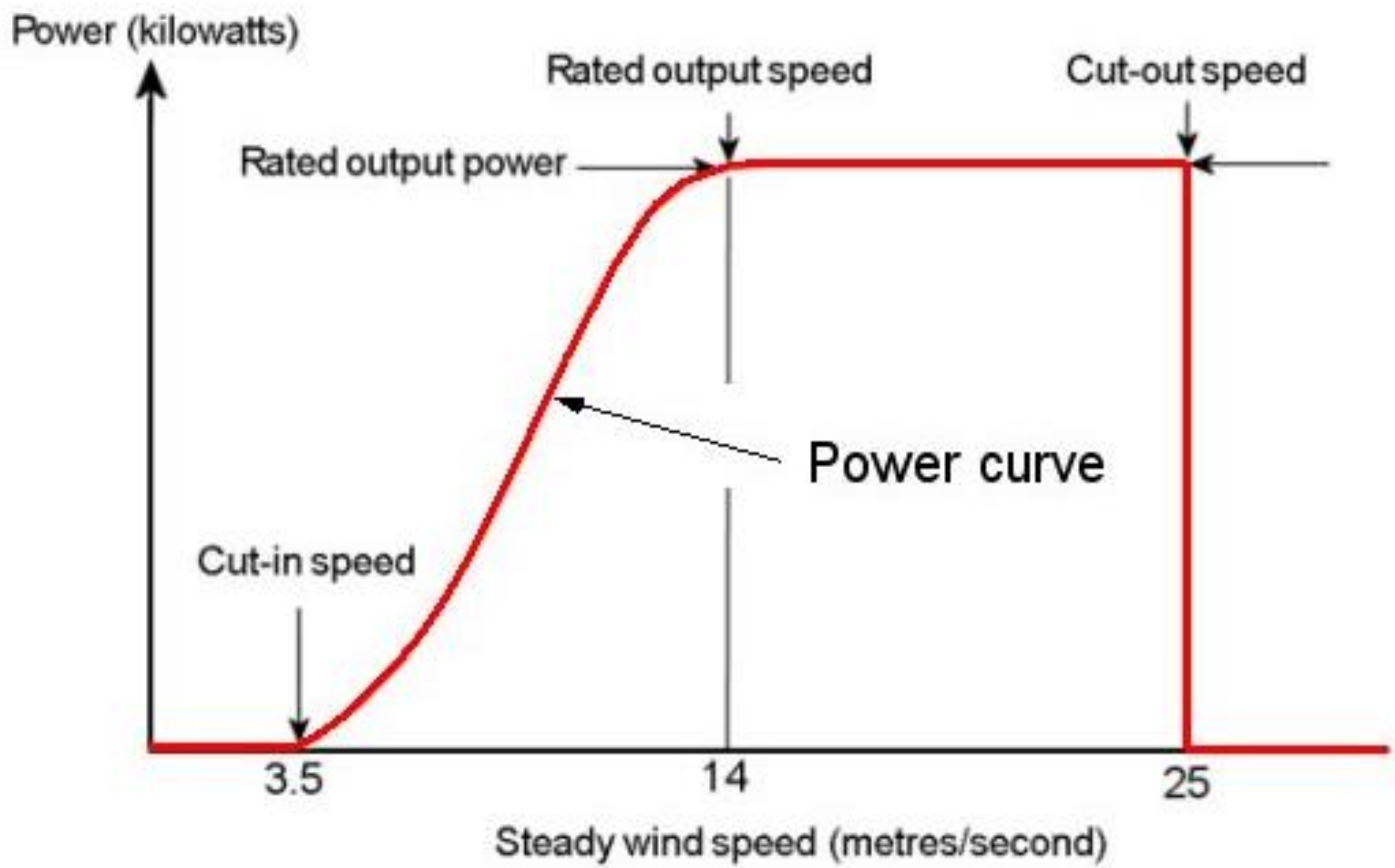
Offshore wind energy

Wind Energy - Technology



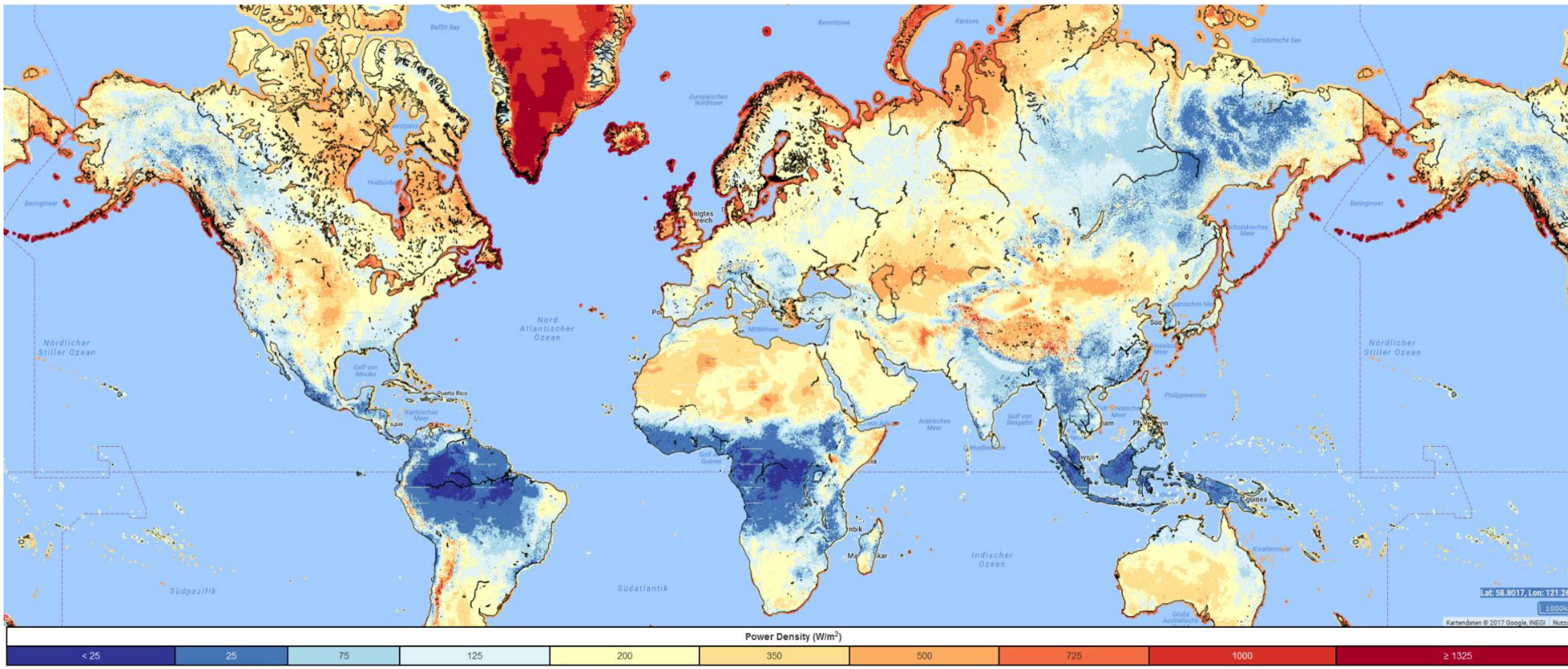
Source: US Department of Energy

Wind Energy - Technology



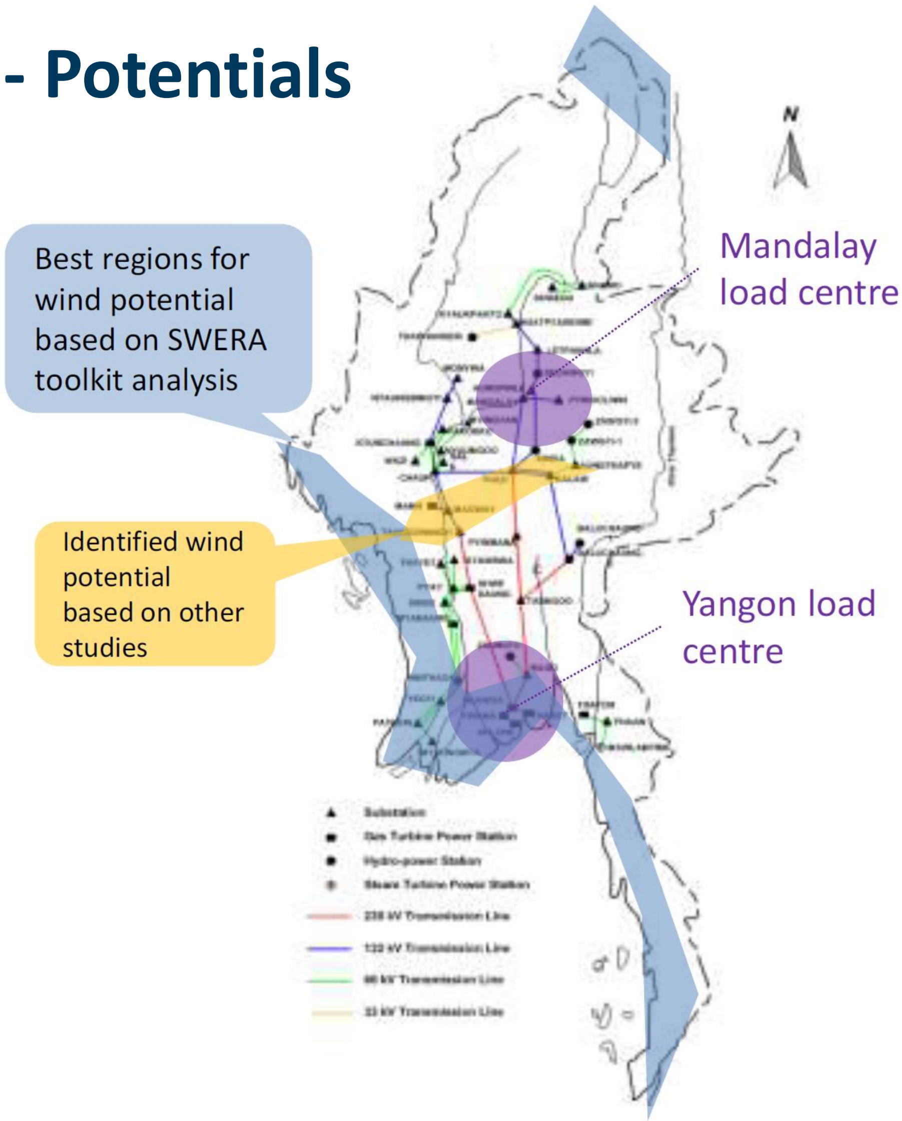
Source: www.wind-power-program.com

Wind Energy - Potentials



Source: DTU Global Wind Atlas

Wind Energy - Potentials

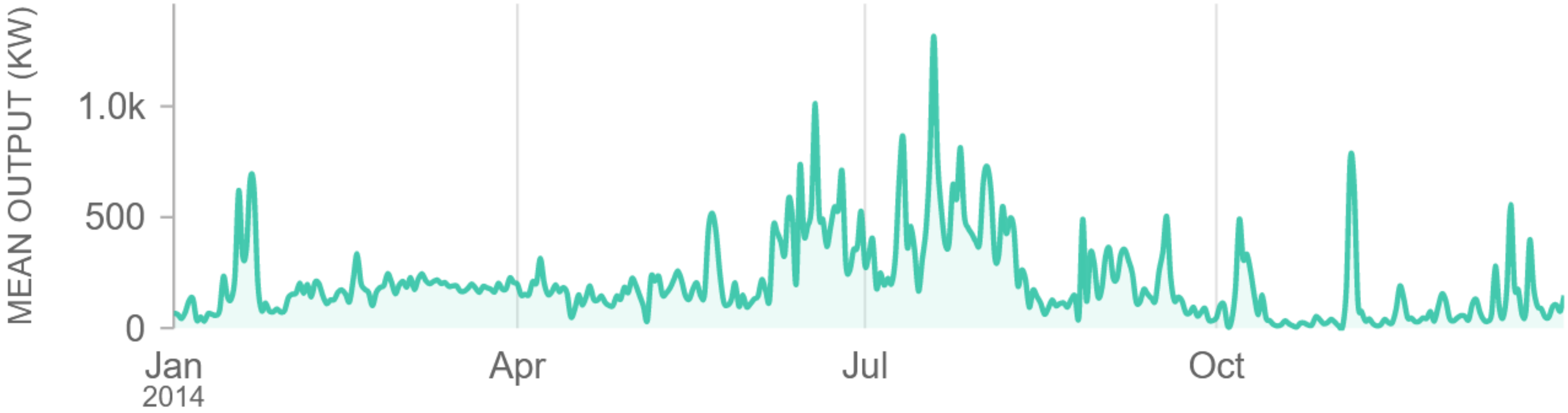


Source: WWF 2016, p. 99

Wind Energy – Potentials Myanmar

1. Turbine model: Enercon E66 (2 MW)
2. Location: Yangon

Daily mean output



Source: renewables.ninja, Pfenninger & Staffel (2016)

Wind Energy – Example Myanmar

1. March 2016: Memorandum of agreement (MoA) for a wind turbine project in the Chaungtha area of Ayeyarwady Region
2. 30 MW
3. „It will take some time to start electricity generation from this project because the company needs to undertake investment and projection activities”

HEARTBEAT OF THE NATION

MYANMAR TIMES

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Home » Business » MOEP signs first wind power deal

MOEP signs first wind power deal

AUNG SHIN | 07 MAR 2016

The Ministry of Electric Power signed a wind power deal with China Three Gorges Corporation last week, said a MOEP official.

The two parties signed a memorandum of agreement (MoA) for a wind turbine project in the Chaungtha area of Ayeyarwady Region, which will generate 30 megawatts of electricity, according to MOEP.

"It is our first MoA in the wind power sector," said U Aye Hsan, director general of the Department of Electric Power under the MOEP. "The company will proceed with a joint venture agreement process as the final step of the project."

China Three Gorges Corporation conducted a feasibility study of wind power potential in Chaungtha after signing a memorandum of understanding with the MOEP a few years ago, added U Aye Hsan.

"It will take some time to start electricity generation from this project because the company needs to undertake investment and projection activities," he said.

The ministry has conducted a series of feasibility studies for other prospective wind power projects and has a long list of candidates.

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Source: Myanmar Times, 2016

Wind Energy – Example Laos

1. First 600 MW wind project placed in southern Laos
2. Vestas, has been selected as preferred technology partner
3. wind farm is set to be completed in 2020
4. Will become the largest wind farm in the Association of South East Asian Nations (ASEAN) and moreover the first in Laos.
5. Project costs approx. 1.5 Billion USD
6. power generated is expected to be sold on the Asean markets, mainly to Thailand and buyers bordering the Mekong
7. newly build 230kV dedicated transmission line
8. Currently Thailand is buying electricity under a 7,000 MW purchase agreement. The amount is expected to be raised to more than 10,000 MW in the coming years. Laos is keen to make renewables a key part of its energy sales.

IEA signs deal for largest Asean wind farm in south Laos

ITTHI C TAN
THE SUNDAY NATION
VIENTIANE

THAI renewable company Impact Energy Asia (IEA) plans to build the largest wind farm in Asean – and generate 600 megawatts on 400,000 rai in southern Laos – under an agreement signed by the Lao government and the company on Friday.

"Called Monsoon Wind Farm, the US$1.5 billion [Bt50 billion] farm will be located near the Mekong River across from Ubon Ratchathani," said Woramol Khamkanist, who heads the firm.

The accord was signed by Laos' Deputy Minister for Investment and Planning Dr Khamniang Phonsena and IEA director Paradai Suebma. Laos' Deputy Minister for Energy and Mining Vilaphon Veelawong and Royal Thai Embassy official in Laos Rujikorn Saengchan also attended the signing.

Woramol said: "We are encouraged by the support from the Lao and Thai governments."

The wind project will be turned over to the Lao government after a 25-year concession.

The wind farm covers two districts: Dak Cheung in Sekong province and Sanxay in Attapeu province. The governor of Attapeu Dr Nam Viyaked also witnessed the signing.

Monsoon Wind is due to deliver its payload in 2019. It will be built on land where 4,000 people live in six scattered villages.

"The wind farm does not encroach on arable land or harm the environment," an IEA engineer said. "It will not disrupt the lives of people."

About 95 per cent of the power is expected to be sold to Asean markets, mainly to Thailand and buyers bordering the Mekong. The project is also critical to Thailand's energy needs.

"In the next 10 years, local production of natural gas and LNG will be depleted and much of our LNG needs will have to be imported to replace local demand," IEA executive Somboon Lertsuwannaroj said.

The project will also play a key role in the Asean Power Grid Policy to sell power from Laos via Thai and Malaysia grids to Singapore, which has pledged to buy Lao power to assist one of the poorer members in the group.

"It is only prudent that we rely on ourselves and a sister nation such as Laos, with which we share a common language, culture and historical ties," Somboon said. "After all, Laos, with its Lan Chang [million elephants] culture is truly a twin of our Lan Na [million ricefields] heritage."

Source: www.evwind.es (2016), IES (2016)

Wind Energy – Example Cambodia

1. 250 kW wind turbine in Sihannoukville harbor
2. Tower 39 meter high
3. Installation 2009
4. Reduces the fuel consumption of the isolated harbour grid
5. Before the turbine was installed, diesel generators generated all electricity for the Port of Sihanoukville
6. Yearly energy production: 300,000 kWh/year (=31,000 l Diesel)

Source: Wind Energy Solutions (NL)

Wind Energy – Example China

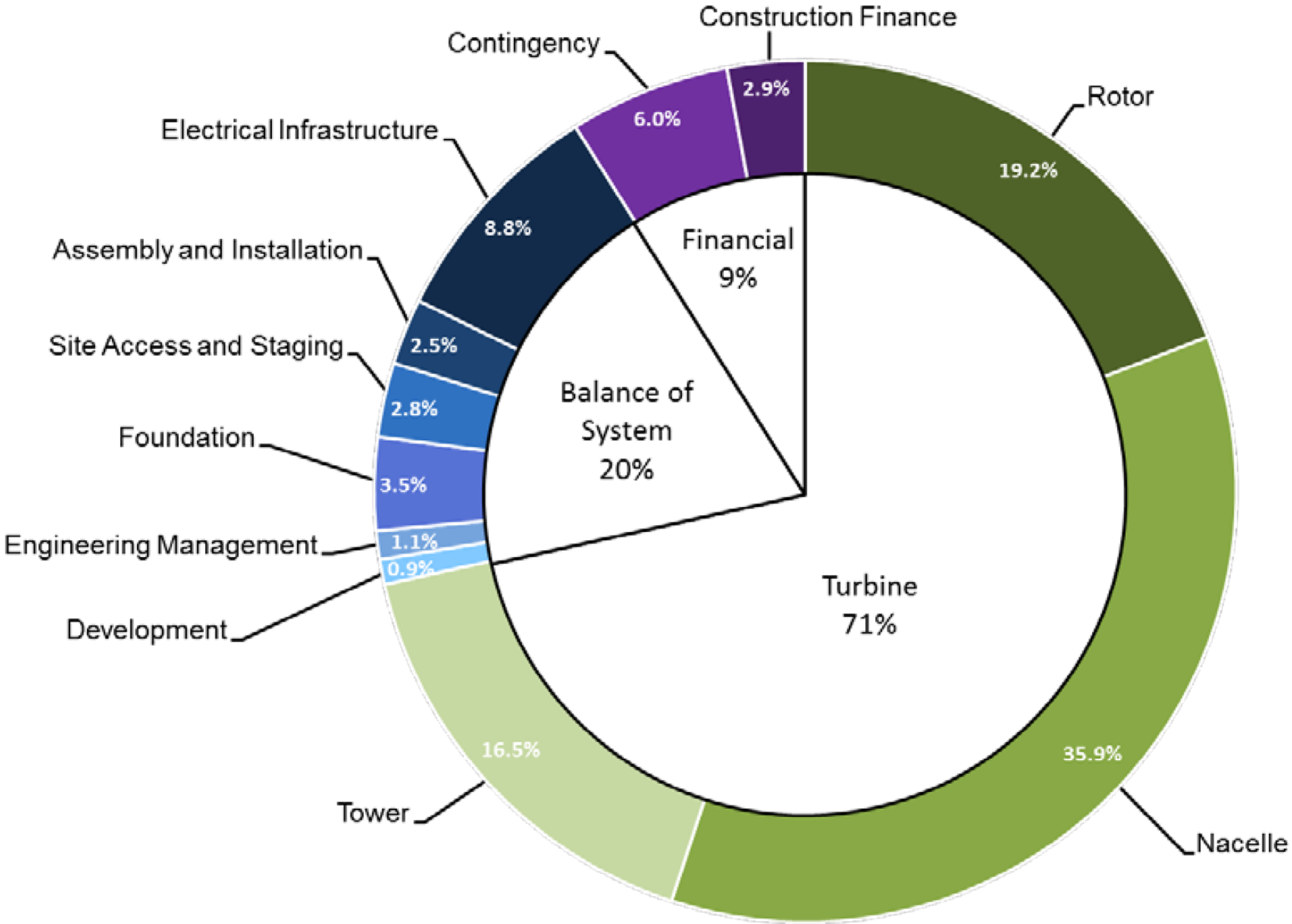
1. Gansu Wind Farm Project
2. construction started in August 2009
3. 2010: completion of the project's first phase (3,500 wind turbines with 5,160 MW)
4. Goal until 2020: 20 GW installed capacity
5. Gansu "now has some of the highest rates of underutilization in the wind sector in China“ → 39 % of wind capacity in 2015 was wasted (Problem: grid and fewer demand in region)

Source: New York Times, 2016

Wind Energy – Example Denmarks Offshore Wind Energy

1. Offshore wind parks
2. Approx. 1,400 MW installed capacity
3. 500 turbines offshore
4. Denmark has the highest proportion of wind power in the world
5. In 2015, Denmark produced 42% of electricity from wind
6. For the month of January 2014, that share was over 61%
7. Major Electricity exports

Wind Energy - Costs

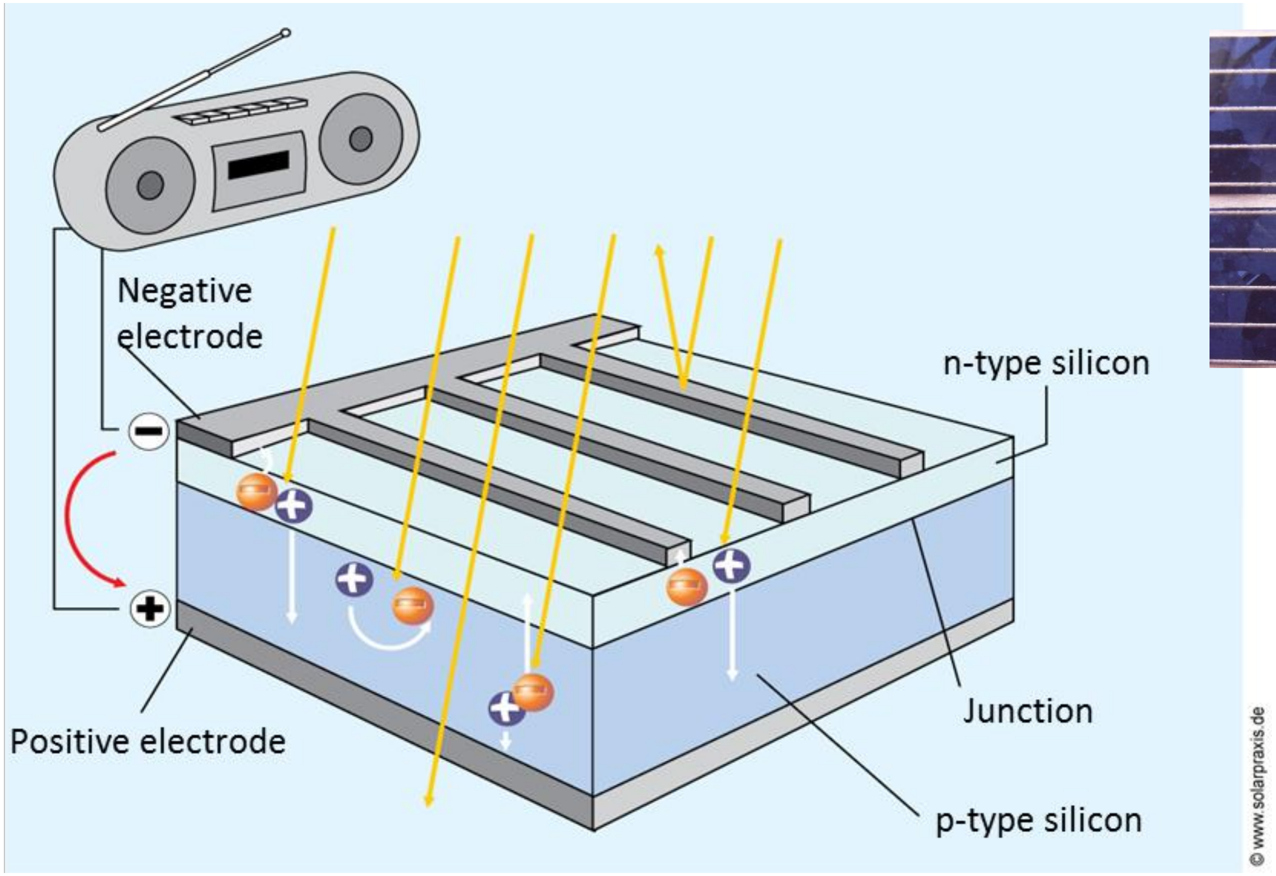


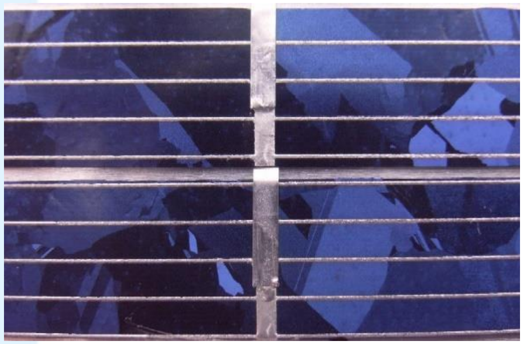
land-based reference wind project

(2 MW)

Source: NREL, 2015

Solar Energy - Technology

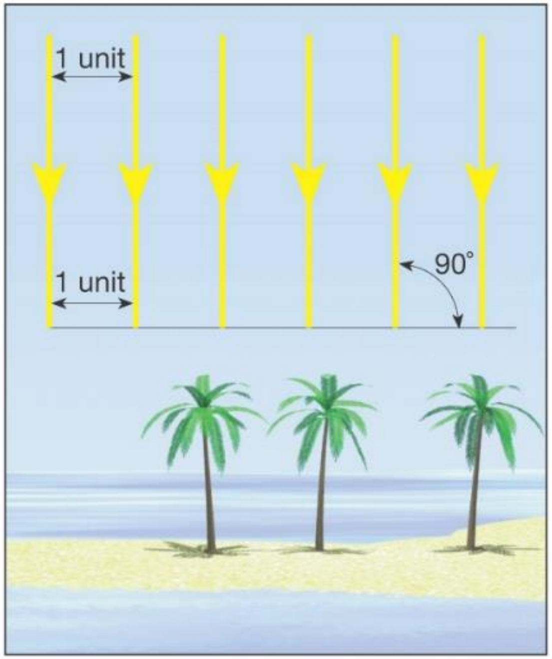




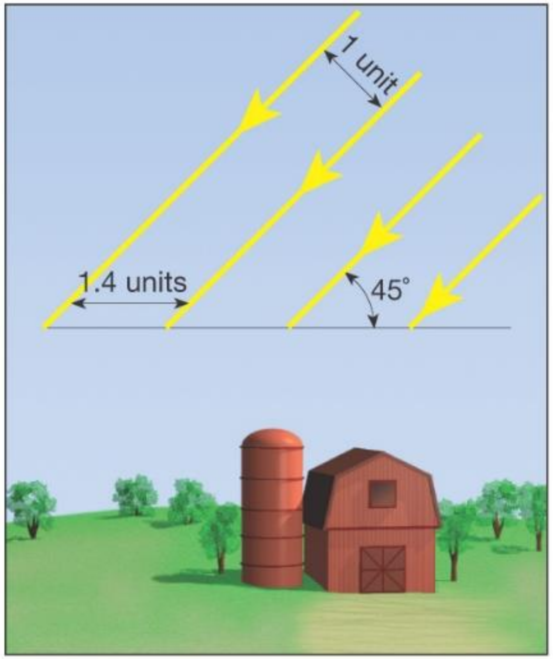
Solar Energy - Technology

Radiation intensity depends on location and incident angle!

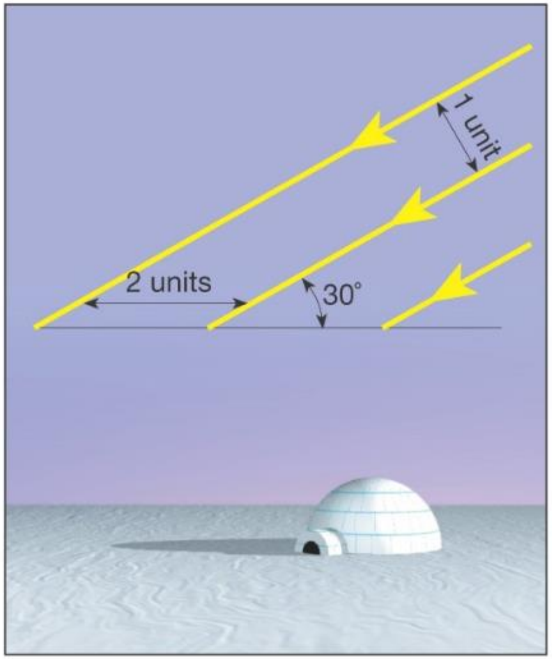
→ Optimum: solar cells in 90°-angle to radiation



Equator



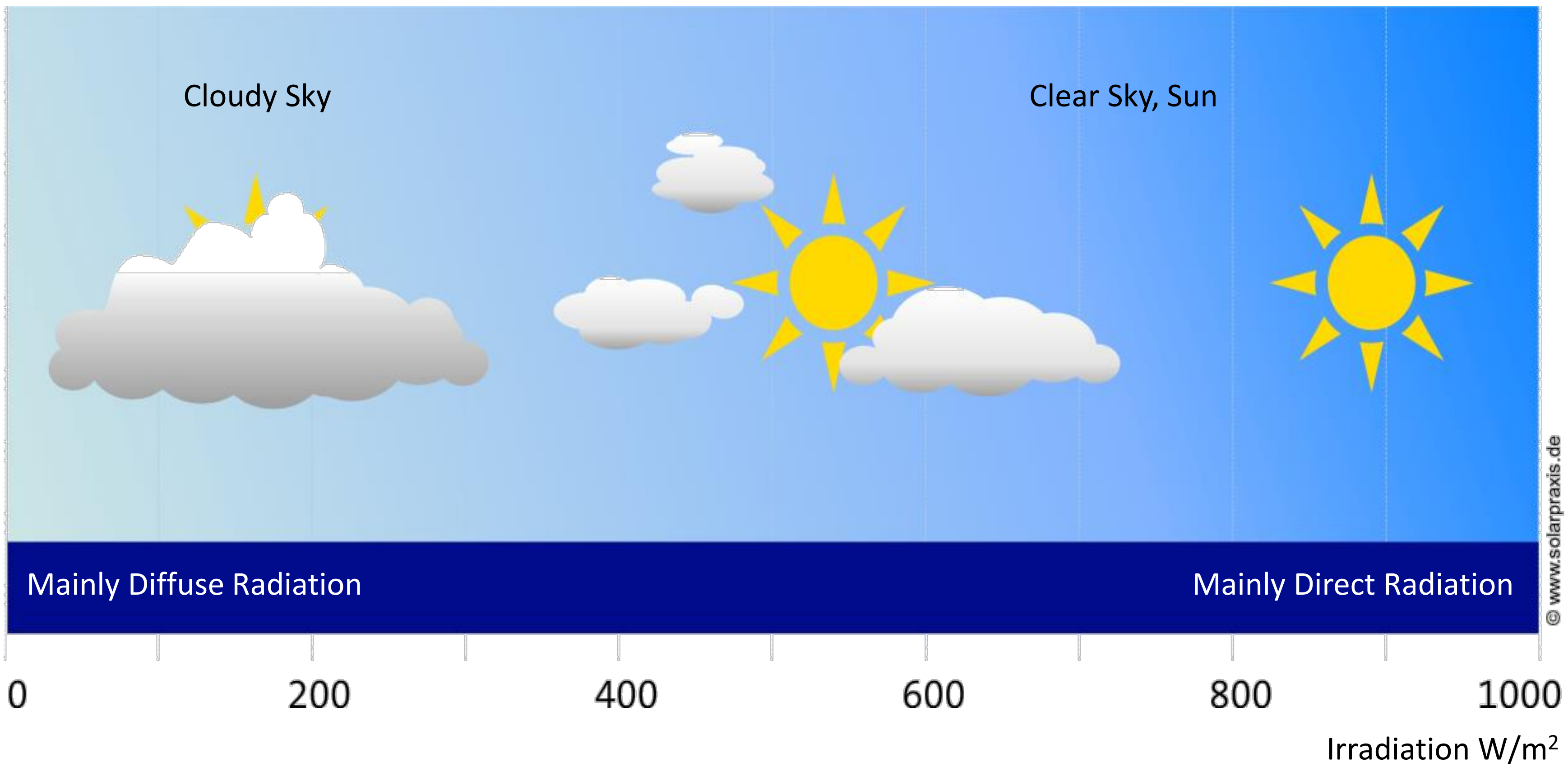
Europe



Polar regions

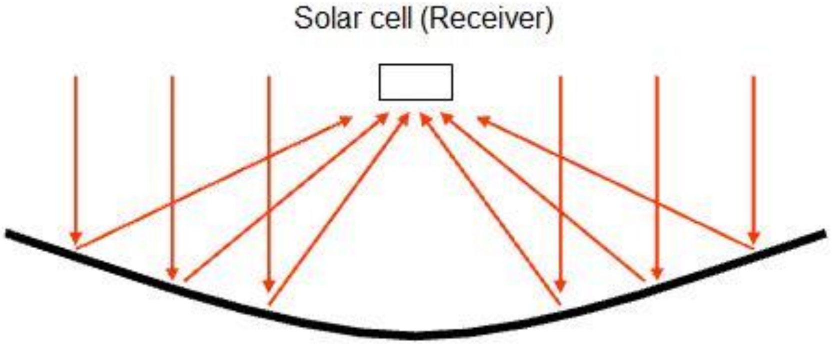
Source: EAS, Saint Louis University

Solar Energy - Technology



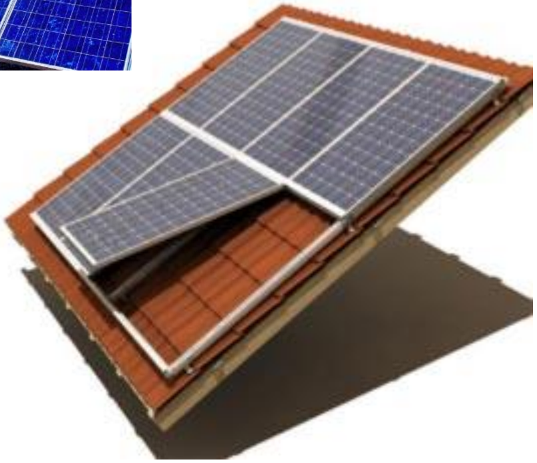
Solar Energy - Technology

1. **Flat-plate vs. concentrator systems**



Solar Energy - Technology

1. Flat-plate vs. concentrator systems
2. **Fixed vs. tracking systems**



Solar Energy - Technology

1. Flat-plate vs. concentrator systems
2. Fixed vs. tracking systems
3. **Rack-mounting vs. roof-mounted**

Solar Energy - Technology

(A) Modules

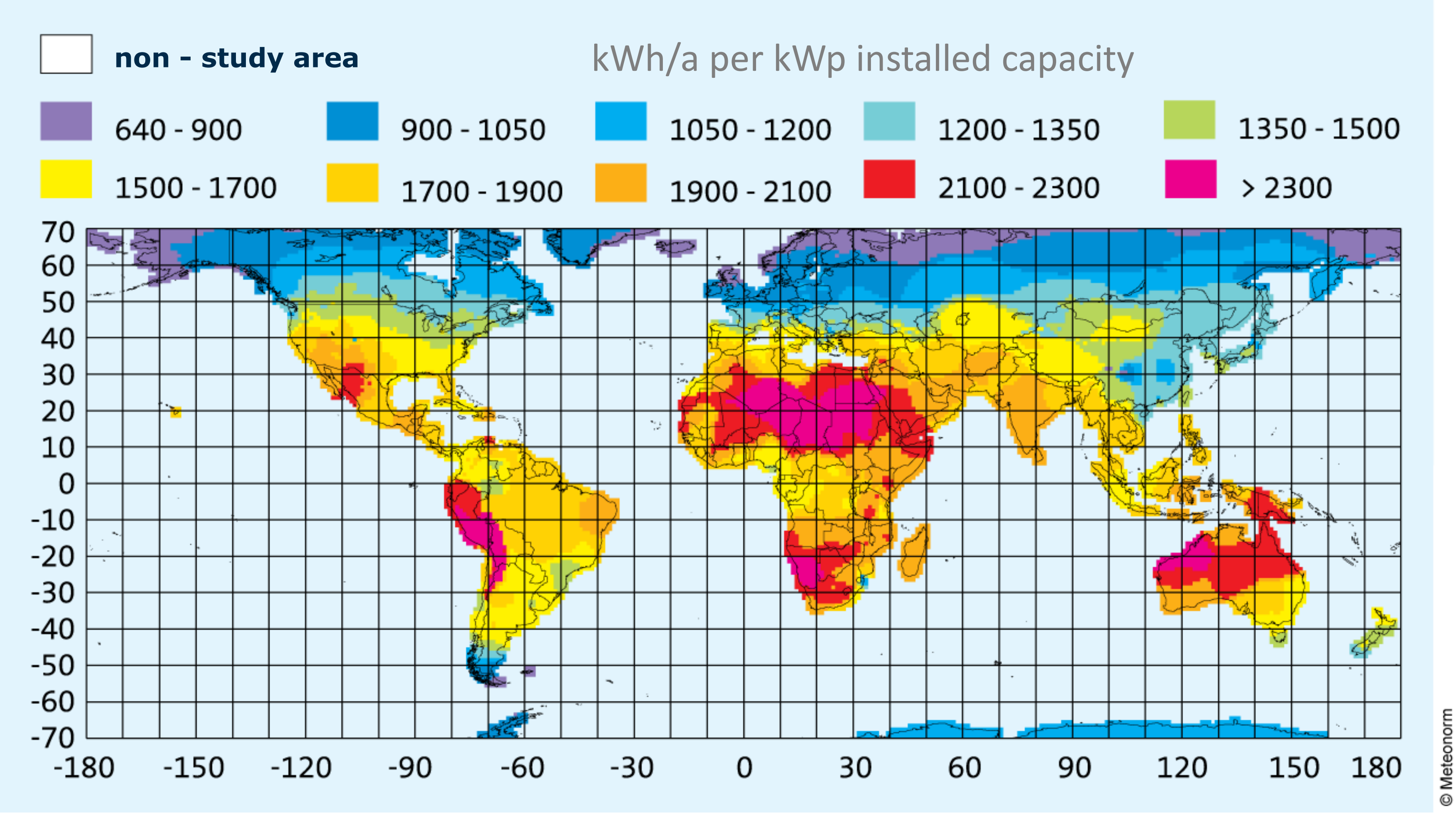
(B) Junction Box, Controllers

(C) Battery

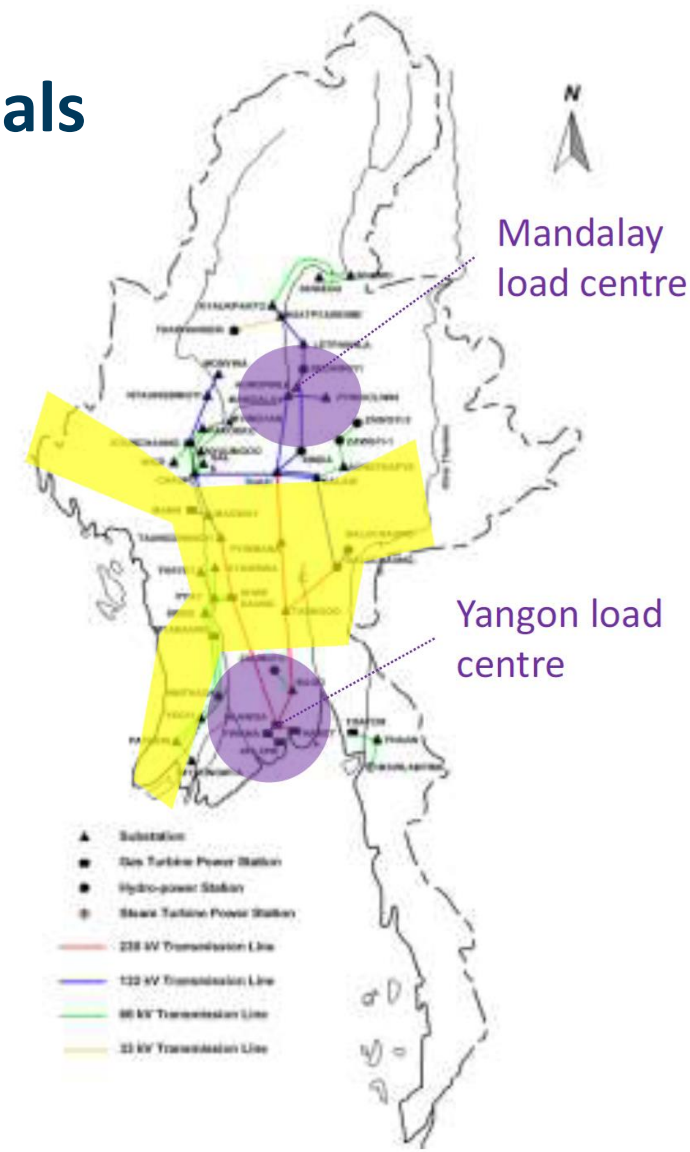
(D) Inverters

(F) Consumption

Solar Energy - Potentials



Solar Energy - Potentials

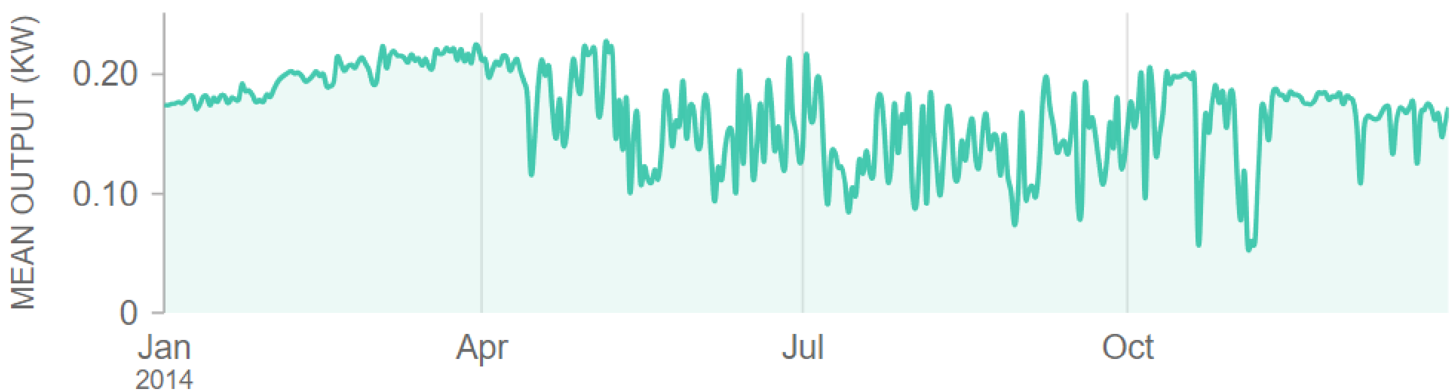


Source: WWF 2016, p-102

Solar Energy – Potentials Myanmar

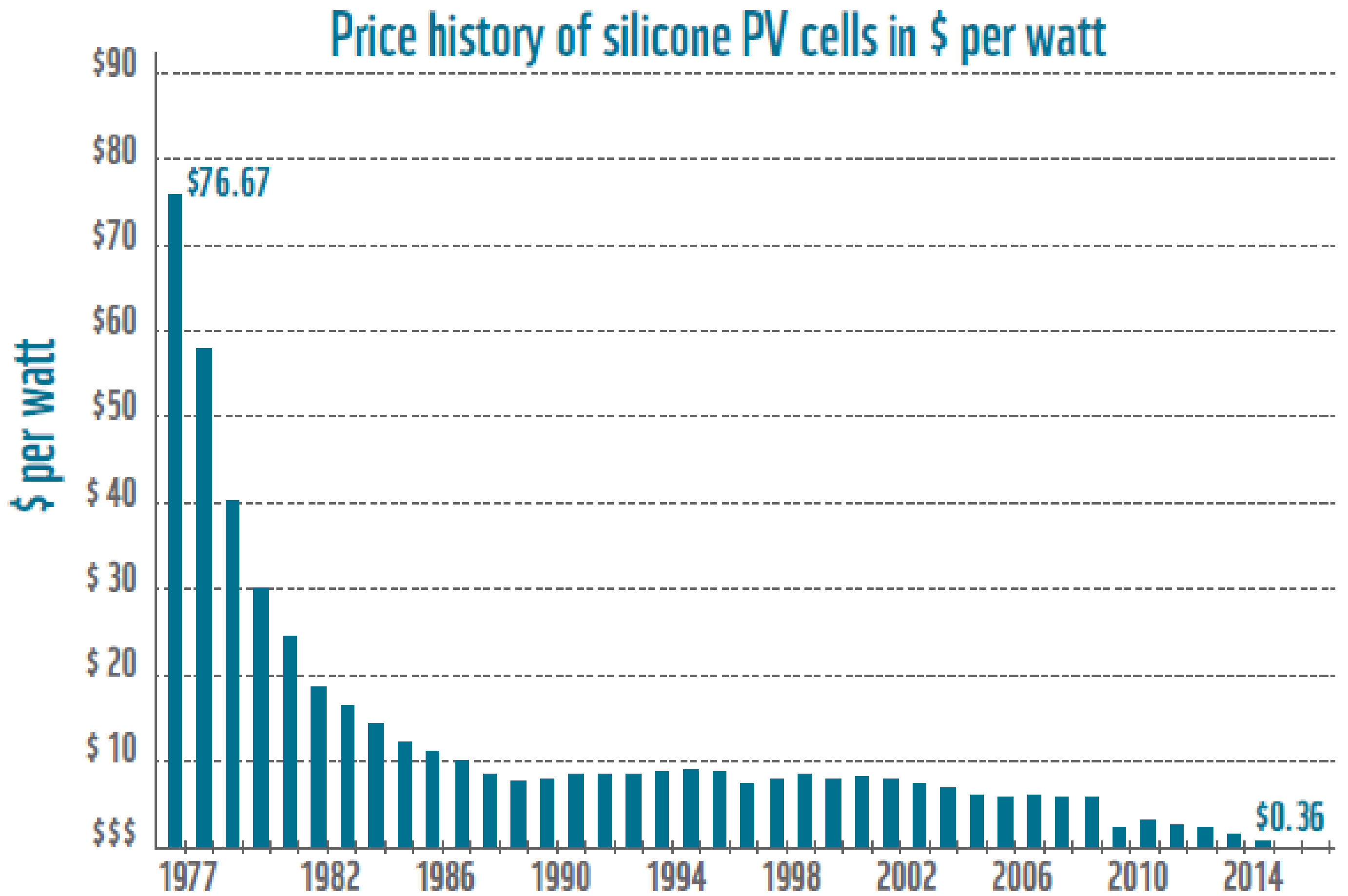
1. 1 kW
2. 15° inclination
3. Yangon

Daily mean output



Source: renewables.ninja, Pfenninger & Staffel (2016)

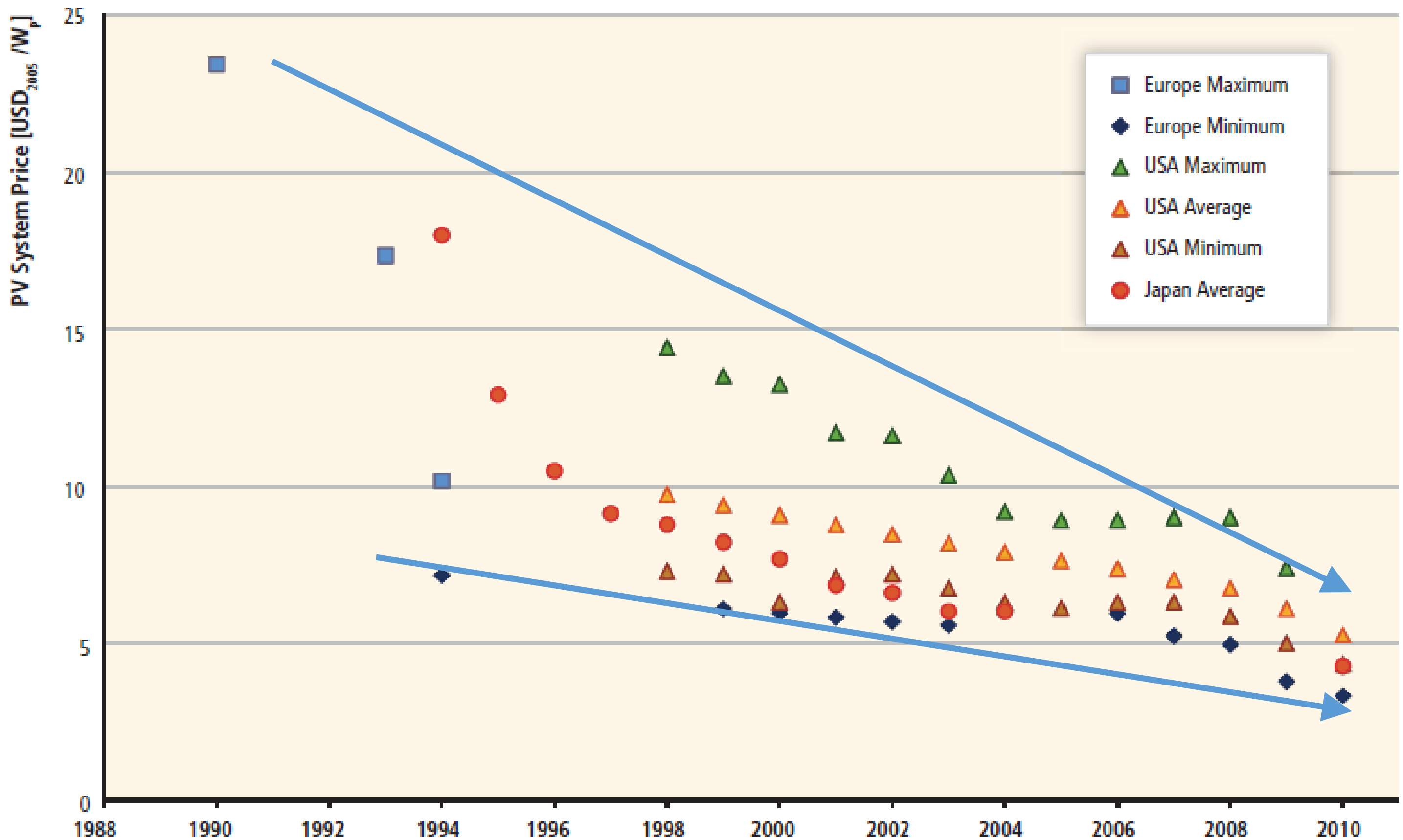
Solar Energy - Costs



Source: WWF, 2016, p. 16

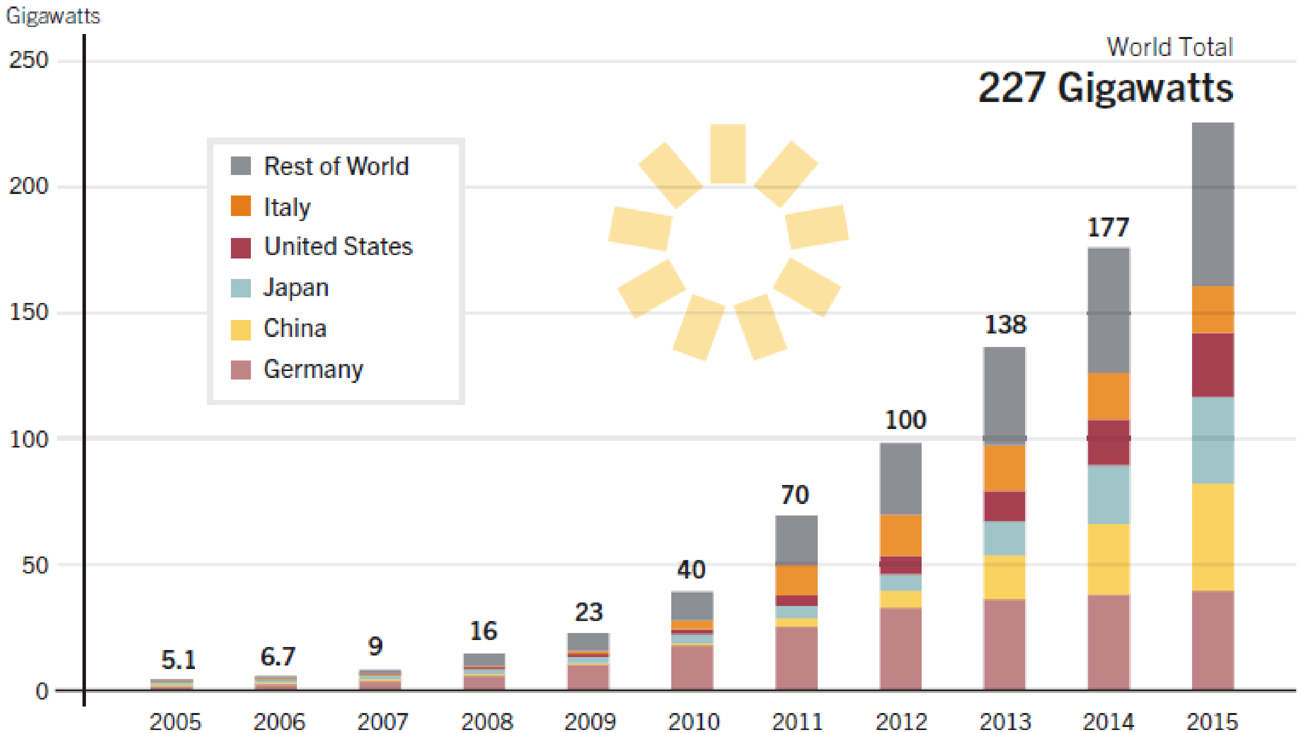
Solar Energy - Costs

Installed system costs for smaller PV systems up to 100 kW



Source: ÍPCC 2012, p. 382

Installed solar PV capacity by country/region 2005-2015 (source: REN 21 2016, p.62)



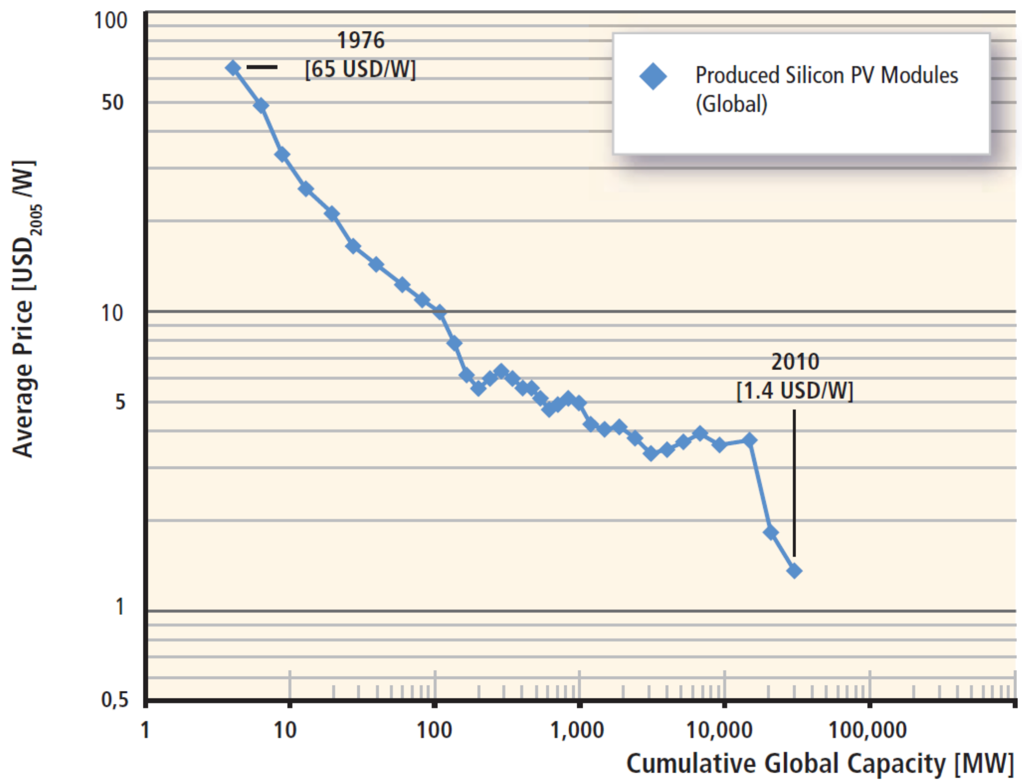


Figure 3.17 | Solar price experience or learning curve for silicon PV modules. Data displayed follow the supply and demand fluctuations. Data source: Maycock (1976-2003); Bloomberg (2010).

Solar Energy – Example Germany

1. Eggebek (Northern Germany)
2. Old airport converted to energy park
3. Approx. 360,000 solar modules
4. Produced by the Chinese company Trina Solar
5. Installed capacity of 83.6 MW
6. Generates electricity for 6,000 households
7. Additionally: wind turbine test field

Solar Energy – Example Tanzania

1. Only 40% of people have access to grid electricity
2. Government: „One Million Solar Homes initiative“ (since 2015)
3. Goal: provide solar energy to 1 million households by 2017
4. “People who have small shops no longer close their shops early because they don’t have electricity. They can now operate until late at night. The availability of solar electricity has helped control immigration of people to urban areas.” (Dr Brenda Kazimili, University of Dar es Salaam)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How Tanzania plans to light up a million homes with solar power

In a country where only 40% of people have access to grid electricity, the government is looking to sunshine to power health centres and homes

A solar panel technician carrying out maintenance work on a corrugated roof, Mlono region, Tanzania. Photograph: Tom Gilks/Alamy

Before solar panels were installed at Masaki village's only health centre, doctors, nurses and midwives had to use dim flashlights or the glow from

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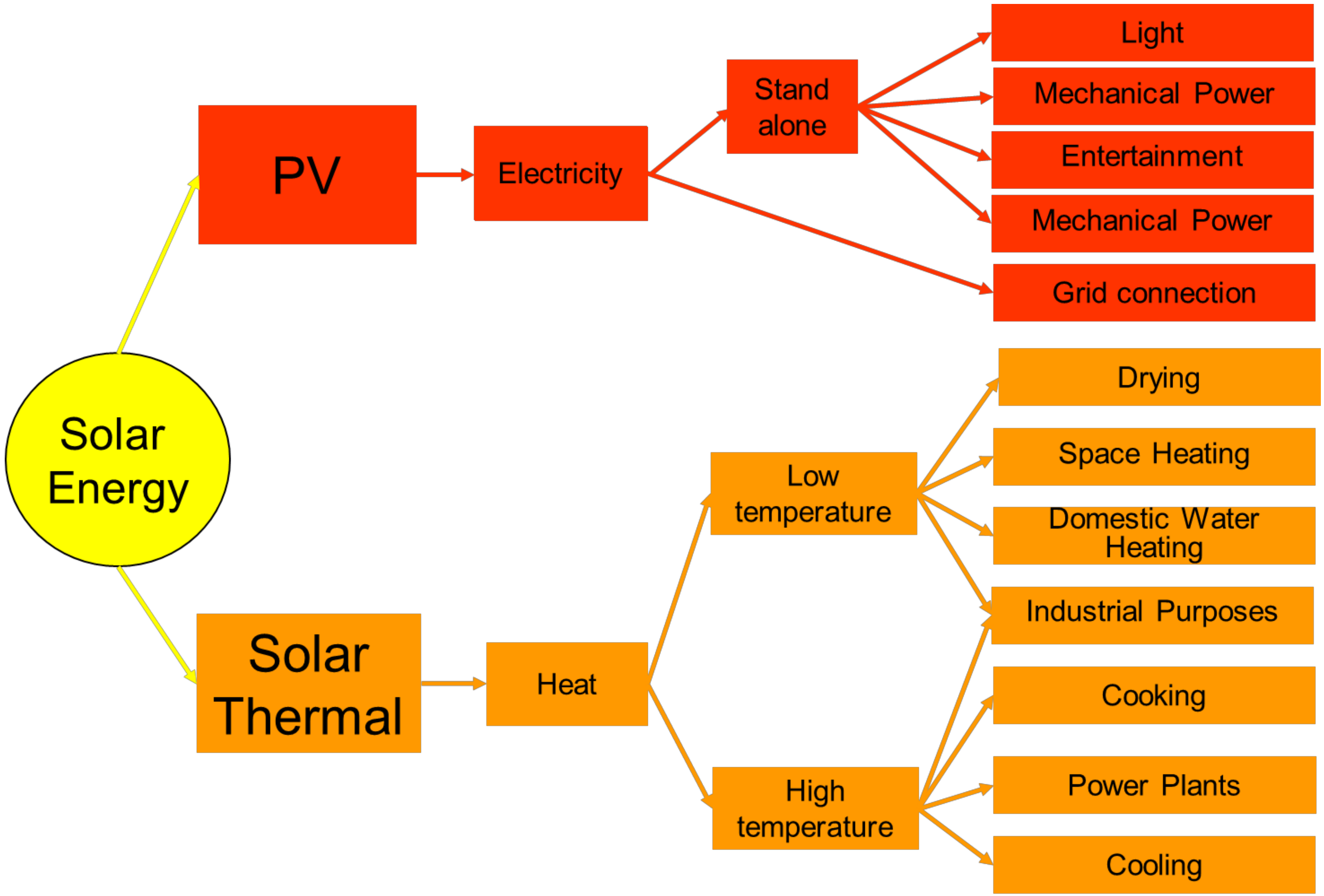
Nobel prize in literature 2017: Kazuo Ishiguro wins - follow it live

Kazuo Ishiguro wins the Nobel prize in literature

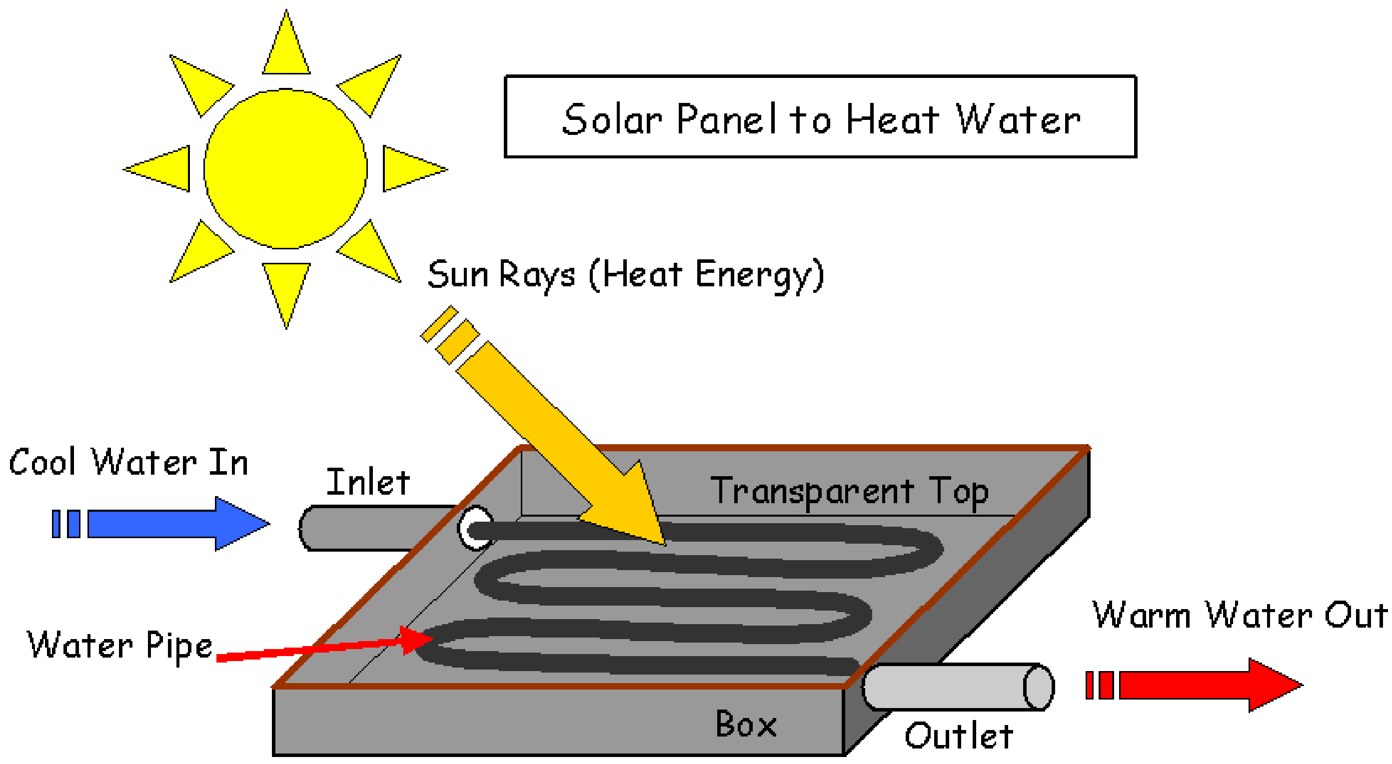
Japanese woman 'dies from overwork' after logging 159 hours of overtime in a month

Source: The Guardian, 2015


Solar Energy
PV
Electricity
Stand alone
Light
Mechanical Power
Entertainment
Mechanical Power
Grid connection
Solar Thermal
Heat
Low temperature
High temperature
Drying
Space Heating
Domestic Water Heating
Industrial Purposes
Cooking
Power Plants
Cooling

Solar Thermal Energy – Technology

1. Uses solar collectors to capture sun energy and heat water

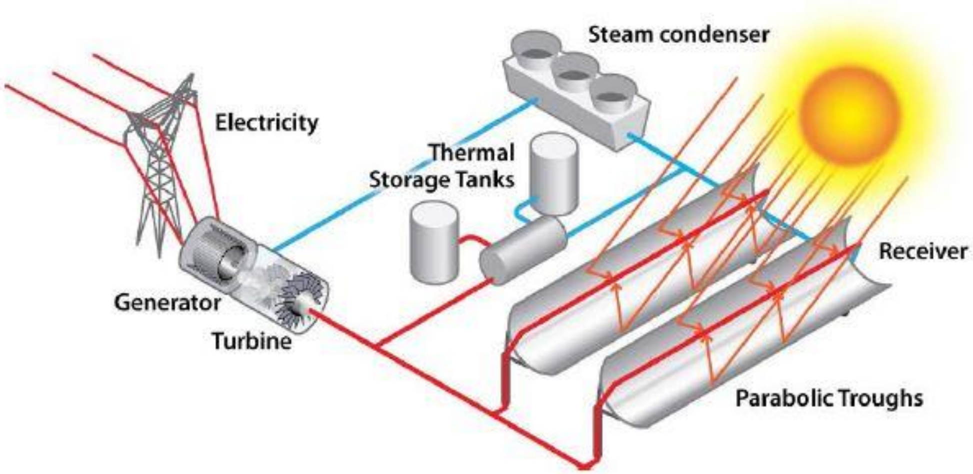


Solar Thermal Energy – Technology

1. Provides hot water
2. Used for cooking

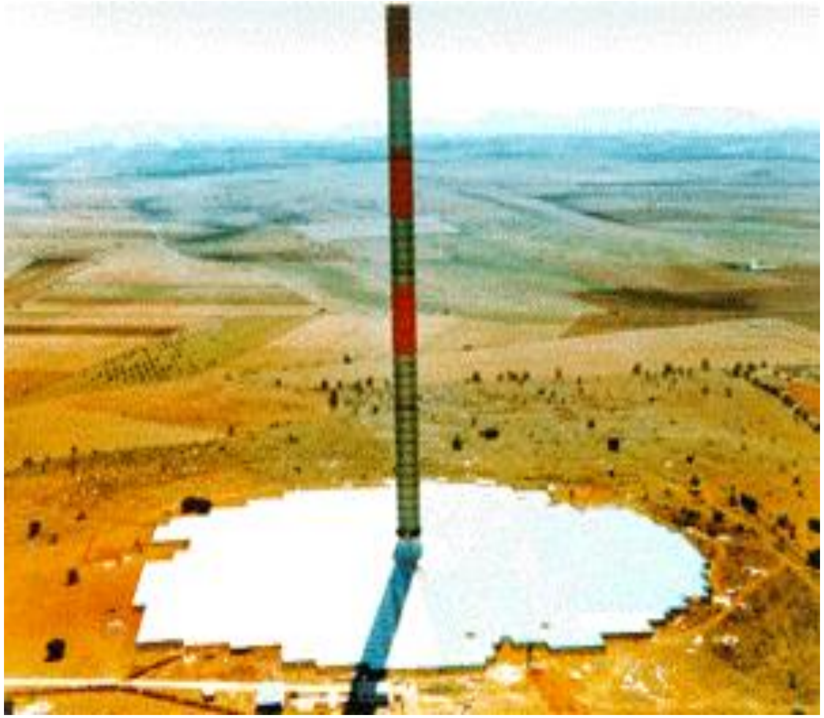
Solar Thermal Energy – Technology

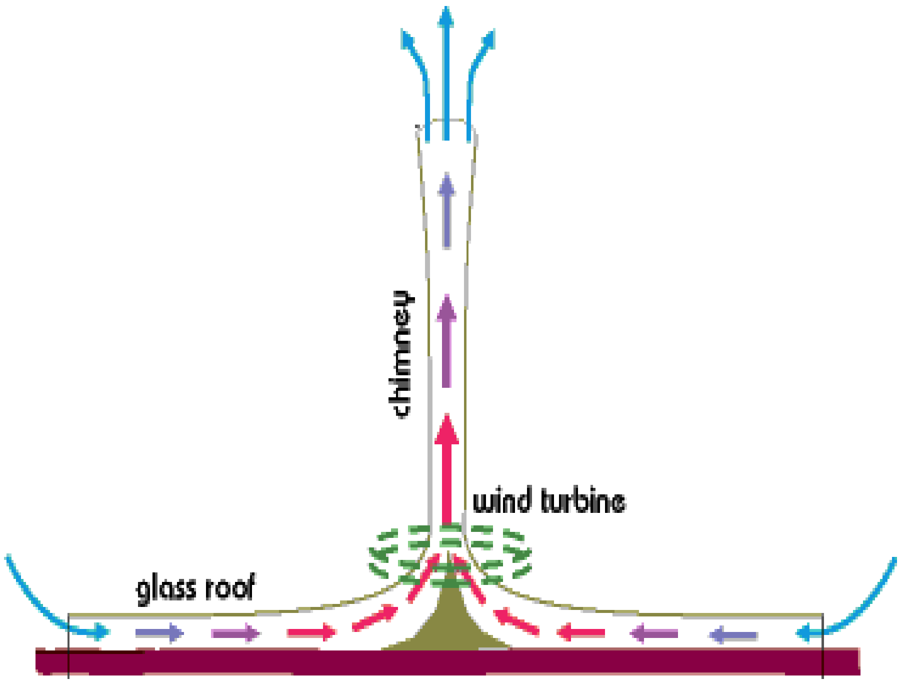
1. Larce-scale applications for electriticy production: Concentrated solar power (CSP)
2. Uses solar collectors/mirrors to concentrate solar radiation on one focus point



Solar Thermal Energy – Technology

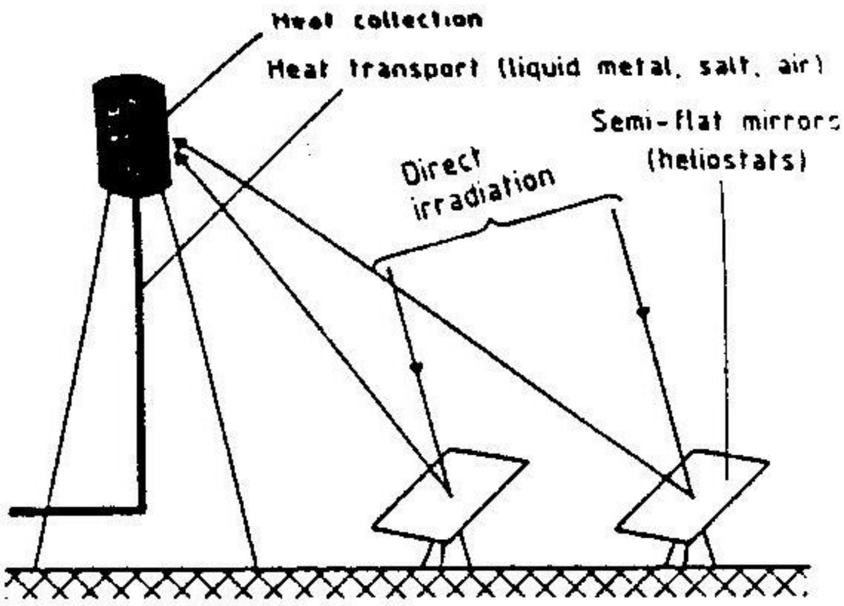
1. Larce-scale applications for electriticy production: „Solar Chimney“





Solar Thermal Energy – Technology

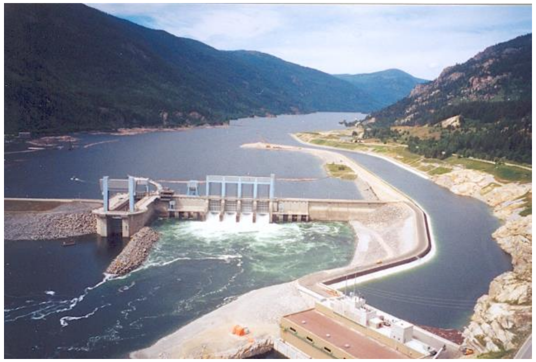
1. Larce-scale applications for electriticy production: Heliostat



Hydro Energy - Technology

Flowing water creates energy that can be captured and turned into electricity

1. **Run-of-river** hydro power plants → no reservoir
2. "Conventional" hydro power from **hydroelectric dams** → huge reservoirs
3. **Small/micro hydro** hydroelectric power system → off-grid-systems for homes/villages/farms
4. **Pump storage** power plant (see storage options)

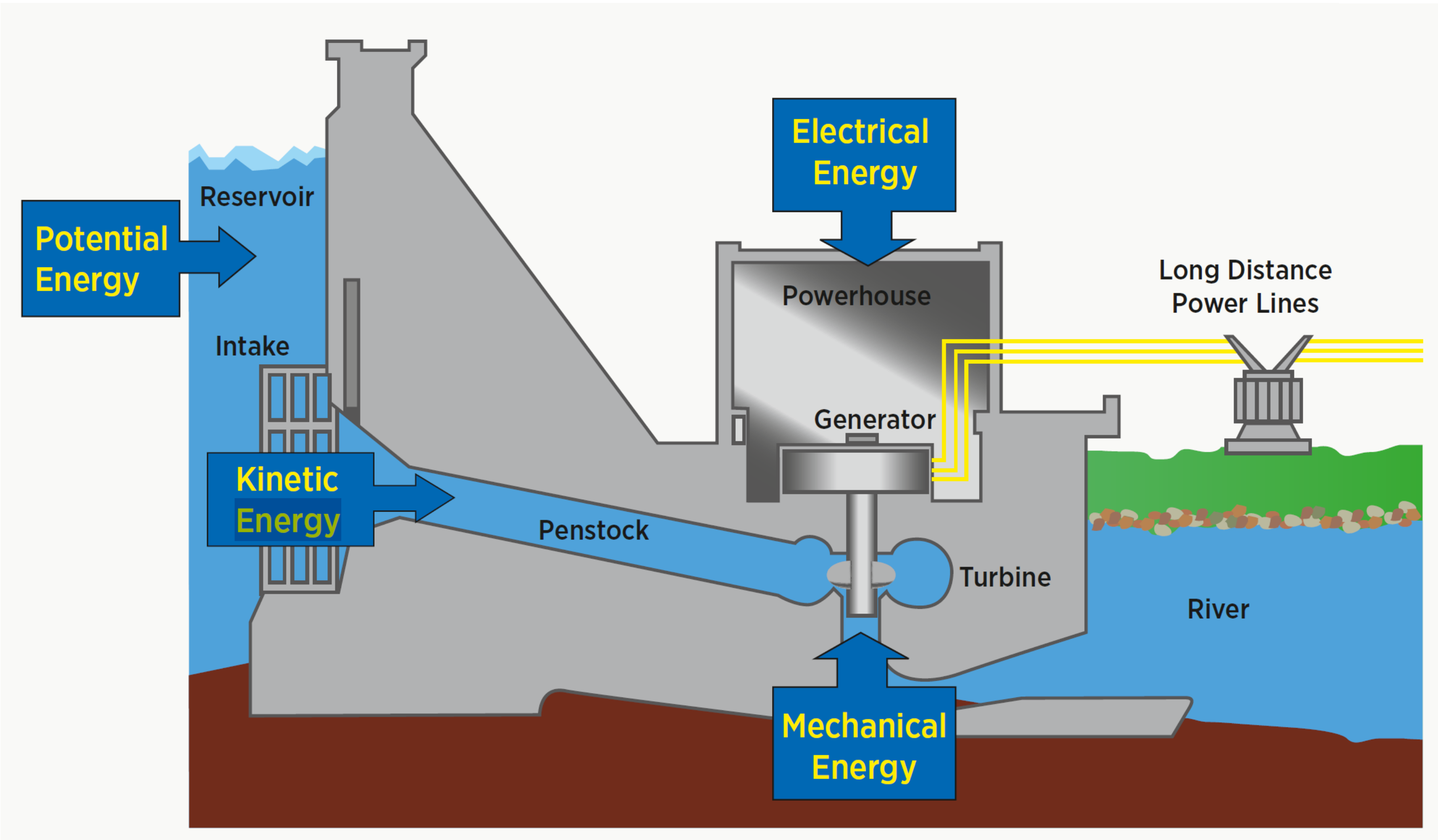


Hydro Power - Technology

1. *Large-hydro*: 100 MW or more of capacity feeding into a large electricity grid;
2. *Medium-hydro*: From 20 MW to 100 MW almost always feeding a grid;
3. *Small-hydro*: From 1 MW to 20 MW usually feeding into a grid;
4. *Mini-hydro*: From 100 kW to 1 MW that can be either stand-alone, mini-grid or gridconnected;
5. *Micro-hydro*: From 5 kW to 100 kW that provide power for a small community or rural industry in remote areas away from the grid; and
6. *Pico-hydro*: From a few hundred watts up to 5 kW (often used in remote areas away from the grid).

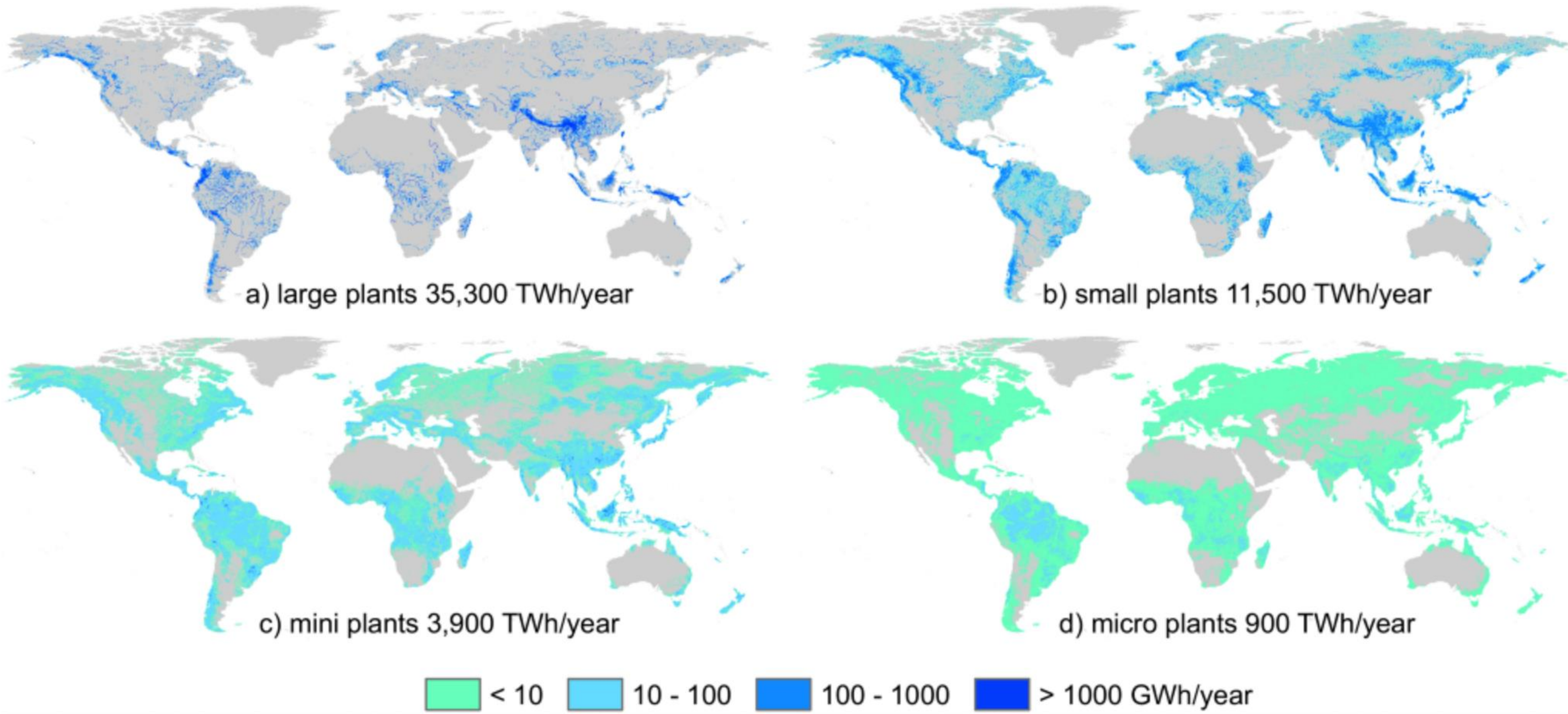
Source: IRENA, 2016, p.16

Hydro Power - Technology



Source: IRENA, 2016, p.12

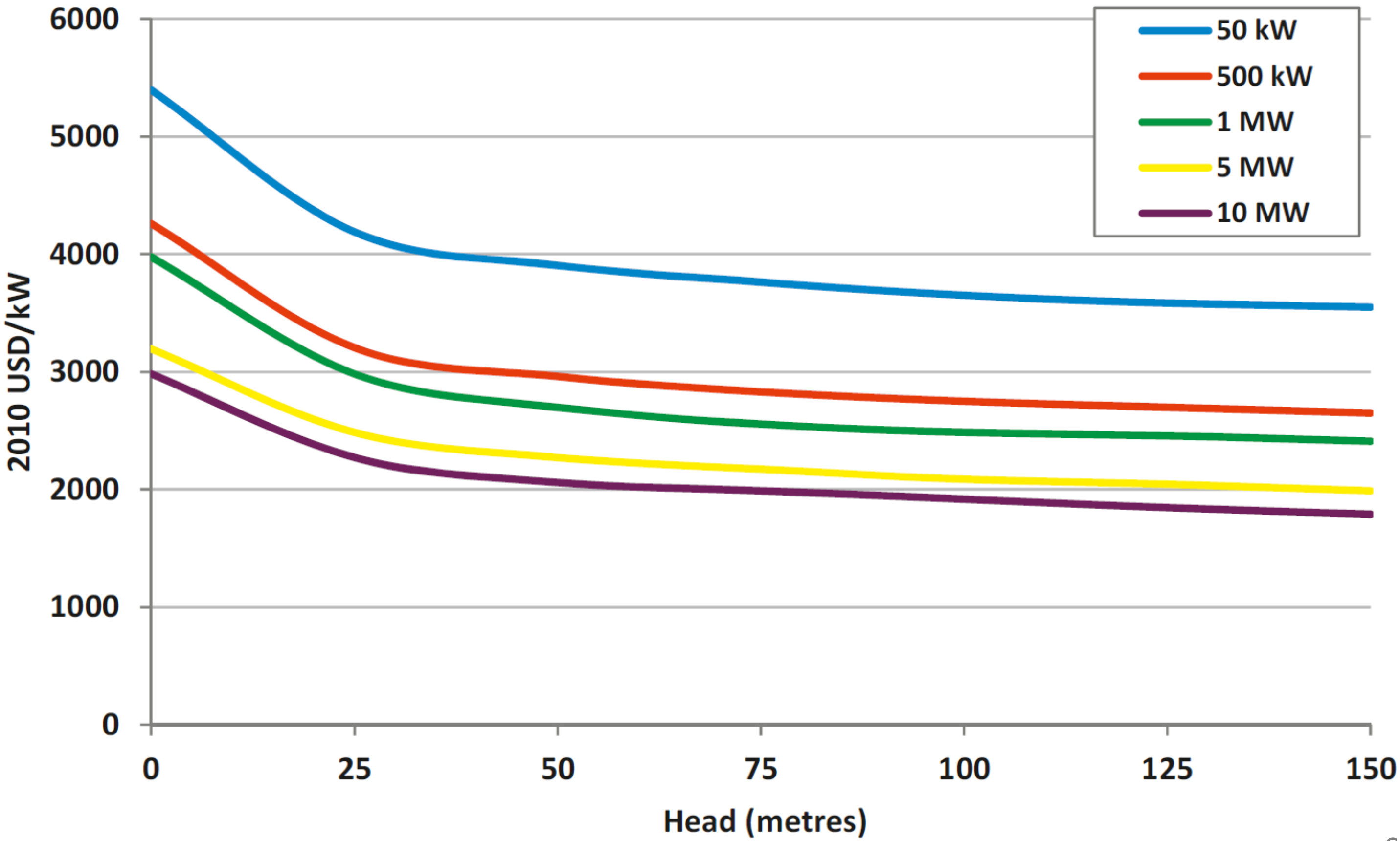
Hydro Power - Potentials



Source: Delft University of Technology, 2017

Hydro Power - Costs

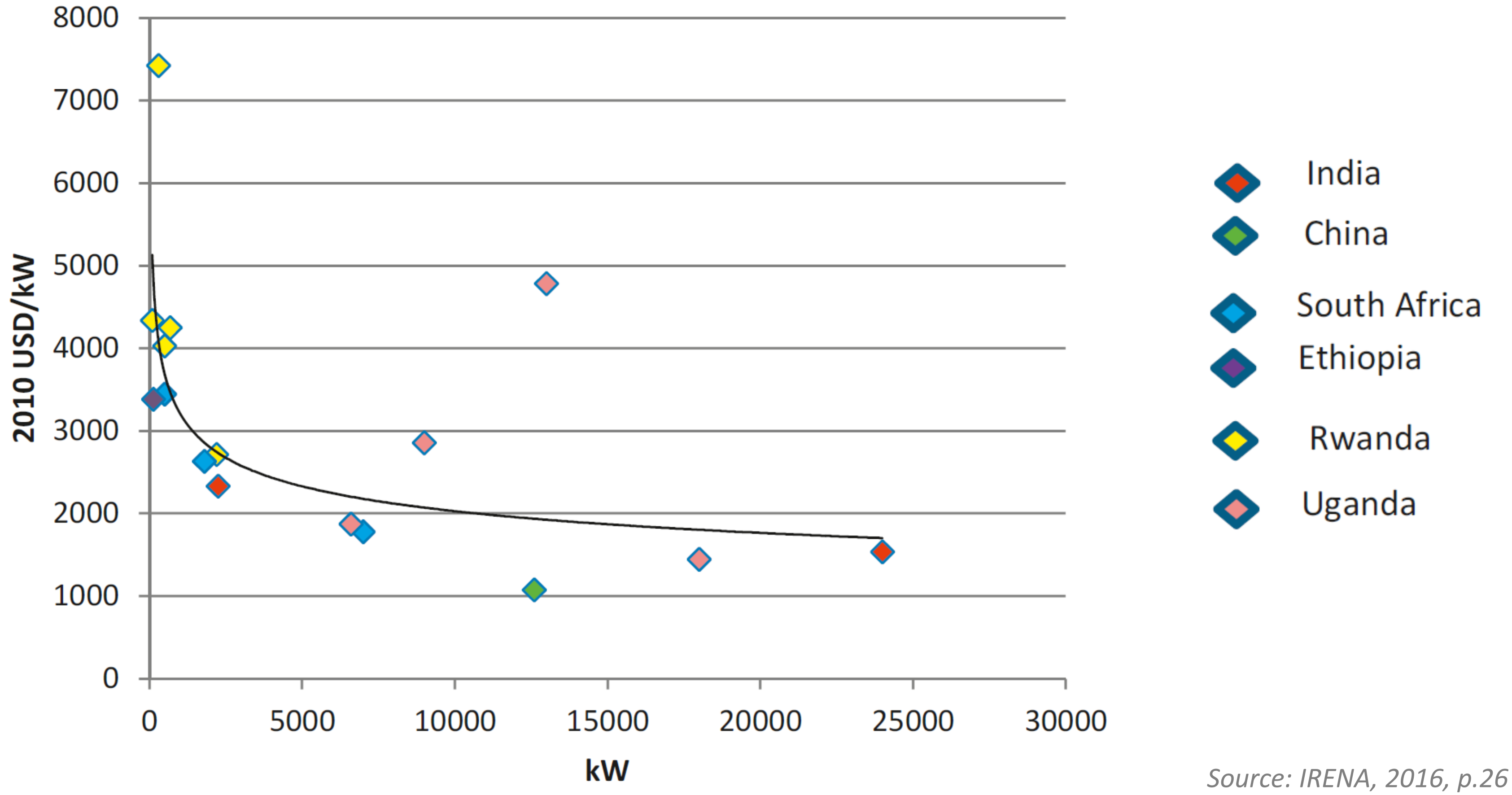
Investment costs dependent on head (height difference)



Source: IRENA, 2016, p.25

Hydro Power - Costs

Specific investment costs dependent on installed capacity



Source: IRENA, 2016, p.26

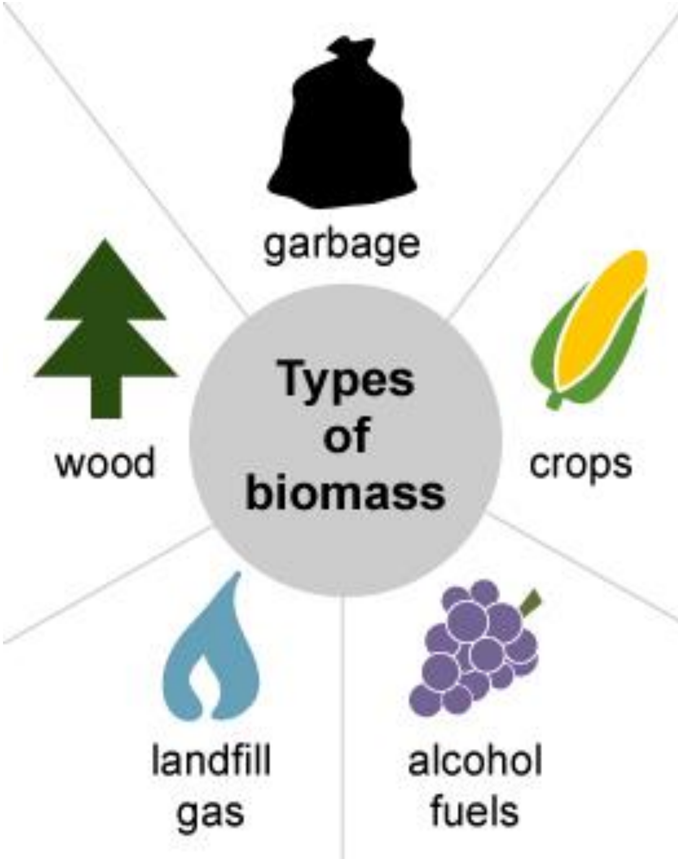
Hydro Energy – Example Nepal

1. Over 3,300 micro hydro plants are providing energy to villages around the country
2. Nearly 30 MW in small scale hydro energy power plants
3. Mostly off-grid to provide electricity to rural areas
4. Provide electricity for about 350,000 households

Source: Nepal Micro Hydropower Development Association7

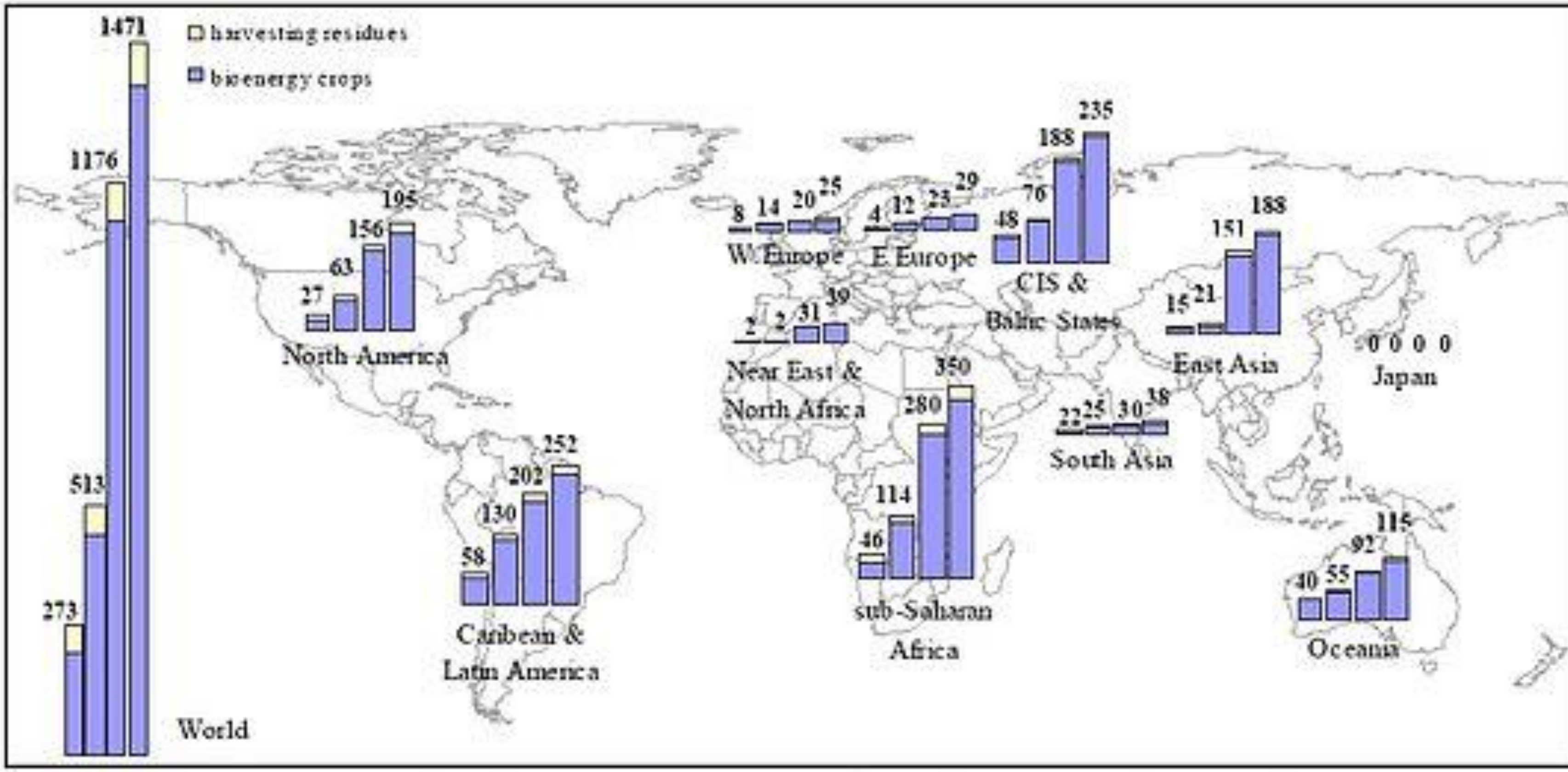
Biomass Energy - Technology

1. Biomass is organic material
2. Biomass directly burned in CHP power plants
   → heat and electricity
3. Or converted to biogas (methane) before burning
4. Or converted to liquid biofuels (ethanol or diesel, can be burned or used to substitute fossil fuel)
5. "Traditional Biomass" = using wood etc. directly for heating/cooking



Source: EIA

Biomass Energy - Potentials

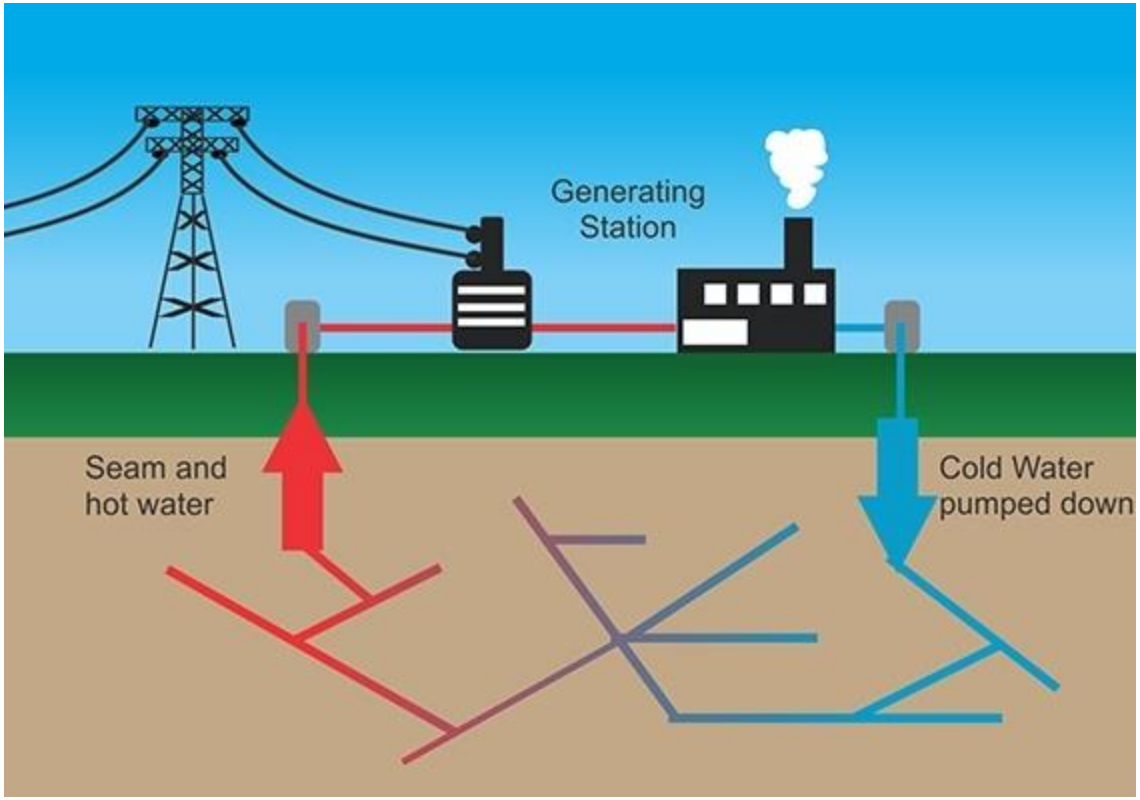


Source: European Biomass Industry Association

Biomass Energy – Jühnde village, Germany

1. Central Germany, 1,100 inhabitants
2. Electricity and heat from biogas plant
3. Wood-powered power plant
4. Heating pipe network to every house
5. -60 % CO_2 emissions
6. Price equal ot lower to other energy sources/conventional energy system

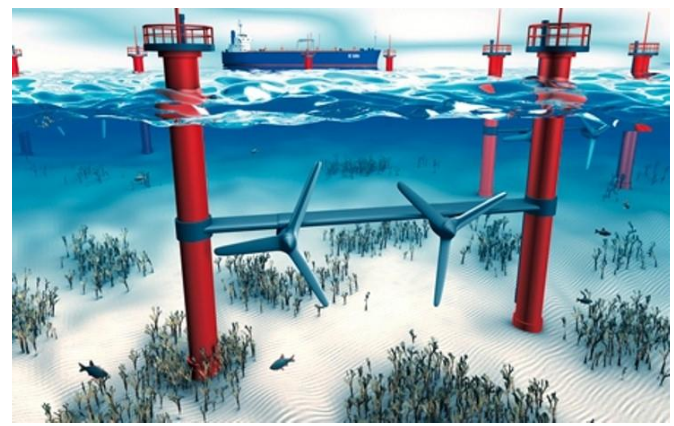
Geothermal Energy - Overview



Ocean Energy - Overview

Current energy

1. Similarly to a wind turbine, but underwater.
2. Water is denser than air, moving water will produce much more power
3. Turbine itself must be stronger and, therefore, is more expensive
4. The environmental impact of current turbines is not clear. It could harm fish populations but fish-safe turbines have been developed.

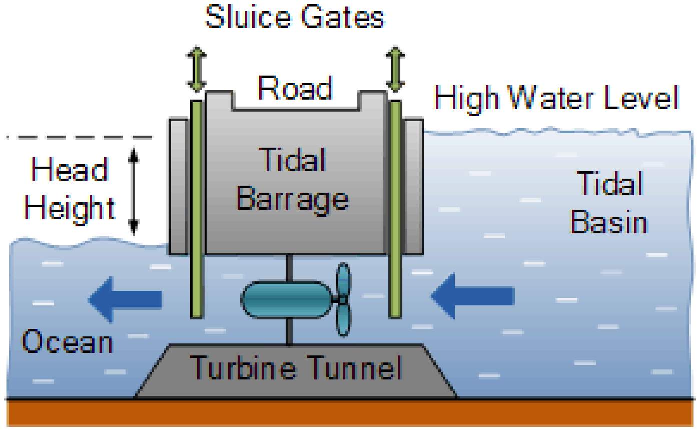


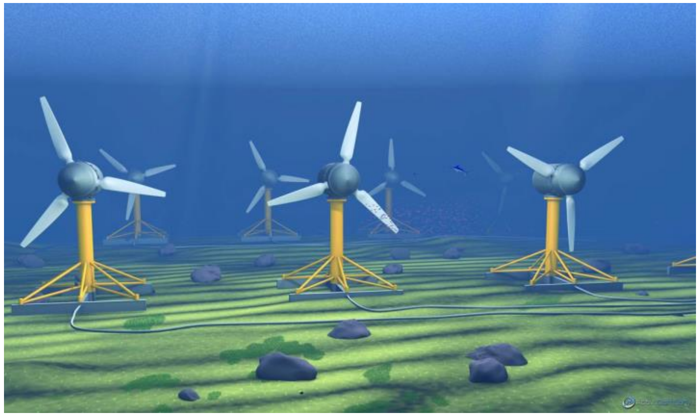
Source: Environmental and Energy Study Institute

Ocean Energy - Overview

Tidal power

1. Using the predictable cycle of low and high tides
2. Tides are more predictable than wind energy and solar power
3. Converts the energy of tides (flow of water) into electricity
4. A) tidal barrage: a dam at the coast
5. B) Tidal current: flow of the water



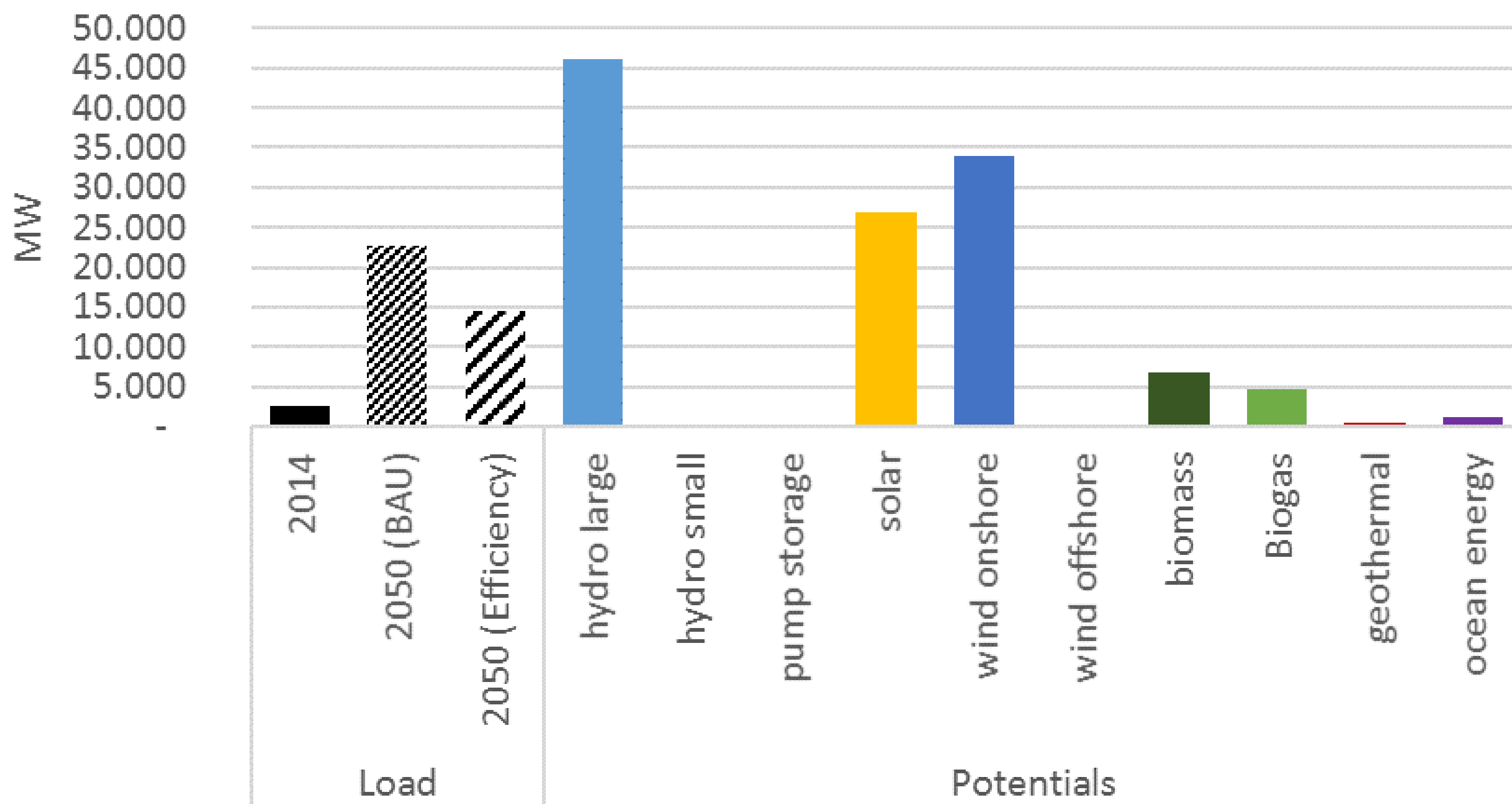


Ocean Energy - Overview

Wave energy

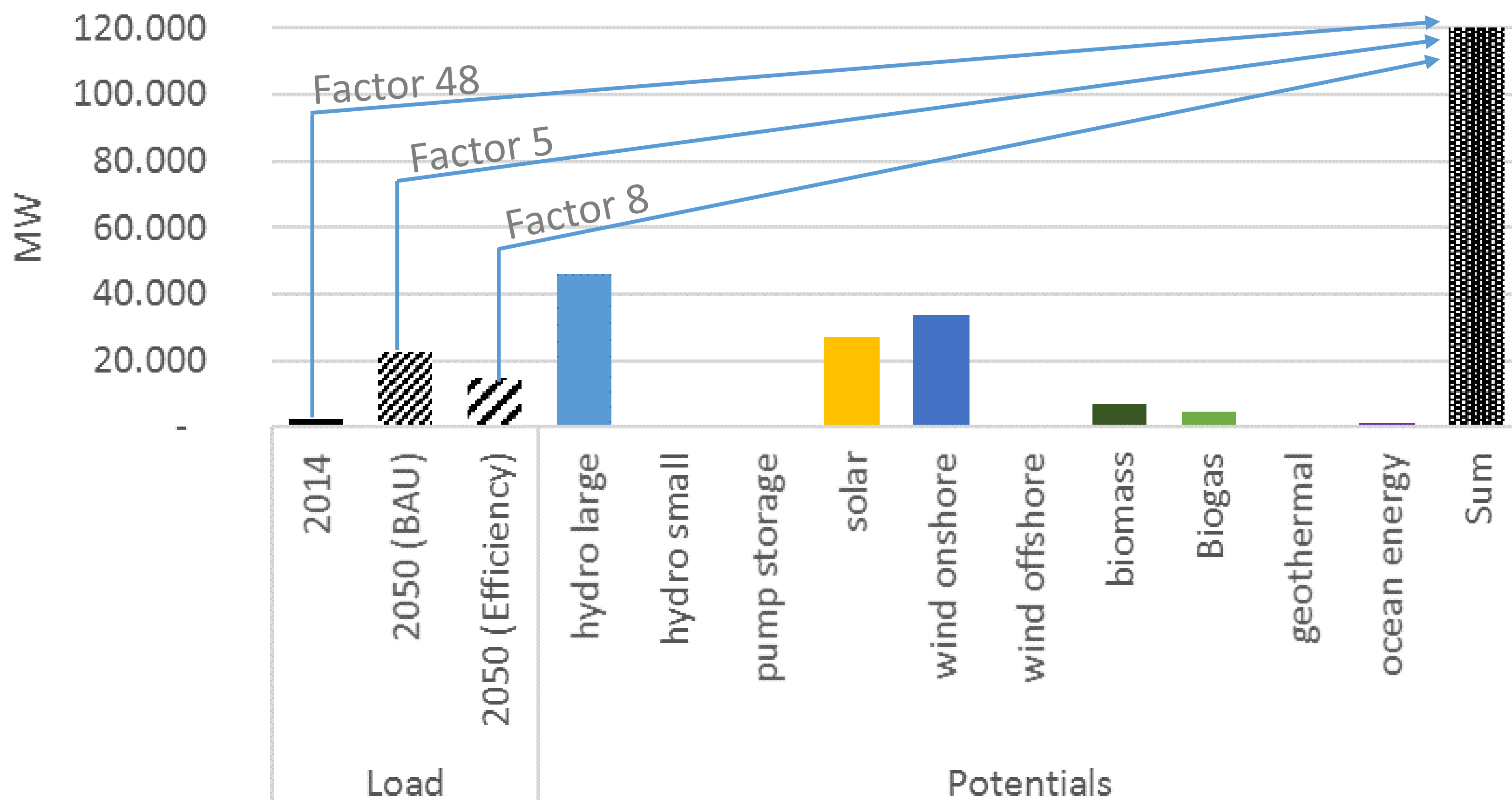
1. Using the energy of waves on the ocean
2. Waves are predictable and are constantly created
3. Swells of waves creates pressure and moves hydraulic pumps or pressurized air
4. Pressurized air or hydraulic fluid drives generator
5. Best potential sites for wave generation are ocean areas with strong wind currents
6. Hybrid wind and wave technology for offshore energy farms are in development

Estimated Renewable Energy Potential Myanmar



Source: WWF 2016, p. 104

Estimated Renewable Energy Potential Myanmar



Source: WWF 2016, p. 104

Estimated Renewable Energy Potential Myanmar

Remember max. demand 2050: 15,000 – 22,000 MW

Myanmar	Potential (MW)	Source and comments
Hydro (Large)	46,000	See Section 3.4
Hydro (Small)	231	See Section 3.4
Pump Storage	0	Lack of studies available
Solar	26,962 MW	Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Wind Onshore	33,829	Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Wind Offshore	No information available	Lack of studies available
Biomass	6,899	IES projections based on data from Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Biogas	4,741	IES projections based on data from Renewable Energy Developments and Potential in the Greater Mekong Subregion (ADB, 2015)
Geothermal	400	See Section 3.7
Ocean	1,150	Ocean renewable energy in Southeast Asia: A review (2014), based on 5kW/m wave potential, 2300km coastline, 10% efficiency

Source: WWF 2016, p. 104

Costs of Renewable Energies

Different costs to consider:

Capital Costs

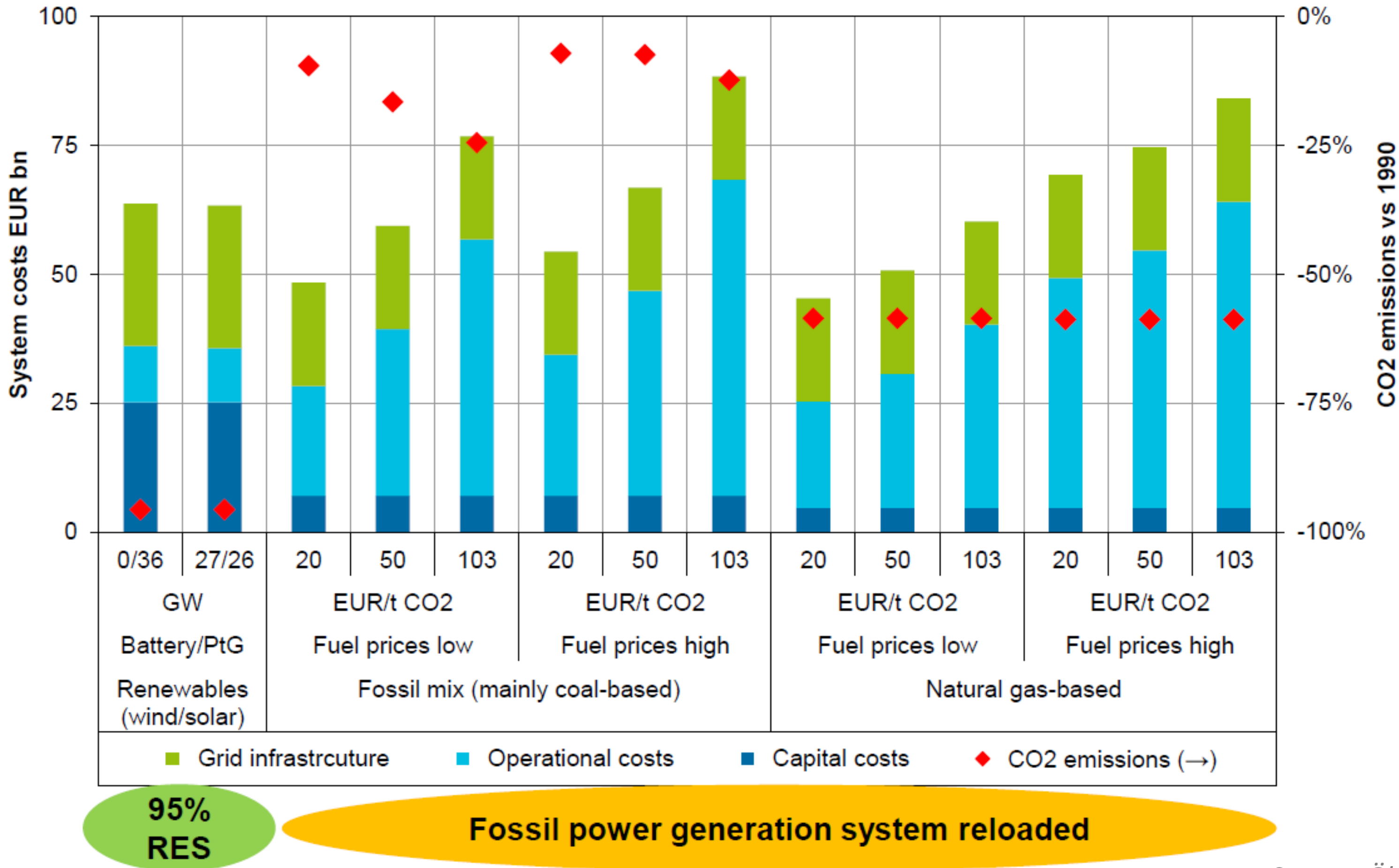
Operational Costs

(usually high)

(fuel costs are low or often zero)

Source: NREL, 2015

Costs of Renewable Energies



Source: Öko-Institut, 2016

Comparison: Levelized Costs of Electricity (LCOE)

1. Method to compare costs over different technologies
2. Costs for different technologies levelized on common set of assumptions
3. Net present value of the unit-cost of electricity (per kWh) over the lifetime of a generation plant
4. Based on a discounted cash flow analysis over the project lifetime (taking into consideration the time value of money, i.e. inflation)
5. Often taken as a proxy for the average price that the generation plant must receive in a market to break even over its lifetime
   - Market price < LCOE: investment not feasible
   - Market price > LCOE: investment is feasible

6. "Projections show conclusively that within a few years, wind and solar electricity will be competing with fossil fuel power plants in the countries of the Mekong region (including coal) while providing price certainty for the next 20-25 years without causing pollution."

Source: WWF, 2016, p. 16 ff.

Comparison: Levelized Costs of Electricity (LCOE)

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

LCOE = the average lifetime levelised cost of electricity generation;

I_t = investment expenditures in the year **t**; — CAPEX

M_t = operations and maintenance expenditures in the year **t**;

F_t = fuel expenditures in the year **t**; — OPEX (M_t, F_t)

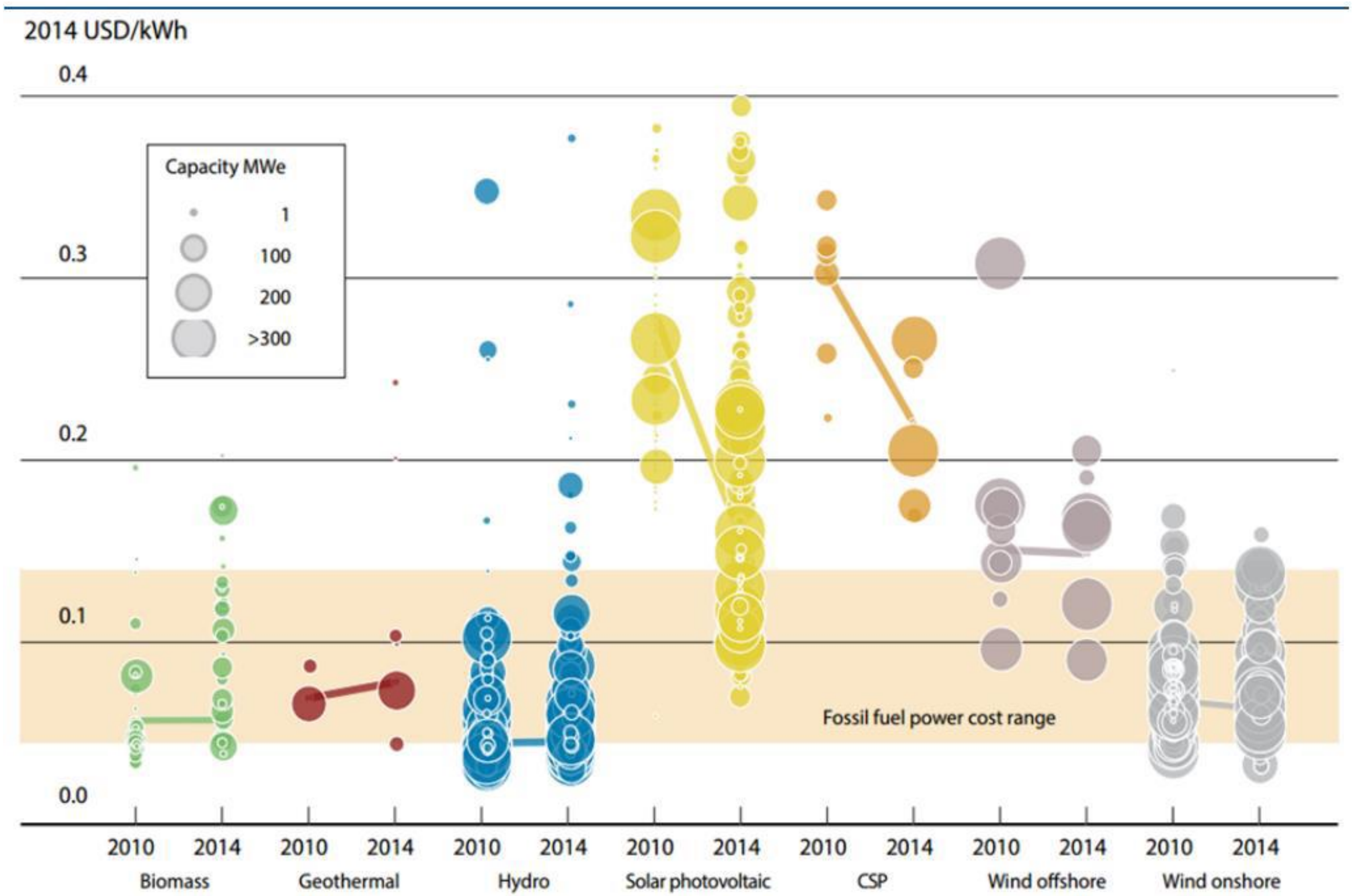
E_t = electricity generation in the year **t**;

r = discount rate; and

n = economic life of the system.

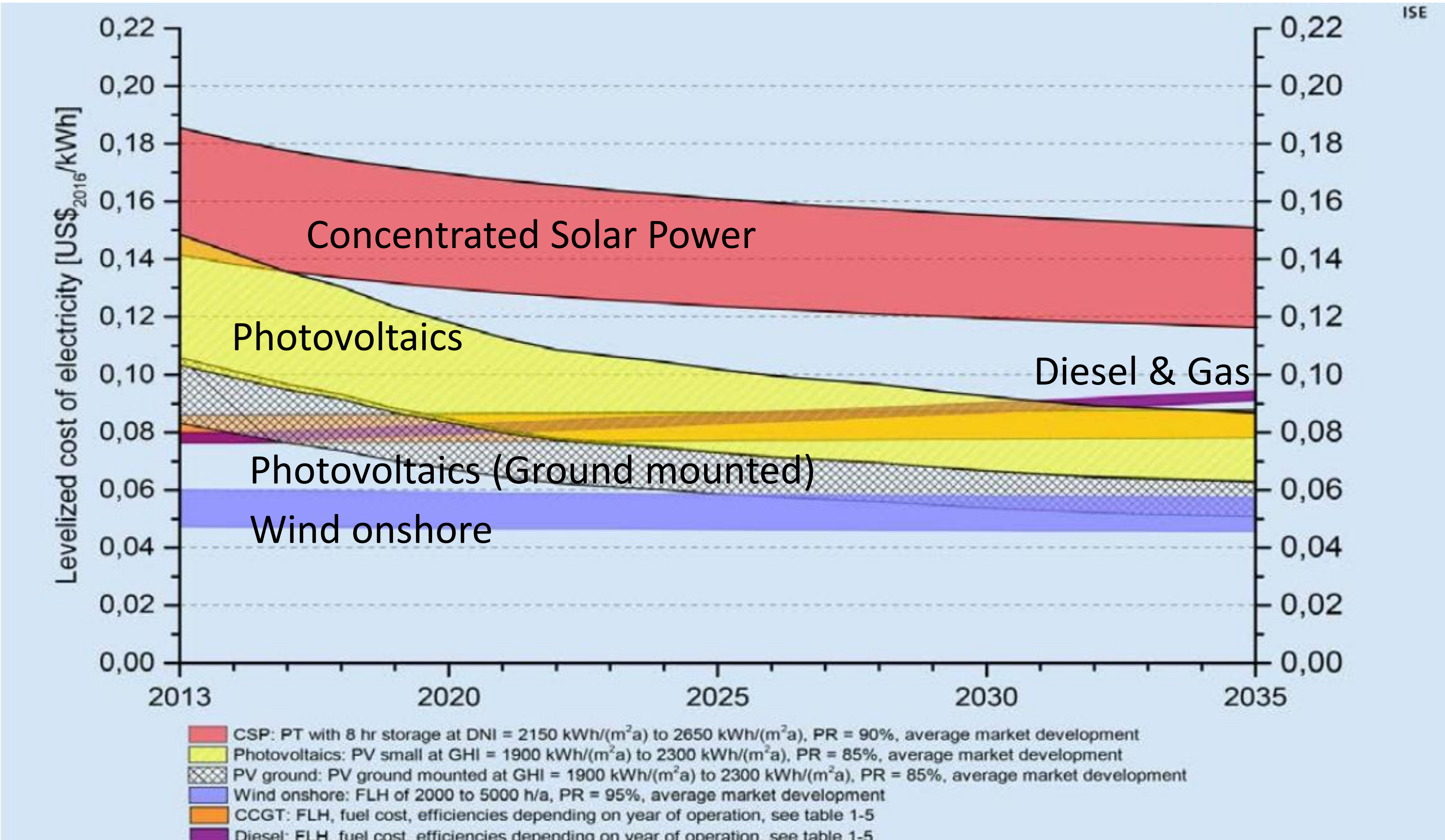
Source: IRENA 2012, p.8 f.

Comparison: Levelized Costs of Electricity (LCOE)



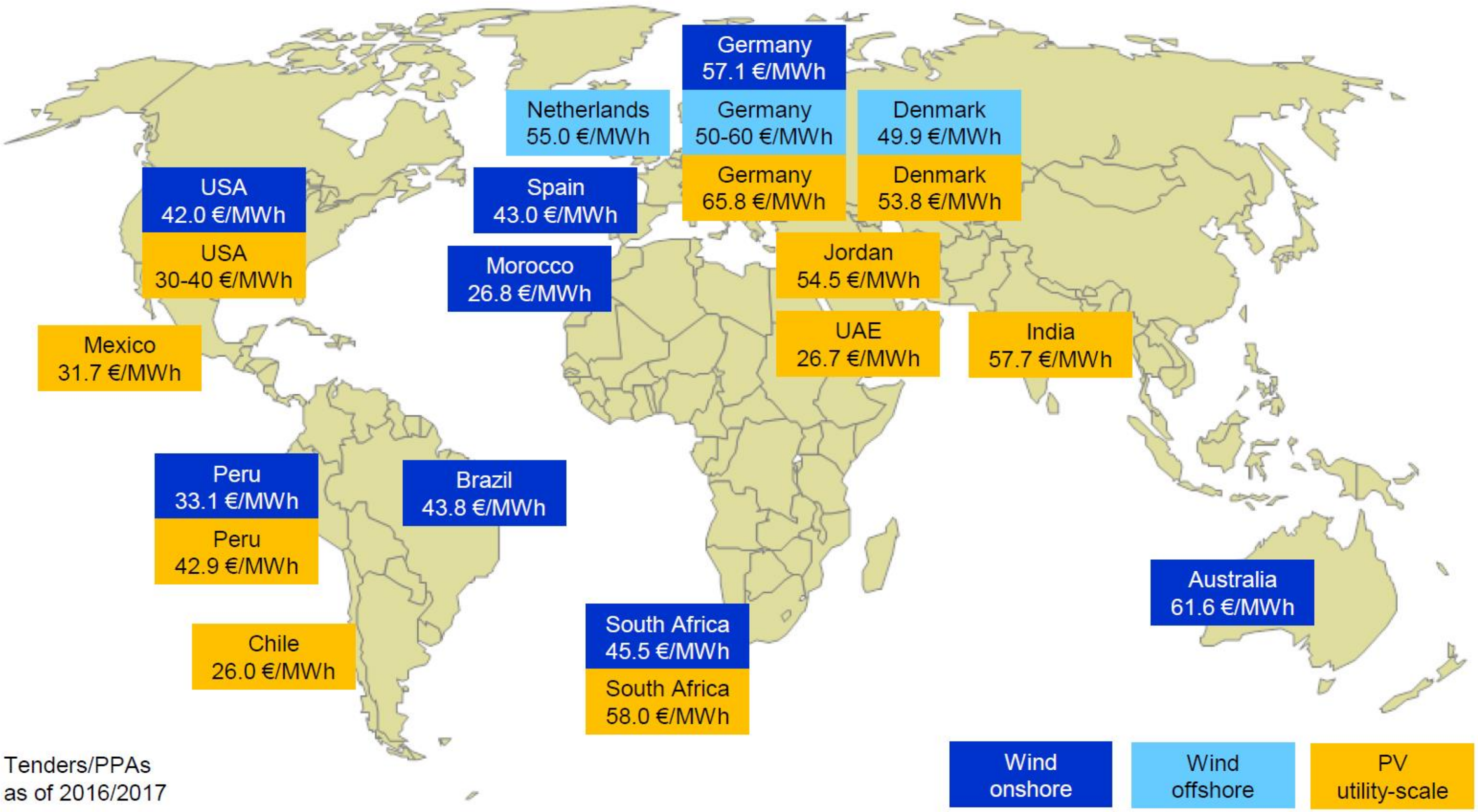
Source: IRENA 2014

Comparison: Levelized Costs of Electricity (LCOE)



Source: Fraunhofer ISE, 2016

Comparison: Levelized Costs of Electricity (LCOE)



Source: Öko-Institut 2017, p.2

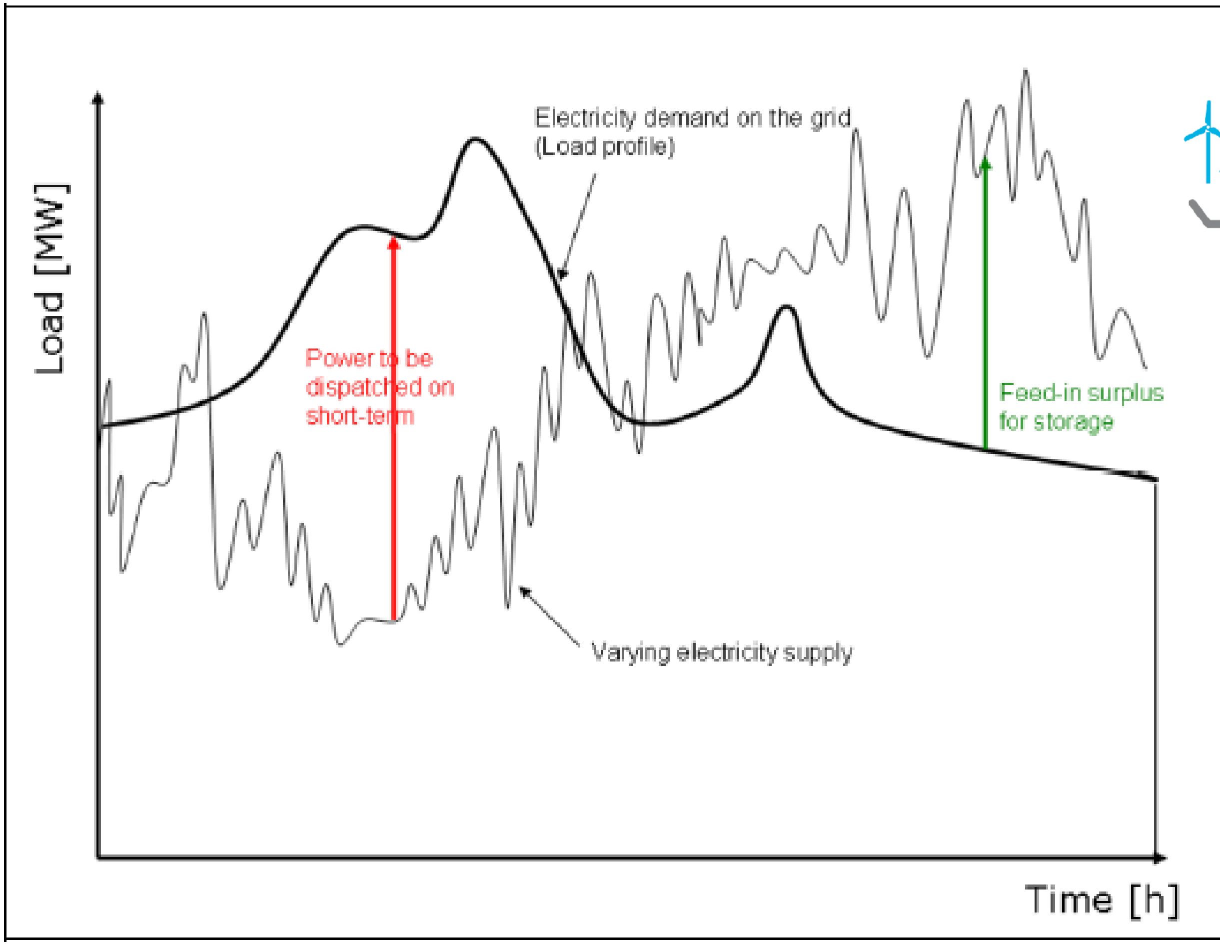
Implementation Challenges of Renewable Energies

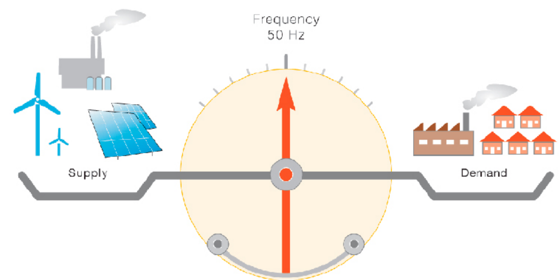
1. National Energy Policy & targets
2. Stable policy framework (laws, rules and regulations)
3. Investment security
4. Clear rules for market entry & participation
5. Reasonable feed-in tarifs
6. Electrical grid
7. Competition for areas of unspoiled nature and cultivating food (biomass)

Mitigation Measures

>> Storage Options: Resources, Technologies and Costs

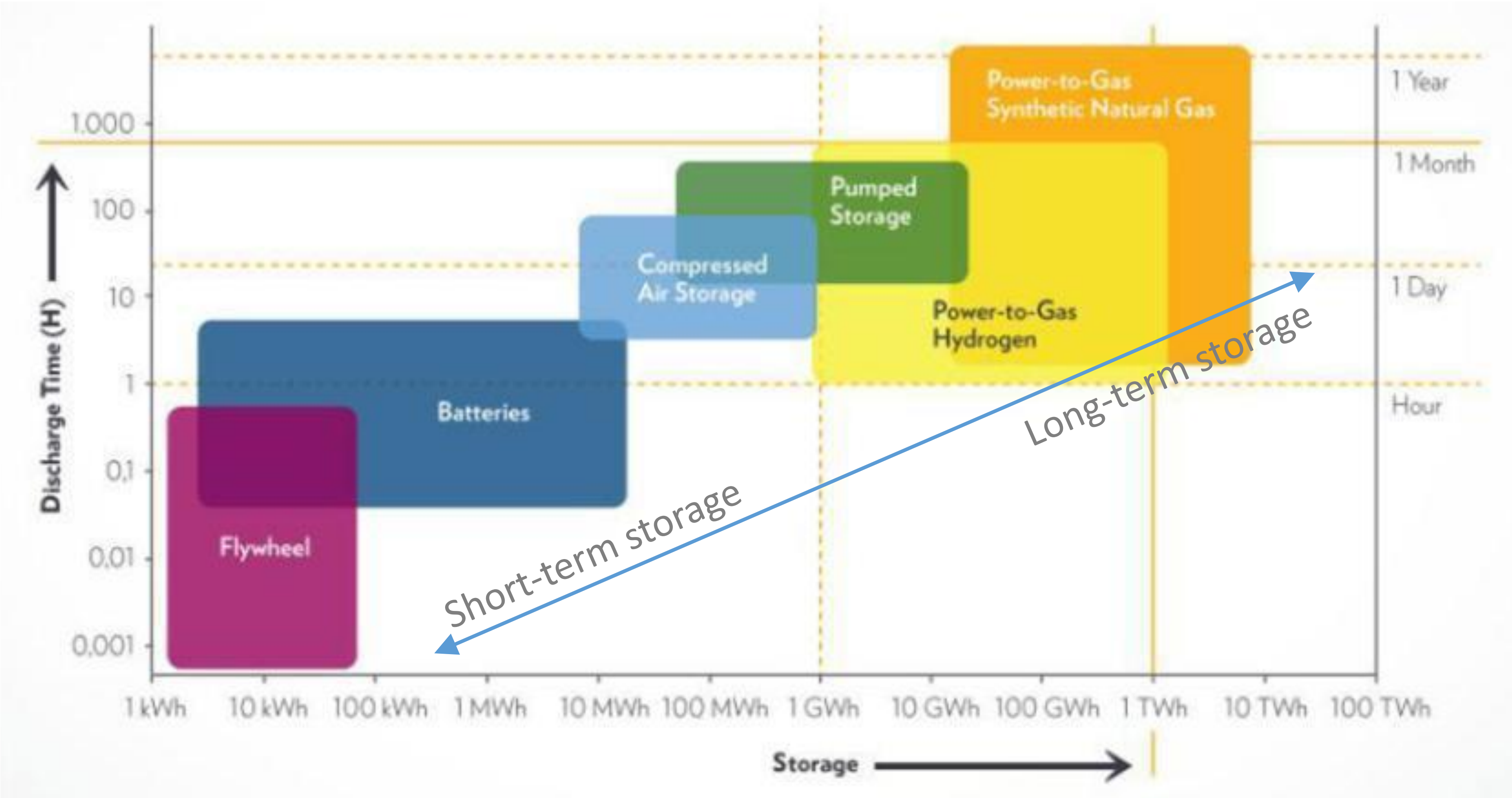
Why do we need Storage Options?





1. To balance supply and demand
2. To save overproduction for times with unterproduction

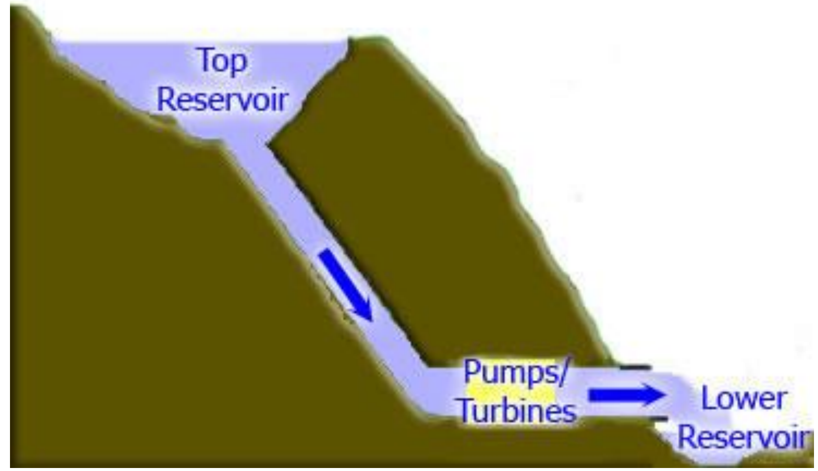
Which Storage Options Do We Have?



Source: ITM Power

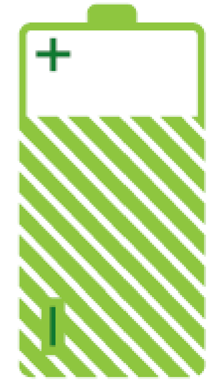
Pump Storage Power Plants

1. Large-scale
2. Long-term/seasonal storage
3. Times with low demand/high production: Stores water pumped uphill into reservoirs
4. Times with high demand/low production: released for generation through turbine
5. Height difference needed



Batteries

1. Electro-chemical storage solution
2. Small-scale, short-team storage
3. Different battery types: Lead–acid, Nickel-cadmium, Lithium-ion, Lithium-polymer, …
4. Current research on batteries is focusing on lowering the cost per stored kWh by
   - Using materials more abundant (= cheaper) materials
   - Using less environmentally harmful materials than the conventional lead/acid or lithium-ion technologies
   - Making battery cells more efficient
   - Increasing life-span of battery-cells



Source: WWF 2016, p.17

Mitigation Measures

>> Foundations of Sustainable Energy Systems

Foundations of Sustainable Energy Systems

1. What is a sustainable energy system for you?
2. What belongs to a sustainable energy system?
3. What does <u>not</u> belong to a sustainable energy system?

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Recap: Sustainability Definition

"A development satisfying the needs of the present generation without impairing the needs of future generations."

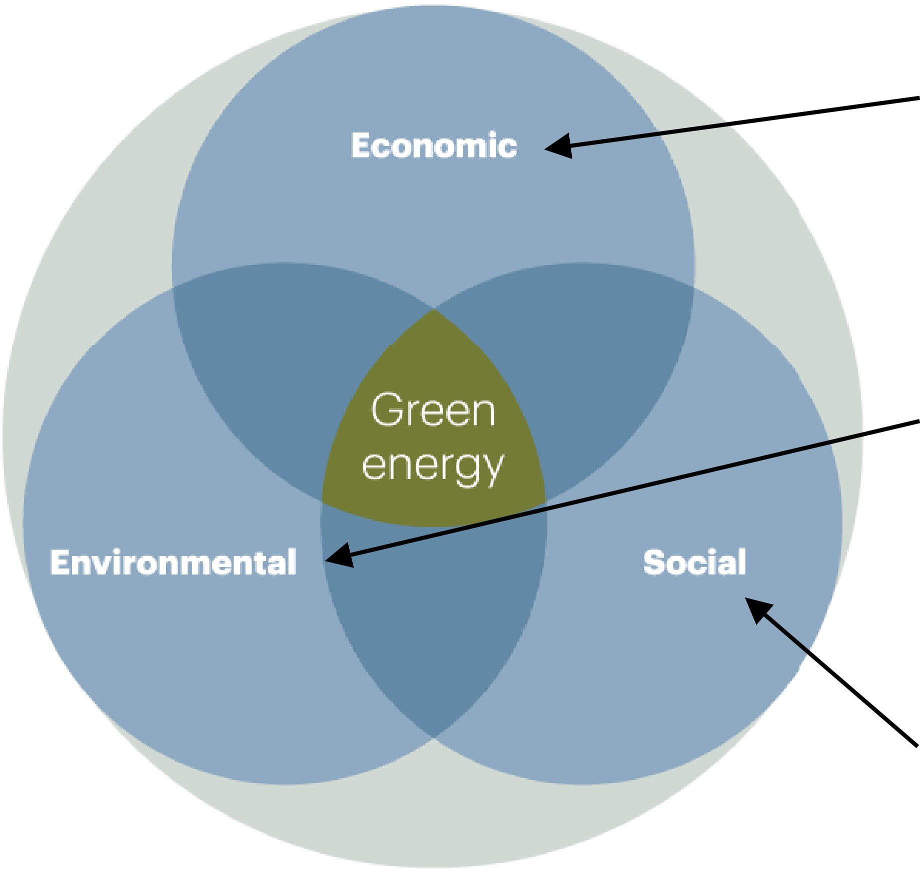
Definition of the Brundtland Commission (WCED 1987)

Sustainability Assessment Methodology – Part I

1. **What is sustainability in terms of the energy system?**
   - Definition sustainability
   - Scope

2. **How will you measure the sustainability for your countries‘ energy system?**
   - What aspects/sectors do you want to include in your assesssment?
   - Which indicators will you use, to evaluate the sustainability?
     - Qualitative (=narrative)
     - Quantitative (=numbers)
     - Levels/threasholds (above which sustainability is achieved)
   - = Evaluation criteria

Sustainability Assessment Methodology - Indicators



- GDP growth
- Local economic development
- Energy efficiency

- Share of renewable energies
- CO_2 emissions
- Area of protected land

- Income equality
- Access to schools
- Health care

Sustainability Assessment Methodology – Part II

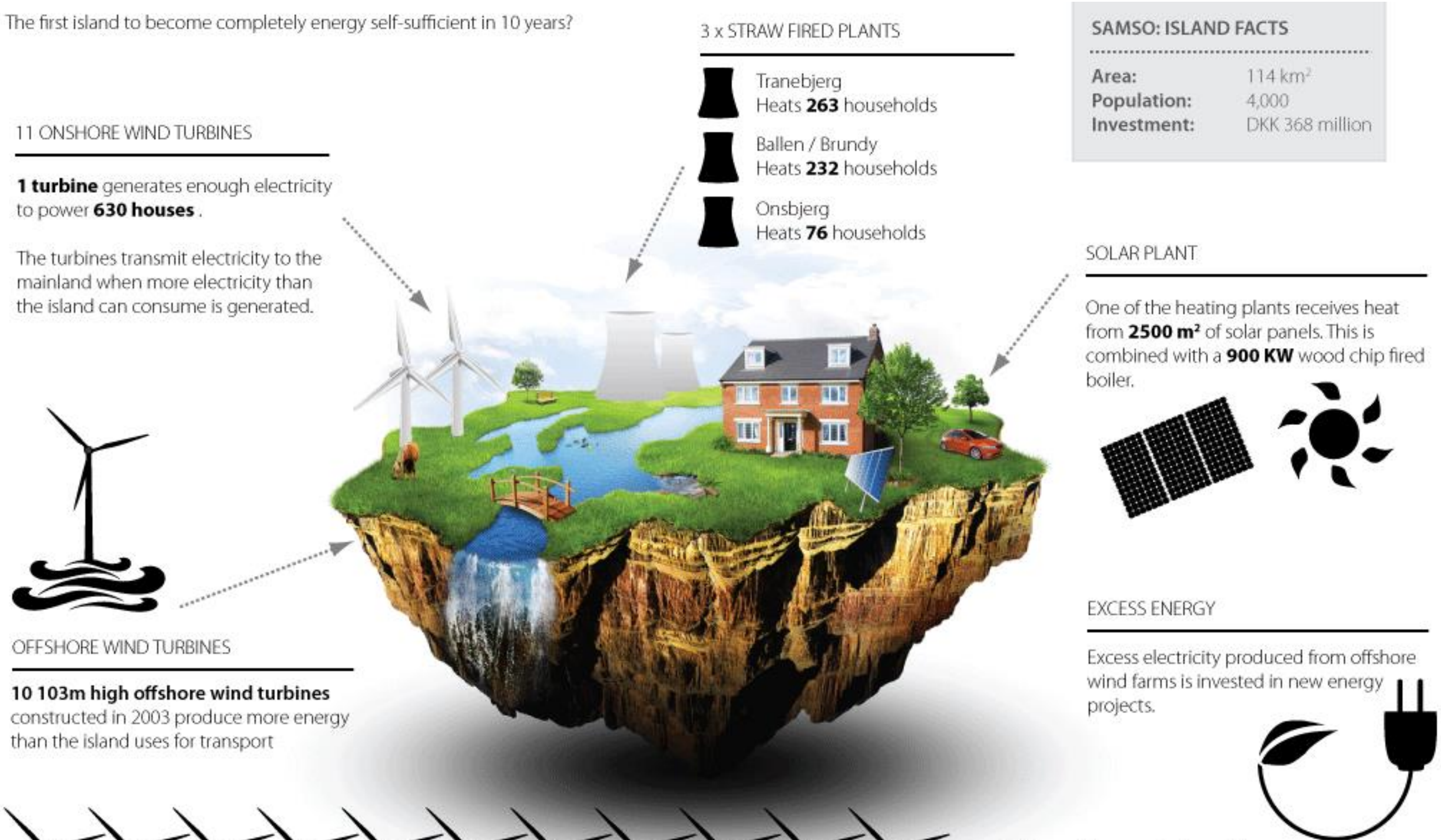
3. Analyze the Status Quo

- Find statistics
- Calculate/compare indicators → do they meet your sustainability criteria?

4. Where are shortcomings and what can be done to adress them?

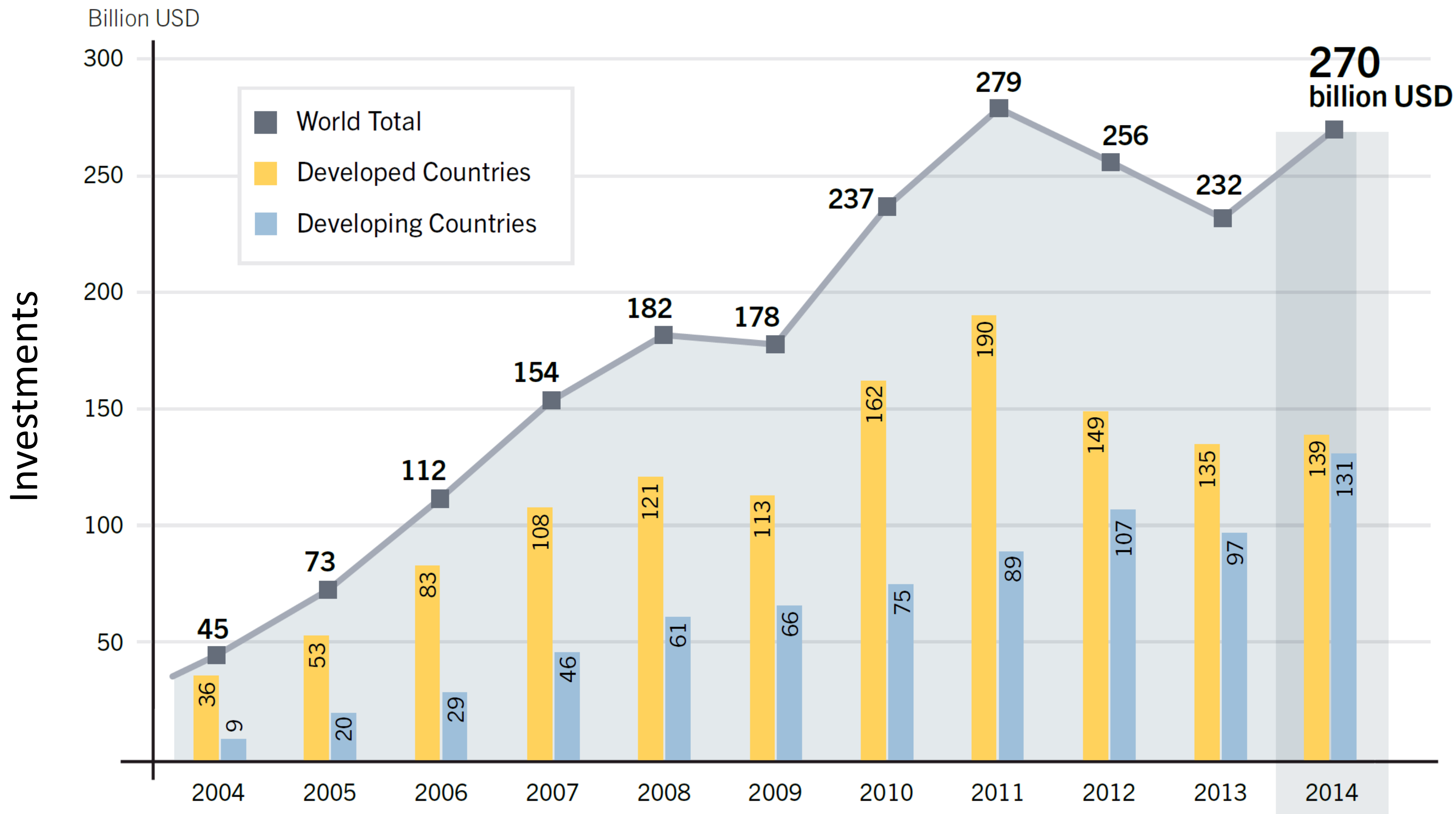
- Which sectors/aspects of the system have shortcomings? (describe and define quantitative goals)
- Which measures can be implemented?
- Add goals/numbers for the measures!
- Who is responsible?
- Until when?
- = „Shaping a sustainable energy system“

Case Study Samso, Denmark



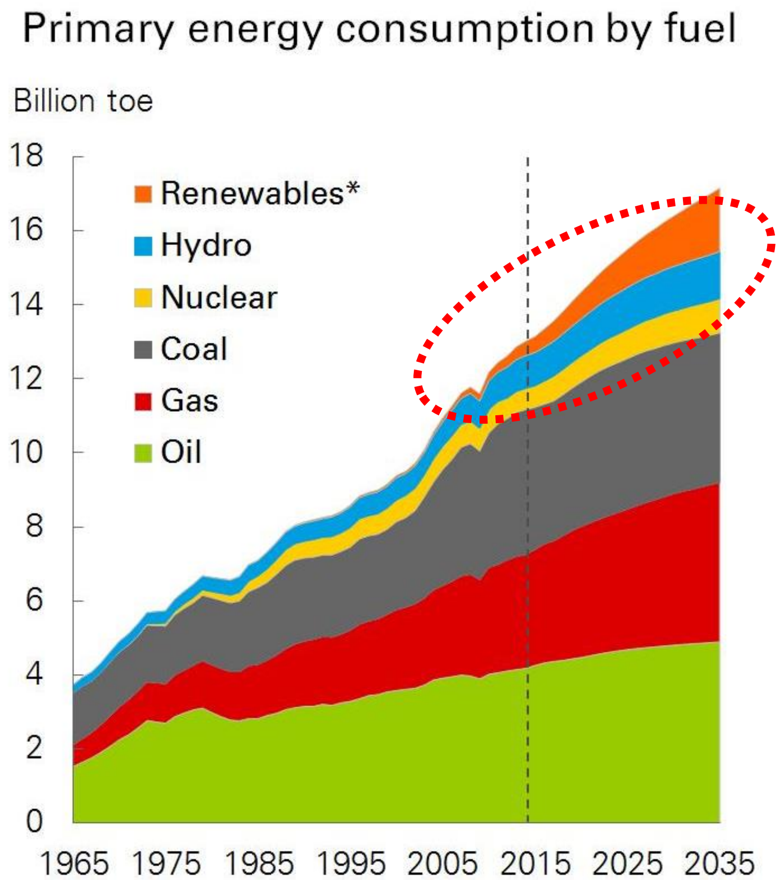
Source: PE Power & Energy

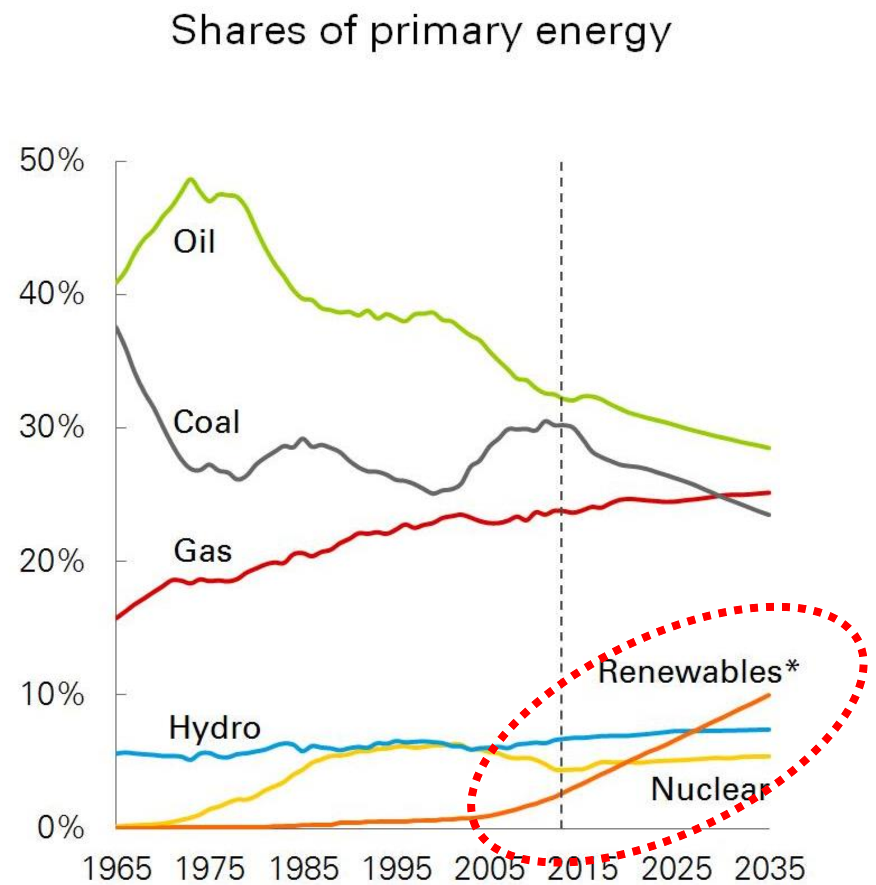
The Transition Towards Renewable Energies Continues



Source: REN21, 2015

The Transition Towards Renewable Energies Continues





*Renewables includes wind, solar, geothermal, biomass, and biofuels

Source: BP Energy Outlook 2016

Summary, Part II

1. Mitigation measures in different sectors
2. Energy efficiency is key to reduce demand and necessary production facilities
3. Renewable energy technologies
   - Multiple options readily available
   - Potentials locally/regionally available
   - Levelized Costs of Electricity (LCOE) are competitive with other energy sources
4. Energy storage necessary
5. Foundations of a sustainable energy system

In any way, a future sustainable energy system is possible with a combination of mitigation options and renewable energies!

Thanks for your attention!

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