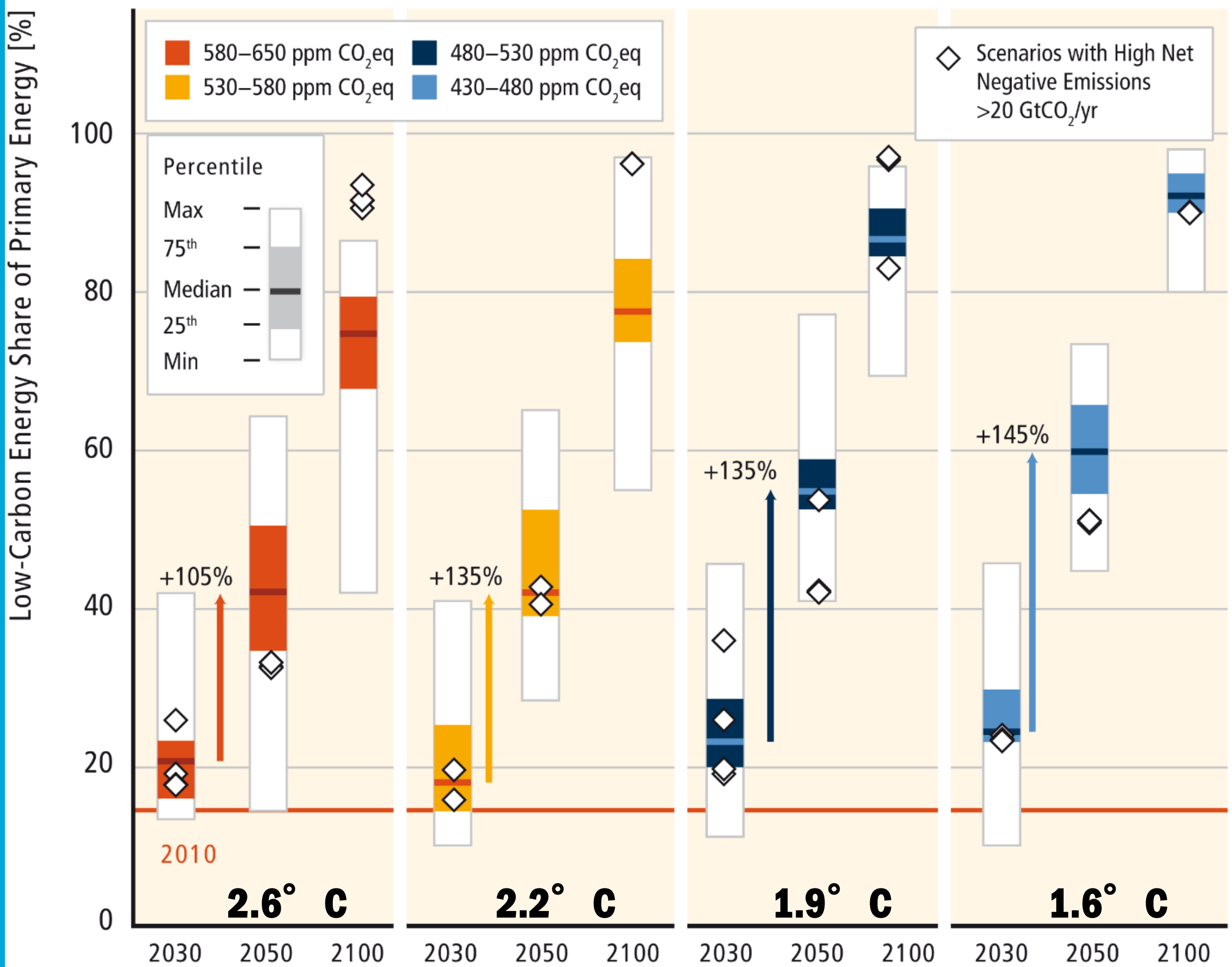
Material requirements for low carbon technology- implications for supply needs and resource policy

Prof. dr. Andrea Ramirez
Energy & Industry
Department of Engineering Systems and Services
Delft University of Technology
c.a.ramirezramirez@tudelft.nl

November 8th, 2016

TU Delft

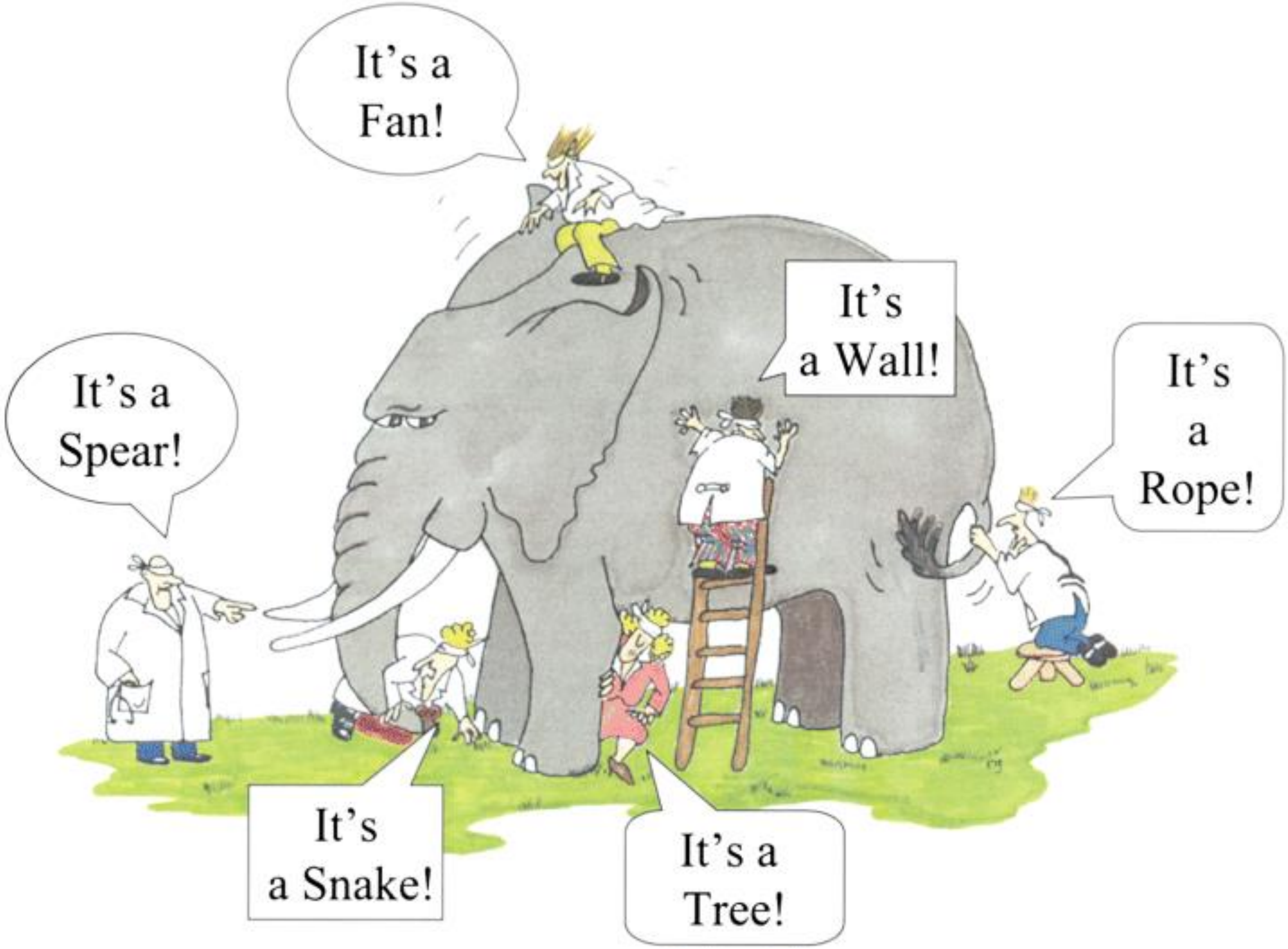
IPCC: A NEAR-COMPLETE SHIFT TO LOW-CARBON ENERGY SOURCES IS REQUIRED FOR ANY STABILIZATION TARGET

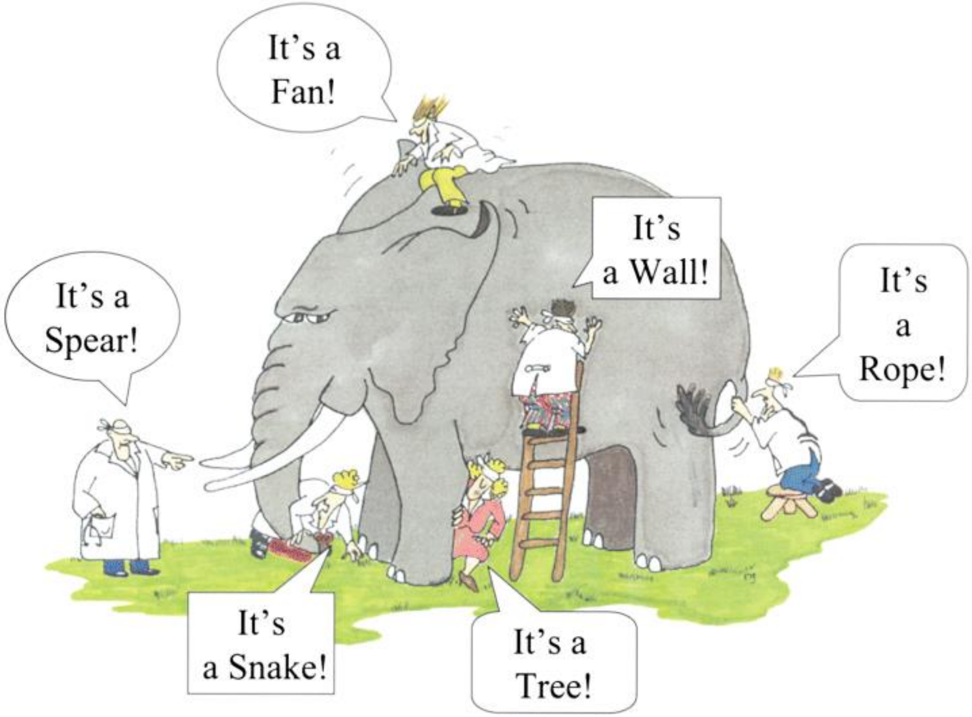


Important: electricity increases in **almost all IPCC scenarios** resulting from wide implementation of low-carbon technologies – **regardless of climate goals**

TU Delft

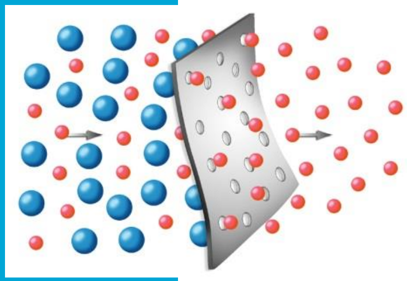
HOW ARE TECHNOLOGIES GENERALLY ASSESSED?





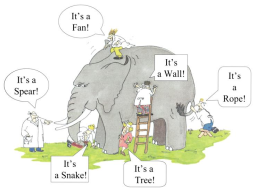
- Each technology is assessed as a separate entity
- Limited integration into the larger context/system
- One element at the time
- Limited assessment of risks
- Simplified systems

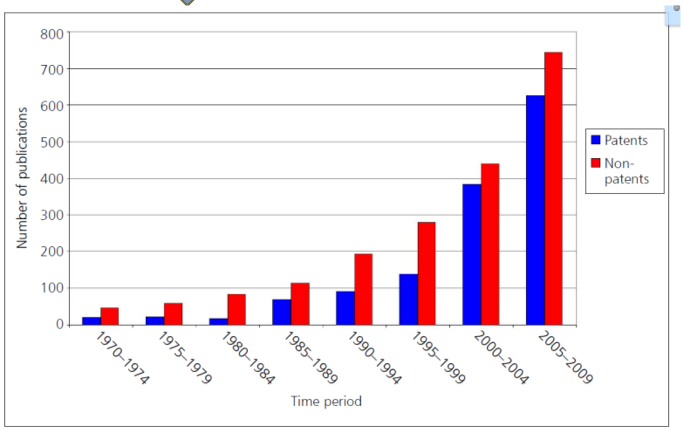
A BRIEF EXAMPLE



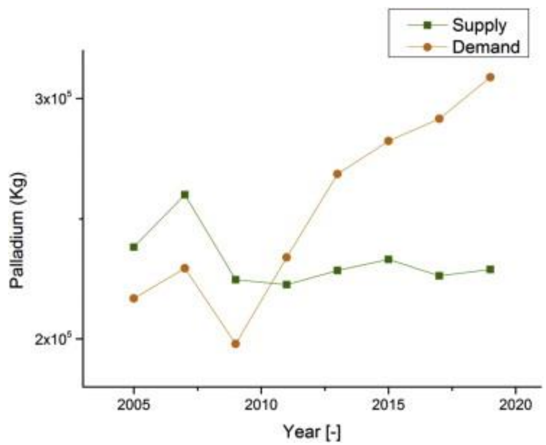
Palladium-based Alloy membranes
To produce H2; to separate CO2

Smaller thickness
High permeability
& selectivity





doi:10.1595/147106711X540346



http://dx.doi.org/10.1016/j.ijhydene.2014.05.009

WHAT ARE THE ENVIRONMENTAL, HEALTH AND RESOURCE USE IMPLICATIONS OF A MASSIVE EXPANSION OF LOW-CARBON ELECTRICITY?

A 5MW offshore wind turbine requires **1200 tons** of steel

350 000 such wind turbines with would be required to provide **12%** electricity in 2050

TU Delft

MATERIALS CAUSE >50% OF INDUSTRIAL GHG EMISSIONS - MATERIAL CYCLES IMPORTANT FOR MITIGATION

(1) Energy efficiency

(2) Clean energy

(3a) Material efficiency in production

(3b) Material efficiency in product design

(4) Product-service efficiency

(5) Reduction in demand

Material efficiency and reduction of material use now recognized as important.

Trade-offs!

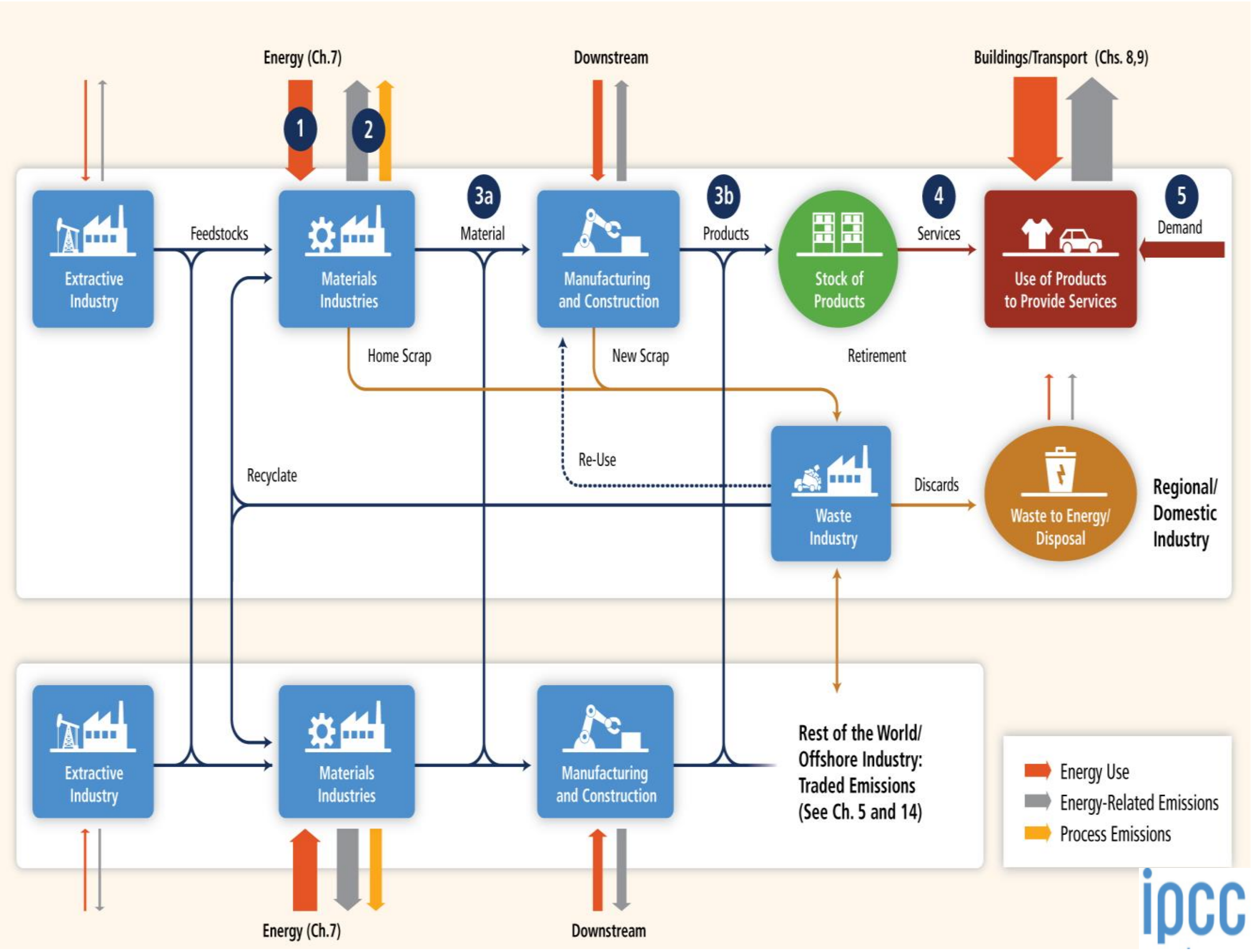
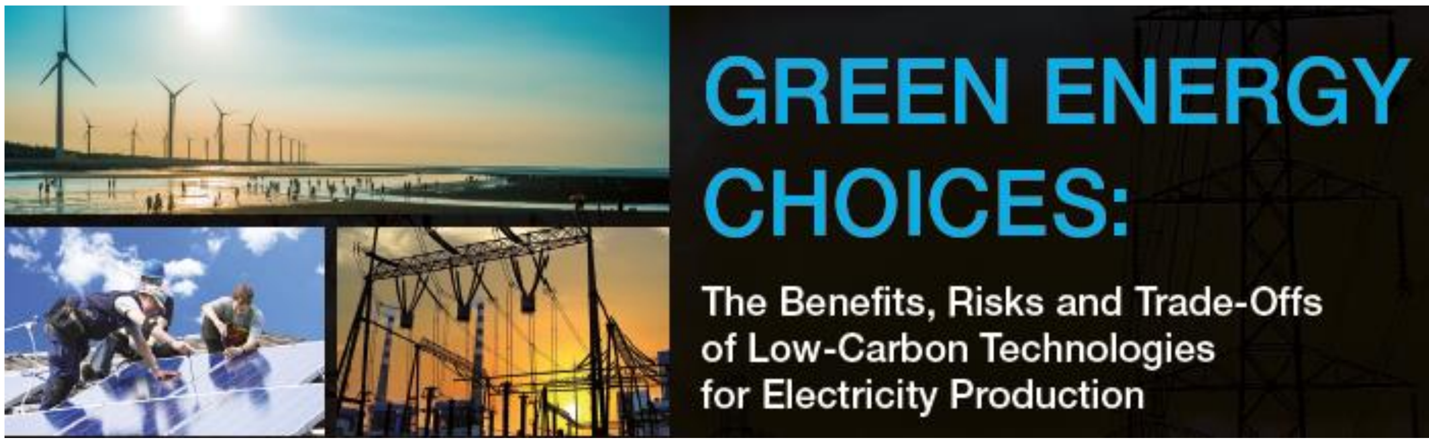


Fig. 10.2: : A schematic illustration of industrial activity over the supply chain

International Resource Panel



Lead authors:

Edgar Hertwich, Thomas Gibon, Sangwon Suh, Jacqueline Aloisi de Larderel, Joe Bergesen

+ about 20⁺ coauthors

www.unep.org/resourcepanel

ASSESSMENT APPROACH, AND METHOD

Electricity technologies

- Coal and gas with and without CO_2 capture and storage (CCS)
- Photovoltaic power
- Concentrated solar power
- Hydropower
- Geothermal
- Wind power
- + Nuclear
- + Biopower

Impact categories

- **Damage on ecosystems**
  - ecotoxicity,
  - eutrophication,
  - acidification…
- **Damage on human health**
  - particulate matter,
  - human toxicity…
- **Resource use**
  - iron, copper, aluminium, cement,
  - energy, water and land

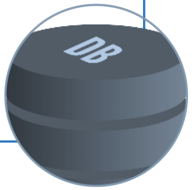
Life cycle perspective

- Extraction of raw materials,
- Fuel supply chain,
- Production of power plants,
- Transportation
- Operation,
- Maintenance,
- Decommissioning

ASSESSMENT APPROACH AND METHOD

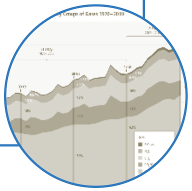
- Life cycle inventories only from reviewed data
- Data collection by a panel of 20 independent experts
- Harmonized and coordinated

Scientific data



- **Baseline**
  - Business-as-usual
  - Continuous investments in fossil technologies
  - No CCS
- **BLUE Map**
  - Renewable deployment
  - Phasing out of fossil fuel plants without CCS

Scenarios



- **Vintage capital modelling 2010-2050**
- The total impact on a given year is the sum of the impacts from the plants
  - built,
  - in operation,
  - repowered,
  - decommissioned
- …that exact year

Time series

TECHNOLOGY SUMMARY
WIND POWER

Climate change

- Very low GHG emissions **(++)**

Human Health

- Reduced exposure to particulate matter **(++)**
- Reduced human toxicity **(–)**

Ecosystems

- Collision fatalities of birds and bats **(+=)**
- Reduced ecotoxicity and eutrophication **(=-)**

Resources

- Increased consumption of bulk metals **(+=)**
- Low water use **(==)**
- Low direct land use **(==)**

©Jeff Adkins

Key (##)

First symbol

(+) high agreement among studies (=) moderate agreement (-) low agreement

Second symbol

(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

TECHNOLOGY SUMMARY
SOLAR PHOTOVOLTAICS

Climate change

- Low carbon **(==)**

Human health

- Low particulate matter emissions **(+=)**
- Low human toxicity (**if proper recycling**, =-)

Ecosystem health

- Low eutrophication and ecotoxicity **(+-)**

Resources

- High metal use (balance of system, module, **+=**)
- High direct land use for ground-based systems **(++)**

©ElenaElisseeva/Shutterstock

Key (##)

First symbol

(+) high agreement among studies (=) moderate agreement (-) low agreement

Second symbol

(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

TECHNOLOGY SUMMARY CONCENTRATING SOLAR POWER

Climate Change

- Low GHG emissions (==)

Human Health

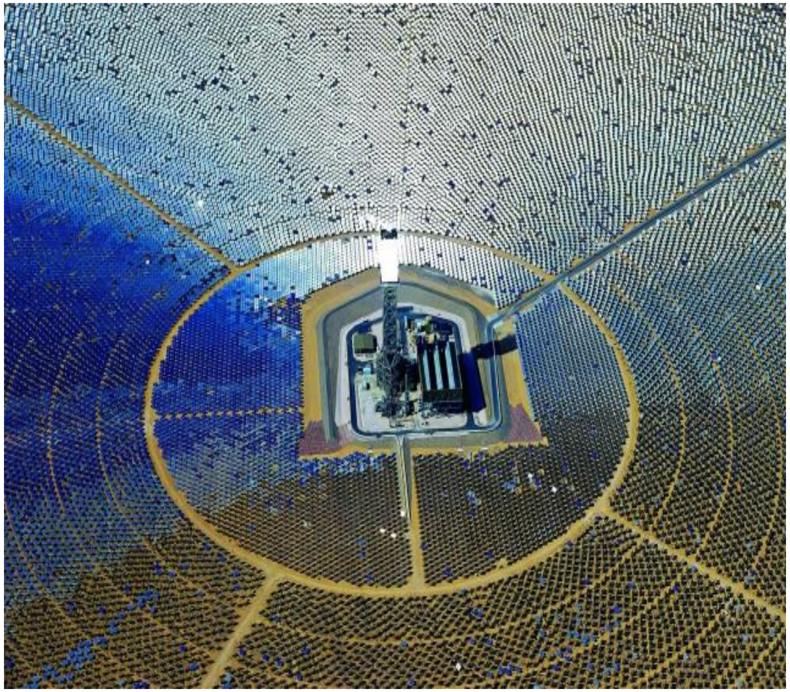
- Low particular matter exposure (+=)
- Low human toxicity (=-)

Ecosystems

- Potential toxicity of heat transfer fluids (+=)
- Low ecotoxicity and eutrophication (+-)

Resources

- High water consumption, unless air cooled (++)
- High land use (++)
- High cement use (power tower, +-)



Key (##)

First symbol

(+) high agreement among studies (=) moderate agreement (-) low agreement

Second symbol

(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

TECHNOLOGY SUMMARY HYDROPOWER

Climate change

- Low **fossil** carbon **(++)**
- High biogenic carbon from tropical dams **(==)**

Human health

- Low air pollution impacts **(=-)**
- Population displacement **(+-)**

Ecosystem health

- Riparian habitat change **(++)**

Resources

- Water use (evaporation, **+-**)
- High land use for reservoirs **(+=)**
- High cement use (tower only, **+-**)

Key (##)

First symbol

(+) high agreement among studies (=) moderate agreement (-) low agreement

Second symbol

(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

TECHNOLOGY SUMMARY GEOTHERMAL POWER

Climate change

- Low carbon **(==)**

Human health

- Low particulate matter **(+=)**
- Low human toxicity **(=-)**

Ecosystem health

- Concern about heat transfer fluid **(+=)**
- Low eutrophication and ecotoxicity **(+-)**

Resources

- High water use (maintenance, **++**)
- High land use **(++)**
- High cement use (**+-**)

Key (##)

First symbol

(+) high agreement among studies (=) moderate agreement (-) low agreement

Second symbol

(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

COAL AND NATURAL GAS POWER, WITH CO_2 CAPTURE AND STORAGE

Climate

- Low GHG (++)
- Substantial fugitive methane emissions (==)
- Concern about CO2 leakage (-=)

Human health

- Solvent related emissions (==)
- High particulate matter (==)
- High human toxicity (=-)

Ecosystem health

- High eutrophication (mining, ++)
- Ecotoxicity (+=)

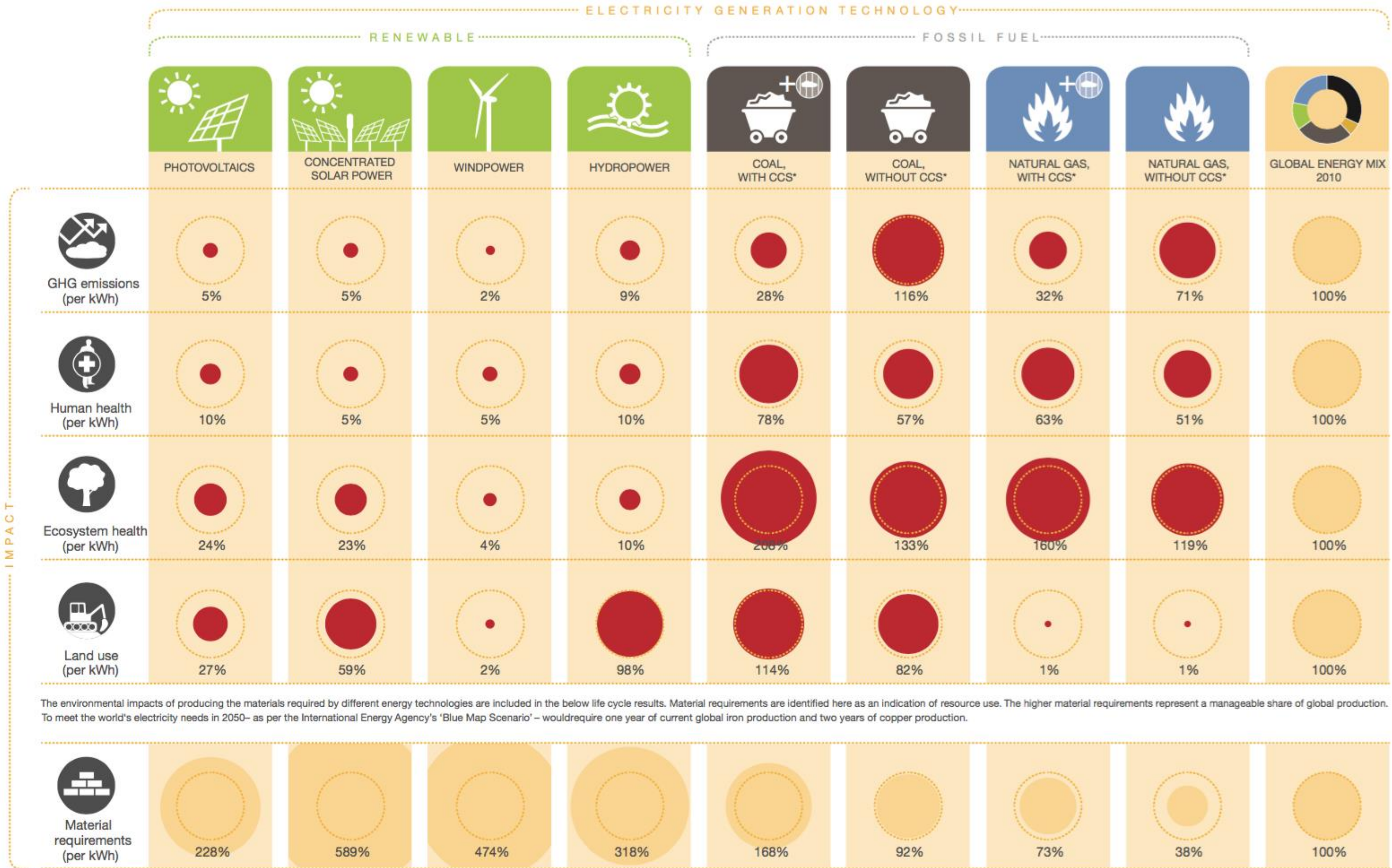
Resources

- Increased fossil fuel consumption (++)
- Increased water consumption (++)
- CO2 storage (++)

Key (##)
First symbol
(+) high agreement among studies (=) moderate agreement (-) low agreement
Second symbol
(+) robust evidence (many studies) (=) medium evidence (-) limited evidence

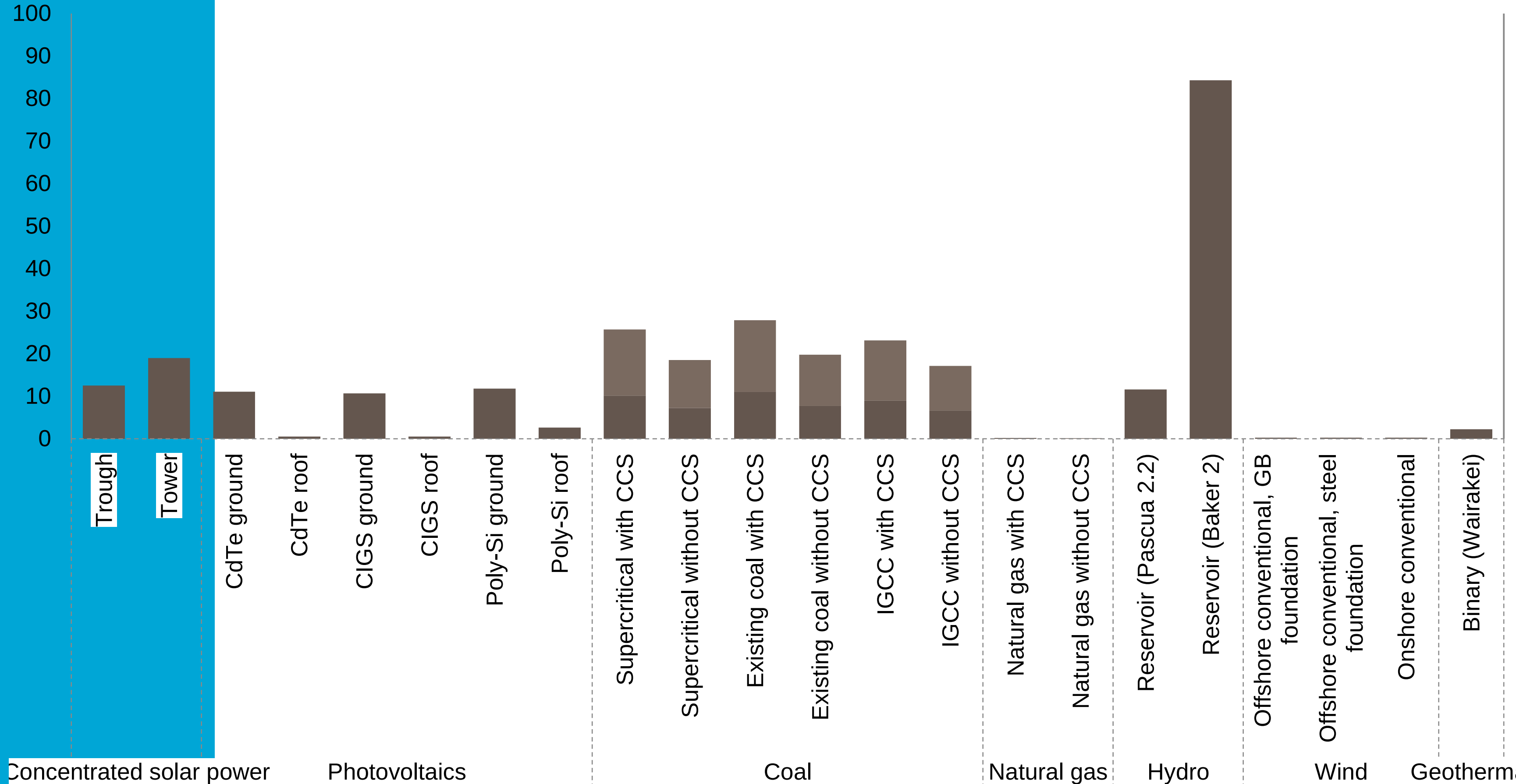
TECHNOLOGY COMPARISON

Figure 7: Overview over the life cycle impacts and material requirements of different technology groups compared to the global electricity generation mix in the year 2010

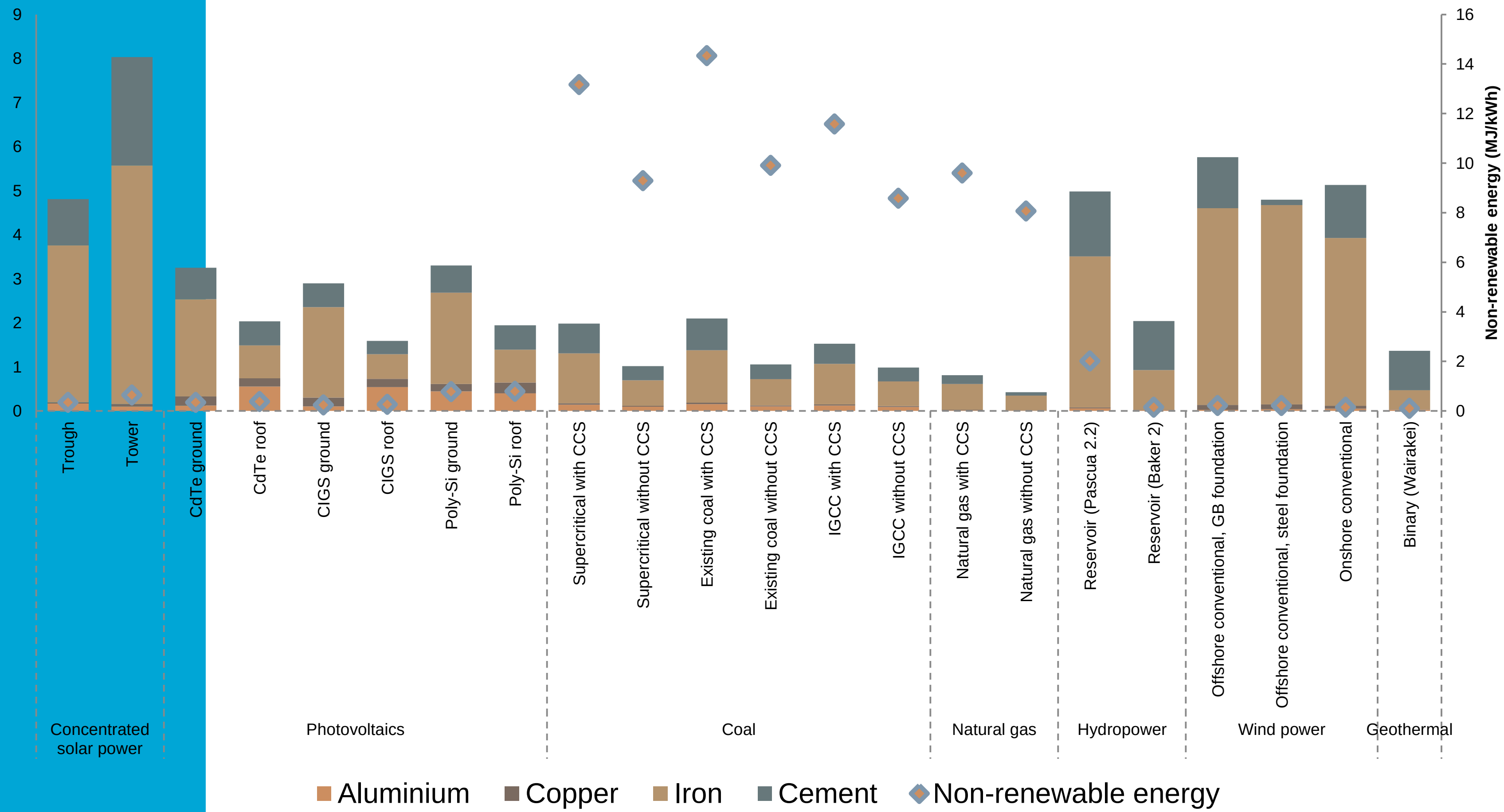


* Carbon capture storage (CCS) technology entails the capture of CO2 from large anthropogenic sources, transport of the CO2 to an underground storage reservoir and long-term isolation from the atmosphere.

LAND OCCUPATION
(M^2A/MWH)

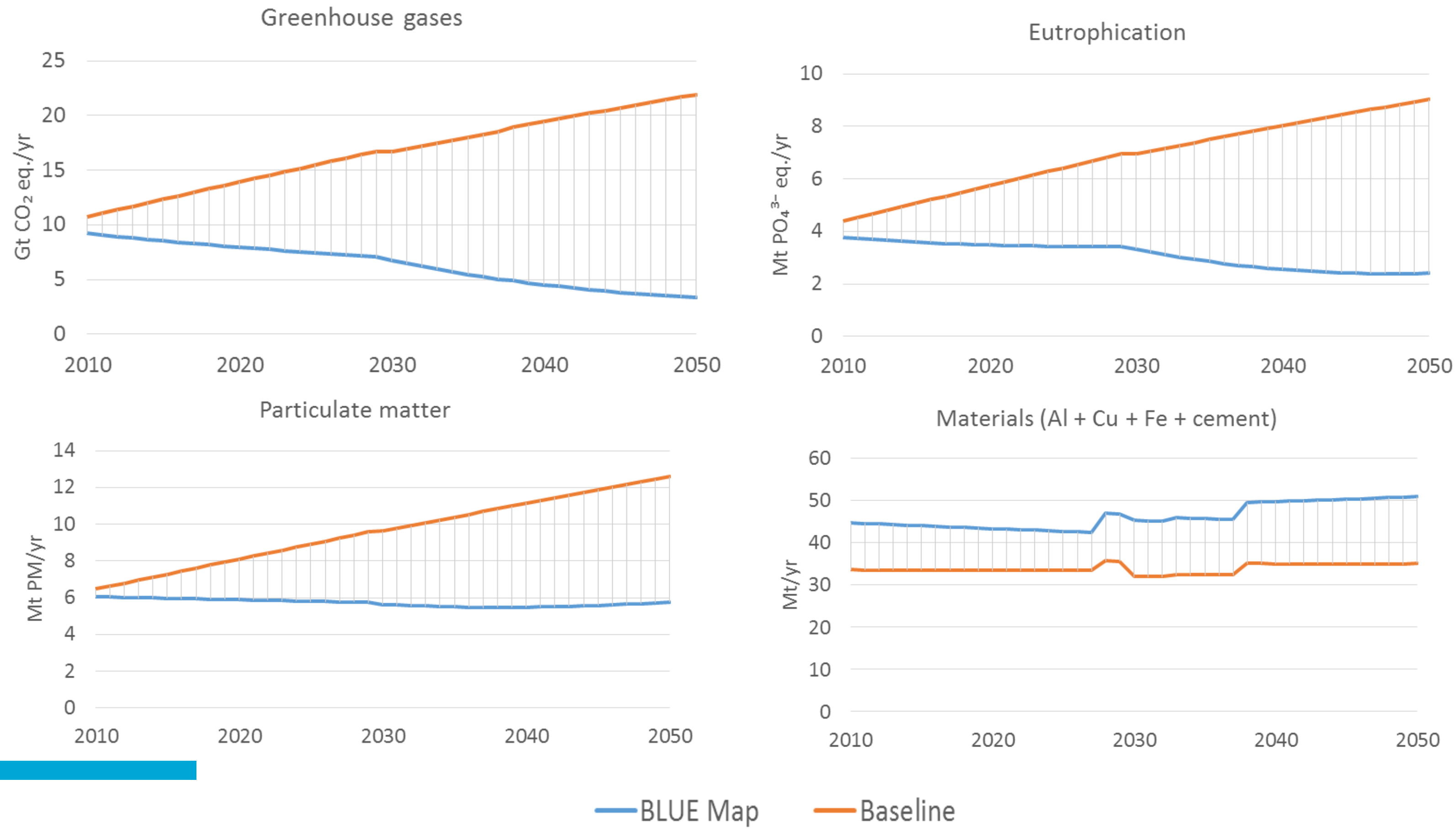


MINERAL RESOURCES
(KG/MWH)



SCENARIO IMPLICATIONS

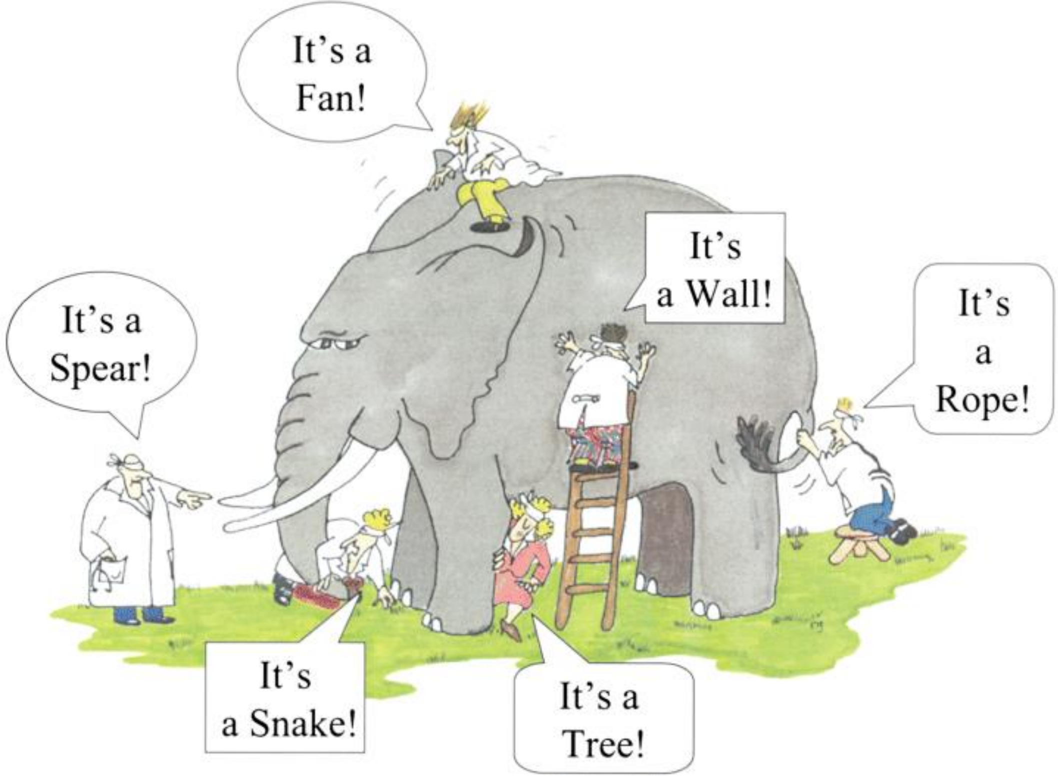
IMPACTS FROM ELECTRICITY GENERATION UNDER IEA BLUE MAP VS *BUSINESS AS USUAL* SCENARIOS



TU Delft

International Resource Panel

- From the life cycle perspective, the GHG emissions of electricity produced from renewable sources are **less than 6% of those generated by coal or 10% by natural gas**.
- Using solar, wind, hydro and geothermal power instead of fossil fuels reduces greenhouse gas emissions and other pollution impacts on human health and ecosystems. **Impacts are reduced by a factor of 3-10.**
- Human health impacts from renewable energy electricity production are **only 10-30%** of those from the state-of-the-art fossil fuel power.
- Natural-gas combined cycle plants, wind power, and roof-mounted solar power systems have **low land use requirements**, while coal fired power plants and ground-mounted solar power require larger areas of land.
- Site-specific environmental impacts, such as the ecological impacts of coalmines, hydropower dams and wind turbine installations, vary greatly, depending on the significance of the species and habitats affected and may be mitigated or offset **by proper site selection and planning**.
- CO_2 capture and storage can **reduce greenhouse gas emissions by 50-75%,** at the expense of **increasing other types of pollution by 5-80%**.

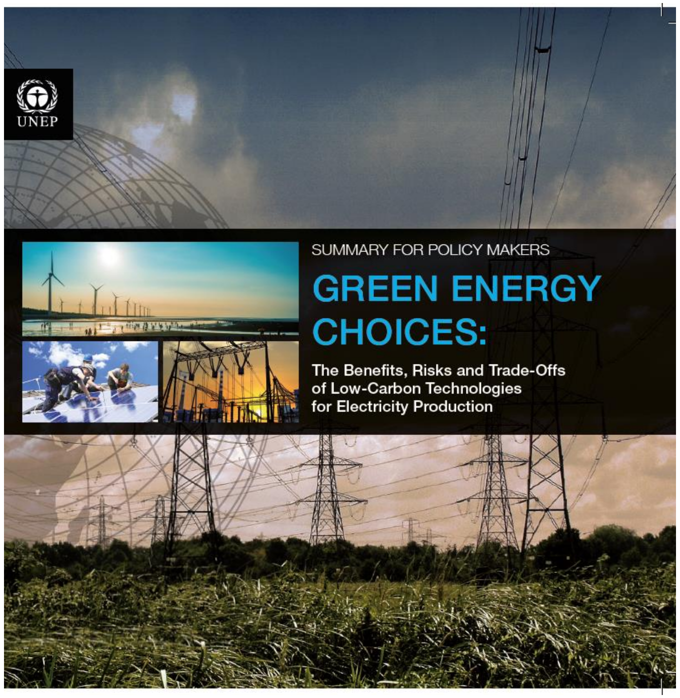


- Materials, water, land, energy are interrelated systems that cannot be properly be addressed independently of each other
- Important not only for assessment of technologies and systems but also for drafting of policies and targets
- Trade-offs are inevitable- the question is whether those are the product of an informed choice based on the best information available

TU Delft

UNEP

International
Resource
Panel



For more information please visit:
www.unep.org/resourcepanel