

# Power Plant Engineering



# Administrative Information

Lecture:

Tuesday

[published on Stud.IP](#)

Prof. Dr.-Ing. Roland Scharf, [scharf@ikw.uni-hannover.de](mailto:scharf@ikw.uni-hannover.de)

Exercise class:

Tuesday

[published on Stud.IP](#)

Christian Koch, M. Sc., [koch@ikw.uni-hannover.de](mailto:koch@ikw.uni-hannover.de)

Christoph Ulrich, M. Sc., [ulrich@ikw.uni-hannover.de](mailto:ulrich@ikw.uni-hannover.de)

Exam:

Oral or written

Further information:

[www.ikw.uni-hannover.de](http://www.ikw.uni-hannover.de), Stud IP

## Material

- Lecture:
- Handouts via Stud.IP
- Tutorials:
- Access via Stud.IP
  - Solutions are published on Stud.IP



An der Universität 1  
Gebäude 8141  
Tel. 0511 762 14252

## Literature

- Baehr, H.D.; Kabelac, S.: Thermodynamik, 16. Aufl. Springer-Verlag, Berlin 2016
- Strauß, K.: Kraftwerkstechnik, 6. Aufl. Springer-Verlag, Berlin 2009

# Content

1. Introduction to Power Plant Technology
2. Conversion of Primary Energy to Electrical Energy
3. Direct Conversion of Energy
4. Thermal Power Plants
5. Combustion Power Plants
6. Combined Combustion and Thermal Power Plants
7. Combined Heat and Power



# What is power plant engineering?

Plant and process engineering for an environmentally responsible, economically viable, and secure supply of electricity and heat



Coal-fired power plant Datteln



Solar thermal power plant Andasol



Waste incineration power plant Premnitz



Nuclear power plant Philippsburg

# Power plant engineering as an applied engineering discipline

Skills, a power plant engineer should be familiar with:

## Knowledge in basic subjects

- Thermodynamics
- Heat transfer
- Fluid mechanics
- Electrical engineering
- Diagnostics- and control engineering

## Knowledge in Non-technical subjects

- Business economics
- Energy- and environmental regulation
- Technical English

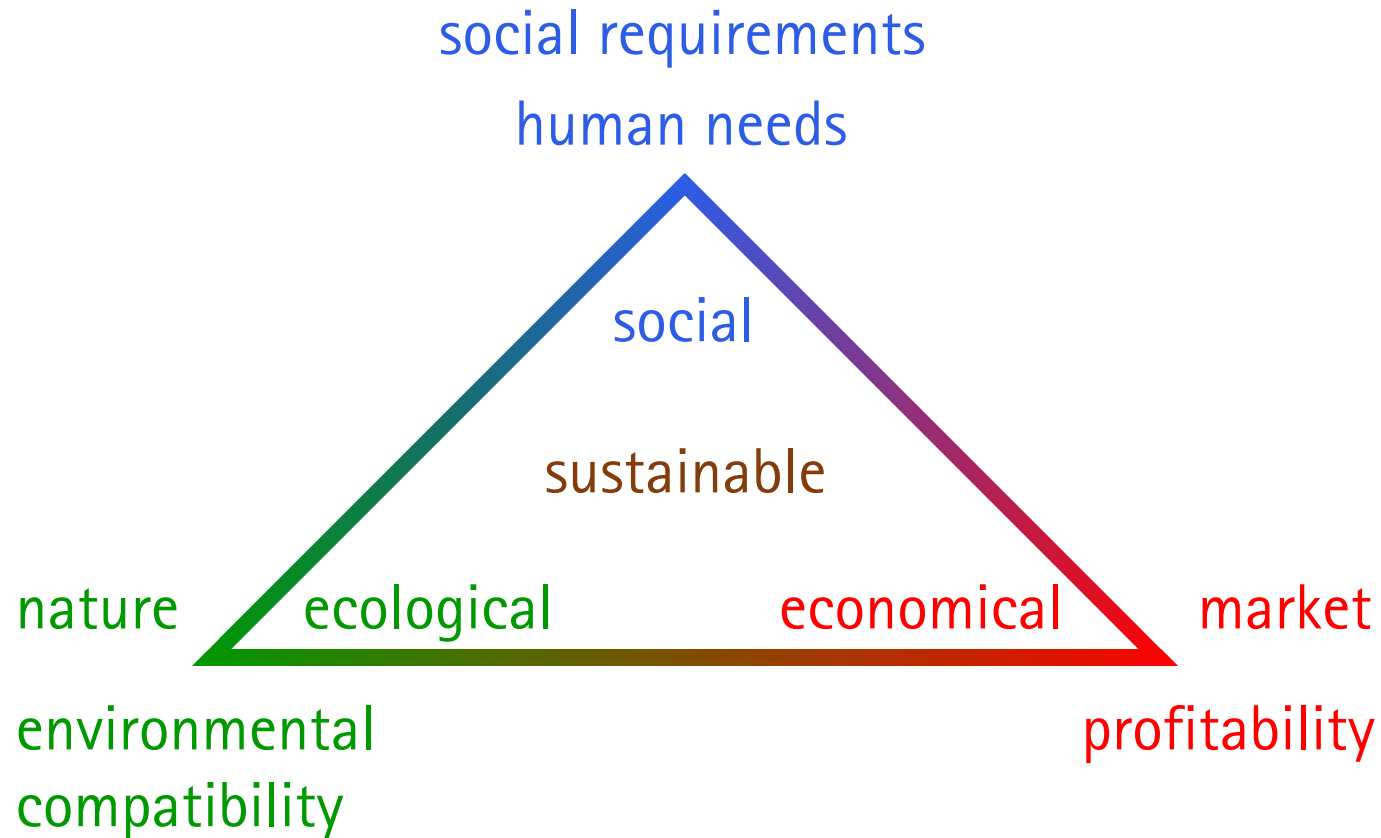


Ref.: <http://blog.rheinenergie.com>

## Knowledge in Applied subjects

- Turbomachinery
- Steam generators
- Electric machines
- Apparatus construction
- Supply and disposal technology
- Exhaust gas treatment and chemistry
- Process engineering and digital data processing

# Triple Objective of the Energy Industry



# Sustainability

## Definition

... is a principle for the use of resources  
on which the permanent satisfaction of needs is to be granted  
by preserving the natural ability for regeneration of the systems involved  
(especially those of creature and ecosystems).

## Global Establishment

### UN Documents

Gathering a body of global agreements

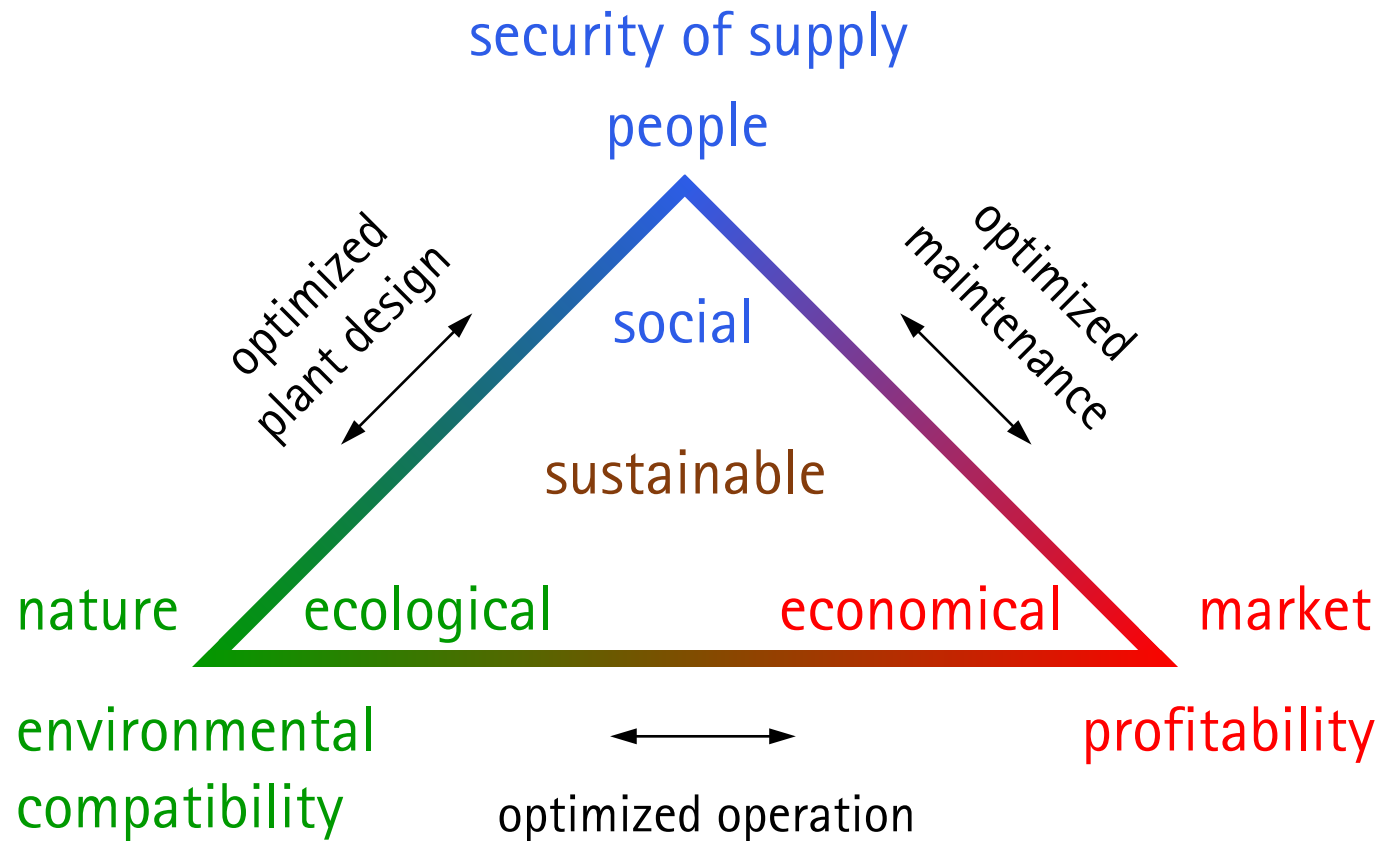
<http://www.un-documents.net/wced-ocf.htm>

### Sustainable Development

## Mission for Engineers

To create, develop, implement and operate  
ecological sound, economical, technical solutions  
for the fulfillment of social demands.

# Triple Objective of the Energy Economy



## § 1 Paragraph (1) Energy Industry Act (Energiewirtschaftsgesetz - EnWG)

security of supply

Zweck des Gesetzes ist eine möglichst sichere, preisgünstige, verbraucherfreundliche, effiziente und umweltverträgliche leitungsgebundene Versorgung der Allgemeinheit mit Elektrizität und Gas, die zunehmend auf erneuerbaren Energien beruht.\*

environmental compatibility

profitability

\*The purpose of the law is to ensure an as far as possible cheap, consumer friendly, efficient, and environmentally compatible performance bound provision of the public with electricity and gas, which is increasingly based on renewable energies.

# Significance of Security of Supply

Tasks for producers:

Provision of:

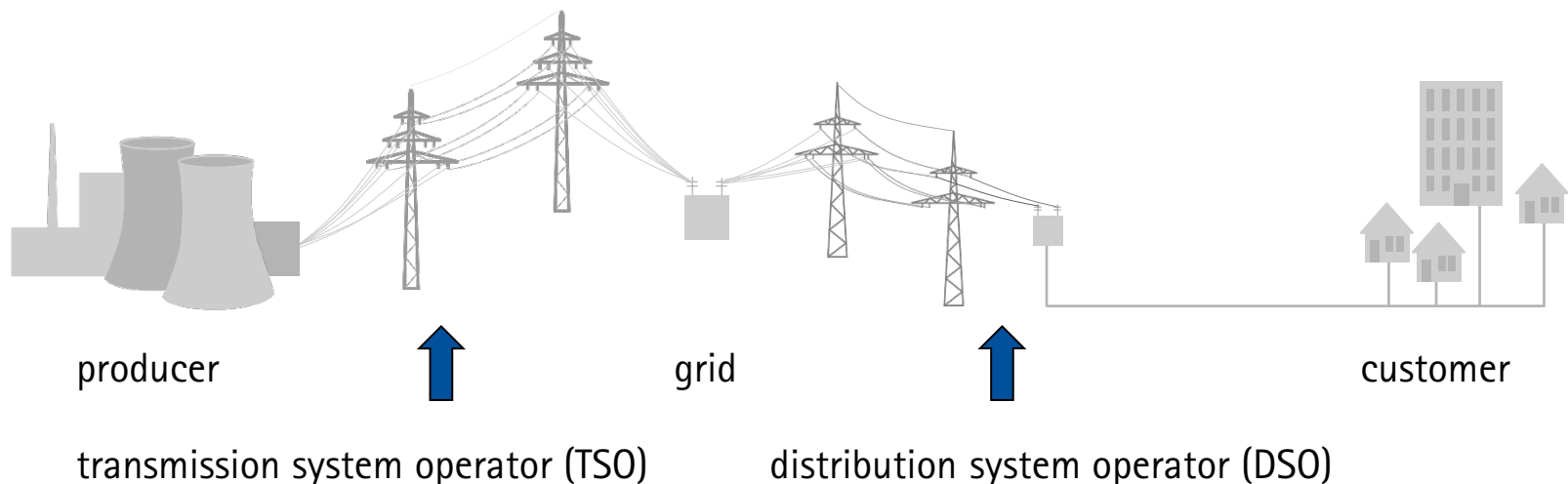
- Firm capacity
- Ancillary services
- High reliability

Task for grid operators:

- Regulation of power output
- Voltage stability
- Frequency control
- Grid recovery
- Grid management
- Bottleneck management
- N-1 security of the grid

Expectations of customers:

- Uninterrupted supply
- Low voltage fluctuations
- Low frequency fluctuations





# Environmental Compatibility

... is a measure of the effect of human actions on the environment, people, animals, plants, soil, water, atmosphere, as well as cultural and other material assets.



## Acting environmentally compatible means:

- Frugal usage of resources and energy
- Prevention and reduction of noise, radiation, pollution of soil, water, atmosphere, and animals
- Risk limitation for nature and humans

# Environmental Compatibility – What Is Affected?

## ■ Greenhouse gas emissions

e.g.

- carbon dioxide
- methane
- nitrous oxide



## ■ Polluting emissions

e.g.

- total dust
- mercury
- carbon monoxide



## ■ Noise

e.g.

- noise map, noise register
- noise action plan
- noise protection measures



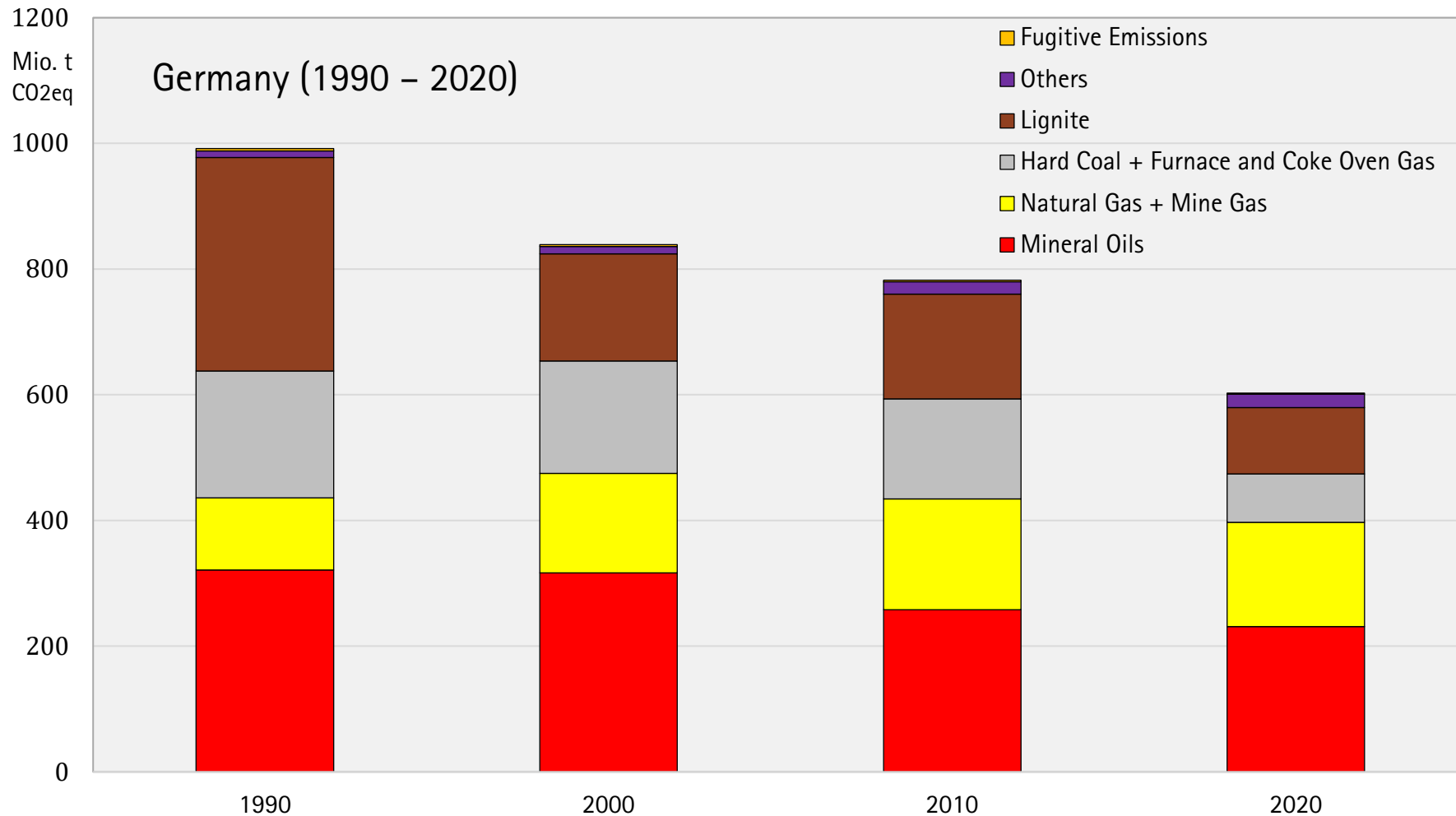
## ■ Water protection, nature preservation, soil protection, inherited liability

e.g.

- water abstraction, sewage disposal
- compensation measures
- soil protection measures
- rehabilitation of inherited waste

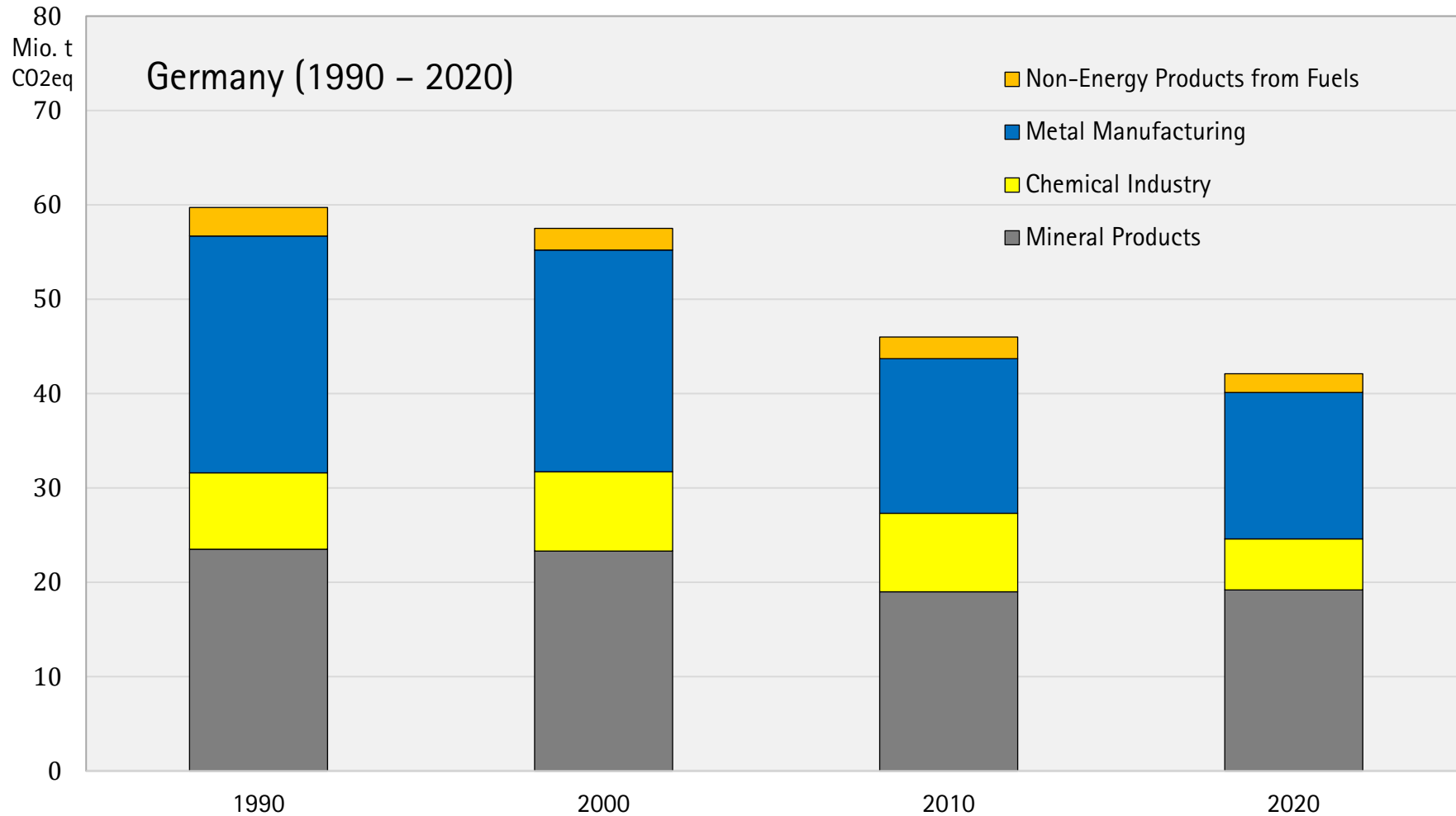


# Greenhouse Gas Emissions at Primary Energy



Source: Energiewirtschaftliche Tagesfragen 73. Jg. (2023) Heft 3

# Greenhouse Gas Emissions at Industry



Source: Energiewirtschaftliche Tagesfragen 73. Jg. (2023) Heft 3

# Profitability of Power Plant Operation

Profitability is the measure of the economical efficiency of power plant operation.

$$\text{profitability} := \frac{\text{revenue}}{\text{expenses}}$$

The **revenue** is the money inflow within a certain period.

The **expenses** include all money expenditures within a certain period.



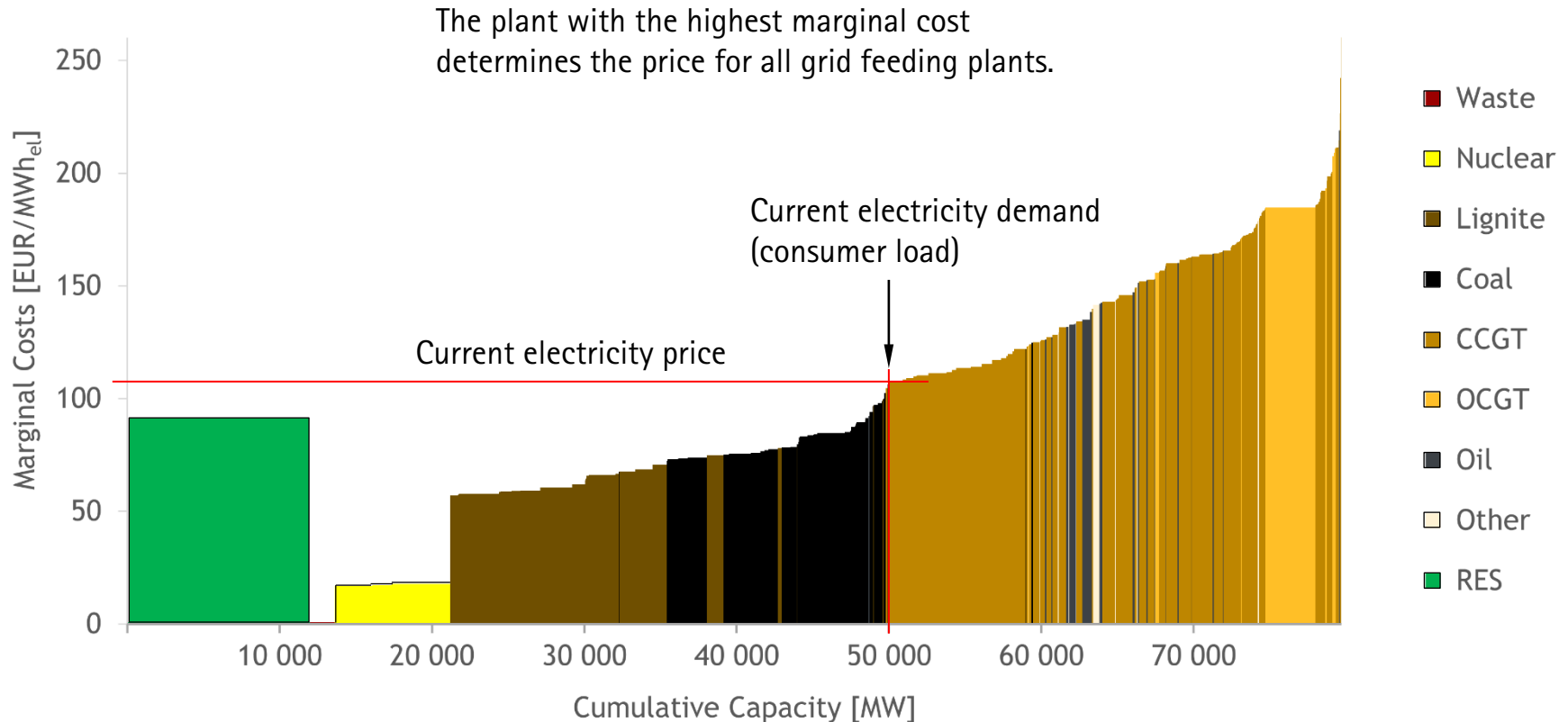
## Revenues of a power plant

Electricity supply	Scheduled revenues, spotlight revenues, etc.
Heat supply	Heat delivery contracts, etc.
Ancillary services	Operating reserve, standby, etc.
Product sales	Flue ash, boiler sand, gypsum, etc.

## Expenses in a power plant

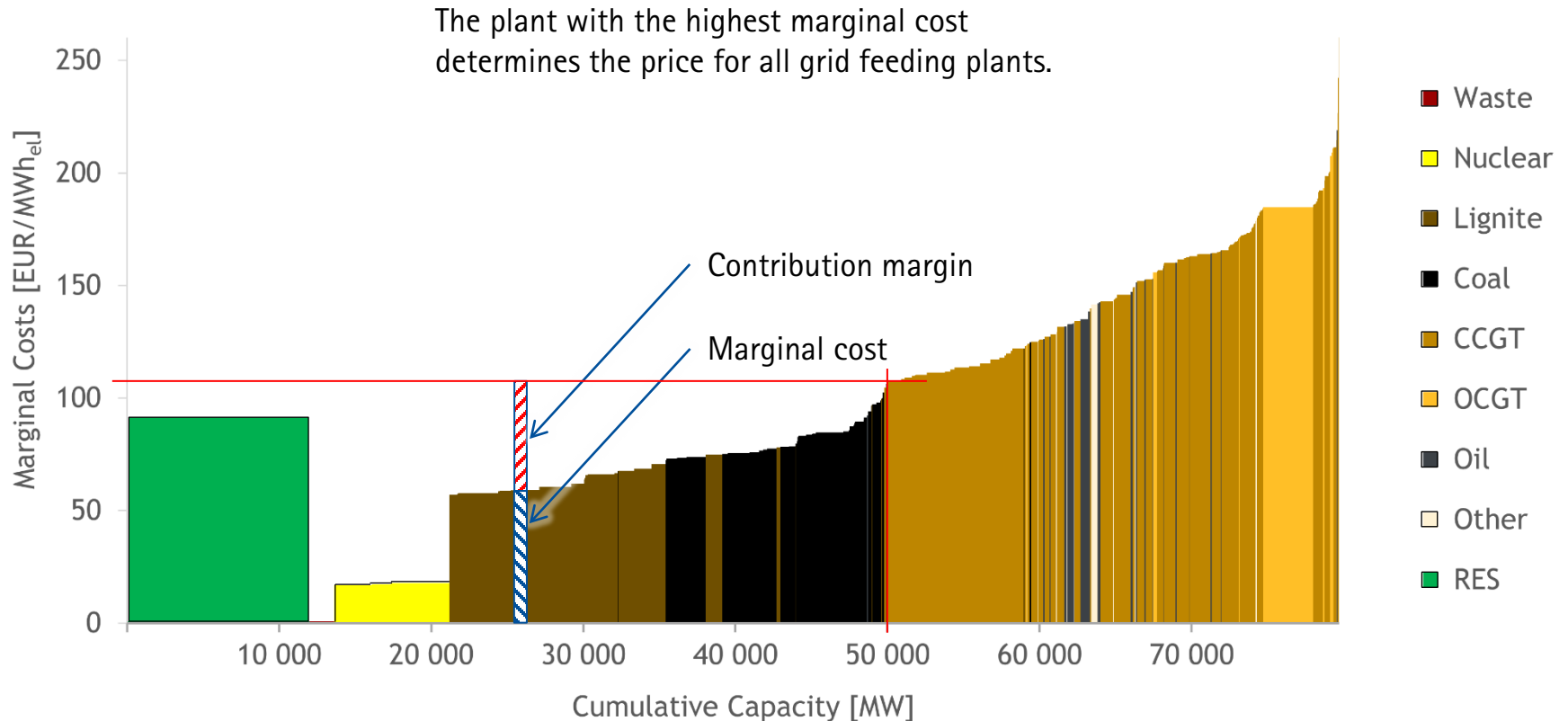
Investment	Retrofit turbomachinery, etc.
Human resources	Production, administration, etc.
Fuel	Coal, substitute fuel, etc.
Maintenance	Contract for services, etc.

# Electricity Exchange – Merit-Order



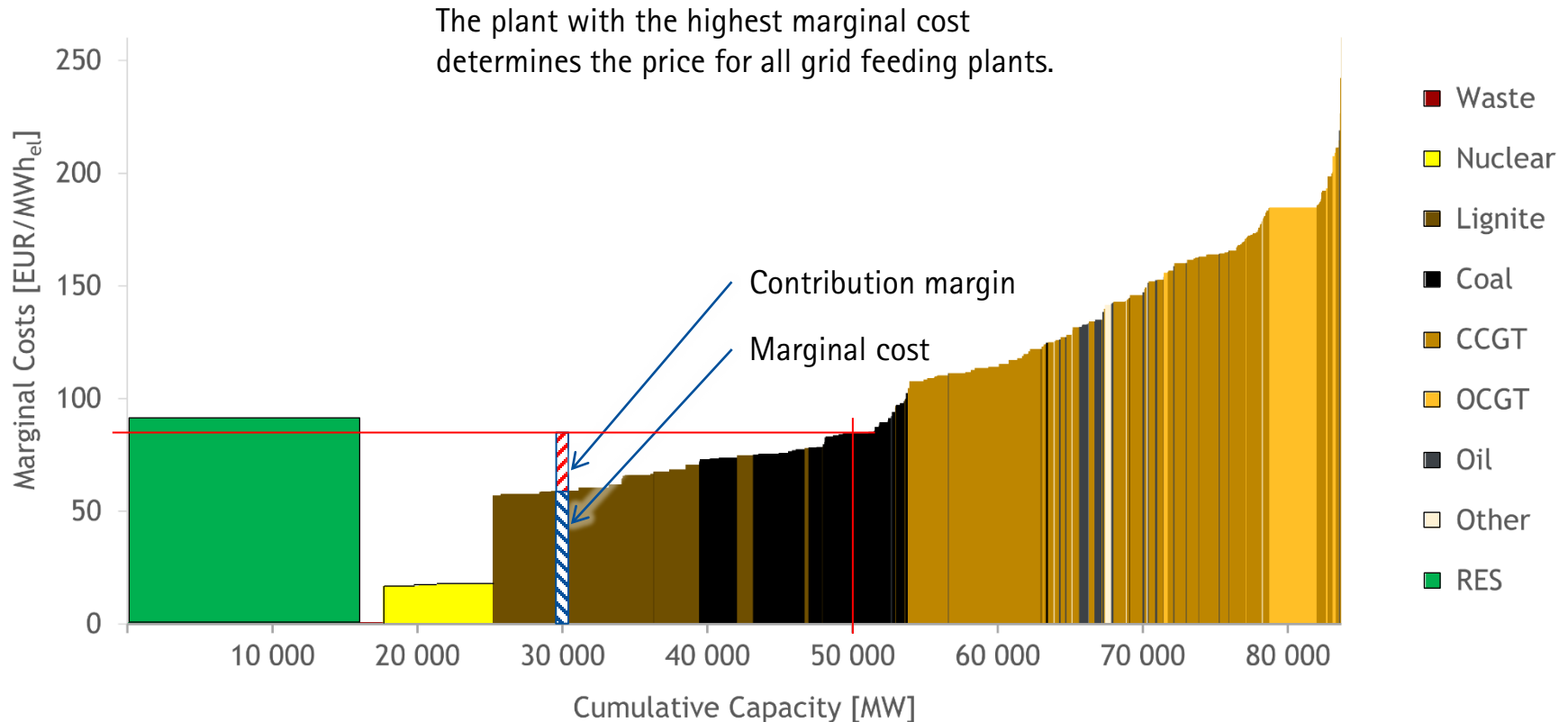
Ref.: EWI Merit Order Tool 2022

# Electricity Exchange – Merit-Order





# Electricity Exchange – Merit-Order



Ref.: EWI Merit Order Tool 2022

## Primary Energy Sources

- Fossil energy sources      hard coal, lignite, crude oil, natural gas
- Nuclear energy              radioactive nuclides, hydrogen

finite  
energies

- Solar energy                  (100 % nuclear fusion)
  - direct                          Radiation energy
  - indirect                       Wind energy, biomass
- Geothermal energy        (50 % decay processes)
- Tidal energy                 (Gravitation)

renewable  
energies

Primary energy can be converted to secondary energy and final energy sources through treatment and transformation.

## Secondary Energy and Useful Energy

Secondary energy: Energy source generated in transformation process

- Electricity, heat
- Petrol, diesel
- Wood pellets, coke, briquettes
- Furnace and coke oven gas
- Hydrogen



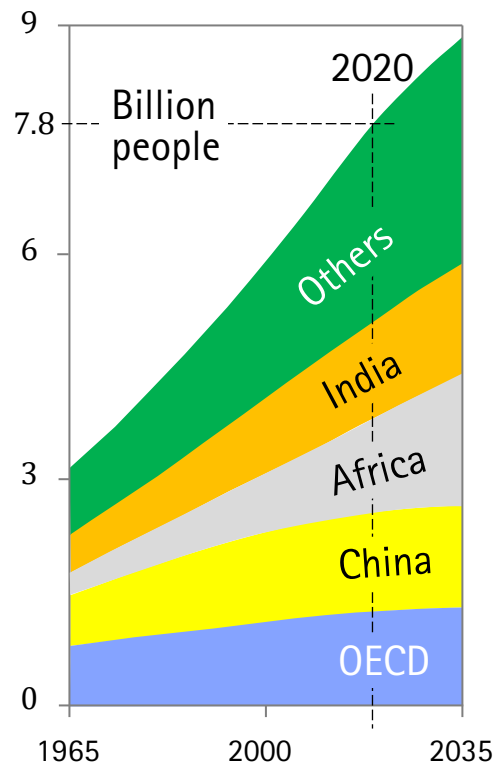
Useful energy: Energy available to end user for individual needs

- Light
- Mechanical work
- Space heating

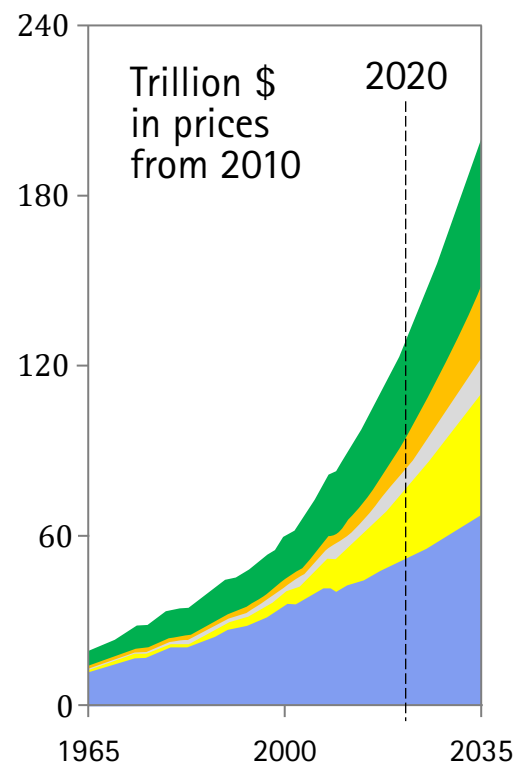


# The world population and its economic strength are growing rapidly ...

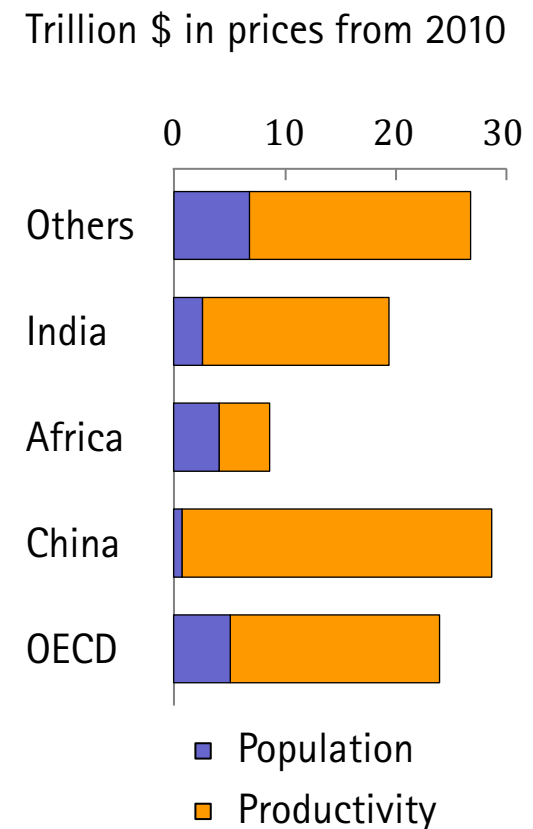
Population



Gross domestic product (GDP)

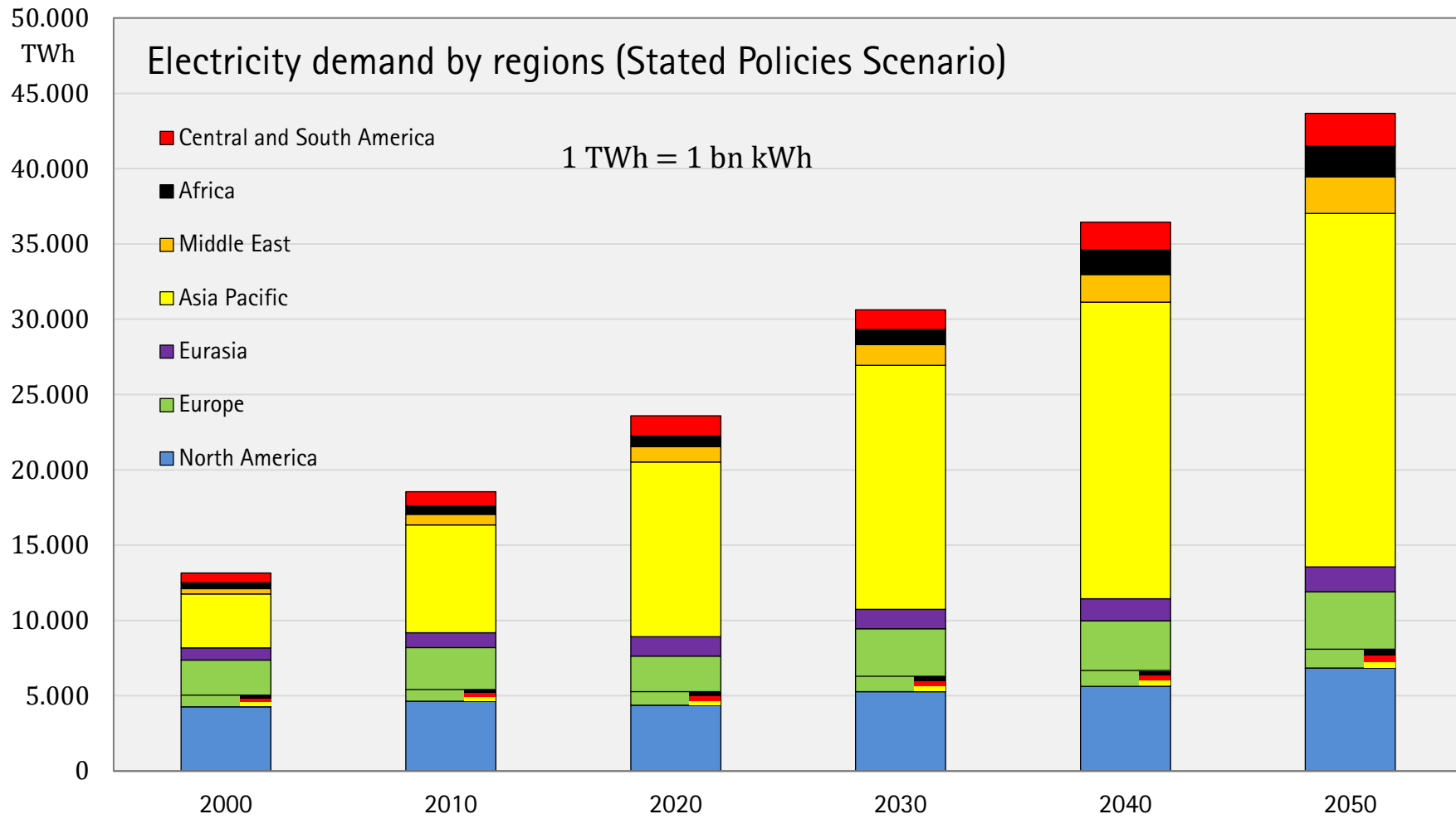


Contribution to GDP-growth



Source: 2016 Energy Outlook, BP p.l.c. 2016

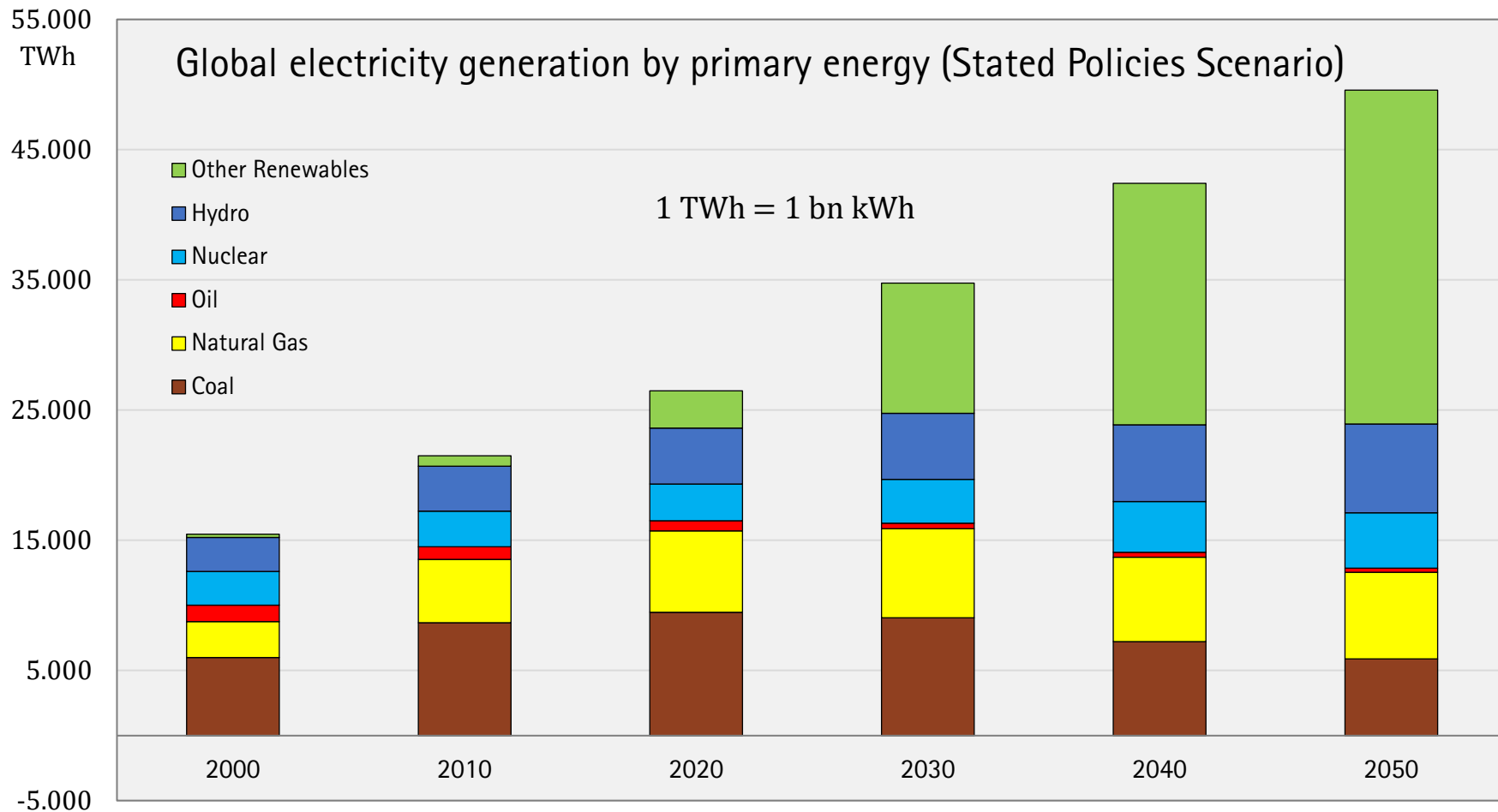
## ... and therefore the energy demand ...



Sources: World Energy Outlook 2022, international energy agency, 2022

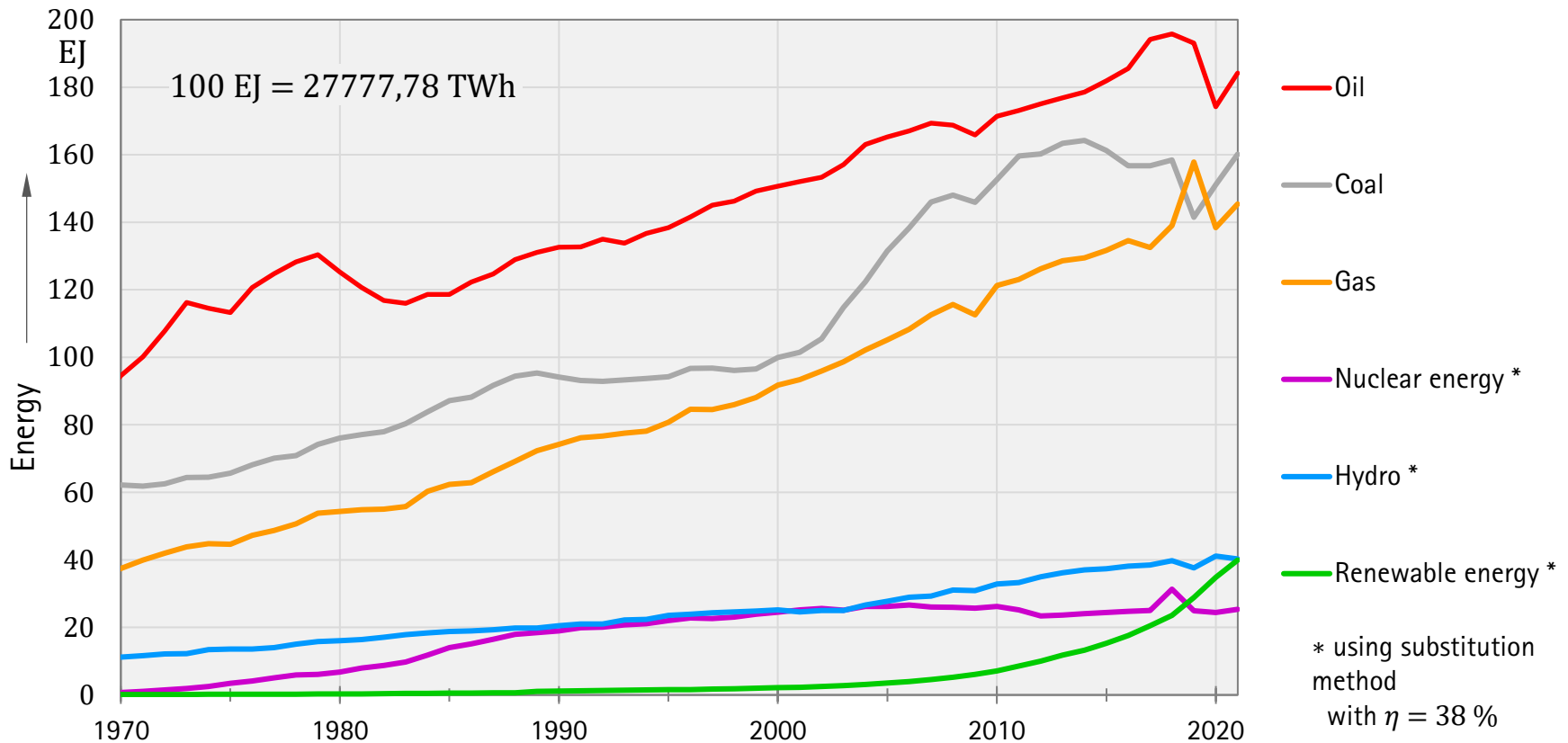
<https://yearbook.enerdata.net/> (for year 2020)

## ... and the primary energy need.



Source: World Energy Outlook 2022, international energy agency, 2022

# Global primary energy consumption by energy source

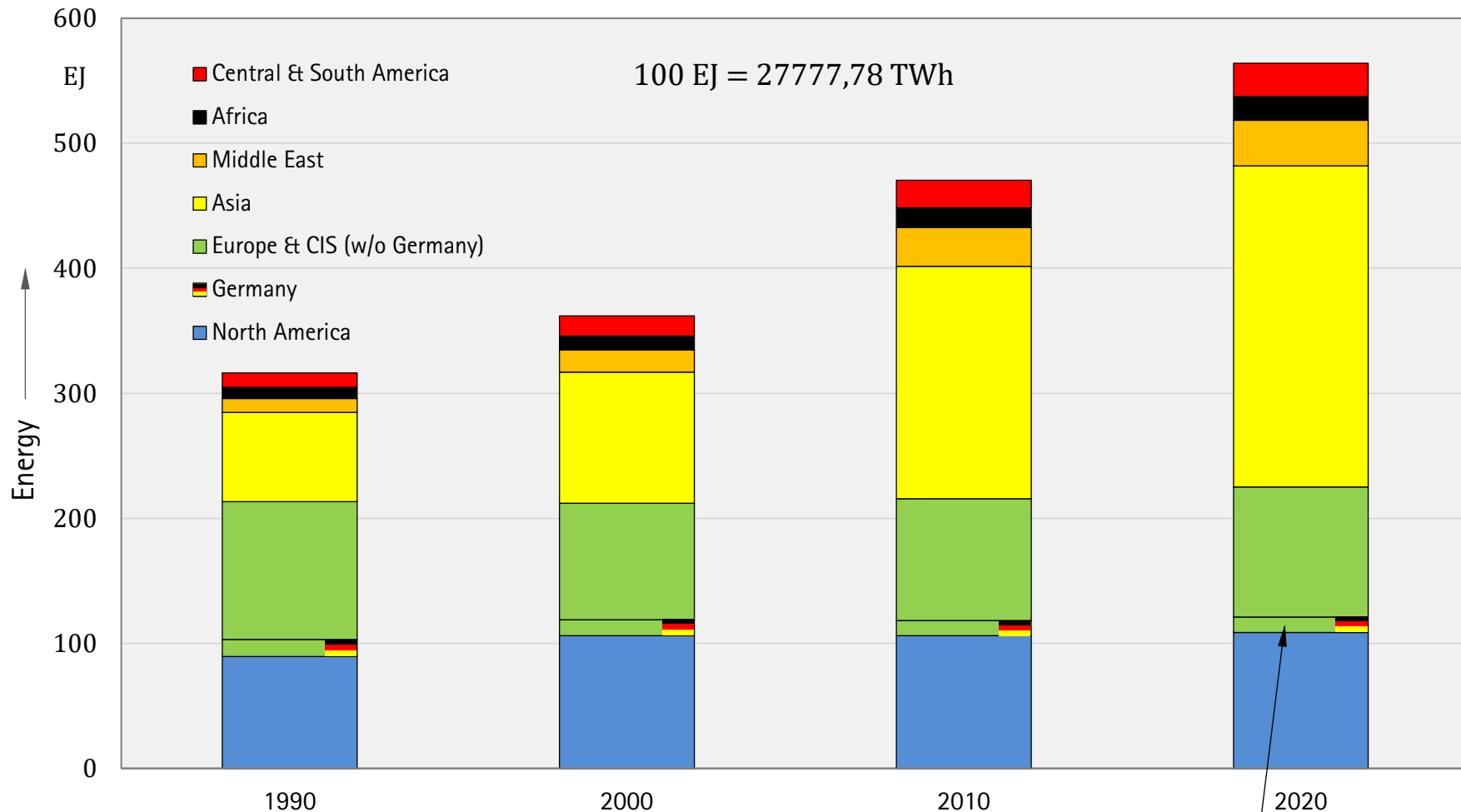


The primary energy consumption includes all primary energies consumed within a certain time interval in the considered areas (city, country, earth).

Quelle: BP, Statistical review of world energy 2022



# Global primary energy consumption by region



Source: BP, Statistical review of world energy 2022

## Disambiguation: Resource, reserve, and range

**Resource:** Maximum available quantity within the earth's crust of targeted mineral-fossil fuel

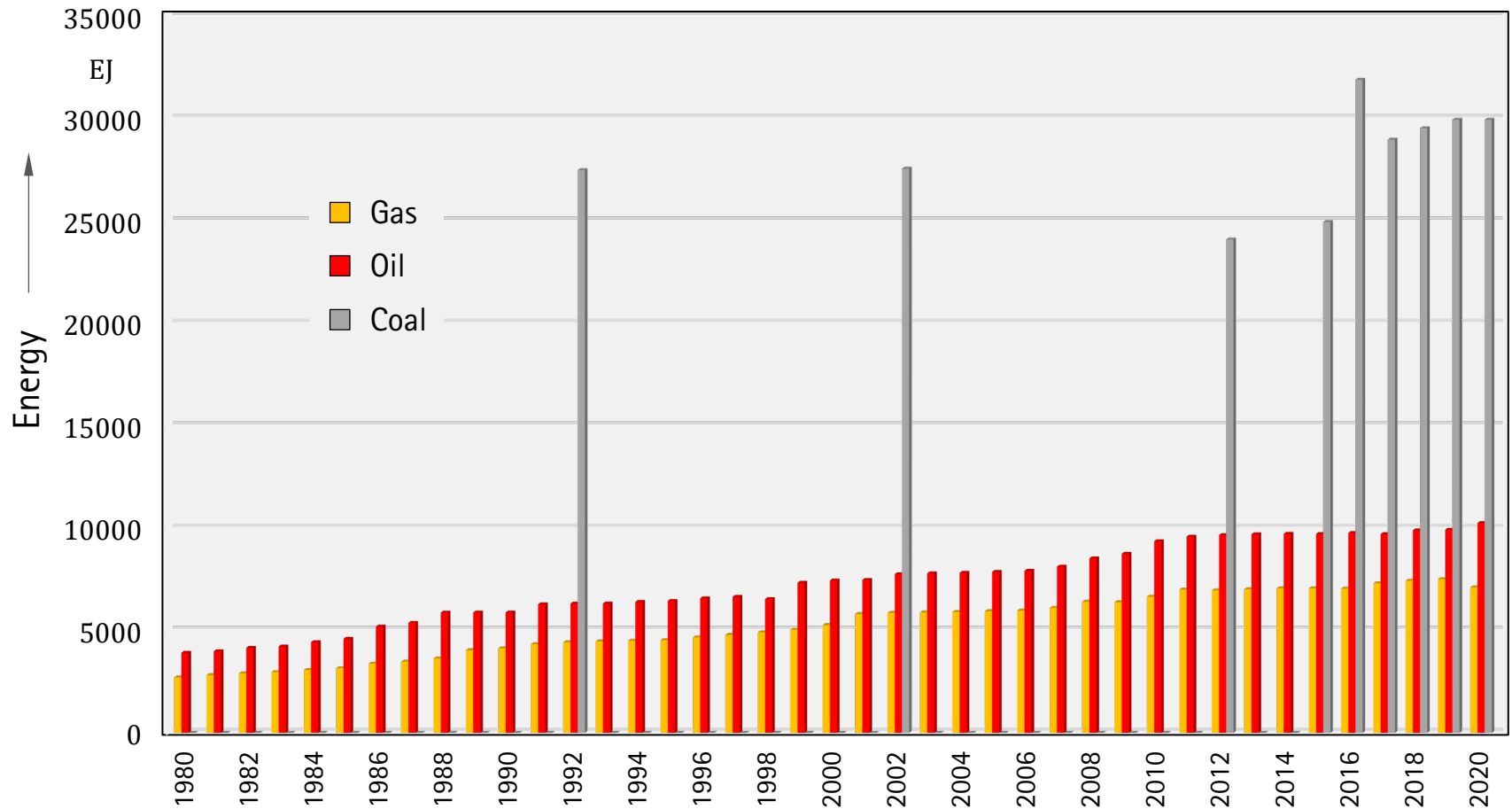
**Reserve:** Share of the resource which can be extracted at any given time while adhering to physical, chemical, and technical minimum requirements

**Range:** Time interval in which the reserves of a non-renewable primary energy source will be depleted

➡ **Static range:** Based on current consumption

➡ **Dynamic range:** Based on an assumed model for the consumption's development

# Global reserves of primary energies



Source: BP, Statistical review of world energy 2022

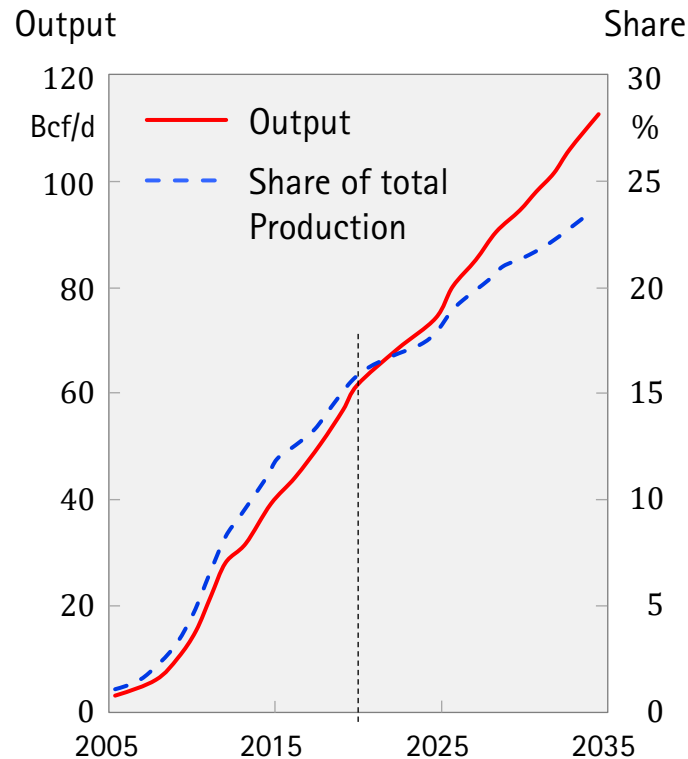
# Potential of shale gas (Schiefergas)

Bcf/d = billion cubic feet per day

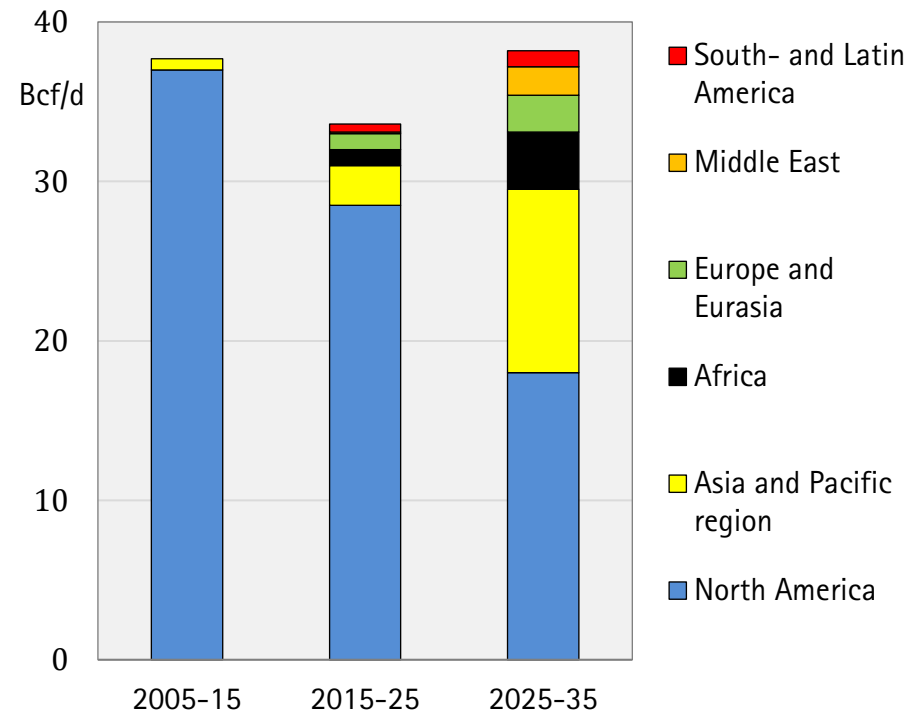
1 Bcf =  $28,317 \cdot 10^6 \text{ m}^3$

at standard conditions: 273,15 K, 1 bar

## Global shale gas production

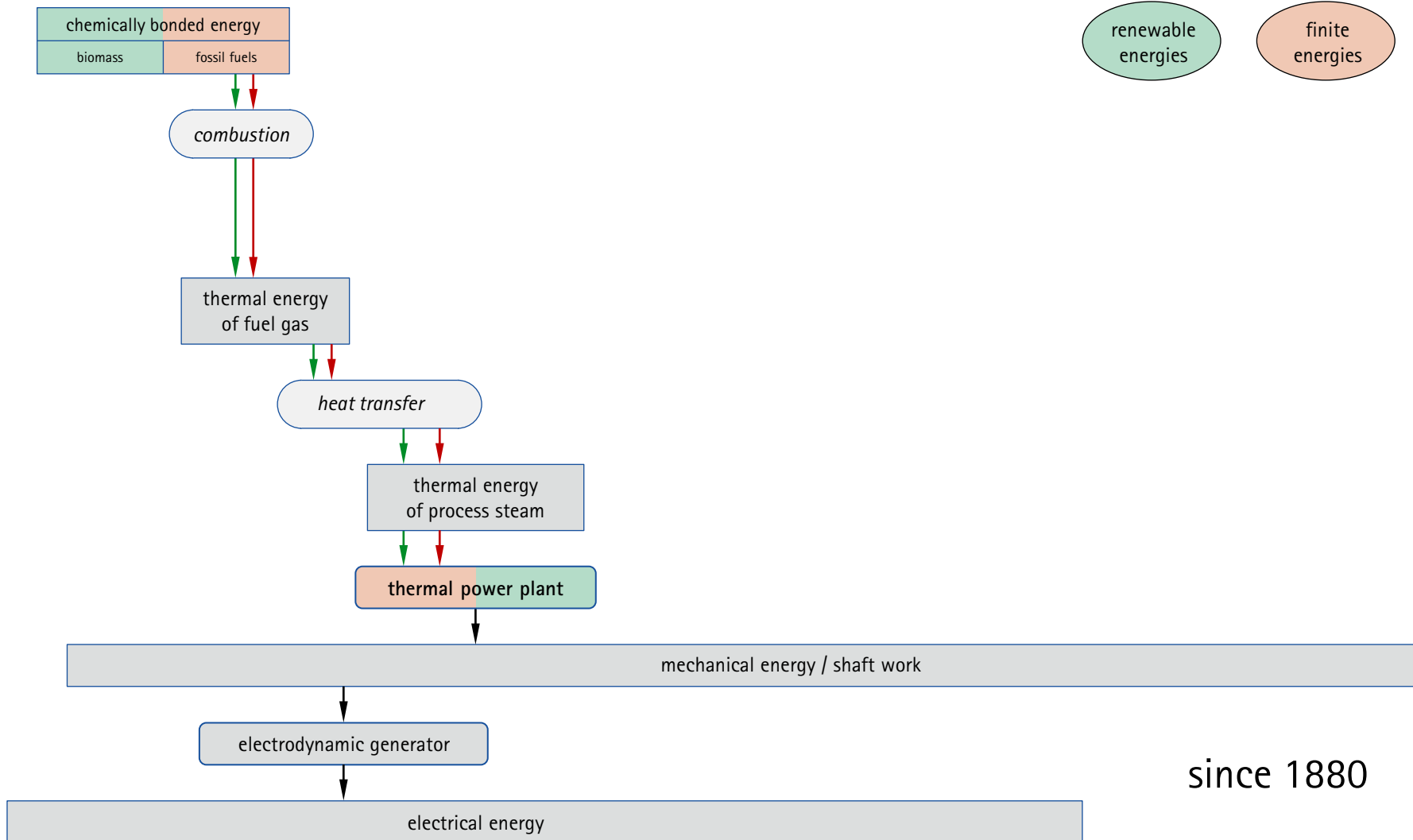


## Ten-year-increase by region

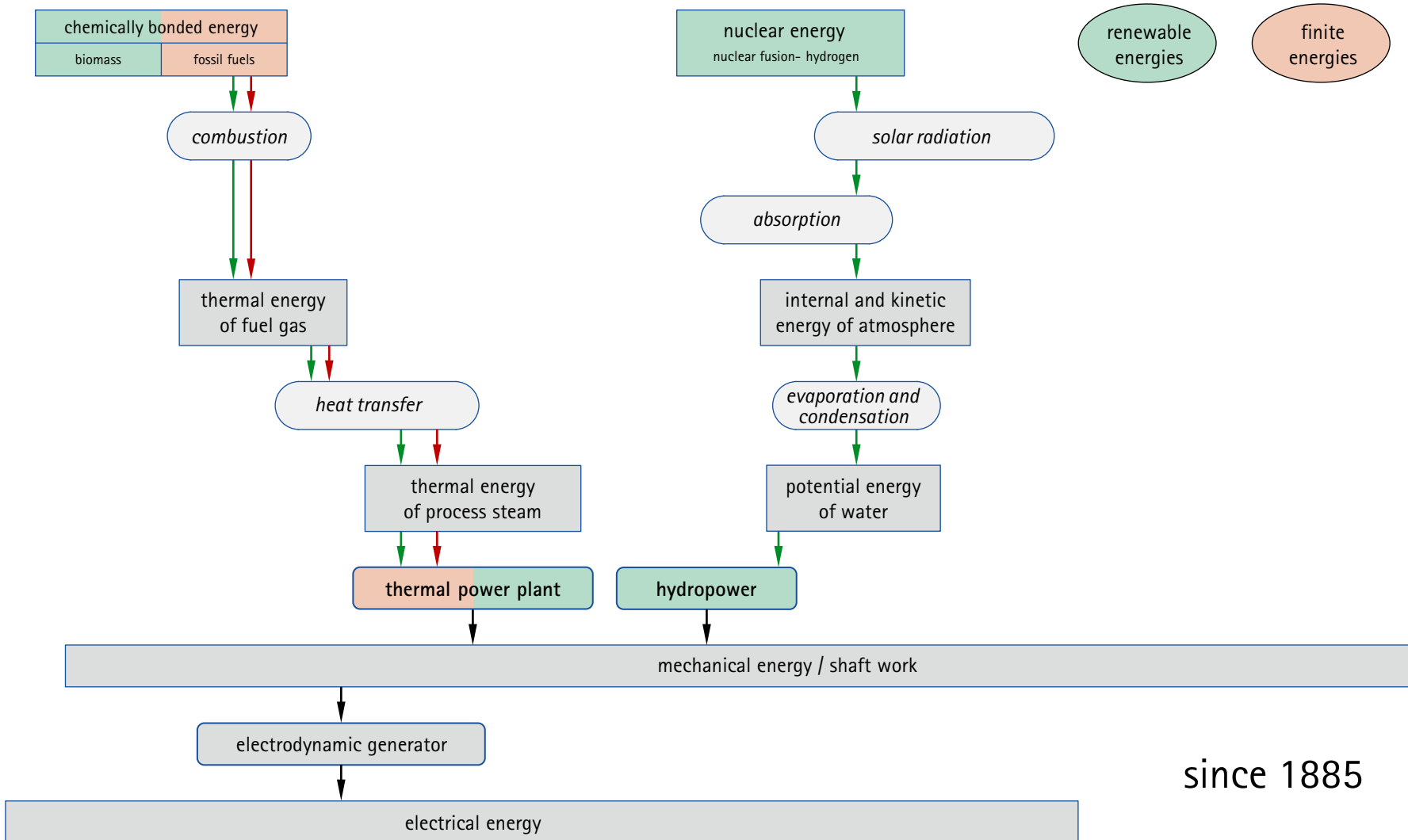


Ref.: BP Energy Outlook to 2035 (2016)

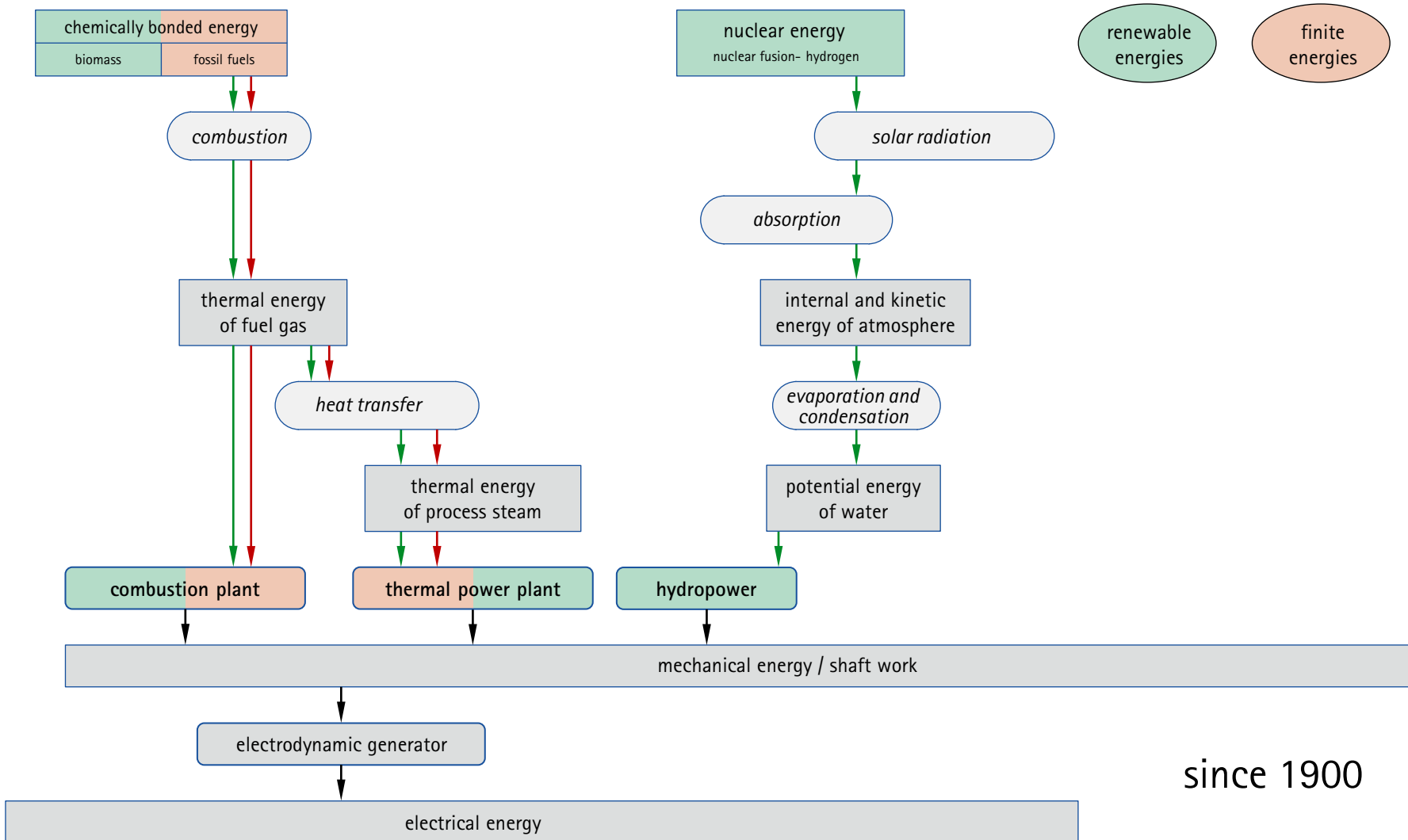
# Wood and coal were the first primary energies for electricity generation



# Electricity generation from hydropower followed soon

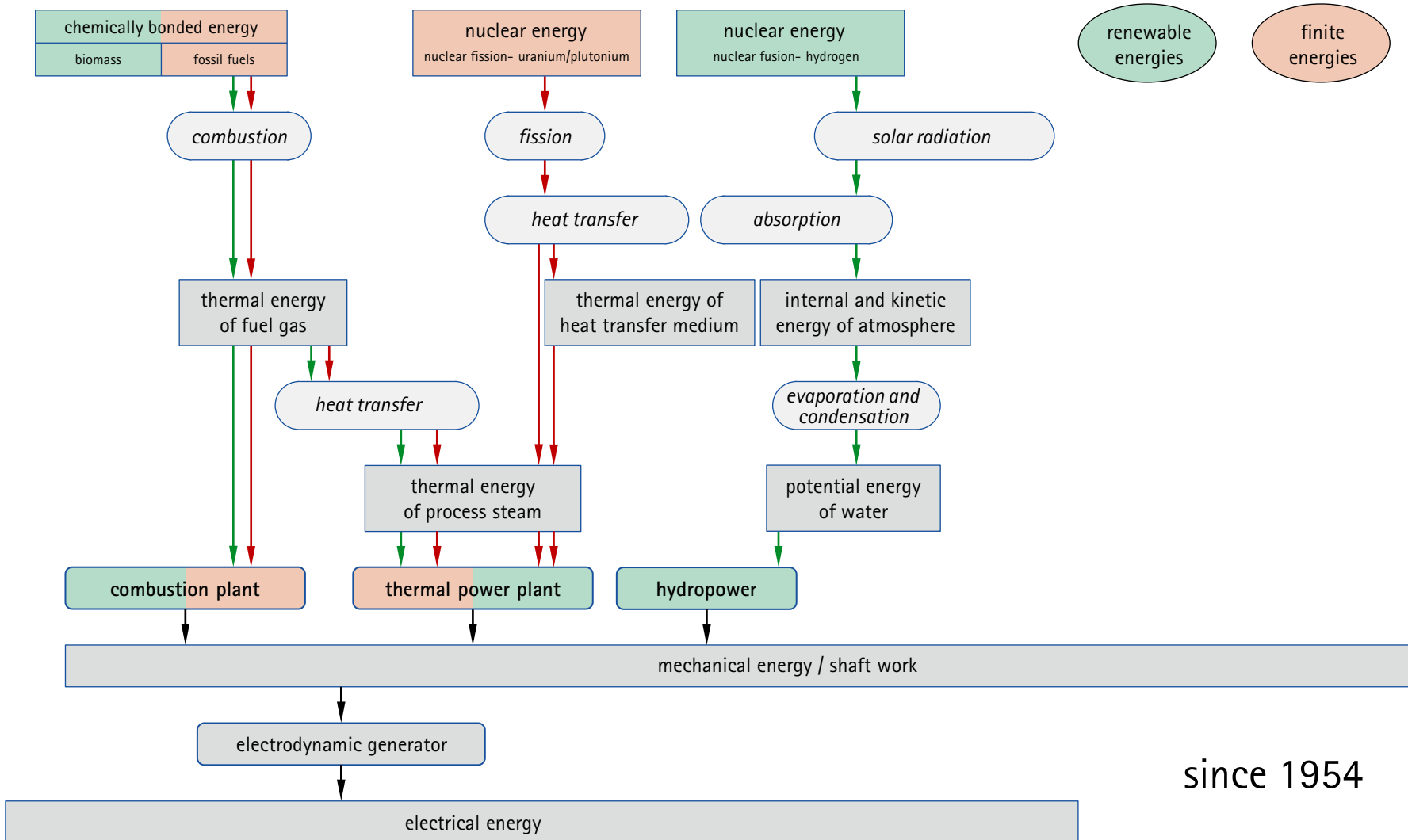


# Electricity generation through combustion

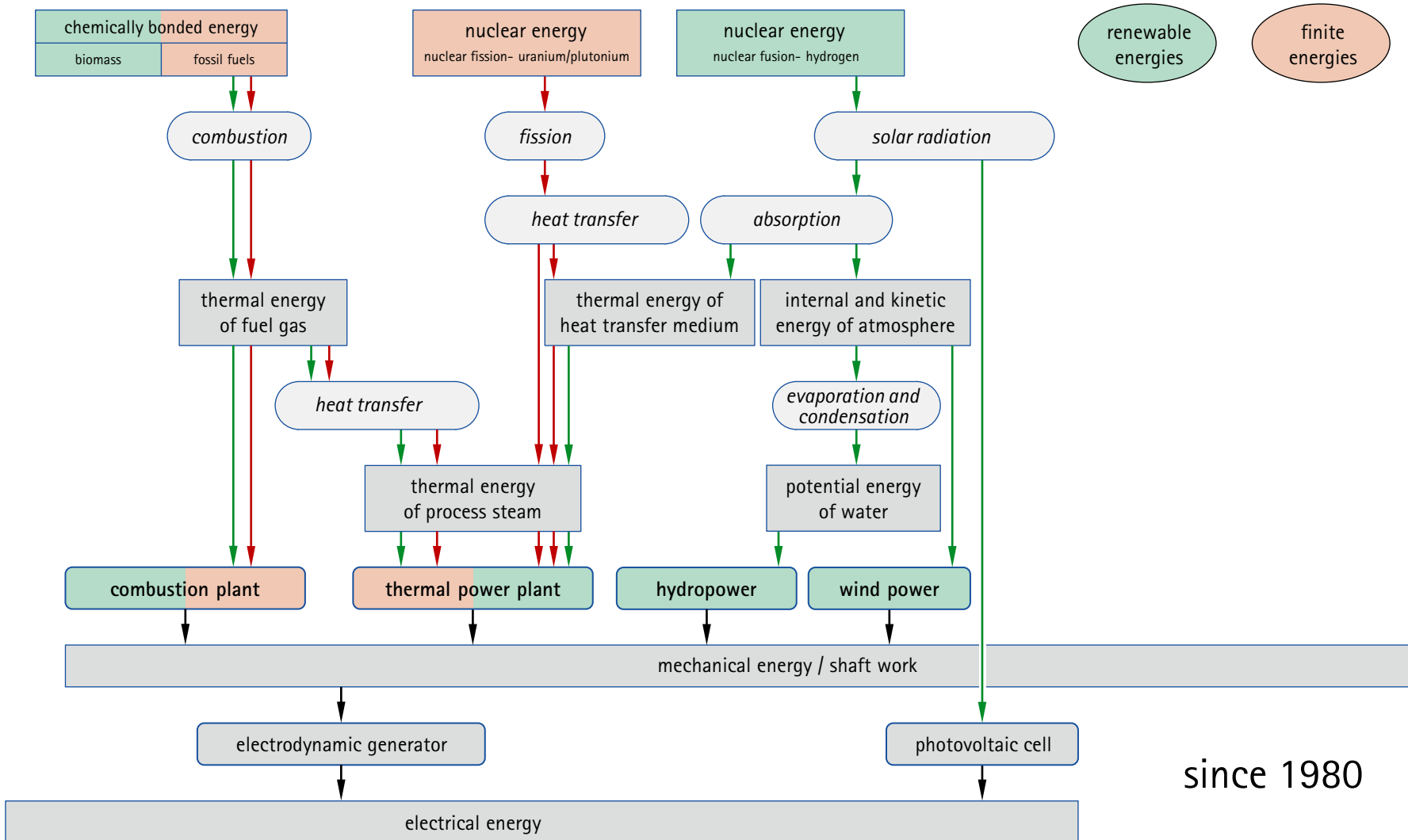




# New primary energy source – nuclear energy

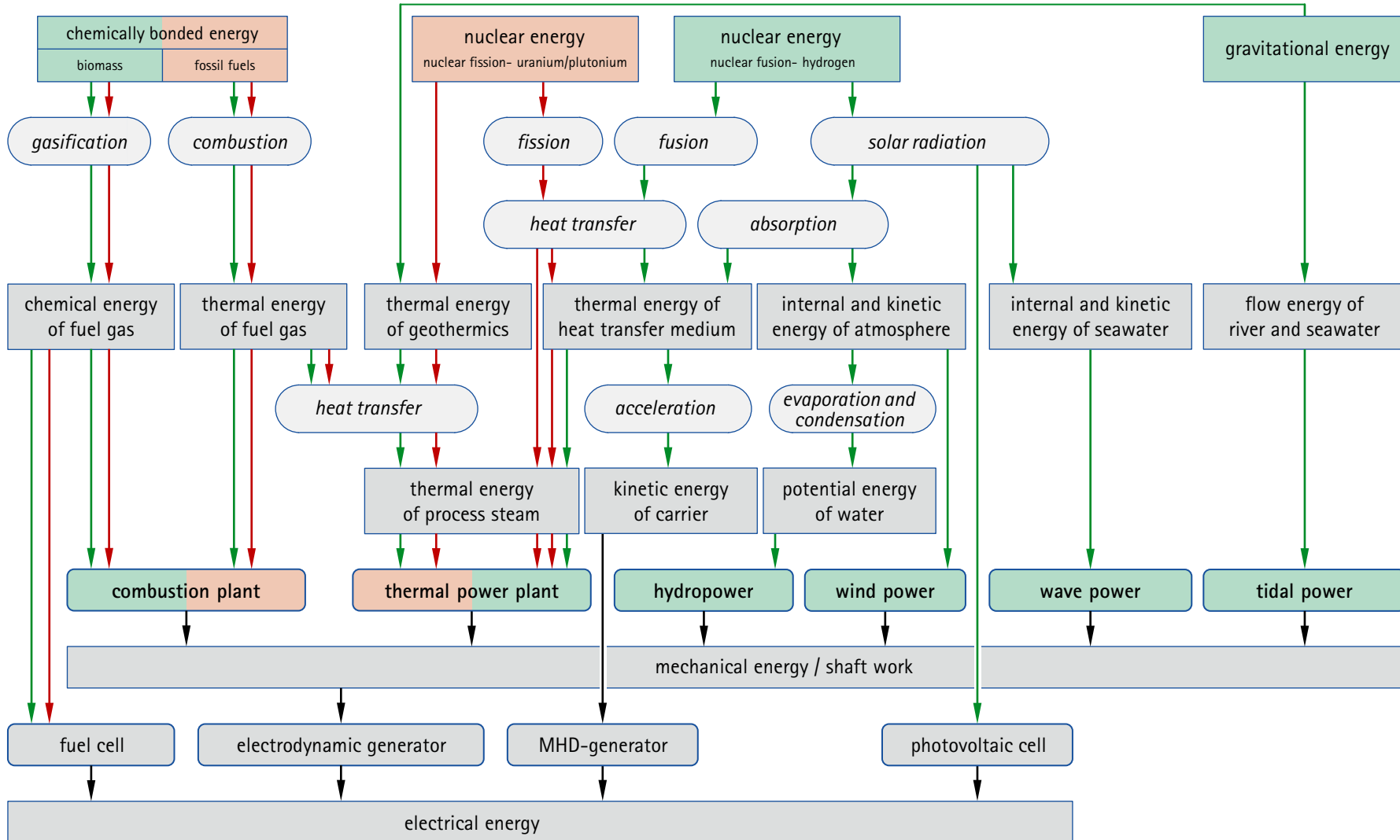


# Renewable energies



since 1980

# Energy conversion– finite and renewable energies



# Energy conversion – technologies significant today

