Sustainable Energy Provision – What are the Key Energy Technologies?

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- **A conceptual framework for sustainable energy provision**

The Brundtland Commission‘s Definition of Sustainable Development

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

It’s “a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are made consistent with future as well as present needs.”

➢ Scientific fundamentals

- Second law of thermodynamics => Life and development of economical and cultural achievements require a permanent input of workable energy and material.

- Growing knowledge (*Gestaltungsfähigkeit*) and the connected possible technological progress create the base for preserving and expanding the abilities of future generations.

- Environmental pollution results from the release of substances into the environment, not from the energy degradation.

➢ Sustainability and the use of finite *(non-renewable)* resources

- Can the use of finite resources (e.g. Oil and Coal) be consistent with the principles of sustainability?
- Supply of energy service requires the use of workable energy, but also the use of non-energetic resources and materials.
- Use of finite resources require a compensation
  => the extension of the technical-economical accessible resource base for the provision of energy services.
- State of technology determines the technological-economical accessible base *(potential)* of raw materials and energy as well as the productivity of the resource base.

➢ Sustainability and the economic principle

- Prudent use of scarce resources (incl. the environmental resources) represents a key aspect of sustainability.

  ⇒Energy services to be provided using the minimal amount of energy, material and other resources possible.

- Also the general economic principle targets at minimising the use of resources.

  ⇒Costs and prices are a measure for use of various scarce resources.

- Total resource use has to be taken into account

  ⇒ Internalisation of external costs (Getting prices right).

Sustainable energy provision if

- The potential for an economic provision of energy services increases (or does not decrease) for the following generation.
- The substance release due to energy service provision does not exeed the assimilation capacity of the natural environment.
- The energy related risk for human health are smaller than the avoided natural risk due to the provision of energy services.
- Energy services are provided with the least resource input possible, including the environmental resources.

- **A scenario-based analysis of the prospects of energy options and technologies to a sustainable energy provision**

Portfolio of technologies and options

- Energy end-use efficiency improvements (e.g heat pump, propulsion systems)
- Energy efficient building technologies
- Advanced fossil fuel power plants
- CO_2 sequestration
- Nuclear
- Combined heat and power production (CHP)
- Renewables for electricity
  - Photovoltaics
  - Wind
  - Geothermal
  - Hydro power
  - Biomass
- Renewables for heat
- Synthetic liquid fuels from biomass, natural gas and coal
- Fuel cell
- Hydrogen

Energy technology advancements by 2030

Power generation technology	Techno-economic Parameter	Unit	2005	2030
Coal	Investment cost	€/kW	840	840
	Efficiency	%	45	52
Gas CC	Investment cost	€/kW	440	385
	Efficiency	%	58	63
Nuclear	Investment cost	€/kW	1750	1400
	Efficiency	%	36	36
Wind (onshore)	Investment cost	€/kW	1200	900
PV	Investment cost	€/kW	4750	2000
Fuel cell	Investment cost	€/kW	4500	1000

Scenario characterization

Reference scenario (REF)

- extrapolation of present energy policy
- phasing-out of nuclear energy
- no targets for climate protection

Preference for Renewable Energy sources (PRE)

- increasing renewable contribution to electricity(30%) and primary energy(25%) by 2030
- phasing-out of nuclear energy
- no CO_2-sequestration

GG-reduction targets:
2010: -21%
2020: -35%
2030: -50%

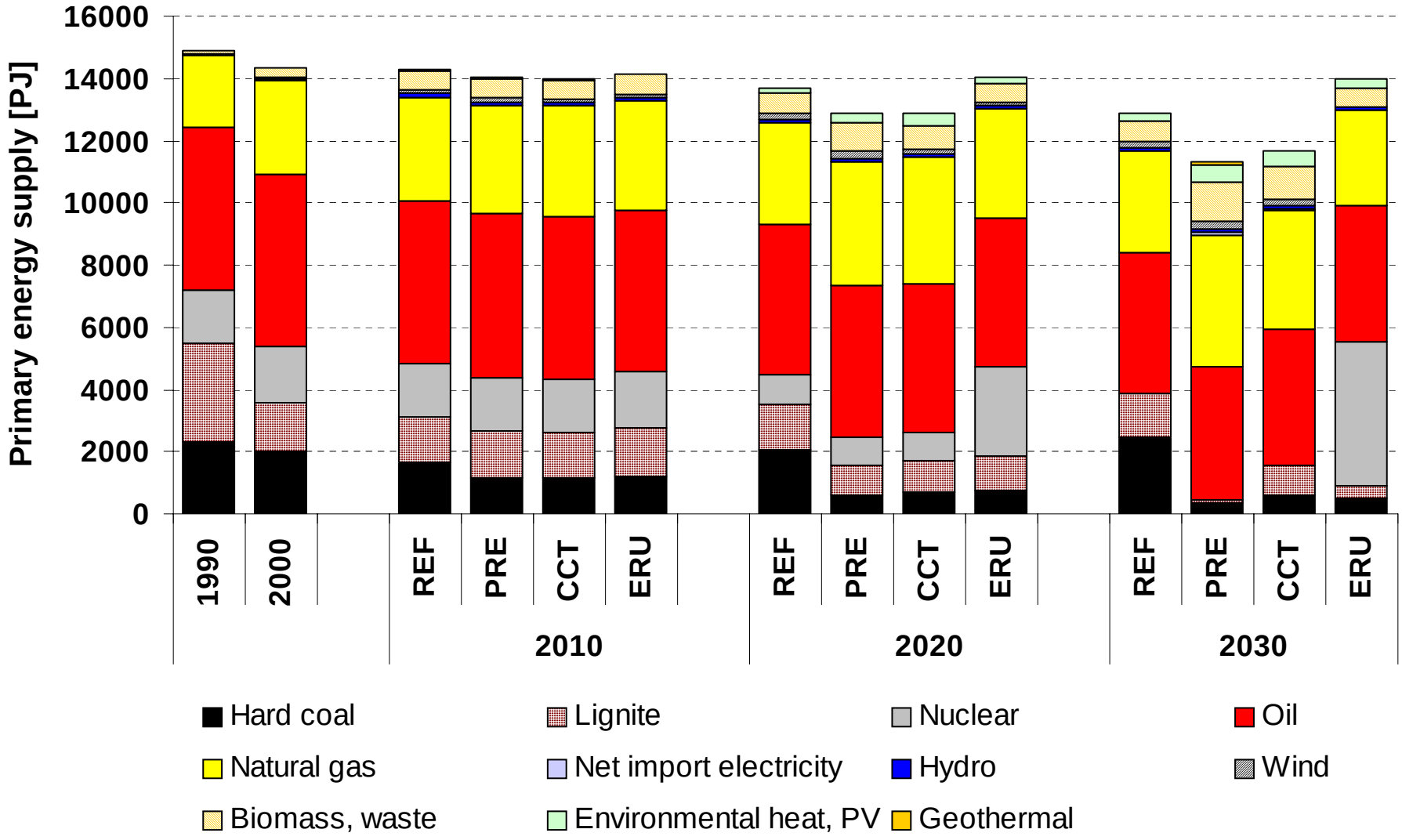
Clean Coal Technologies (CCT)

- CO_2-sequestration and disposal allowed
- phasing-out of nuclear energy

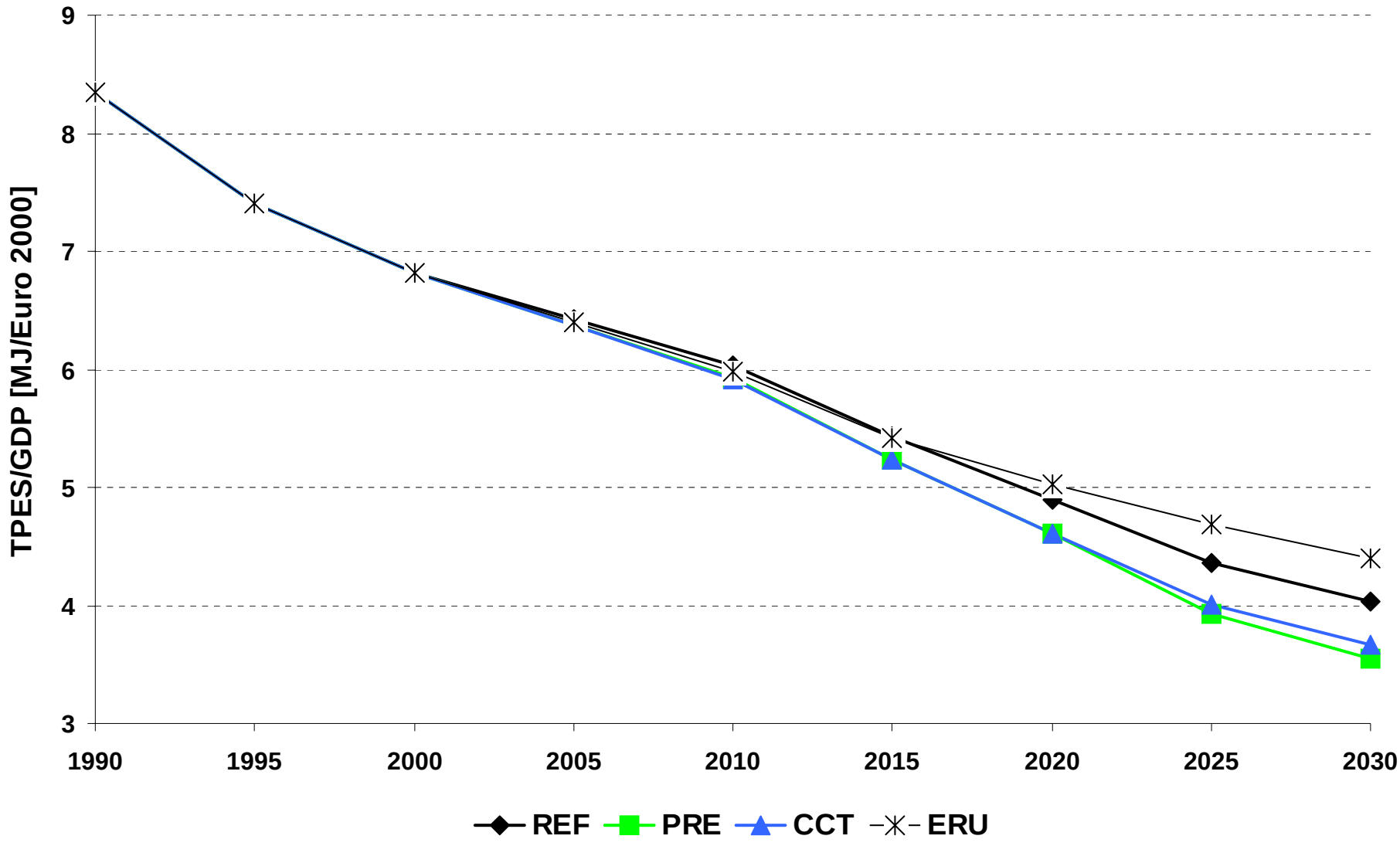
Efficient Resources Utilization (ERU)

- cost efficient attainability of reduction targets
- nuclear energy: expansion possible

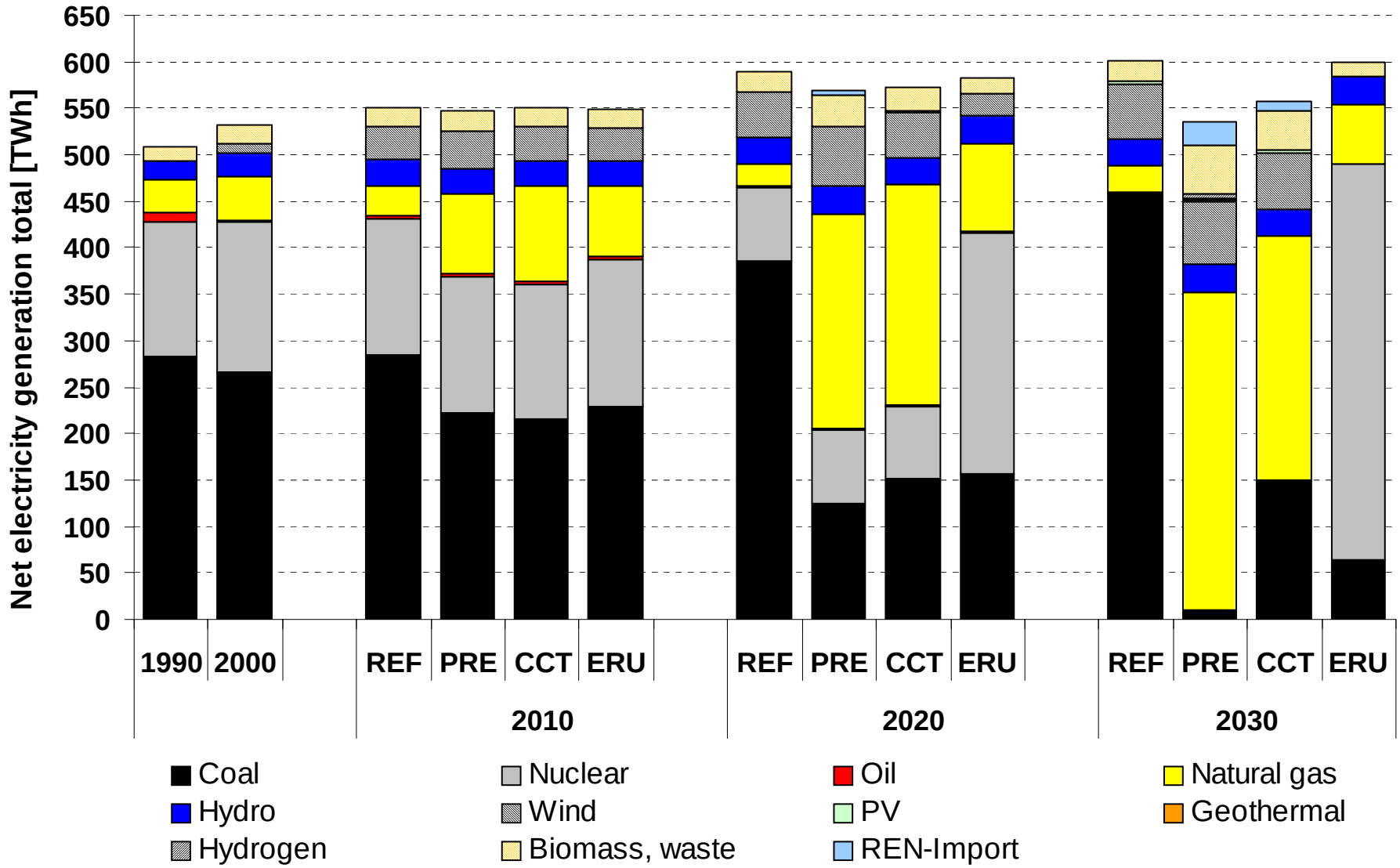
Development of total primary energy supply



Energy intensity of GDP



Development of electricity production structure



Cost implications

Scenario	Total Cost Difference to REF to 2030 [bn $Euro_{00}$]	Marginal CO_2 reduction costs to 2030 [$Euro_{00}$/t CO_2]	Average electricity generation costs in 2030 [$Cent_{00}$/kWh]
Reference scenario (REF)			**3.6**
Preference for Renewable Energy Sources (PRE)	**110**	**79**	**5.5**
Clean Coal Technologies (CCT)	**86**	**57**	**5.0**
Efficient Resource Utilization (ERU)	**-113**	**27**	**2.5**

Key technologies and energy options for a sustainable energy provision in Germany

- End-use efficiency improvements
  - in buildings
  - in industry
  - in transport
- Heat pumps
- Nuclear power
- Biomass
  - liquids
  - heat
- (District heat and CHP)


Thank you very much for your attention!