„Life cycle assessment“ of RE systems and the IER-tool BALANCE

Dr. J. Moerschner

Institute of Energy Economics and the Rational Use of Energy

Lecture during the IER-Workshop
„Topics and Tools of Energy and Environmental Research“

On Wednesday 02.07.2003

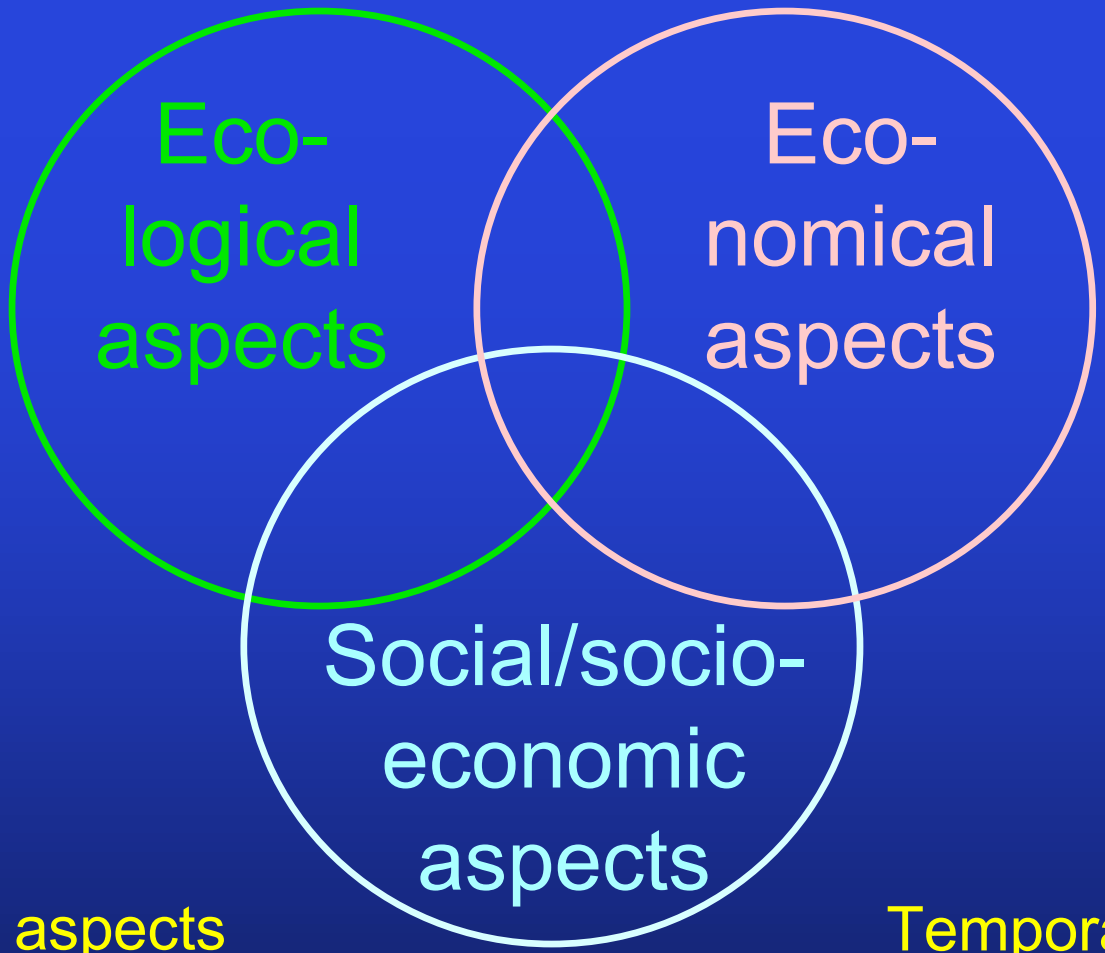
Structure of presentation

- Introduction: Sustainability, RE and LCA
- Methodology: LCA and other tools for environmental measurements
- Instrument: The IER-software tool BALANCE for LCA's of energy systems
- Results: FNR-study on environmental behavior of RE
- Discussion
- Summary, conclusions

Sustainability: Definition of the Brundtland-commission (1987)

„Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs“

Dimensions of sustainability



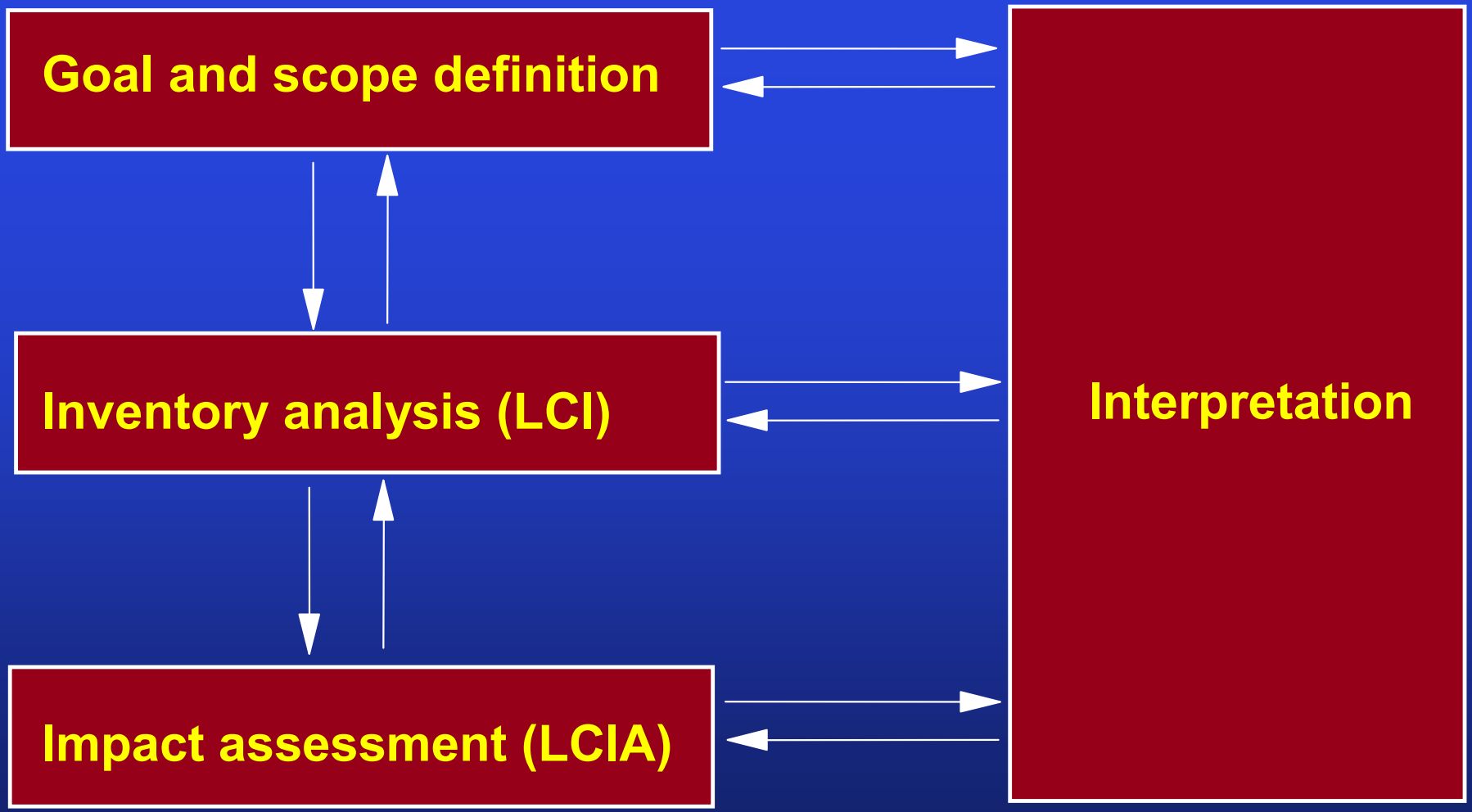
Spacial aspects
(Field, business, region, country)

Temporary aspects
(short-term, long-term)

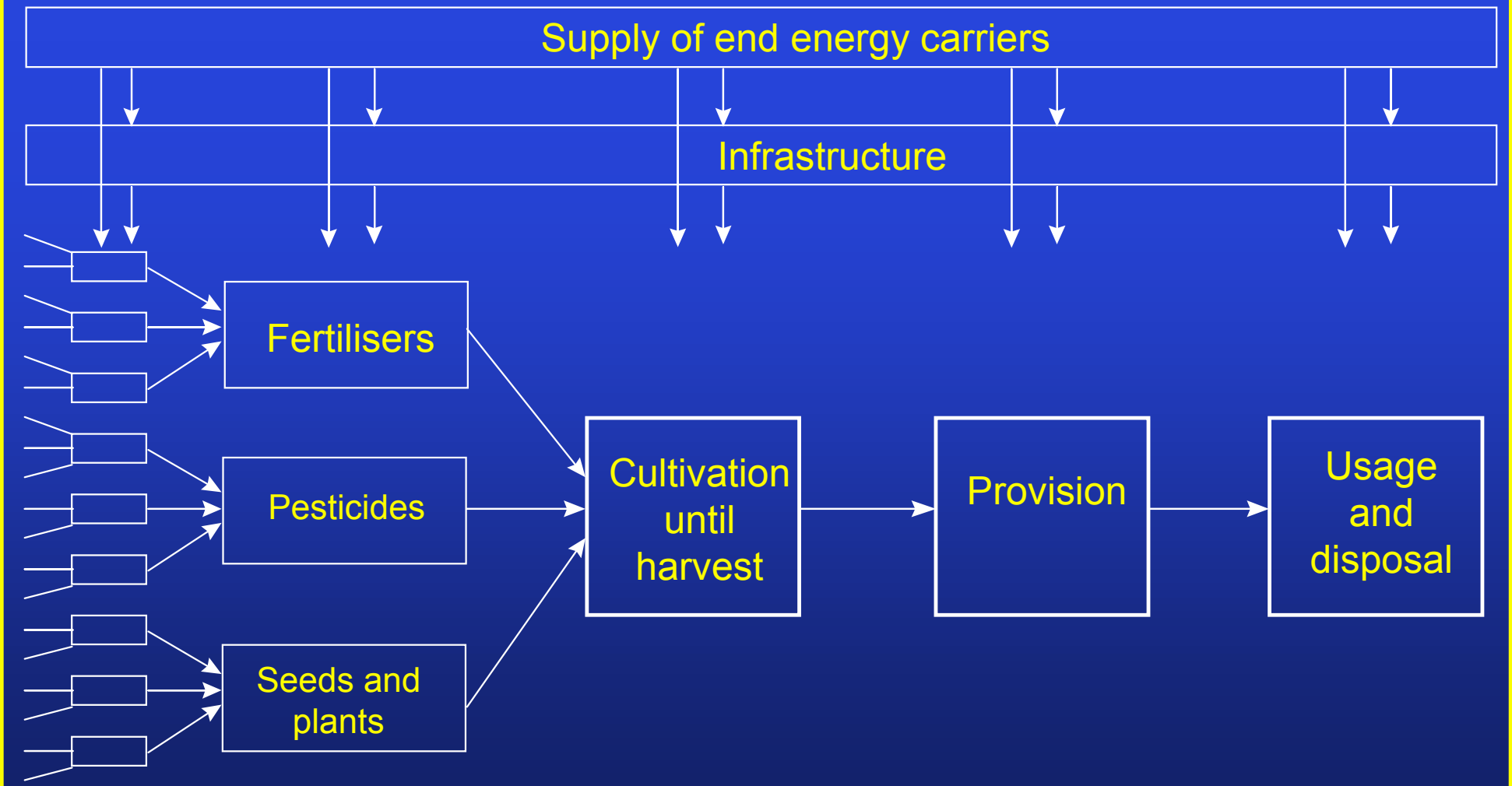
Selected instruments for environmental analysis

	Subject of investigation and it‘s extent	Dimensions
techn. impact assessment	technique / technology	ecology, economy, social aspects
env. risk assessment	single project / plant	ecology
eco-auditing	production location	ecology
product chain analysis (PCA)	product (whole life cycle)	ecology, economy, social aspects
integrated assessment	product (whole life cycle)	ecology, economy
life cycle assessment (LCA)	product (whole life cycle)	ecology

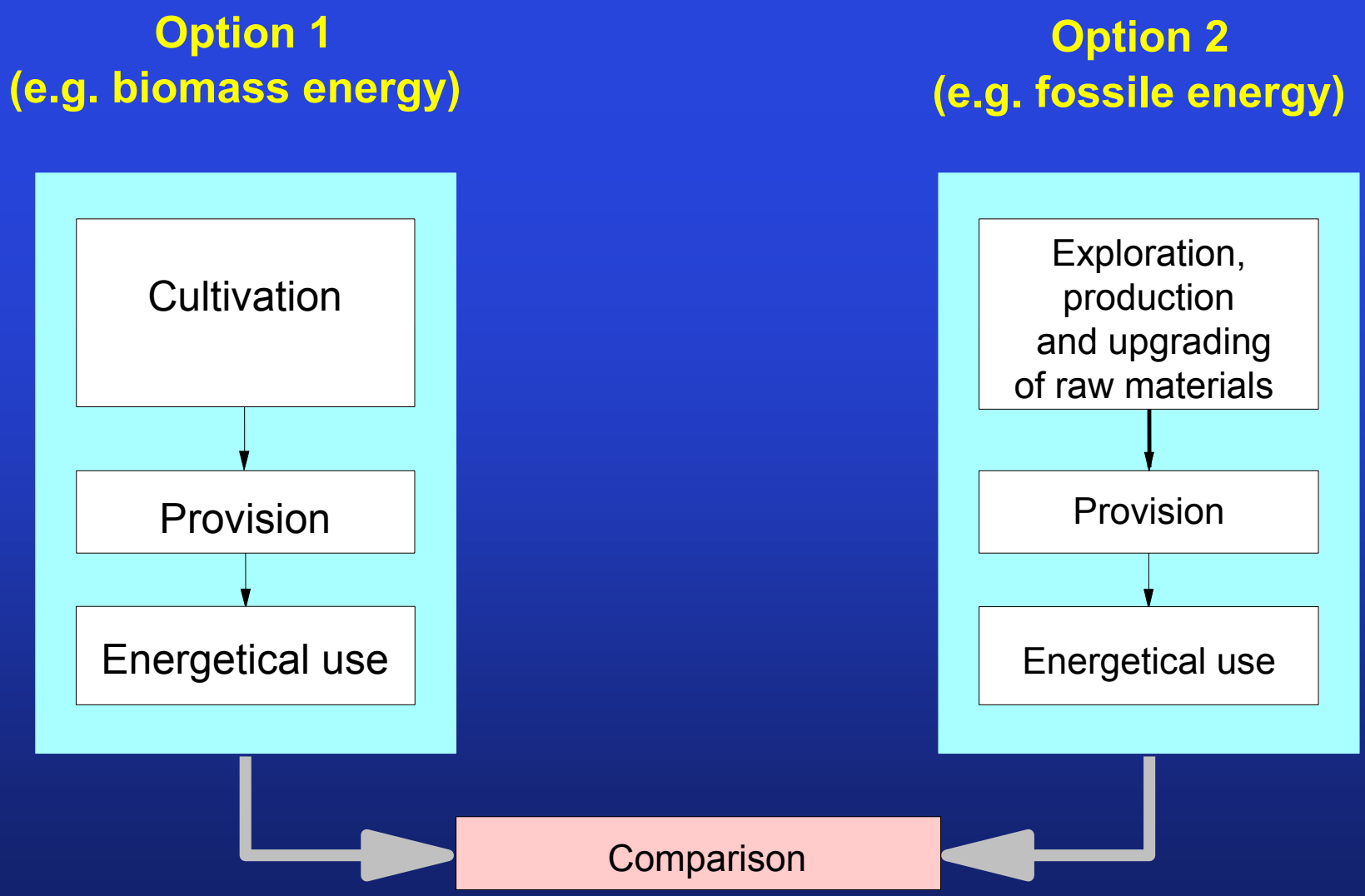
Elements of an LCA (ISO 14040)



Methodology: Process chain analysis as basis for life cycle assessment

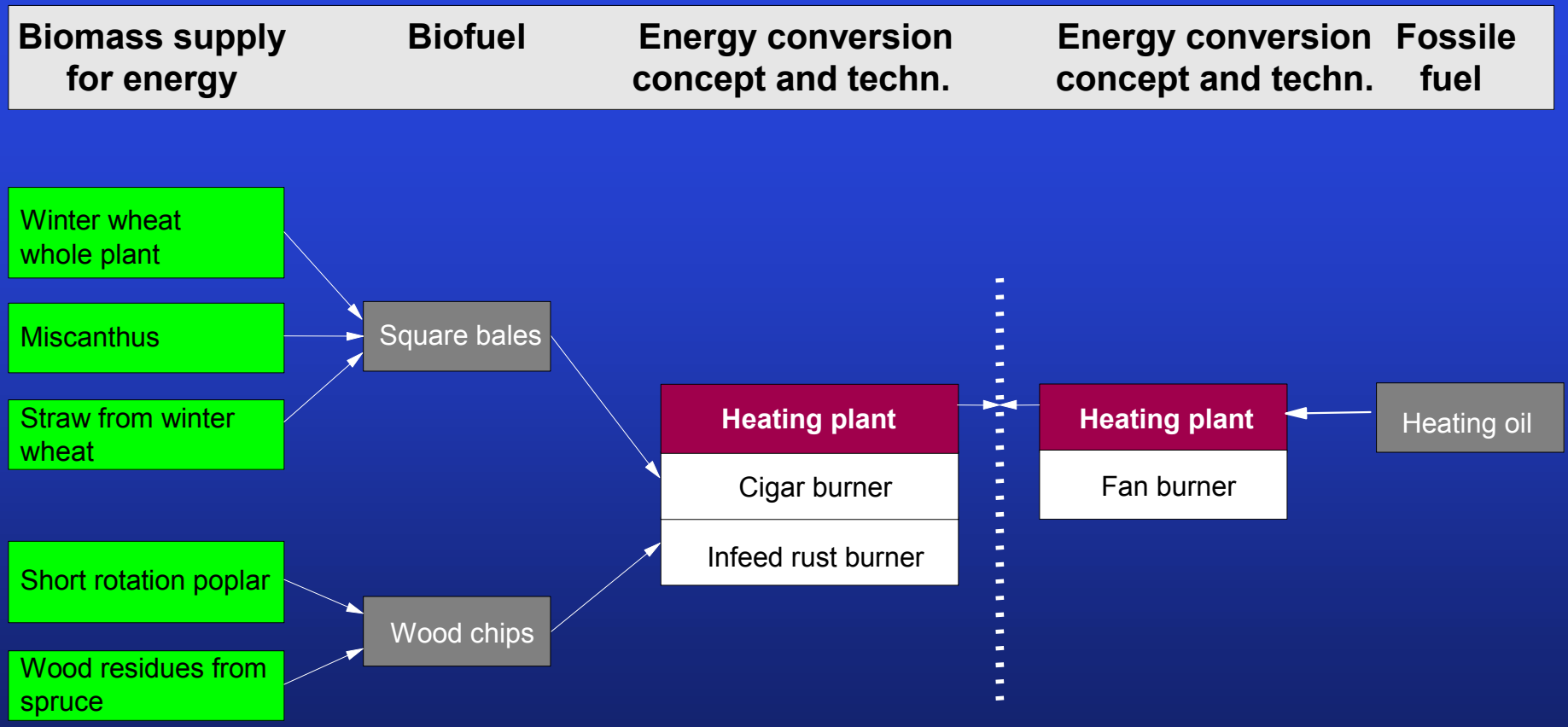


Life cycle comparison of energy systems

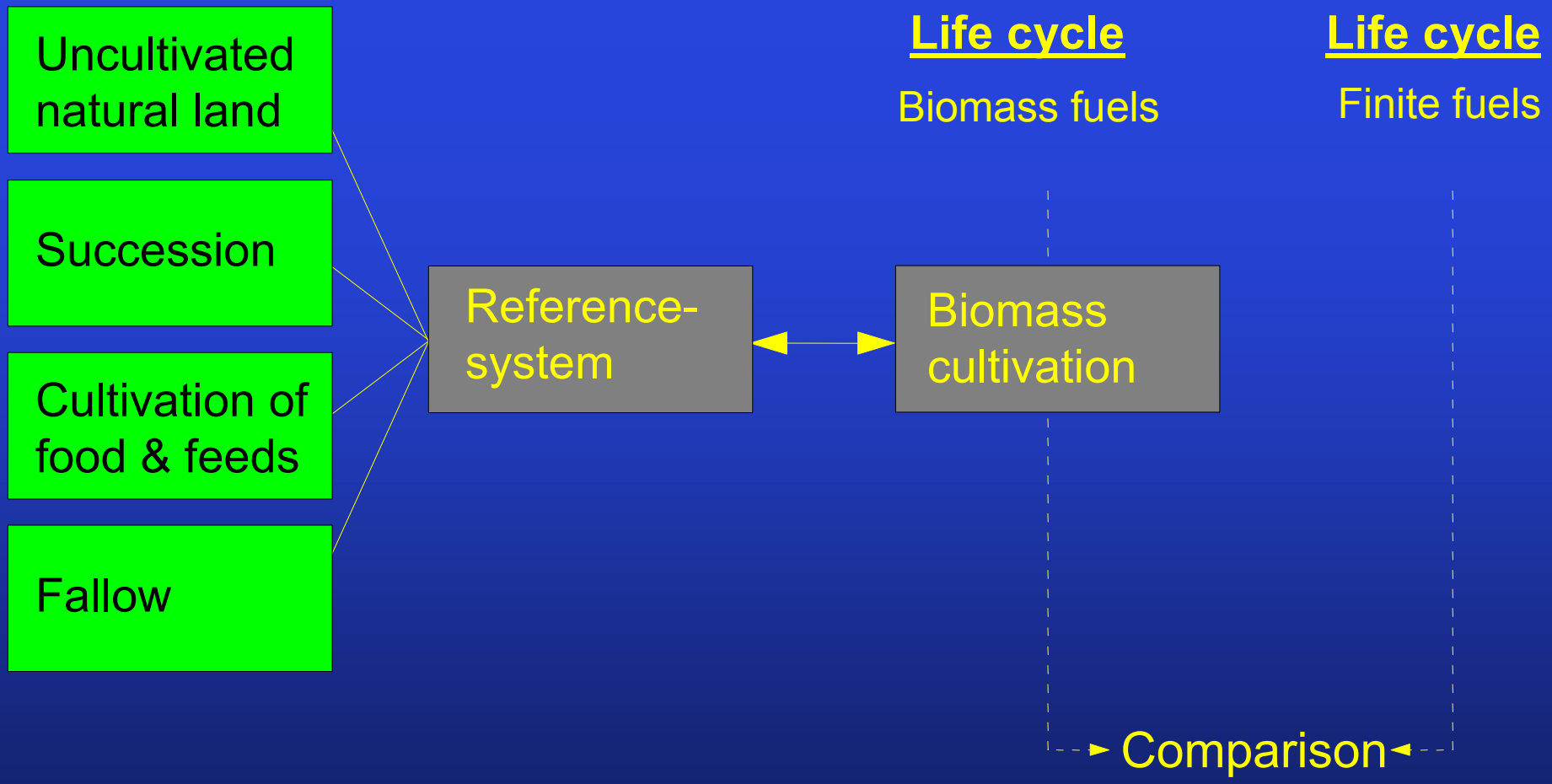


Specification of process chains for a study

- Bioenergy compared to a fossile fuelled reference system -



Possible reference systems



Standard listing of LCIA-categories, along DIN-NAGUS

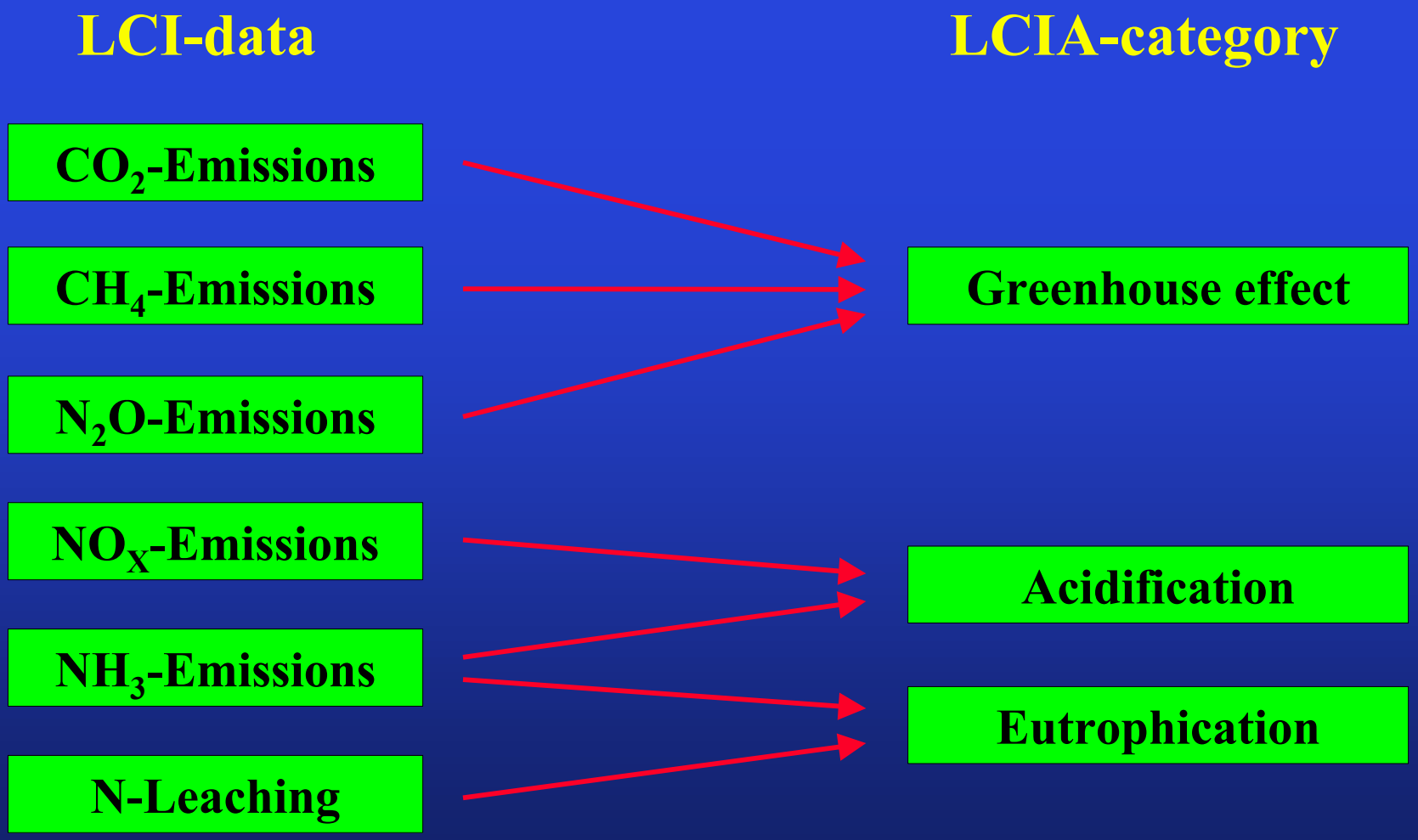
1. Primary energy use/depletion of natural resources
2. Utilisation/degradation of natural areas/environment
3. Greenhouse effect
4. Ozone layer depletion
5. Acidification
6. Eutrophication
7. Ecological toxicity
8. Toxicity for human beings
9. Summer smog
10. Noise

Reinhardt, Zemanek (1998)

Bioenergy: Further environmental aspects of cultivation and harvest of biomass raw materials

- Erosion
- Soil compaction
- Humus conservation
- Contribution to use liquid manure
- Tolerance against weeds or plant deseases
- Application of pesticides
- Biodiversity
- Nutrient leaching into ground water or surface water
- Contribution to landscape cultivation and recreation value (e.g. tourism)
- Water consumption
- Specific space requirements for crop cultivation
- Specific nitrogen fertiliser requirements

Example for the classification of LCI-data for LCIA:



Geier (2000)

Allocation rules: Share of selected by-products of biofuel-production when referring to different allocation units

Allocation	Soy bean oil/ Soy bean extraction pellet	Rape seed oil/ Rape seed extraction pellet	RME/ Glycerine
Mass	18,8 : 81,2	39,7 : 60,3	89,4 : 10,6
Lower heating value (LHV)	34,4 : 65,6	59,6 : 40,4	96,0 : 4,0
Price	35,0: 65,0	70,0 : 30,0	79,2 : 20,8

IFEU (1999)

Software BALANCE 3.1

"Main Database"

- LCI-, LCIA-, valuation factors
- I-O-Data (tables, LCI-coefficients)
- Predefined modules, e.g. for:
  - fuels
  - materials
  - transportation tasks
  - waste disposal
  - ...

"Study Database"

- Selection of LCI-kategories for study
- Definition of own modules
- Selection of main database modules
- Grafic-supported analysis of balance results
- Storage of user specific program settings

"I/O-Table Database"

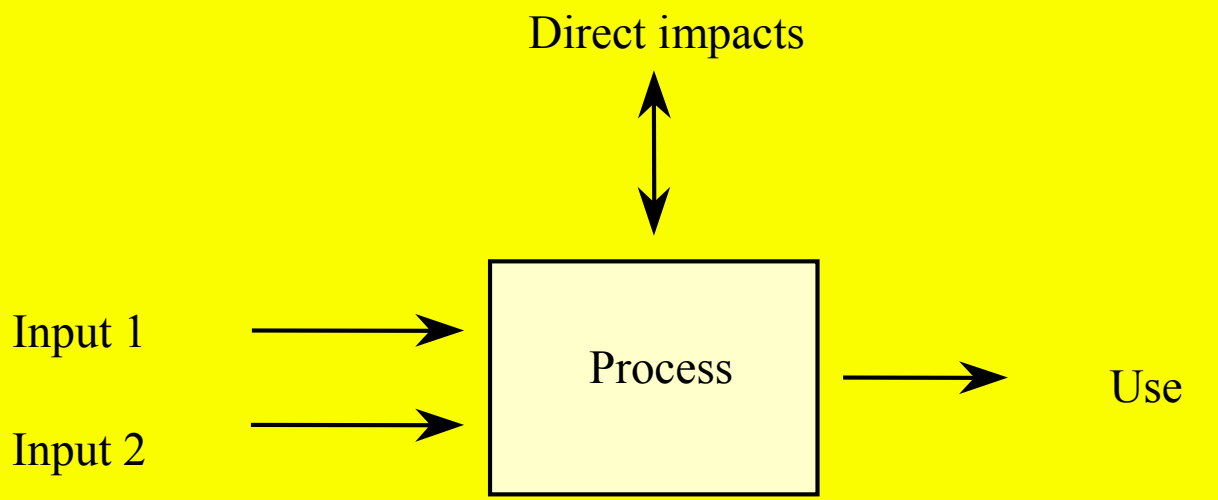
- Definition of sectors
- Sectoral inputs
- Sektoral parameters, e.g.:
  - specific energy use
  - amount of waste
  - ...
- Emission factors
- LCI-koefficients

Marheineke (2001)

BALANCE – the hybrid approach (1)

1

Definition of the process chain (matter and energy balances for all contained sub processes)



2

Monetary balance for each process in the process chain

Economical value of the inputs assessed by process chain analysis

\+ Net added value of the processes assessed by process chain analysis

\+ Net added value of the processes NOT assessed by process chain analysis

= Economical value of the use supplied

Marheineke (2001)

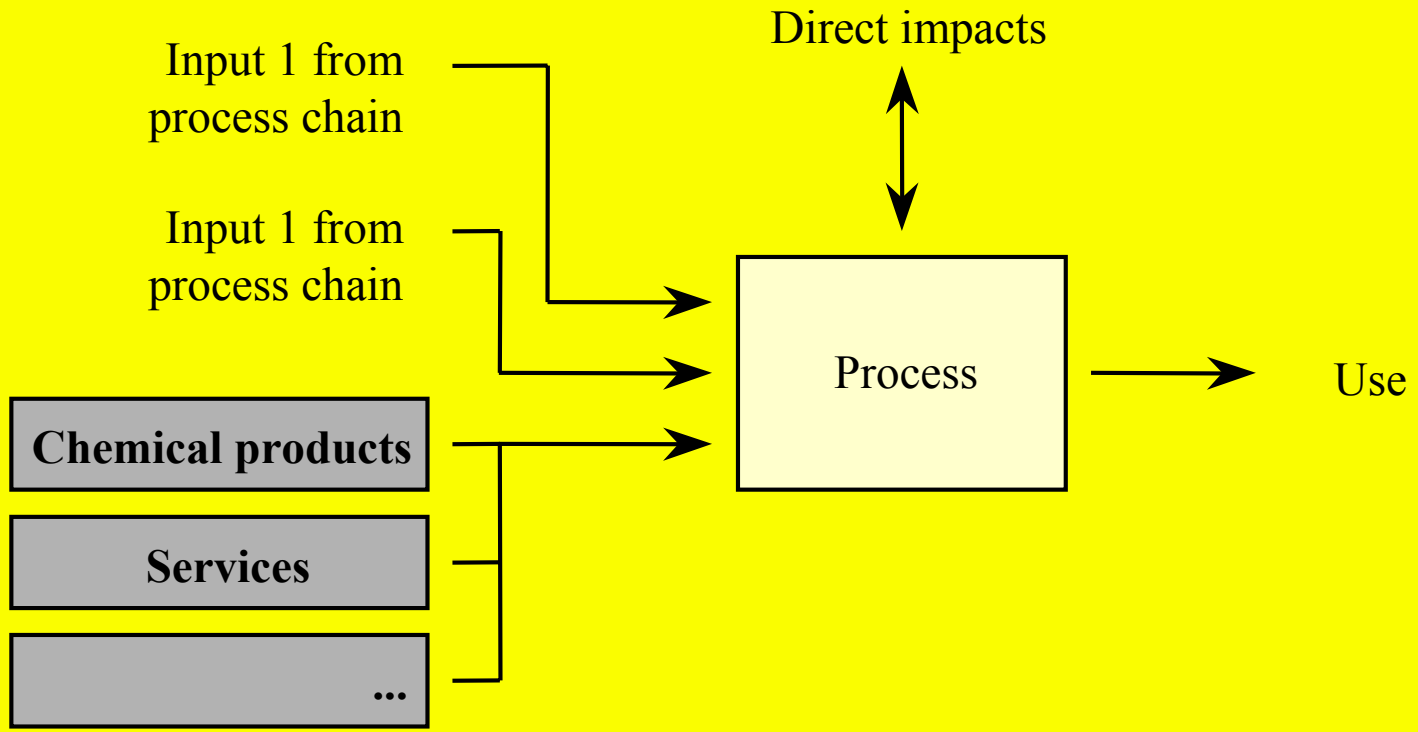
BALANCE – the hybrid approach (2)

1

2

3

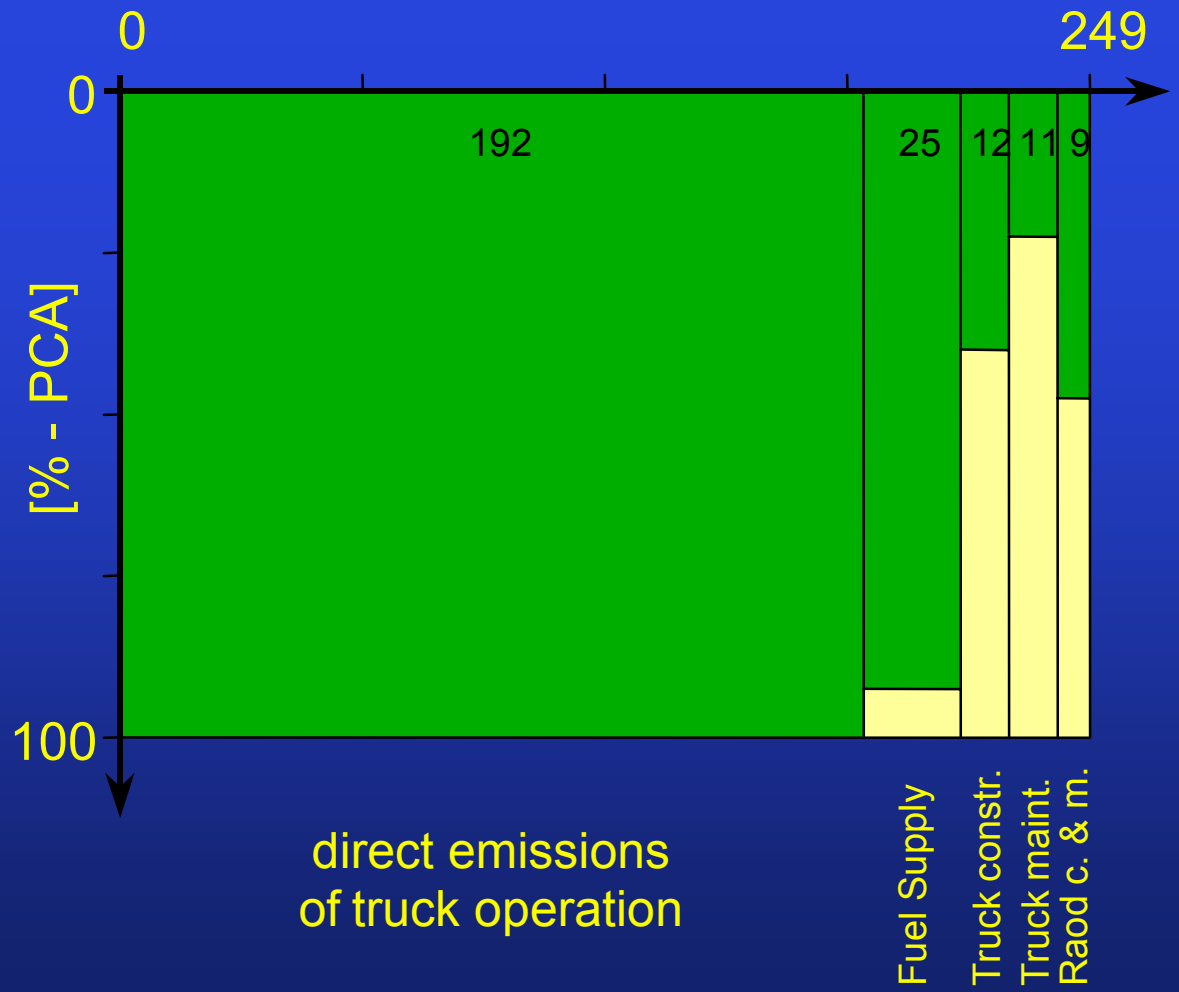
Allocation of the Value of not in process chains assessed inputs to sectors of the I/O-table and assessment of environmental loads by the Input-Output-Analysis



Marheineke (2001)

BALANCE – Hybrid balance for a freight transportation task

(kg CO_2-equiv.)



Process-Chain-Analysis (PCA)

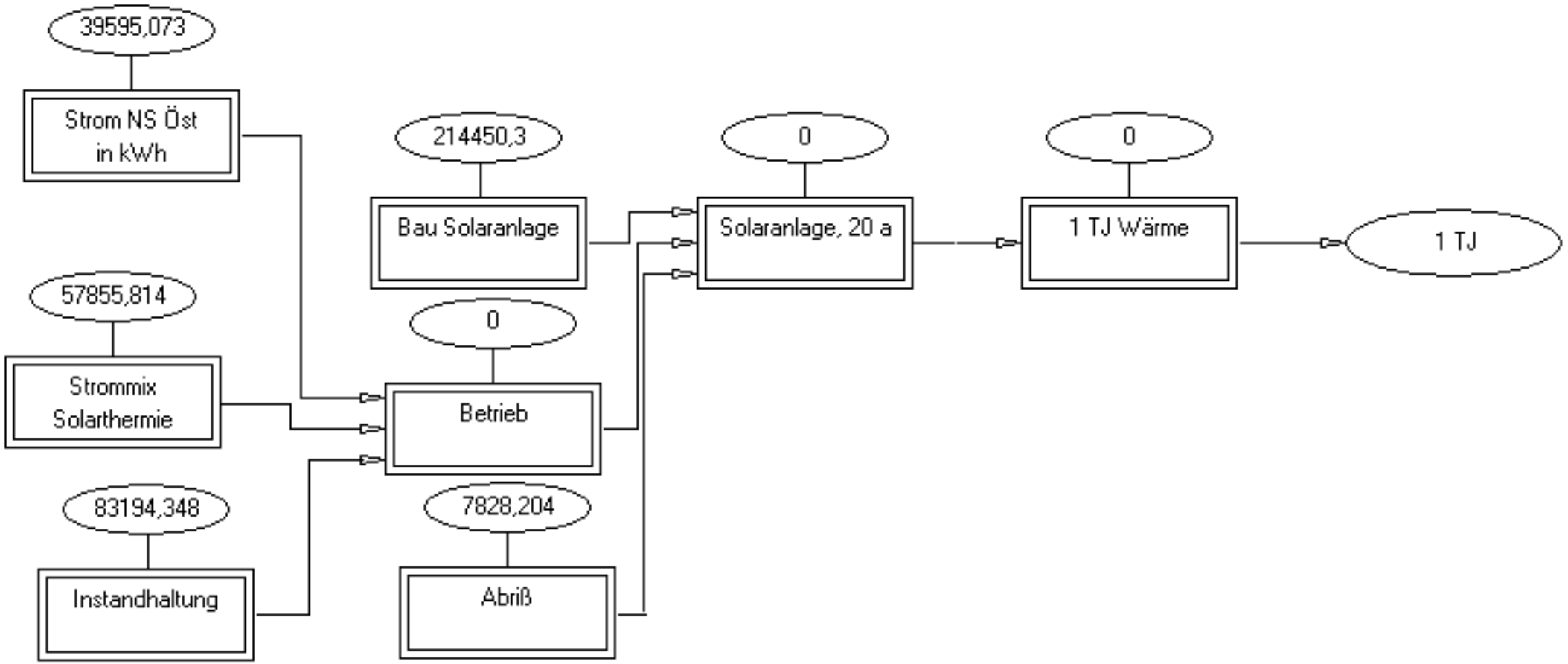
Input-Output-Analysis (IOA)

IOA-Shares:

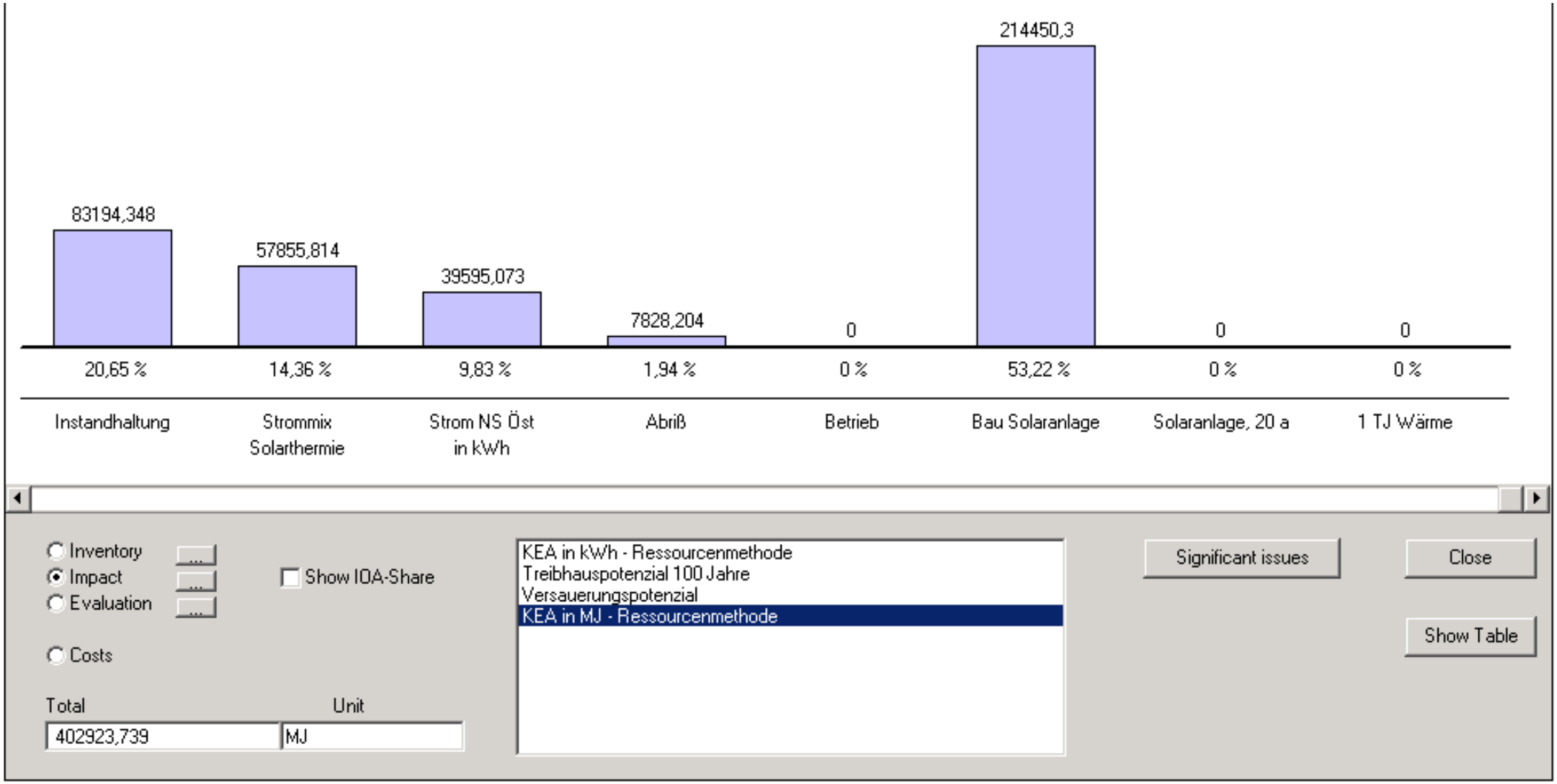
CO_2-eq.	9 %
CO_2	8 %
CH_4	21 %
N_2O	40 %

Marheineke (2001)

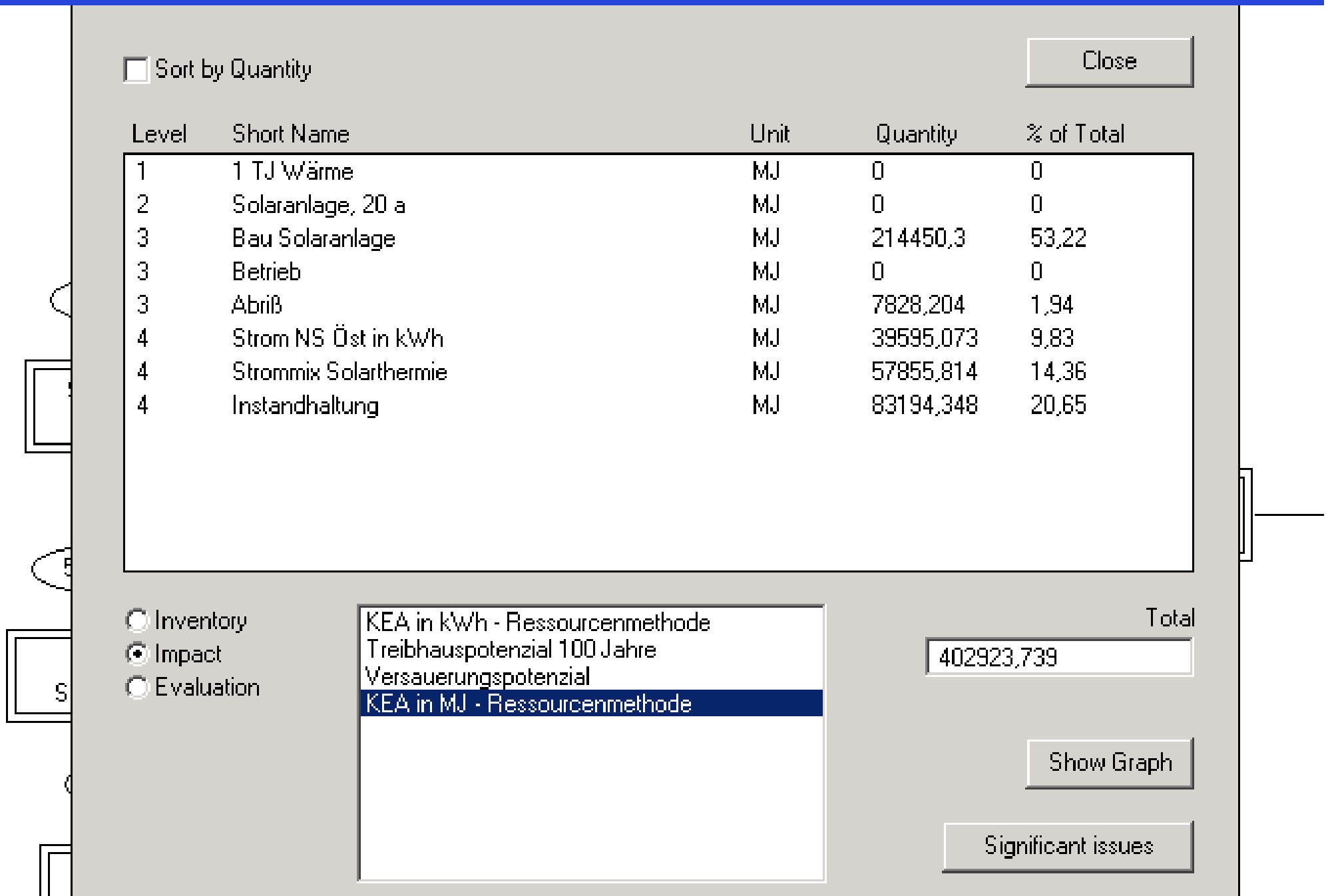
Opportunities for analysis of results within BALANCE (1)
- Grafical overview of a whole process chain -



Opportunities for analysis of results within BALANCE (2)
- grafical presentation of environmental impact allocation -



Opportunities for analysis of results within BALANCE (3)
- table of impact allocation within a process chain -



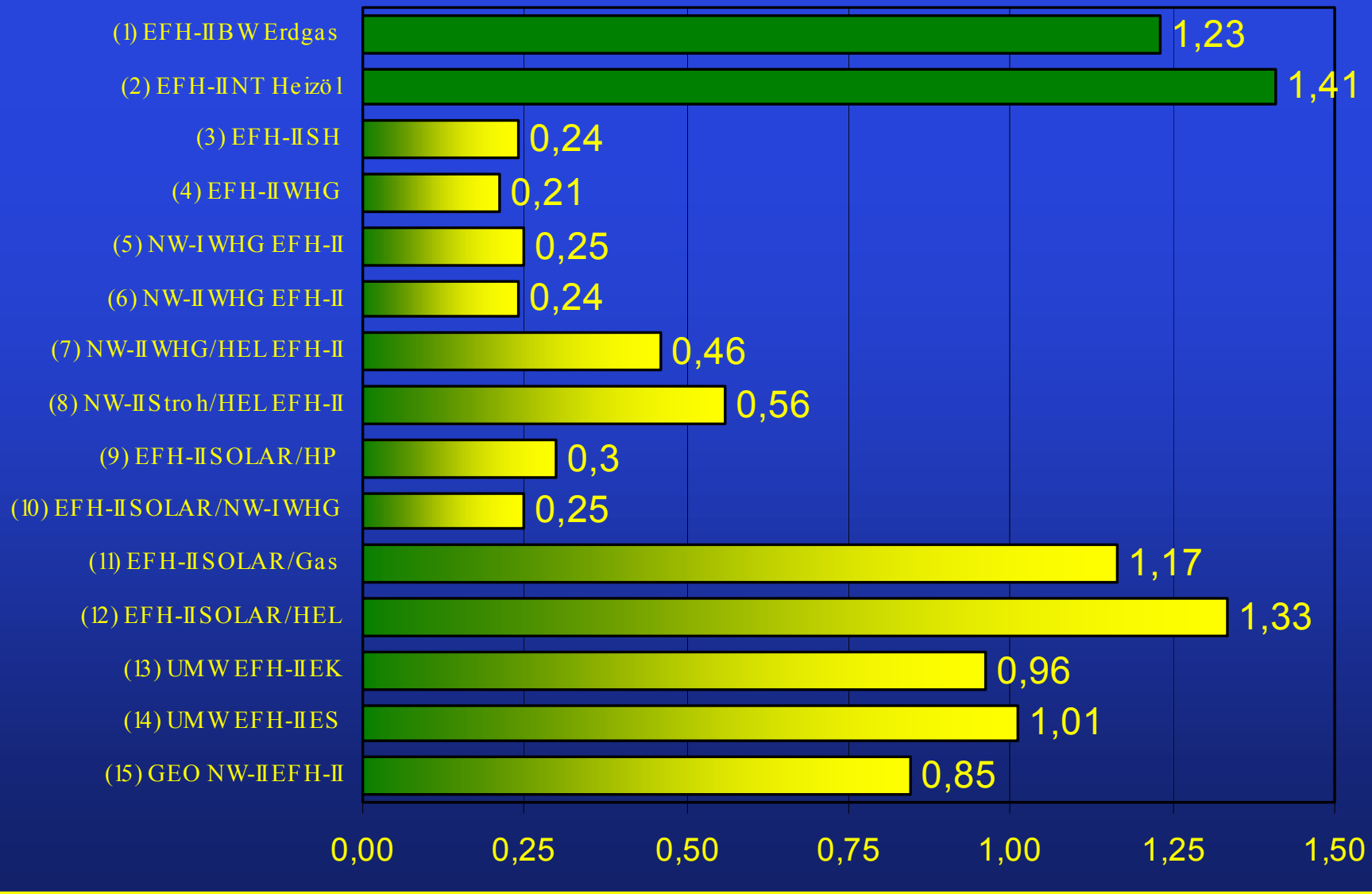
Comparison of environmental impacts from different renewable energy technologies

- **Bioenergy in comparison to other RE and fossile fired energy solutions**
  - **Heat supply**
  - **Fuels for the transportation sector**
  - **Power generation**

- **Environmental criteria under study:**
  - **Non-renewable primary energy use**
  - **Greenhouse gas emissions**
  - **Emissions with acidifying effects**
  - **Human- and ecotoxicological emissions**
    - Nitrogen oxide (NO_X)
    - Sulfur dioxide (SO_2)

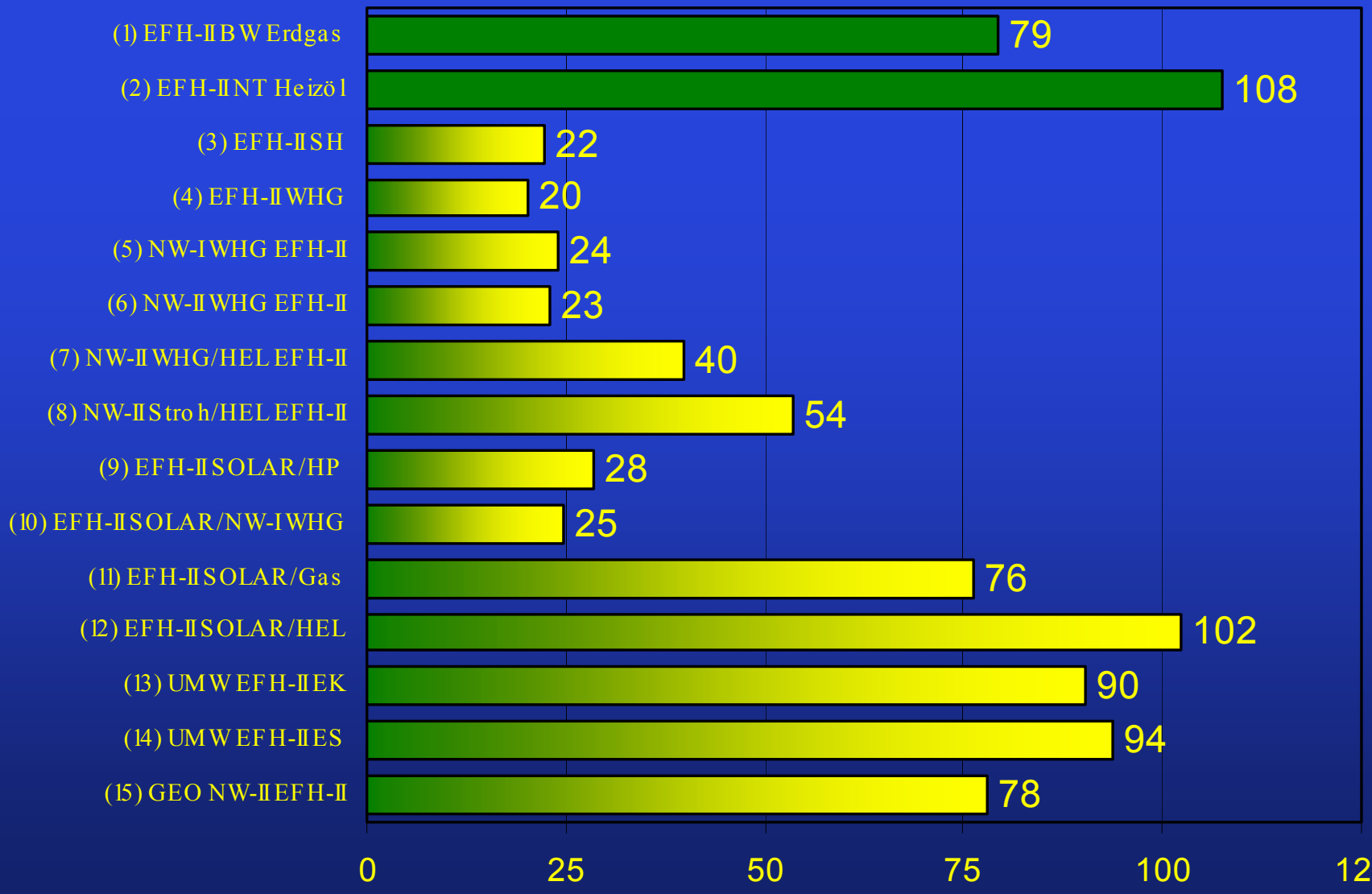
Heat supply from renewable energy

- Primary energy use (TJ_{Prim}/TJ_{Nutz}) -



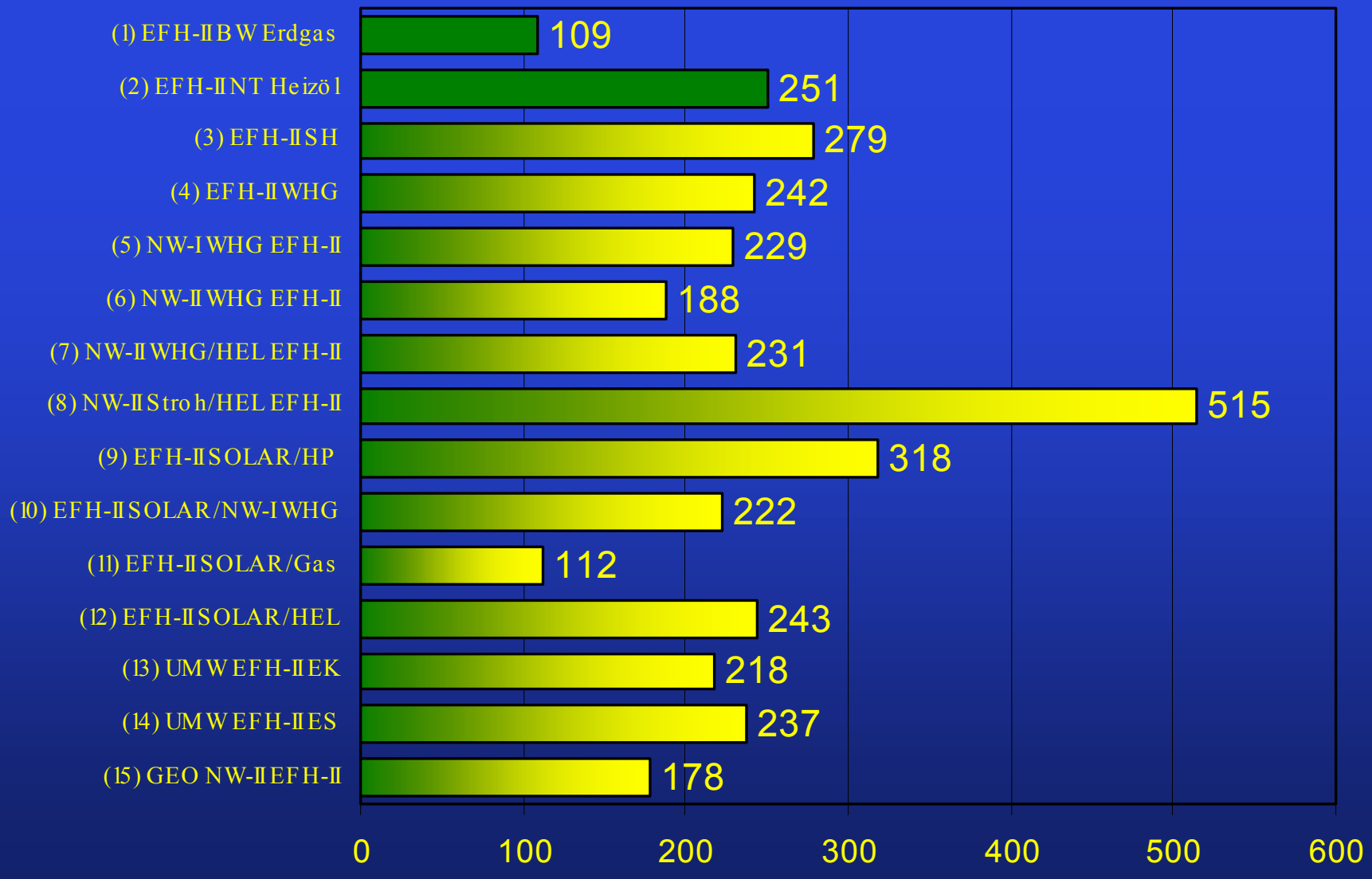
Heat supply from renewable energy

- Greenhouse gas emissions (t CO_2-Äquivalent/TJ_{Nutz}) -



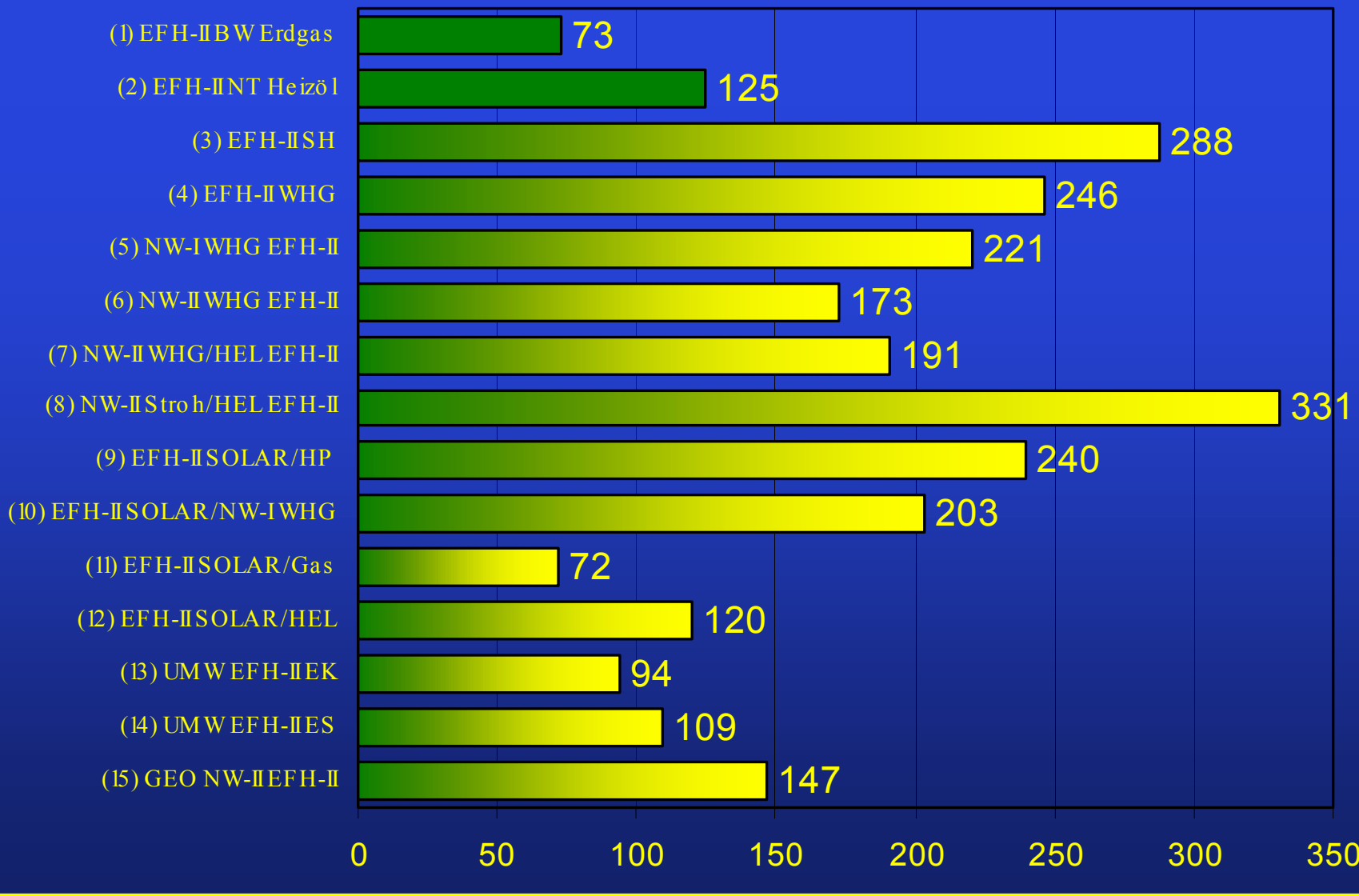
Heat supply from renewable energy

- Acidifying emissions (kg SO_2-Äquivalent/TJ_{Nutz}) -



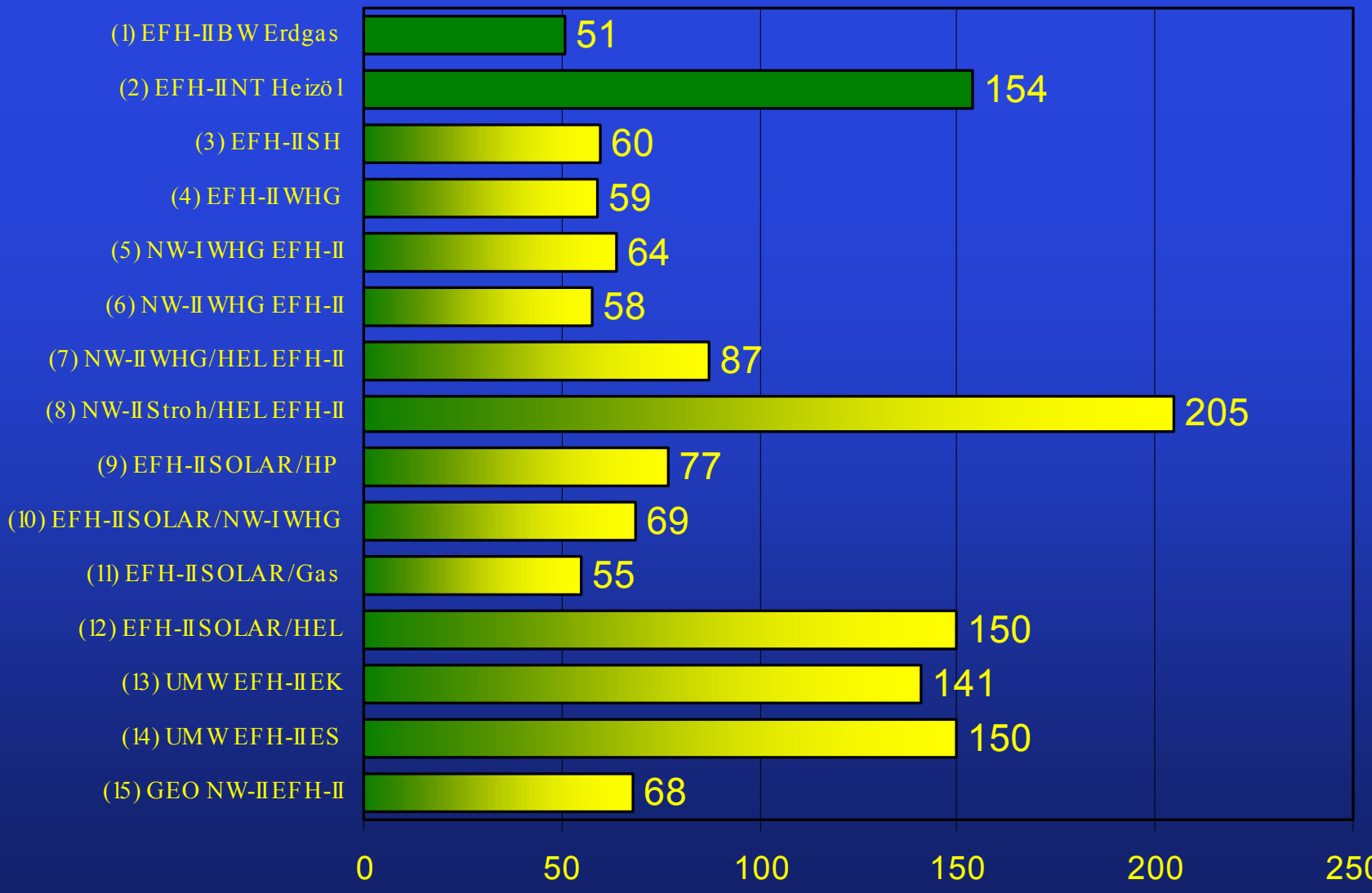
Heat supply from renewable energy

- Nitrogen oxide emissions (kg NO_X/TJ_{Nutz}) -



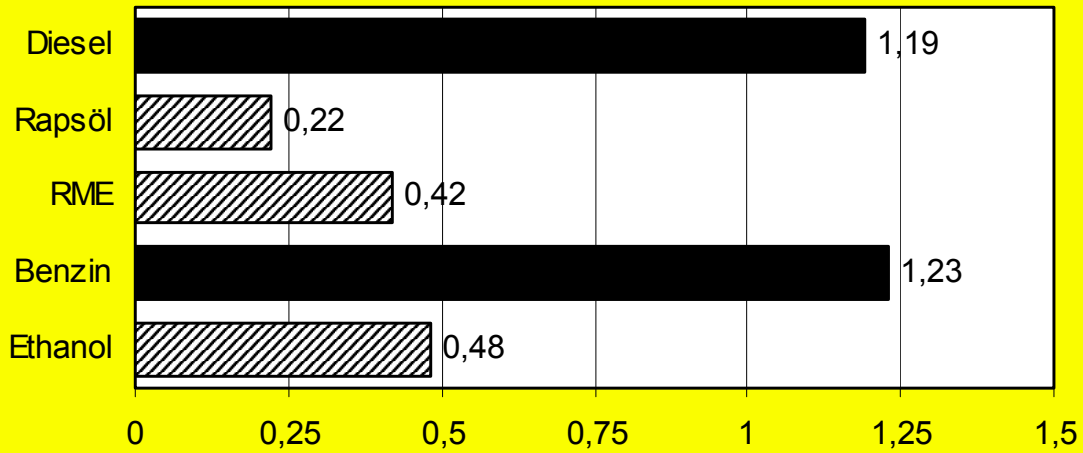
Heat supply from renewable energy

- Sulfur dioxide emissions (kg SO_2/TJ_{Nutz}) -



Motor fuels from renewable energy
- Primary energy use -

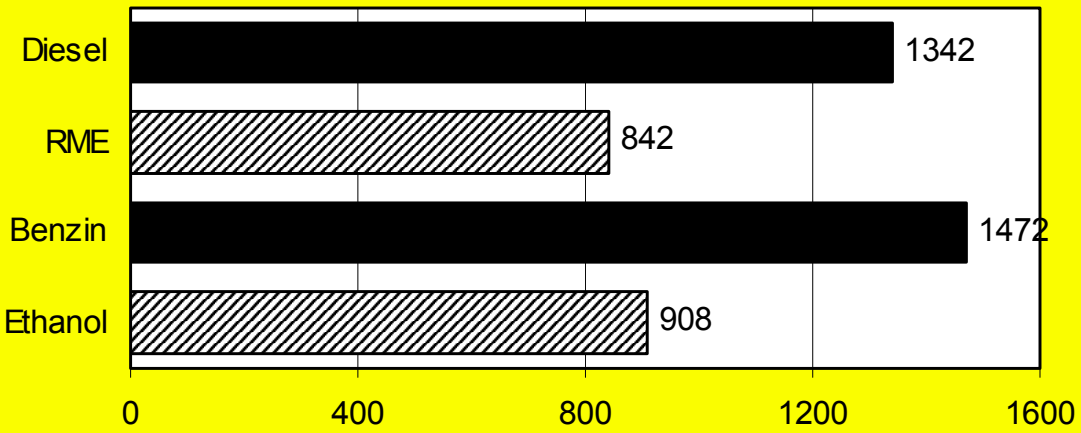
A - Primärenergieaufwand [TJ_{Prim}/TJ_{Hu}]



Motor fuels supply

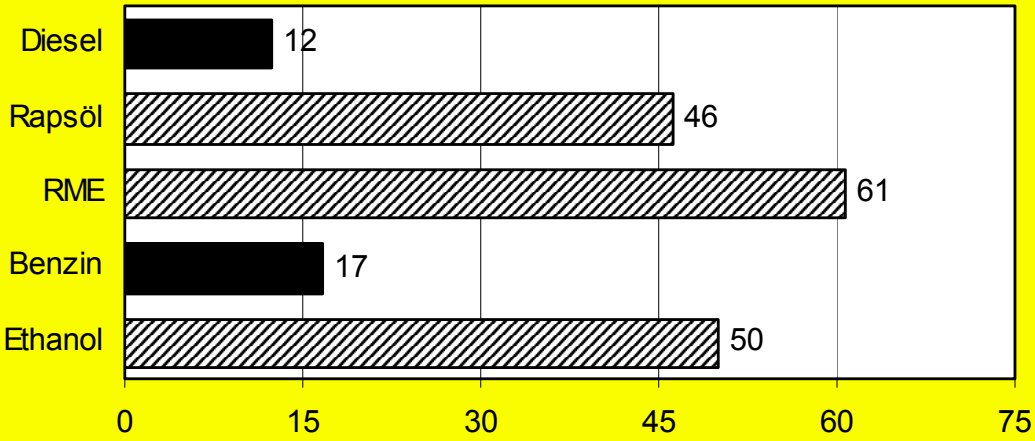
Motor fuels supply and use

A - Primärenergieaufwand [kWh_{Prim}/1000 Pkw-km]



Motor fuels from renewable energy
- Greenhouse gas emissions -

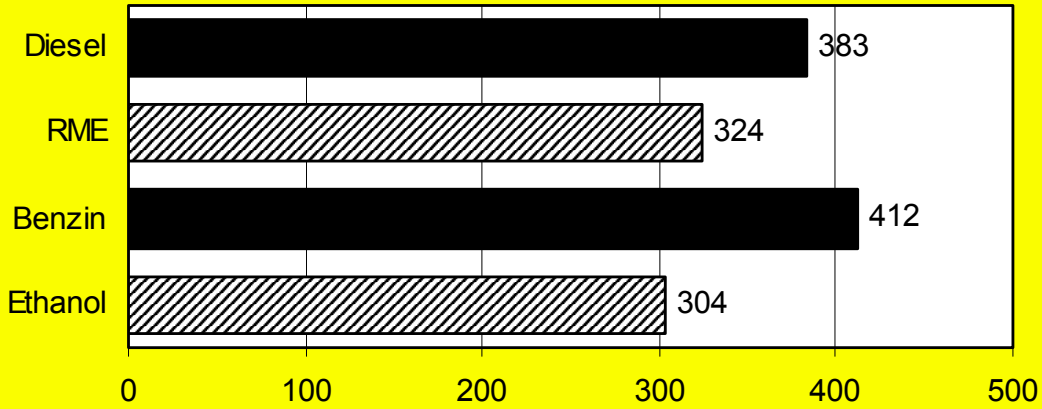
B - Treibhausgasemissionen
[t CO_2-Äquiv./TJ_{Hu}]



Motor fuels supply

Motor fuels supply and use

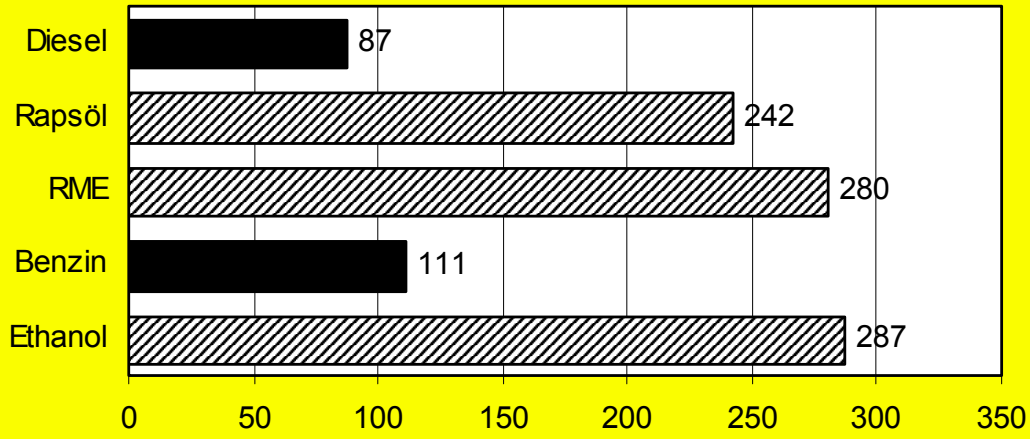
B - Treibhausgasemissionen
[kg CO_2-Äquiv./1000 Pkw-km]



Motor fuels from renewable energy
- Acidifying emissions -

C - Emissionen mit versauernder Wirkung

[kg SO_2-Äquiv./TJ_{Hu}]

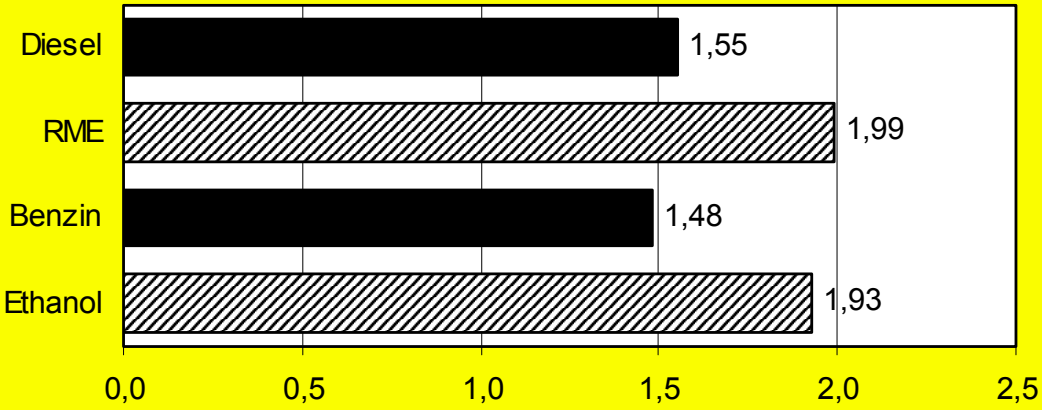


Motor fuels supply

Motor fuels supply and use

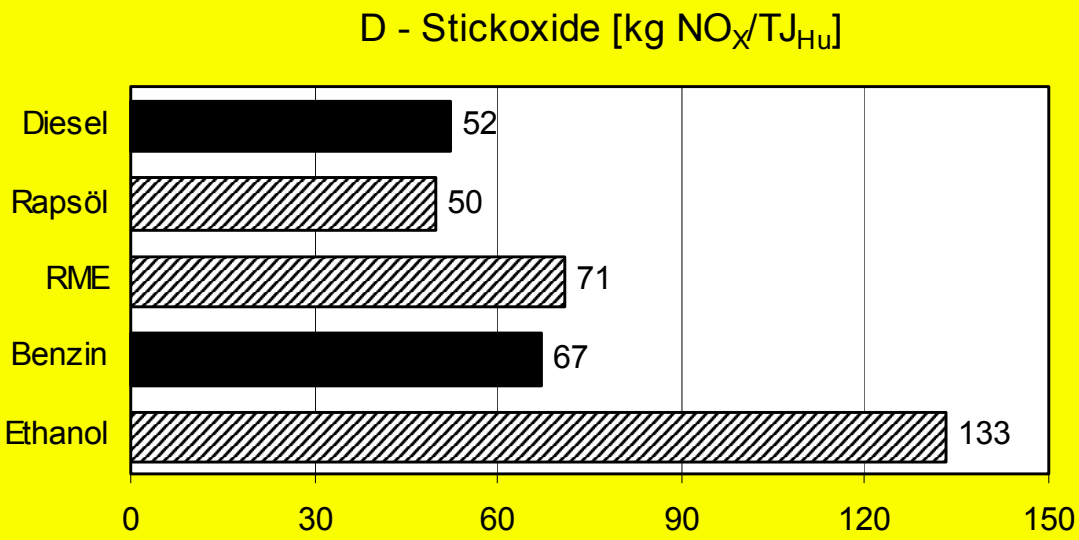
C - Emissionen mit versauernder Wirkung

[kg SO_2-Äquiv./1000 Pkw-km]

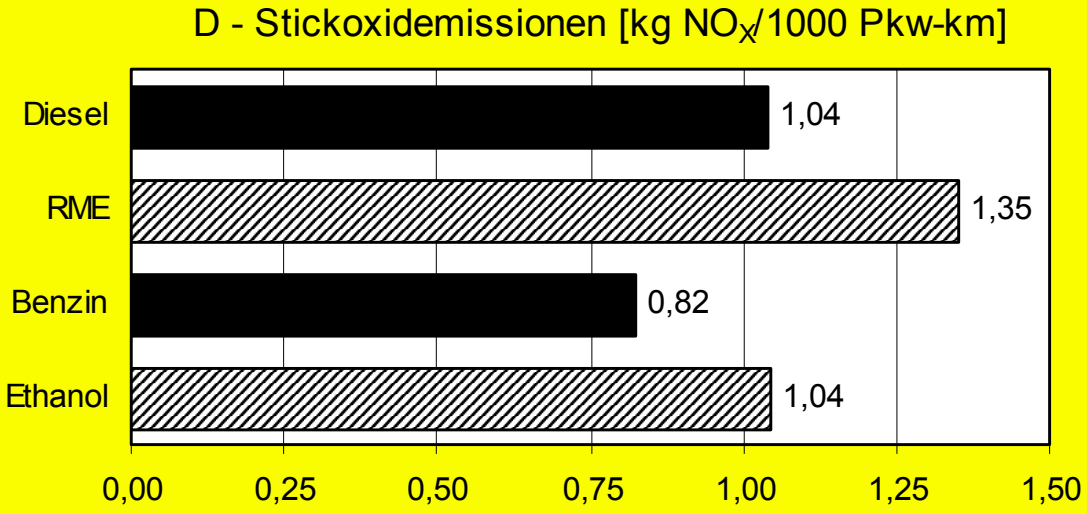


Motor fuels from renewable energy
- Nitrogen oxide emissions -

Motor fuels supply

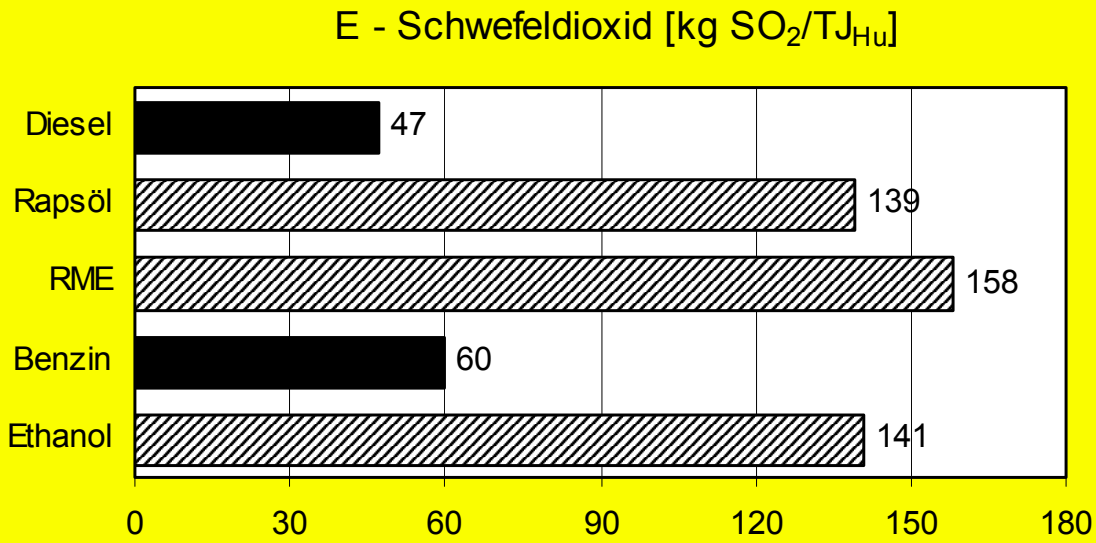


Motor fuels supply and use

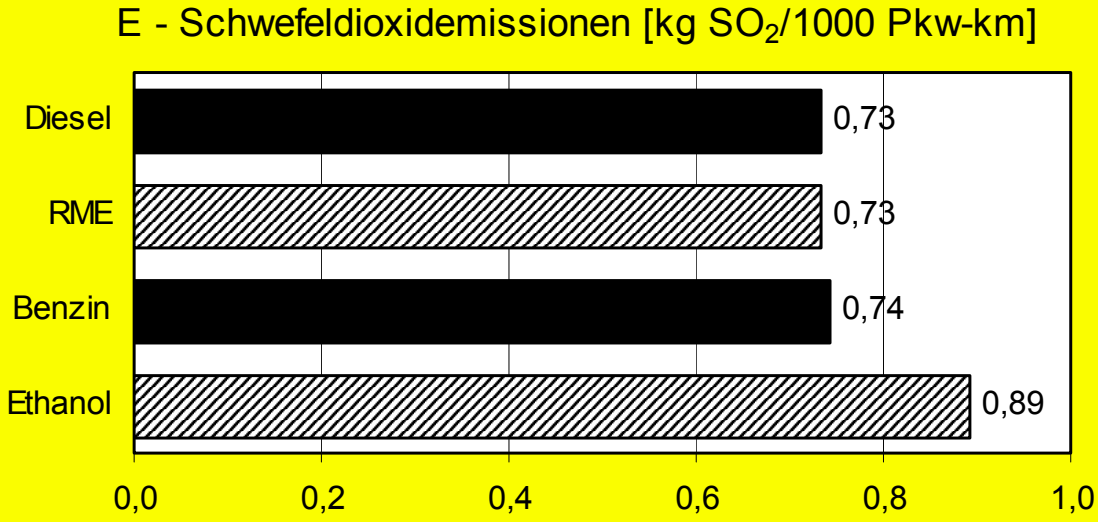


Motor fuels from renewable energy
- Sulfur dioxide emissions -

Motor fuels supply

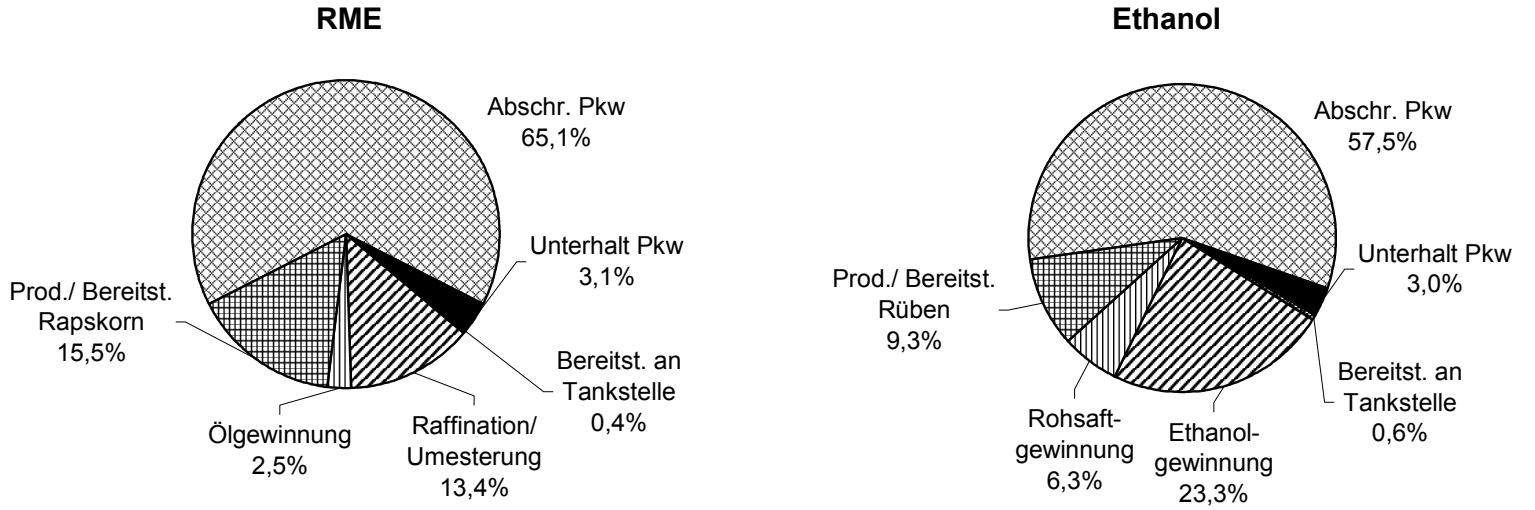


Motor fuels supply and use

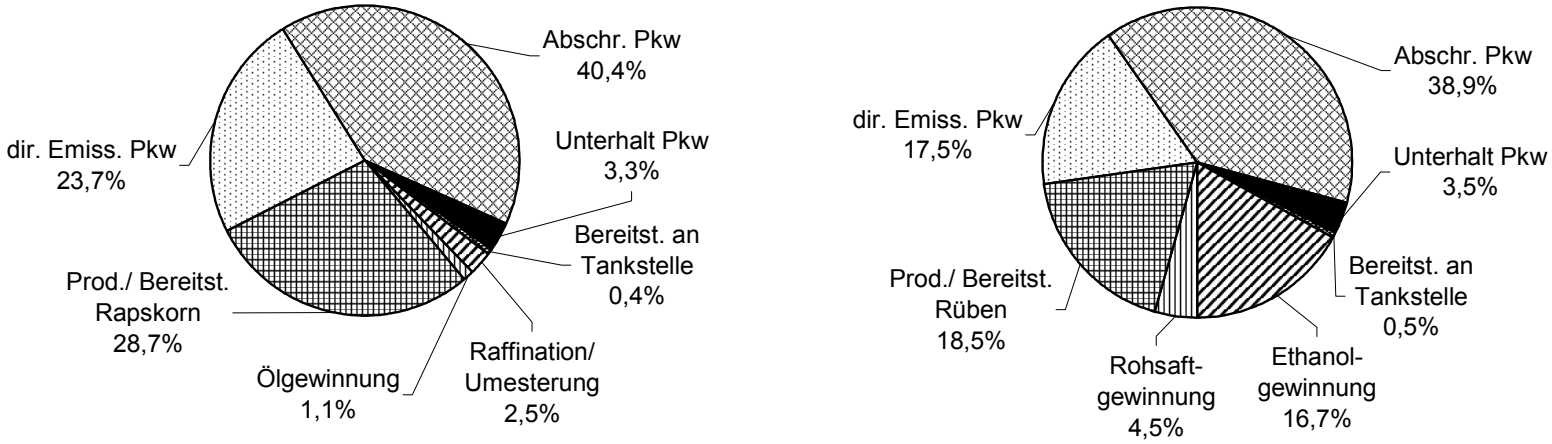


Motor fuels from renewable energy

- Life cycle contributions of different process chain segments -



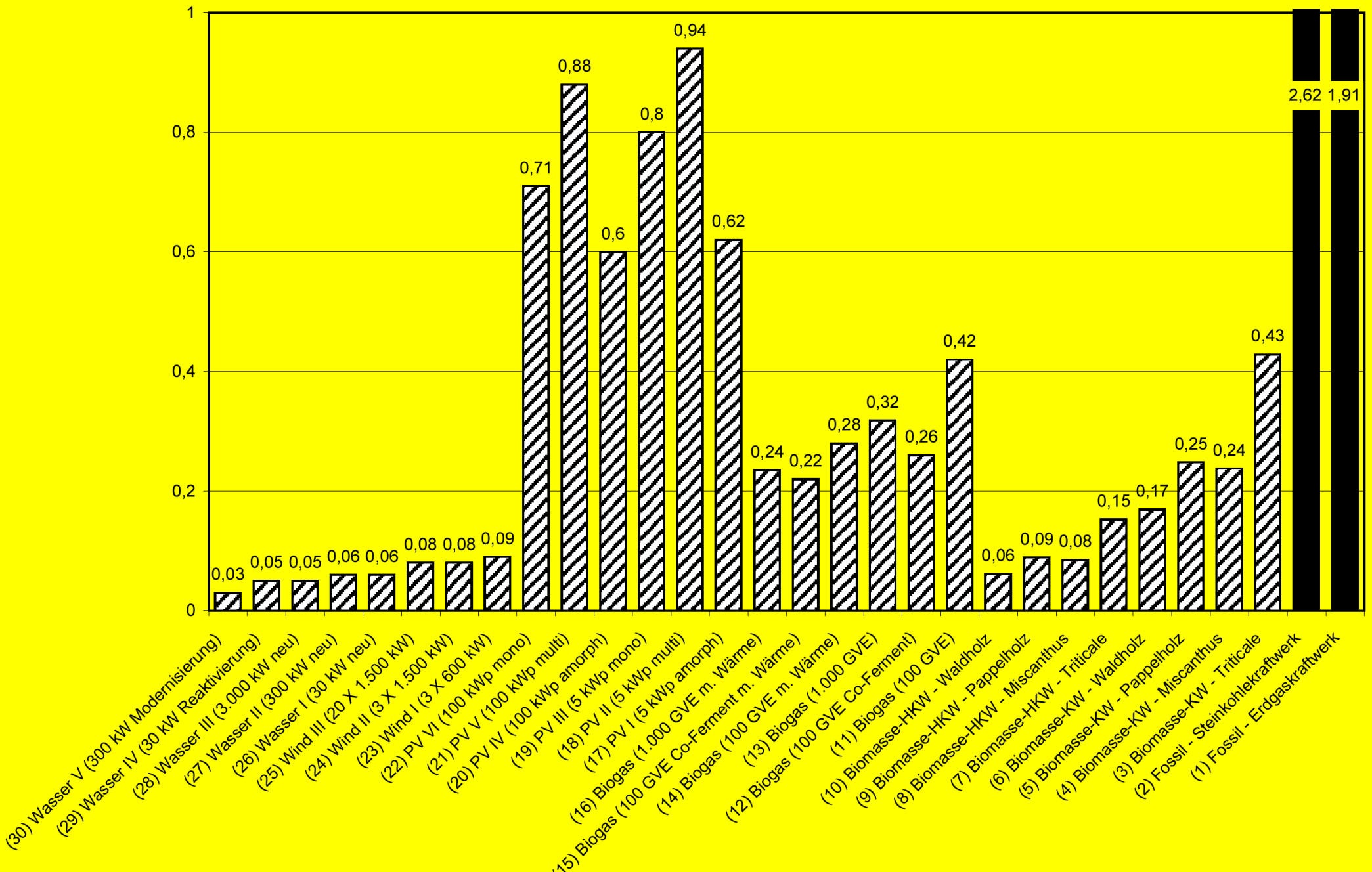
Primary energy use



Acidifying emissions

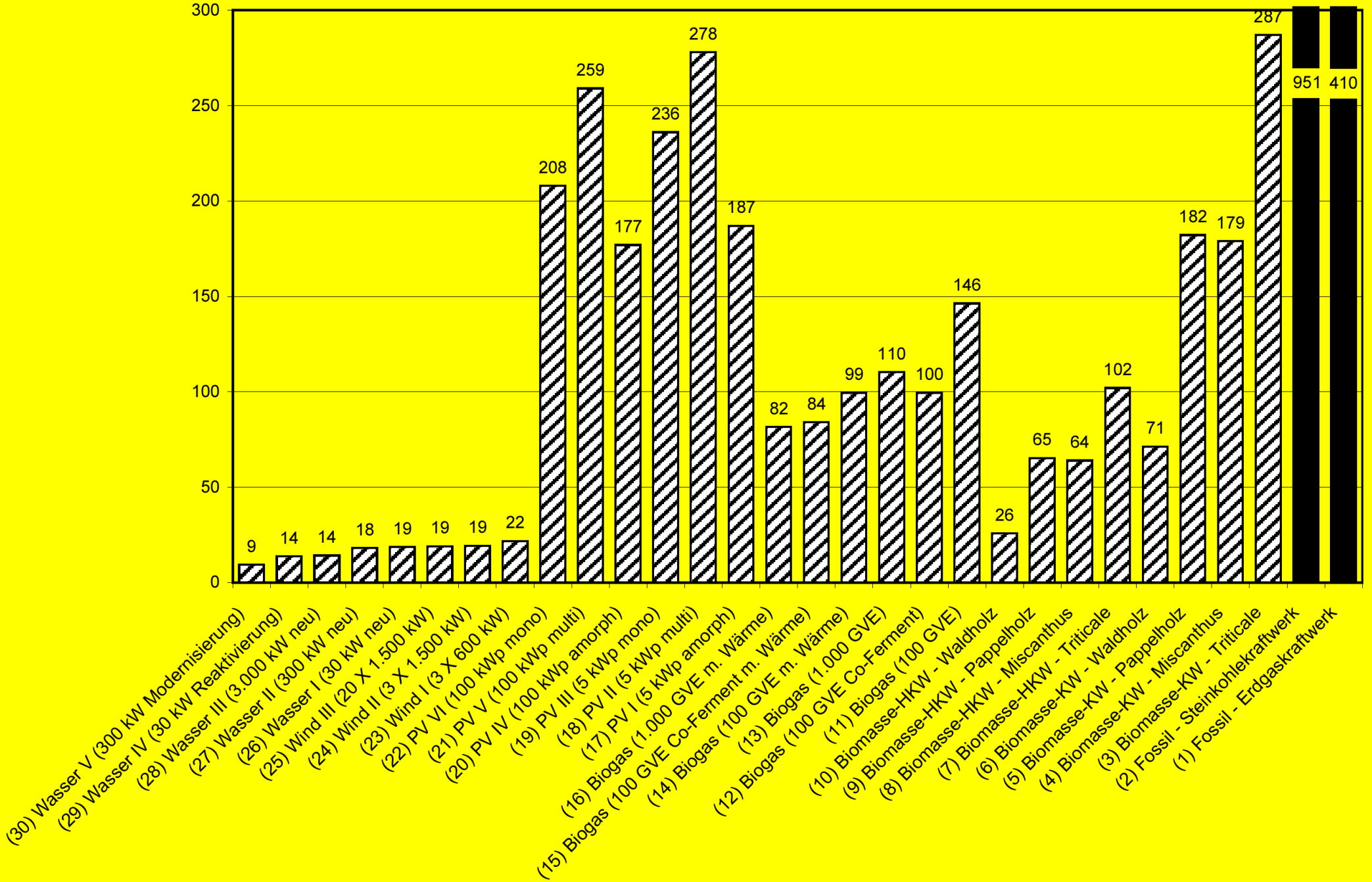
Power production from renewable energy

- Primary energy use (GWh_{Prim}/GWh_{Nutz}) -



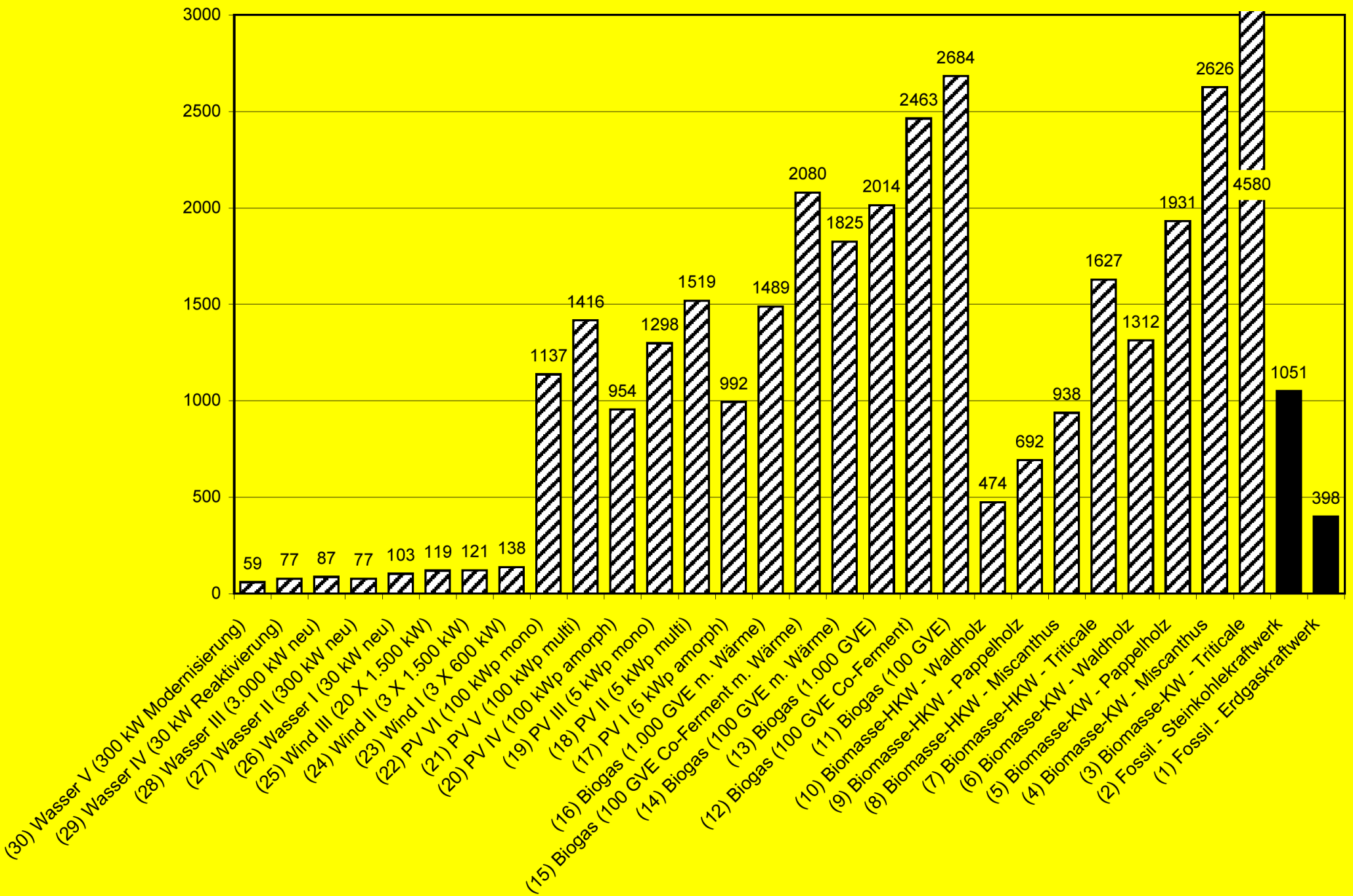
Power production from renewable energy

- Greenhouse gas emissions (t CO_2-Äquiv./GWh_{Nutz}) -



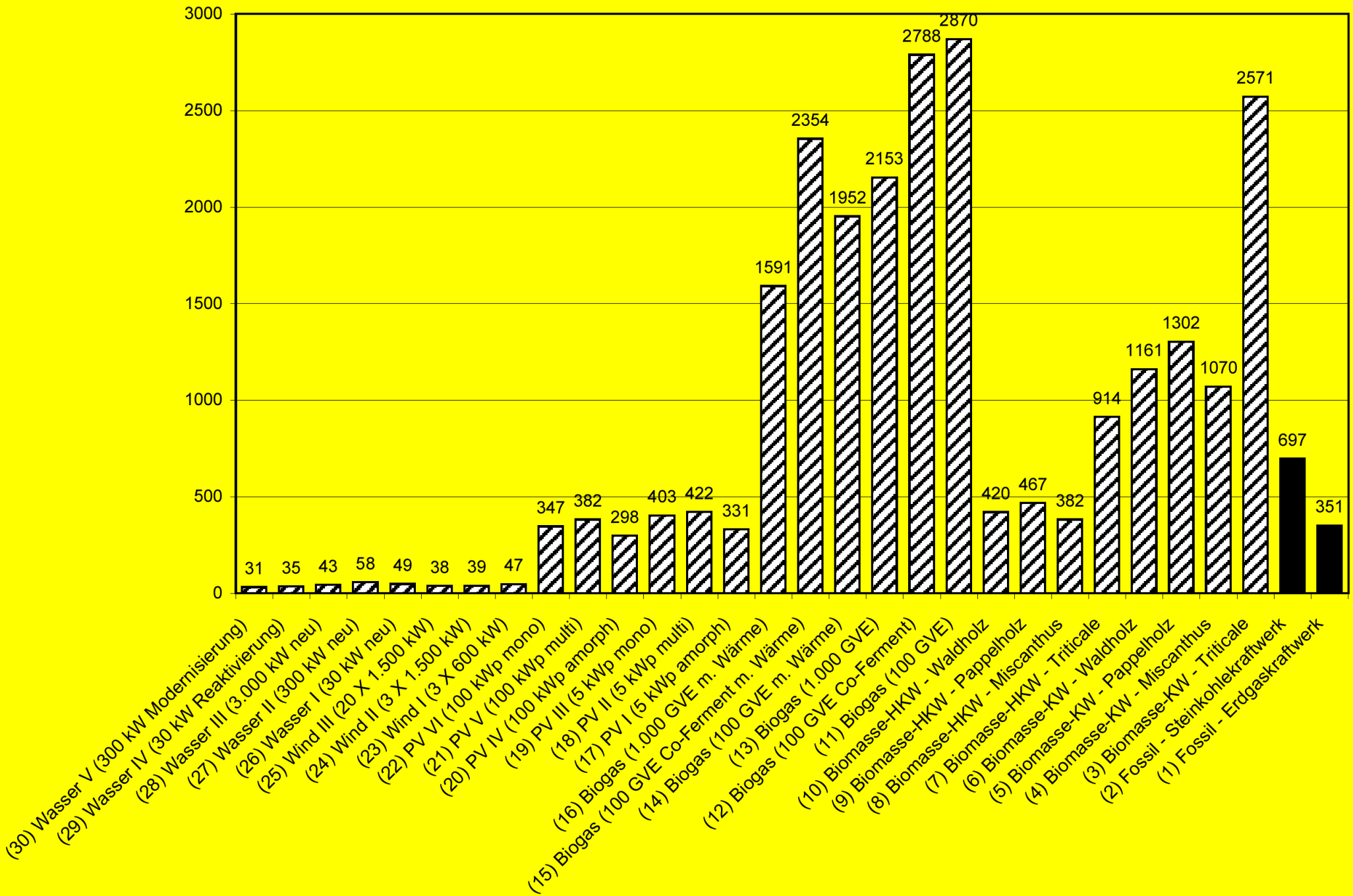
Power production from renewable energy

- Acidifying emissions (kg SO_2-Äquiv./GWh_{Nutz}) -



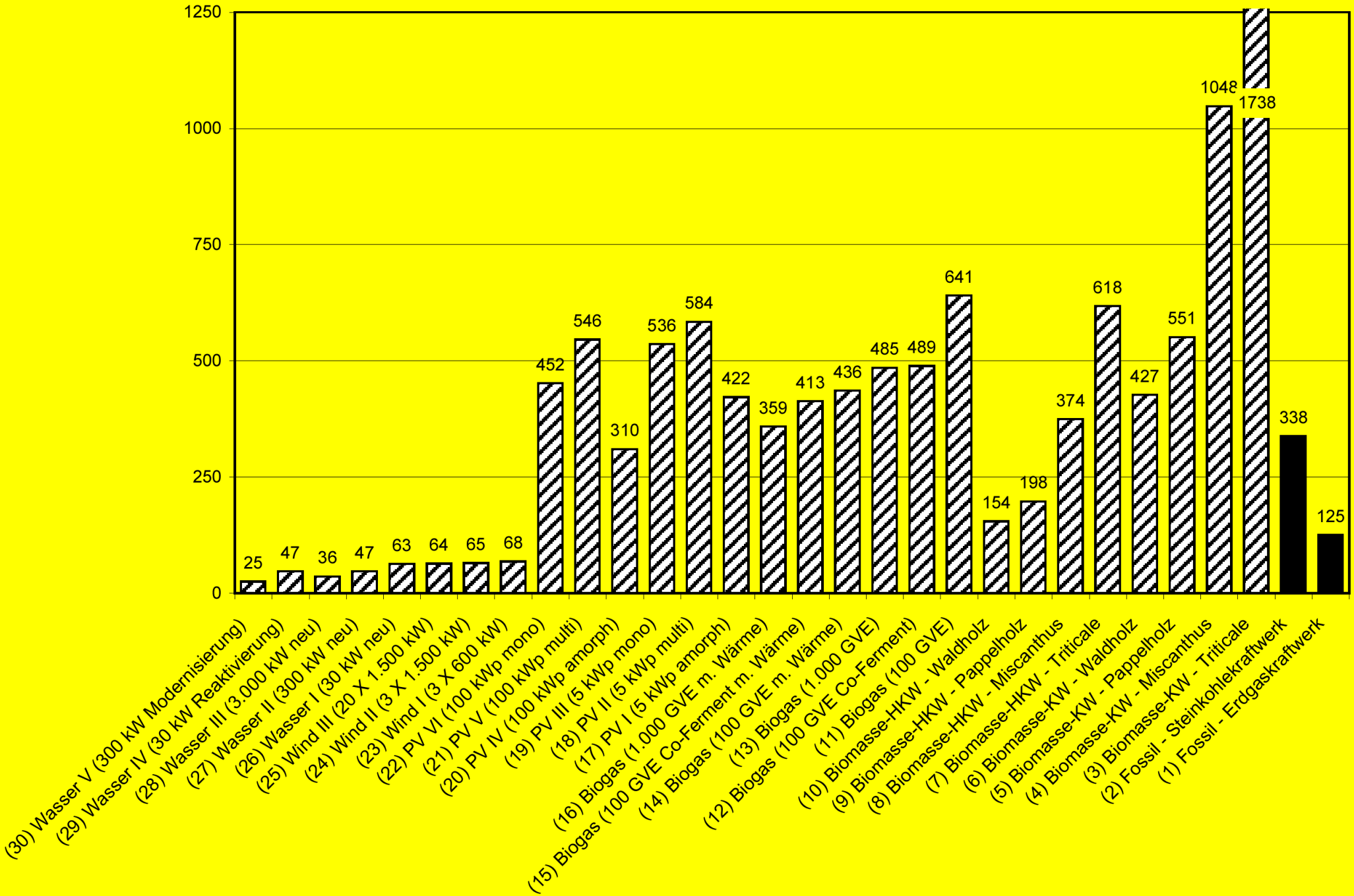
Power production from renewable energy

- Nitrogen oxide emissions (kg NO_x/GWh_{Nutz}) -



Power production from renewable energy

- Sulfur dioxide (kg SO_2/GWh_{Nutz}) -



Thank you for your attention!