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Environmental performance of electricity supply in Switzerland

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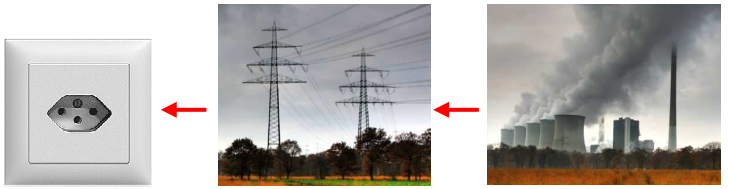
Boundary conditions

- **Initial situation**
  - Environmental performance of power generation as an important aspect for the Swiss energy policy/strategy
  - Requirement: up-to-date life cycle inventories
  - Partially only outdated data available in 2011
- **Goal**
  - Establishment of up-to-date & consistent inventories
  - Quantification of environmental burdens of current electricity supply technologies
- **Project funding**: Swiss Federal Office of Energy (SFOE)
- **Lead authors**: Christian Bauer (PSI), Rolf Frischknecht (today: treeze Ltd.)

Scope



- **Functional unit:** 1 kWh at low-voltage outlet
- **Technologies included**
  - Natural gas: combined cycle (CC) & small CHP plants *
  - Nuclear: BWR & PWR *
  - Hydro power: reservoir, run-of-river, small hydro *
  - Photovoltaic (roof-top) *
  - Biogas & wood CHP
  - Wind turbine

* Major update of ecoinvent v2.2 inventory data reflecting up-to-date conditions in the fuel chains

Environmental indicators used for evaluation

Indicator	LCIA method used for quantification
Greenhouse gas emissions	IPCC 2007
Particulate matter formation	ReCiPe (H) (Goedkoop et al. 2009)
Ecosystem damage due to land occupation	Koellner 2001
Cumulative energy demand (CED), non-renewable / renewable	Frischknecht et al. 2007
Abiotic resource depletion: metals & minerals	CML 2001 (Guinée et al. 2001)
High-level radioactive waste	Cumulative inventory result
Ionising radiation	ReCiPe (H) (Goedkoop et al. 2009)

Technology specification (I)

Technology	Capactiy electric	Lifetime	Full load hours	Electric efficiency	Thermal efficiency
	kW_{el}	a	h/a	%	%
Nuclear, BWR	1'220'000	50	7'700	32	-
Natural gas CC	400'000	22.5	8'000	58	4.5
Natural gas CHP	50	25	4'000	33	56
Natural gas CHP	160	25	4'000	37	53
PV, mono-Si	3	30	922	14.0	-
PV, multi-Si	3	30	922	13.6	-
PV, CdTe laminate	3	30	922	11.7	-

Technology specification (II)

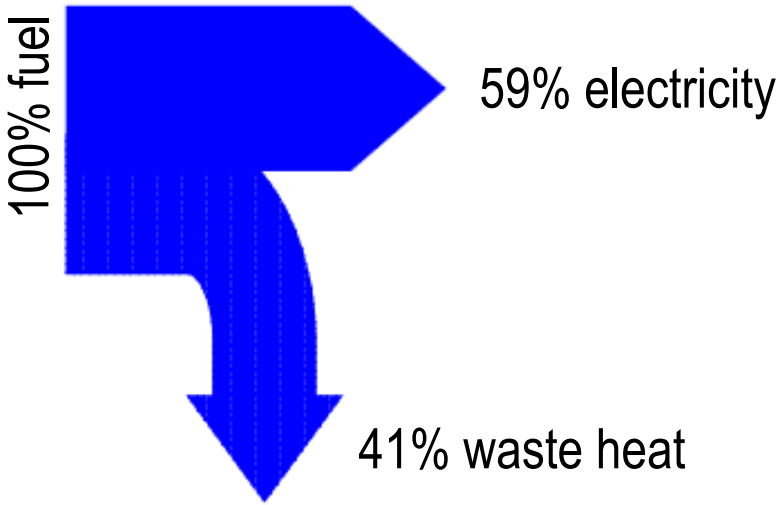
Technology	Capactiy electric	Lifetime	Full load hours	Electric efficiency	Thermal efficiency
	kW_{el}	a	h/a	%	%
Hydro: reservoir	95'000	150	2'000	78	-
Hydro: run-of-river	8'600	80	4'500	82	-
Small hydro	180	70	6'100	82	-
Municipal waste incineration	n.s.	n.s.	n.s.	8.6	18.4
Wind turbine	800	20	1'230	25	-
Wood CHP	335	20	6'250	3.2	76.8
Biogas CHP	160	25	4'000	33	30

Natural gas

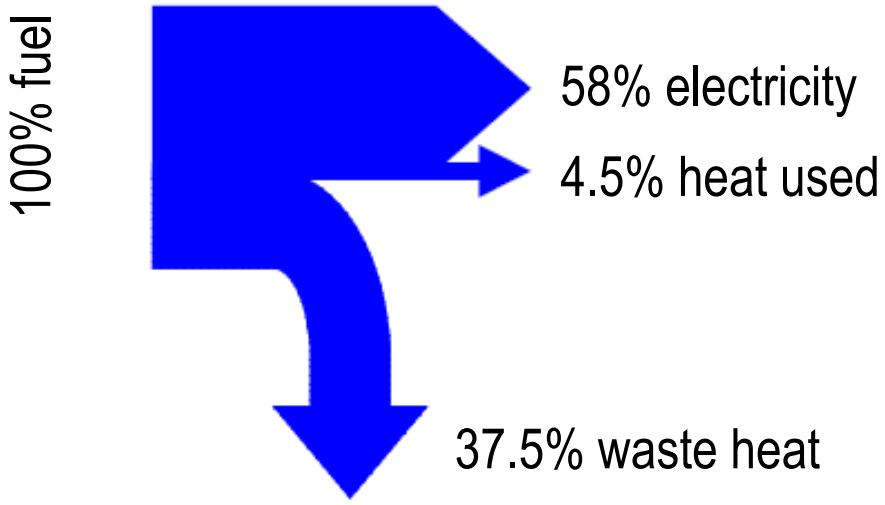
- **Production & transport**
  - Latest data on origin: 1/3 from RU, ~25% from NO & NL, 3% LNG
  - Update of losses in transport & distribution
- **Combined cycle plant**
  - Use of waste heat considered → CHP mode due to legal regulation
- **Small CHP plants**
  - Efficiencies updated according to techologies available on the Swiss market today

Natural gas combined cycle plant

Electricity generation only



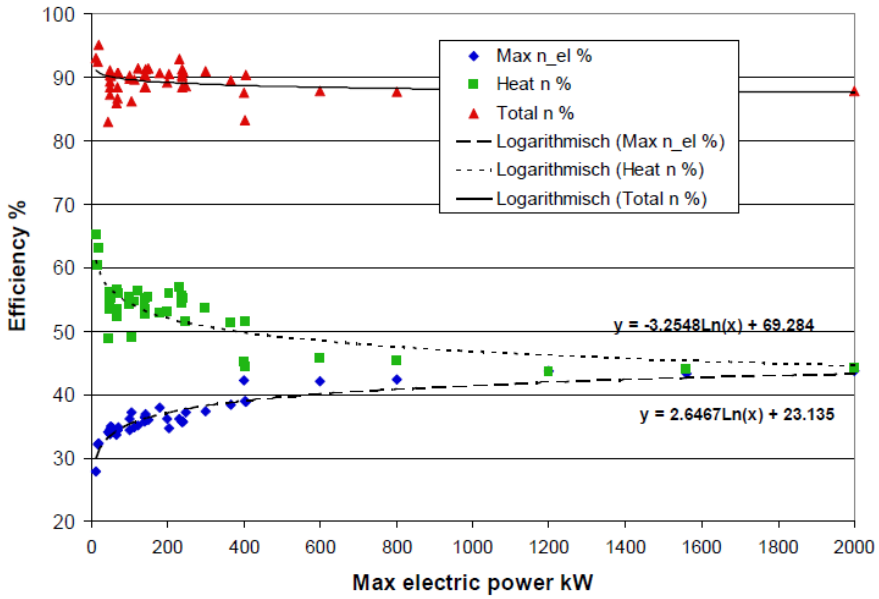
CHP mode: >62% efficiency



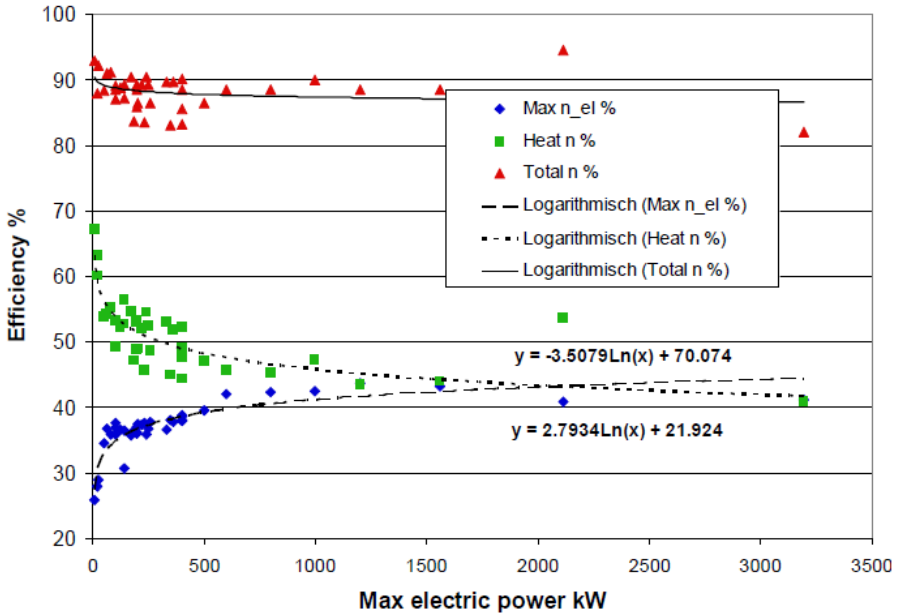
Allocation: exergy

Natural gas small CHP plants: efficiencies

Lambda=1 CHPs



Lean burn CHPs



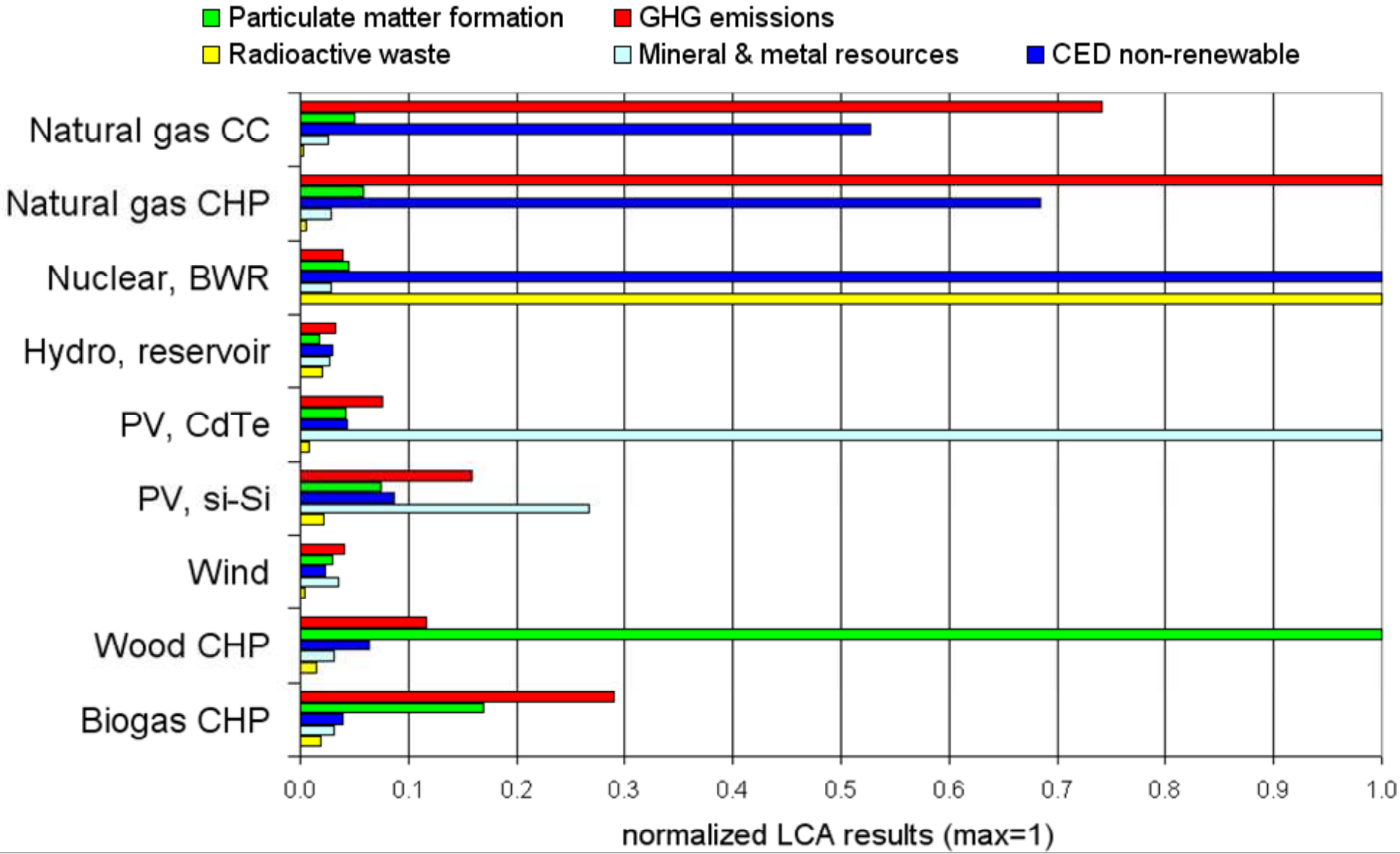
Nuclear

- **Focus on upstream chain**
  - No CH-specific info for fuel supply available → GLO avg. conditions
- **Uranium mining**
  - New processes for ISL, and mining in RU, AU, CA, BR, NA, NE, MW, UA representing 96% of world production in 2010
  - GLO mix: 36% ISL (KZ, UZ, USA), 21% CA, 16% AU, 10% NA, 7% RU
- **Enrichment**
  - 65% centrifuge, 35% diffusion
- **Reactor**
  - 50 years lifetime

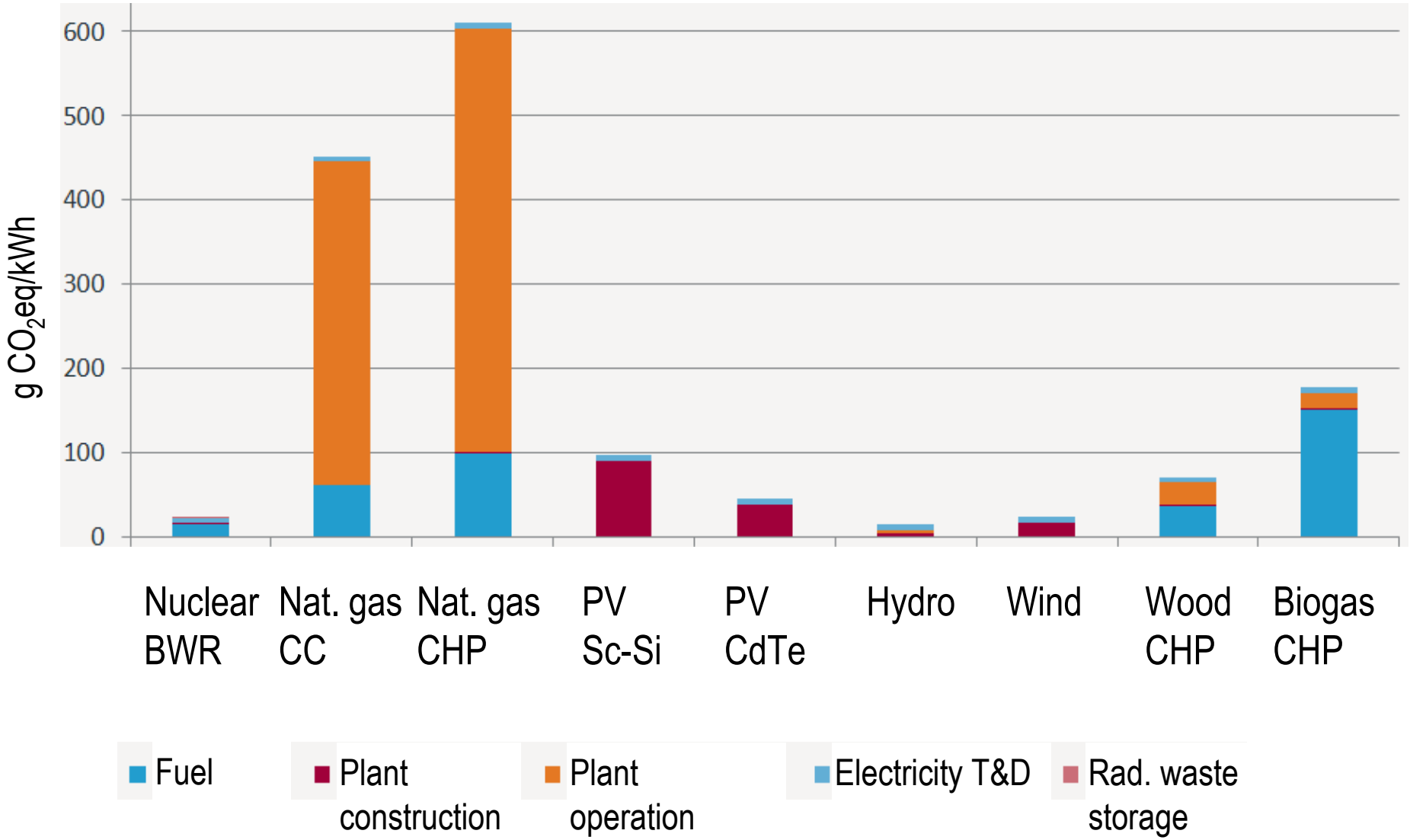
Photovoltaic

- **Origin of modules**
  - 2/3 Europe, 1/3 China
- **Production of mc-Si**
  - Sites in CN, DE, NO, US with specific electricity supply
- **Wafer production**
- **CdTe modules**
- **Module efficiencies**
  - sc-Si: 14%; mc-Si: 13.6%; CdTe: 11.7%
- **Avg. CH annual yield**: 922 kWh/kWp

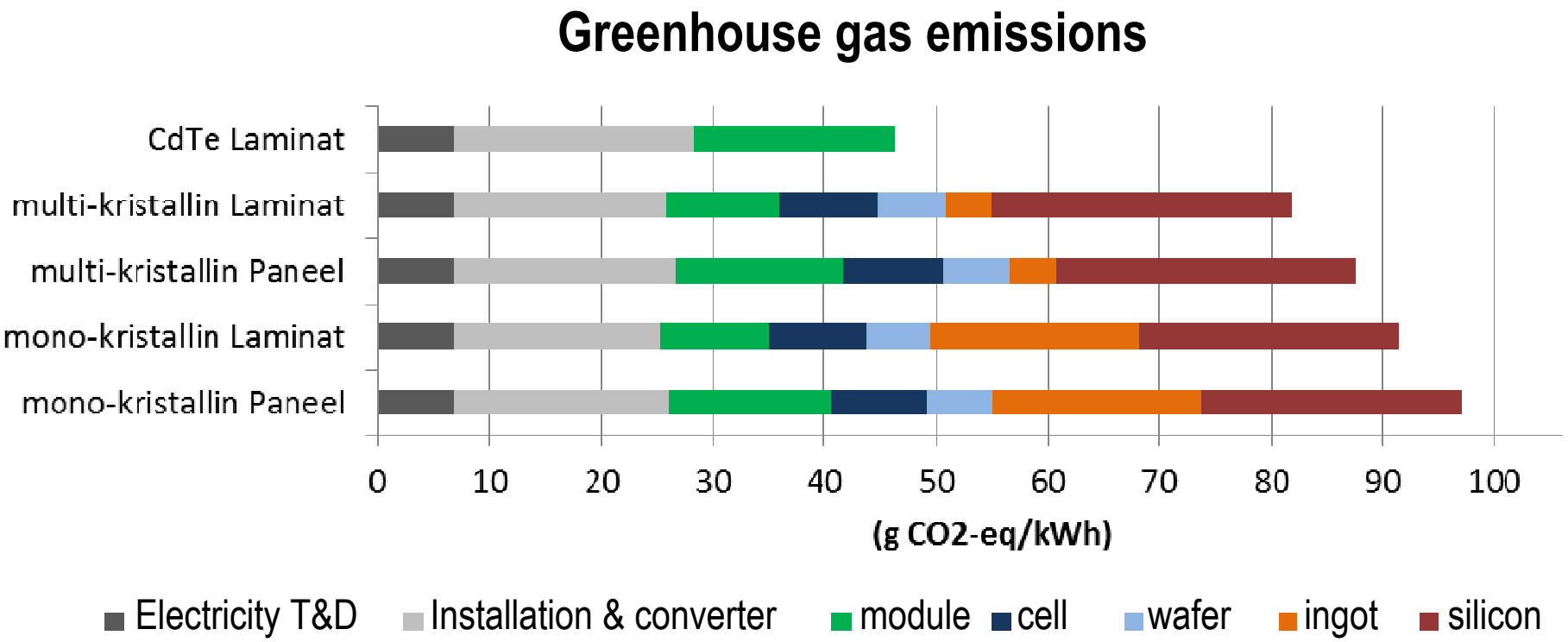
LCA results: overview



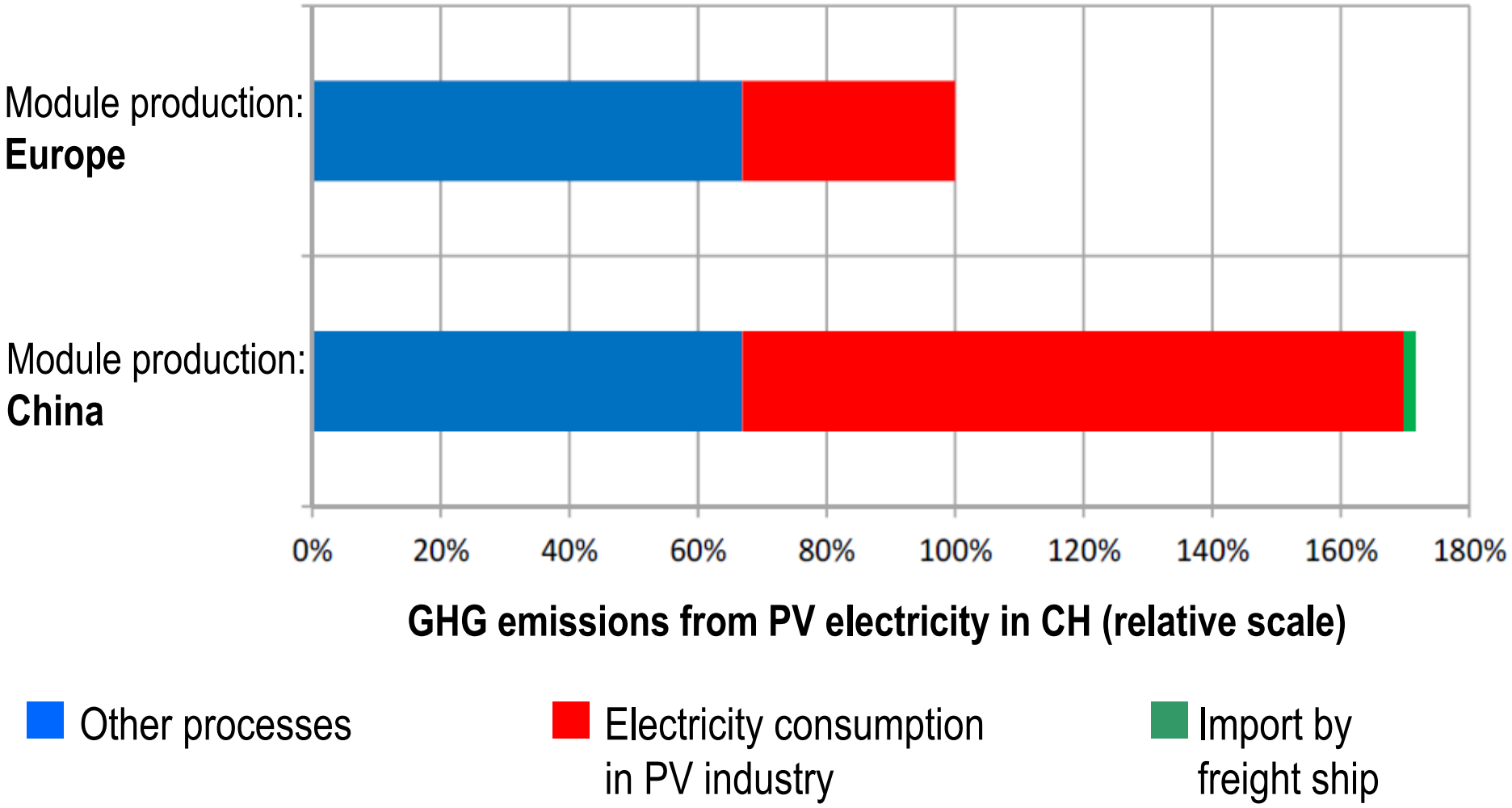
LCA results: GHG emissions



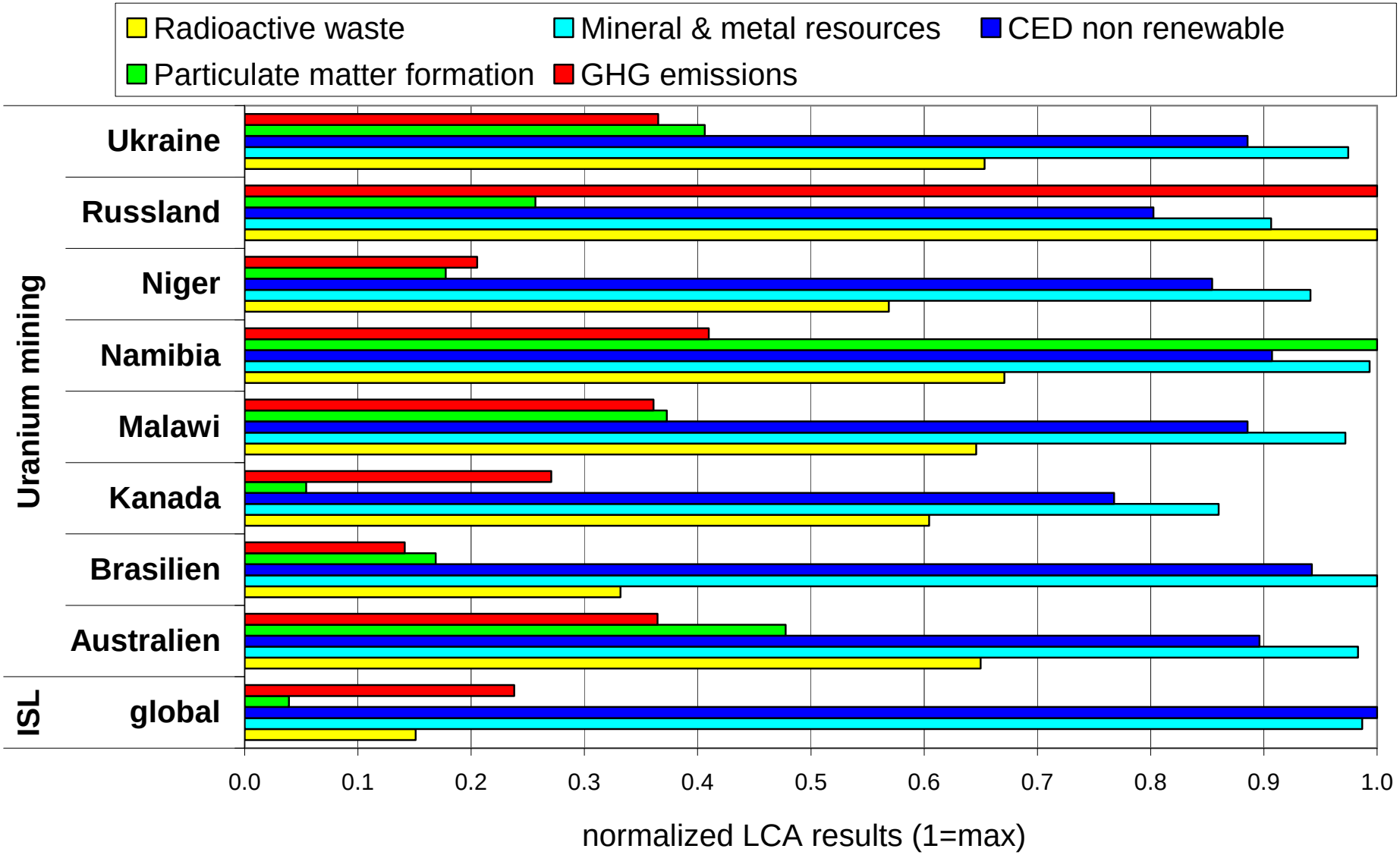
Photovoltaic: contribution of components



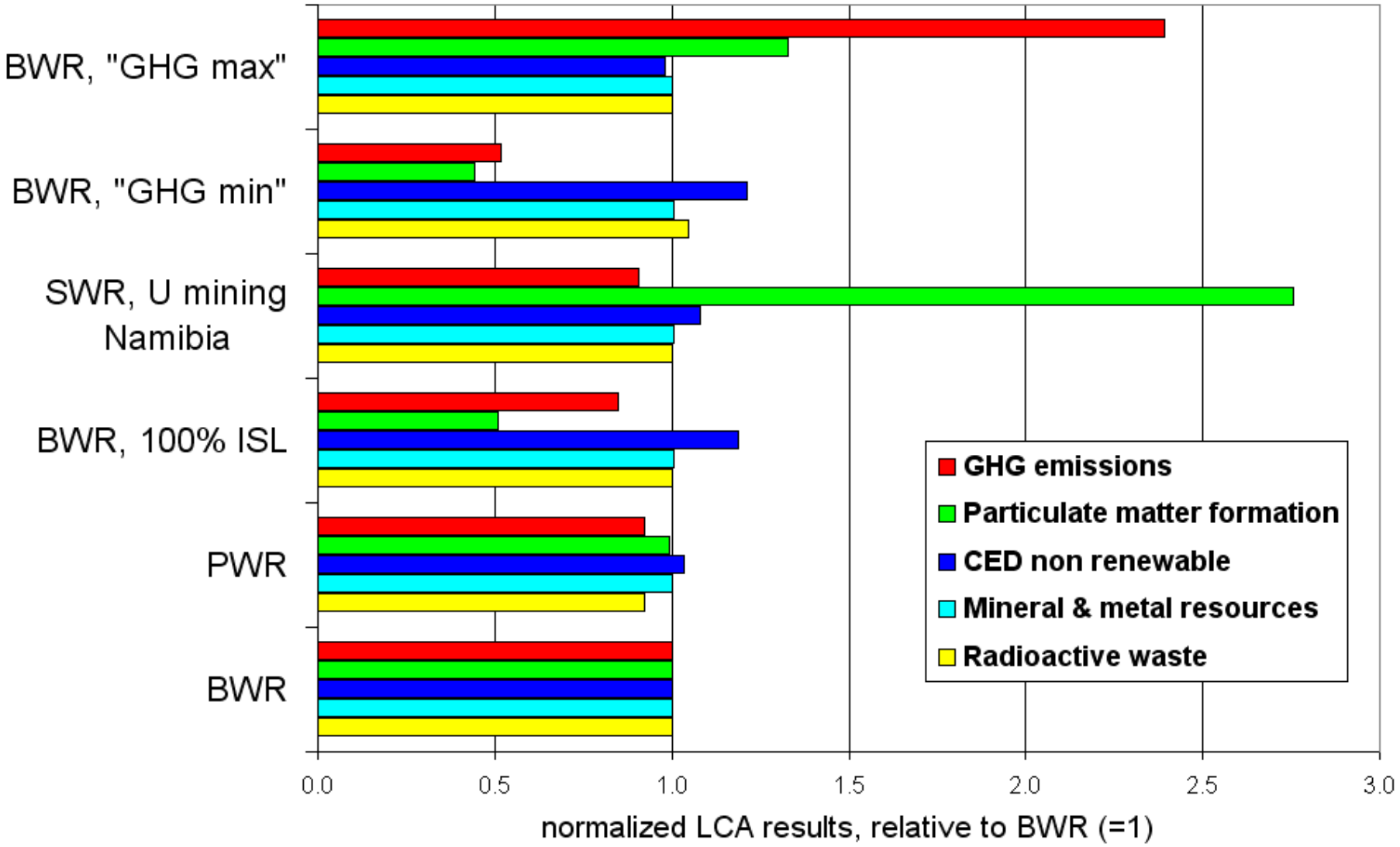
Photovoltaic: module production EU vs China



LCA results: nuclear, uranium production



LCA results: nuclear, sensitivity



Conclusions – results of this study

- Hydro & wind power: lowest environmental impacts
- Natural gas: high GHG emissions
- Low GHG emissions from most renewables & nuclear
- Air pollution: only biomass can be problematic
- Mineral resources: recycling as a key aspect (photovoltaics)
- Energy resouces: nuclear & nat. gas with highest non-renewable demand

Conclusions – recommendations for energy strategy

- **Maintaining LCA** as the central tool for evaluating environmental impacts
- Only use of **up-to-date inventory data** for decision support
- Also **electricity imports** should be evaluated
- **Long-term strategy** would very much profit of prospective LCA, i.e. assessment of **future technologies**

Thanks to:

All co-authors

Rolf Frischknecht & colleagues from treeze & esu-services (collaboration)

Federal office of energy (funding)

Report:

„Umweltauswirkungen der Stromerzeugung in der Schweiz “

http://www.bfe.admin.ch/themen/00526/00527/index.html?lang=en&dossier_id=05673

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