CO_2 Emissions of nuclear electricity generation

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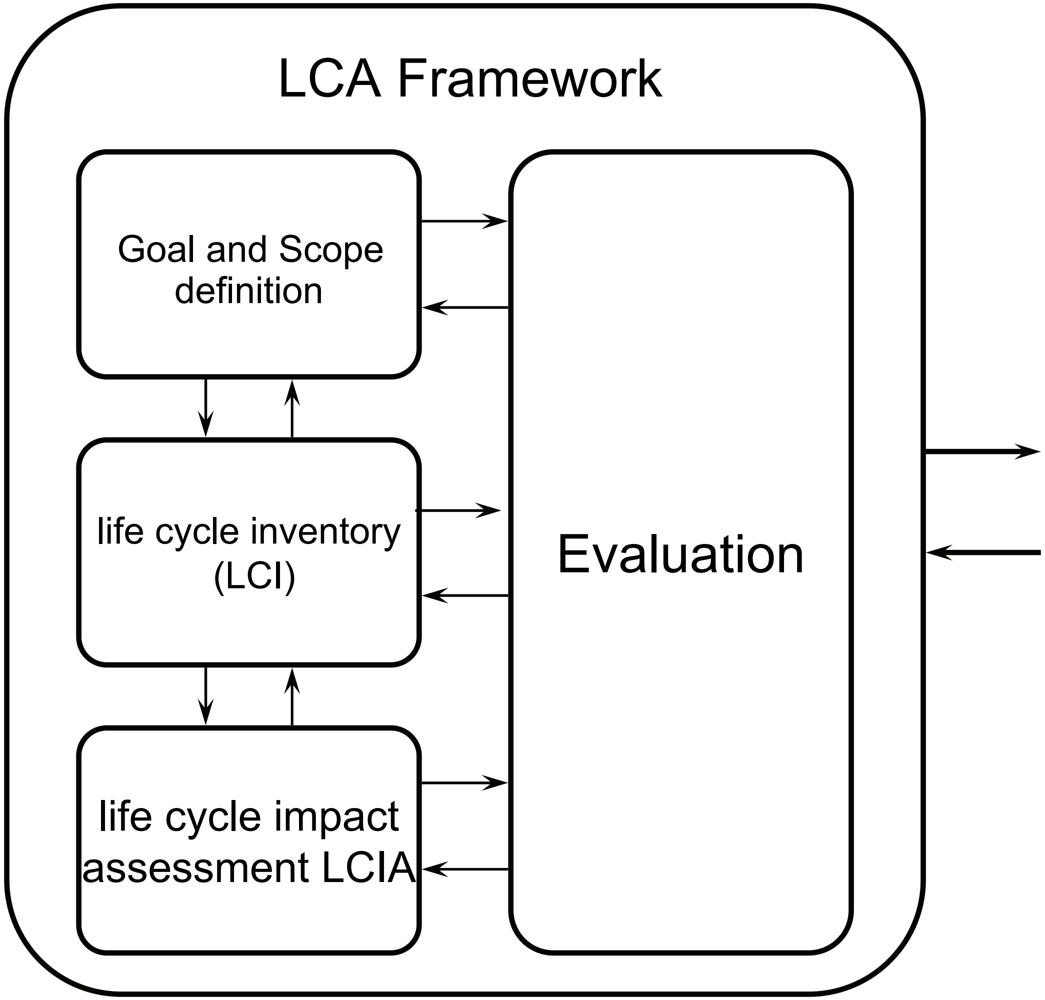
Introduction

Due to the growing concerns over anthropogenic climate change, which are strengthened by the latest report of the IPCC (Intergovernmental Panel on Climate Change), political, social and scientific institutions postulate an increasing deployment of nuclear power in order to minimize the release of greenhouse gas emissions.

In recently published studies /Bossel 2007/, /University of Sidney 2007/ and /van Leeuwen 2005/ authors argument that by a global expansion of nuclear power capacity the life cycle CO_2 emissions of this technology will increase significantly. Their results are based on the assumption that CO_2 emissions from nuclear power will steadily rise, e.g. due to growing energy expenditures for both uranium preperation and extraction of uranium from very low-grade ores in mines.

Procedure of a LCA study according to ISO 14040 et seqq.

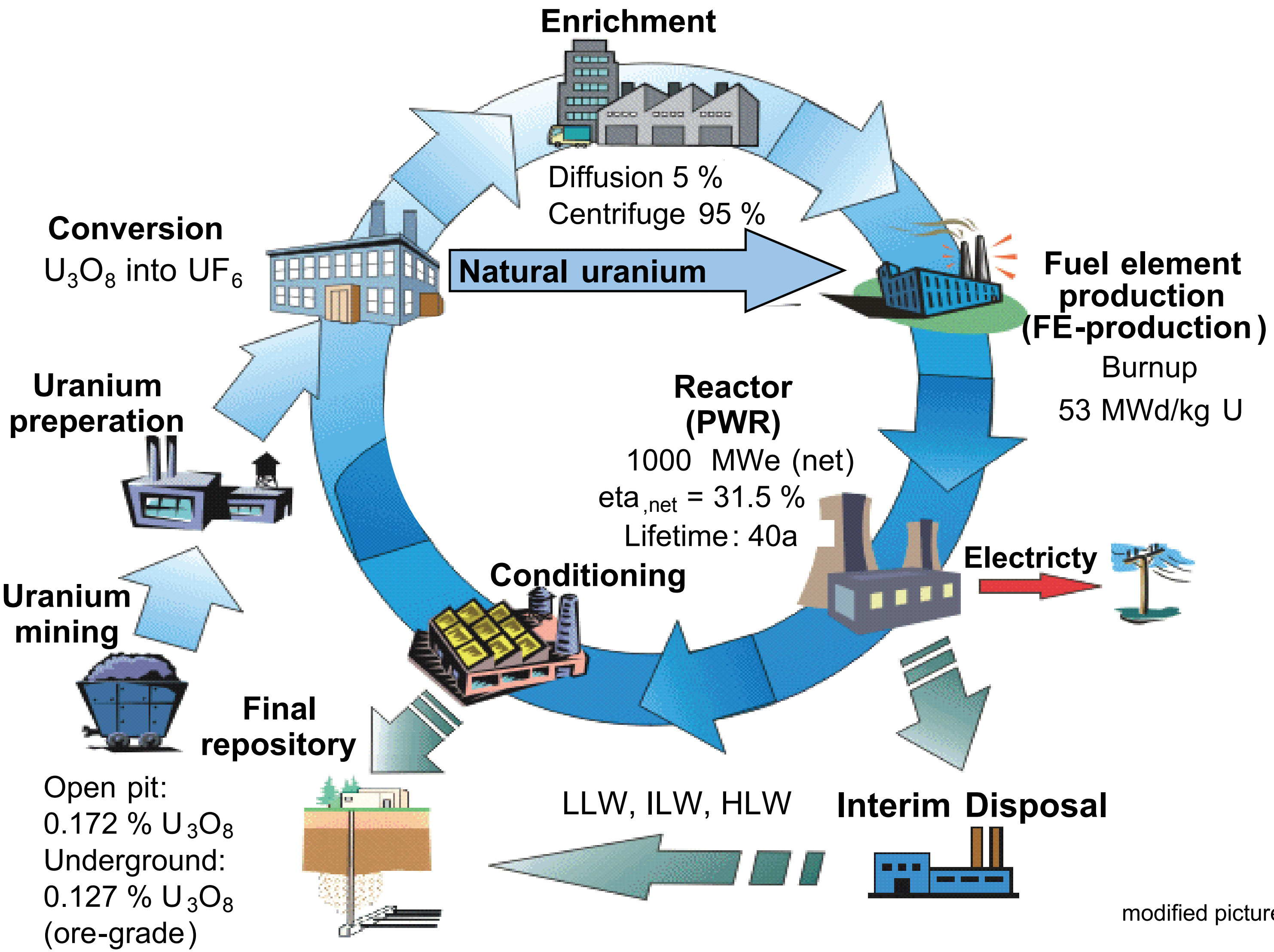


Direct applications:

- Product development and optimisation
- Strategic planning
- Support of legislative action
- Marketing

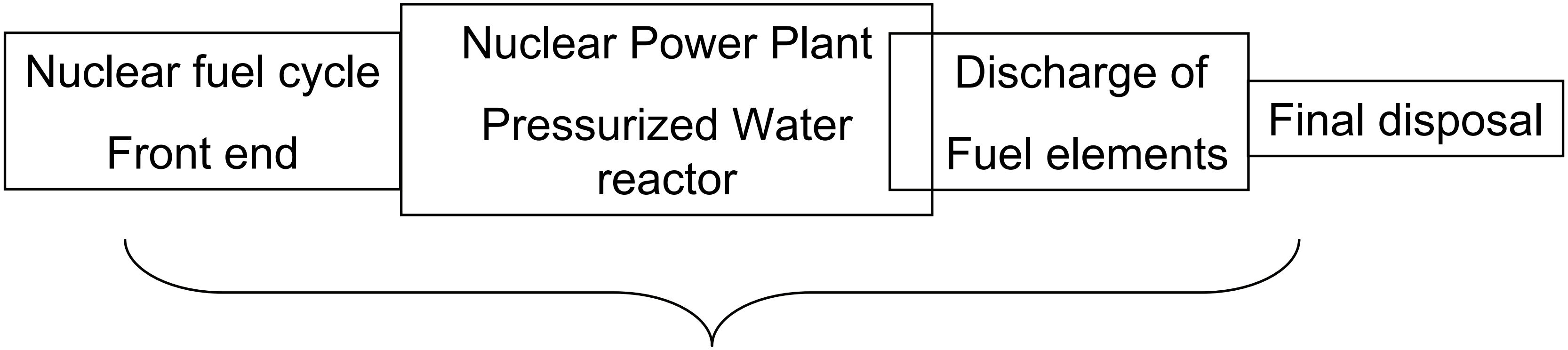
/DIN-ISO 14 040/

Scope: Nuclear fuel cycle



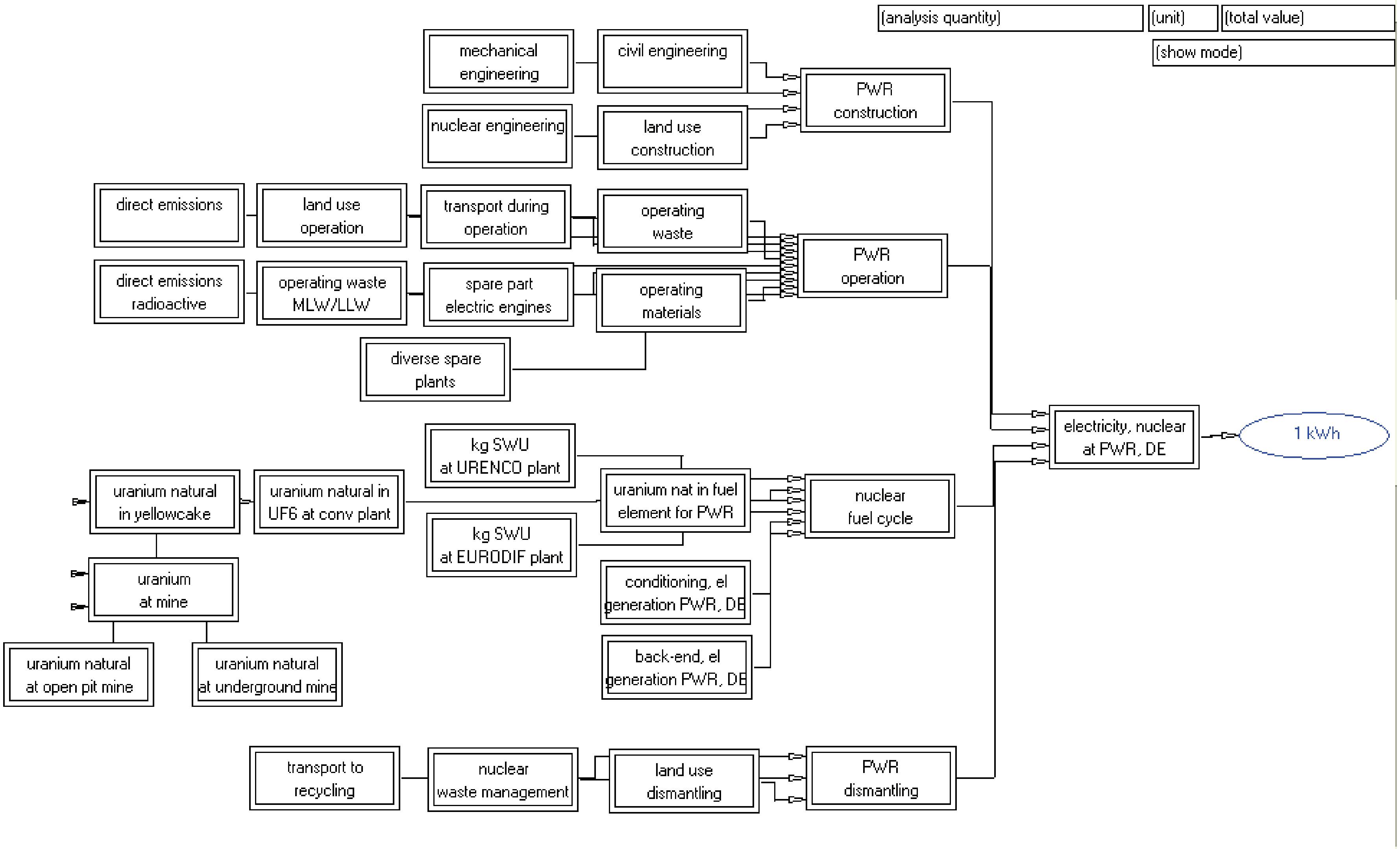
modified picture /IAEA 2007/

Methodology: Investigated Product System



- Integration of Parameters into the LCI calculation
- Calculation of all material and energy flows of the process chain, analyses based on formulae containing parameters
- Parameter variation allows the illustration of different assumptions, site specific conditions and technical characteristics of the investigated nuclear reference system

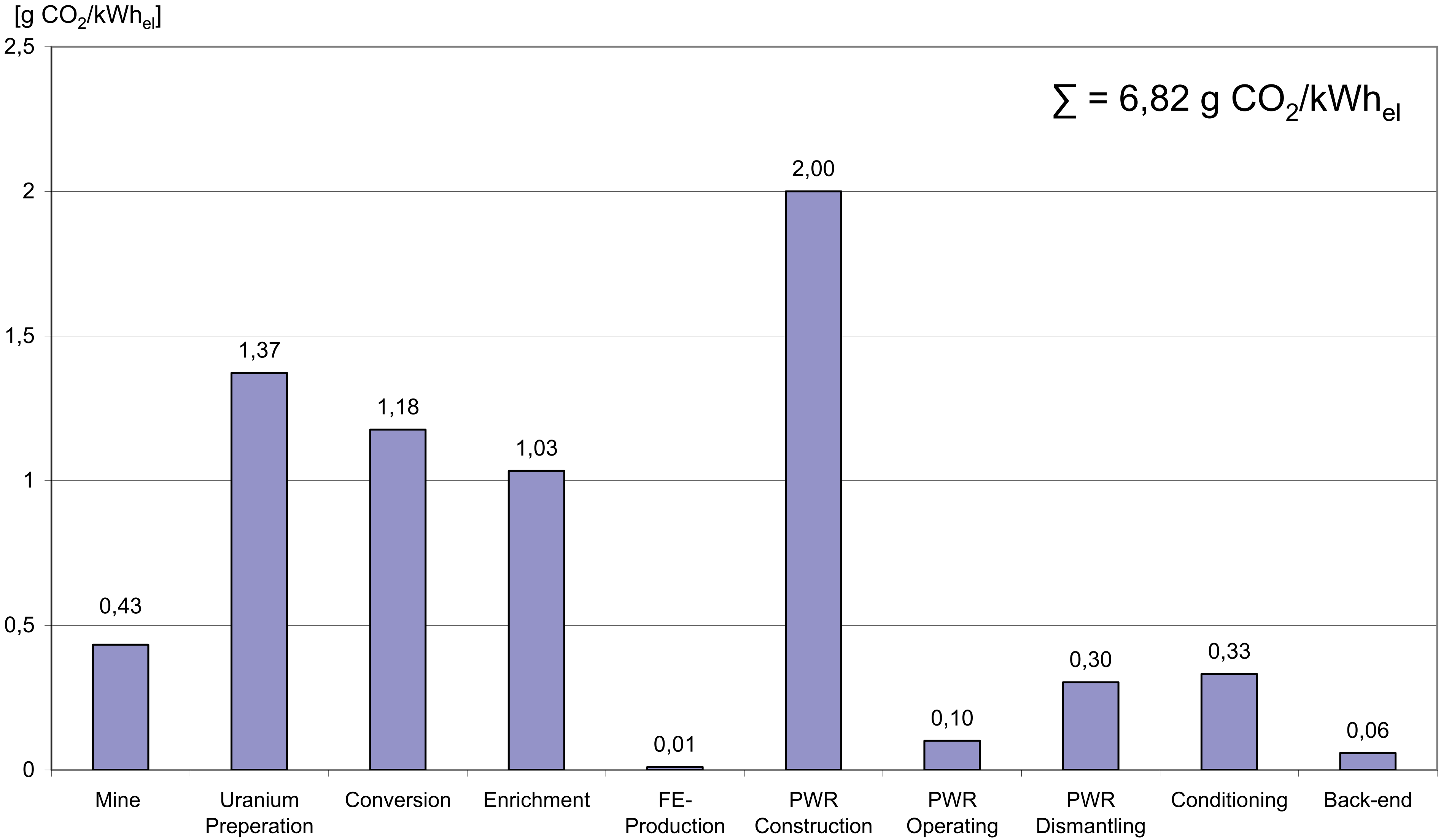
Methodology: Life Cycle Inventory (LCI) of nuclear power



Scope: Main characteristics of the reference process chain

Process step	Characterisation
Uranium mining	Open-pit mine (0,172 % U_3O_8); 52% Underground mine (0,127 % U_3O_8); 48%
Uranium preparation	Natural uranium into U_3O_8
Conversion	U_3O_8 into UF_6
Enrichment	Gaseous Diffusion; 5% Gaseous Centrifugation; 95%
Fuel fabrication	Fuel elements for a PWR
Nuclear Power Plant	Pressurized Water Reactor (PWR), Net-Power: 1000 MW_{el} Net-efficiency: 33,0 % Lifetime: 40 years
Conditioning	Conditioning for long term storage
Final repository	Disposal of LLW, ILW, HLW
Electricity mix	UCTE generating mix

CO_2-Emissions from the nuclear reference system for Germany

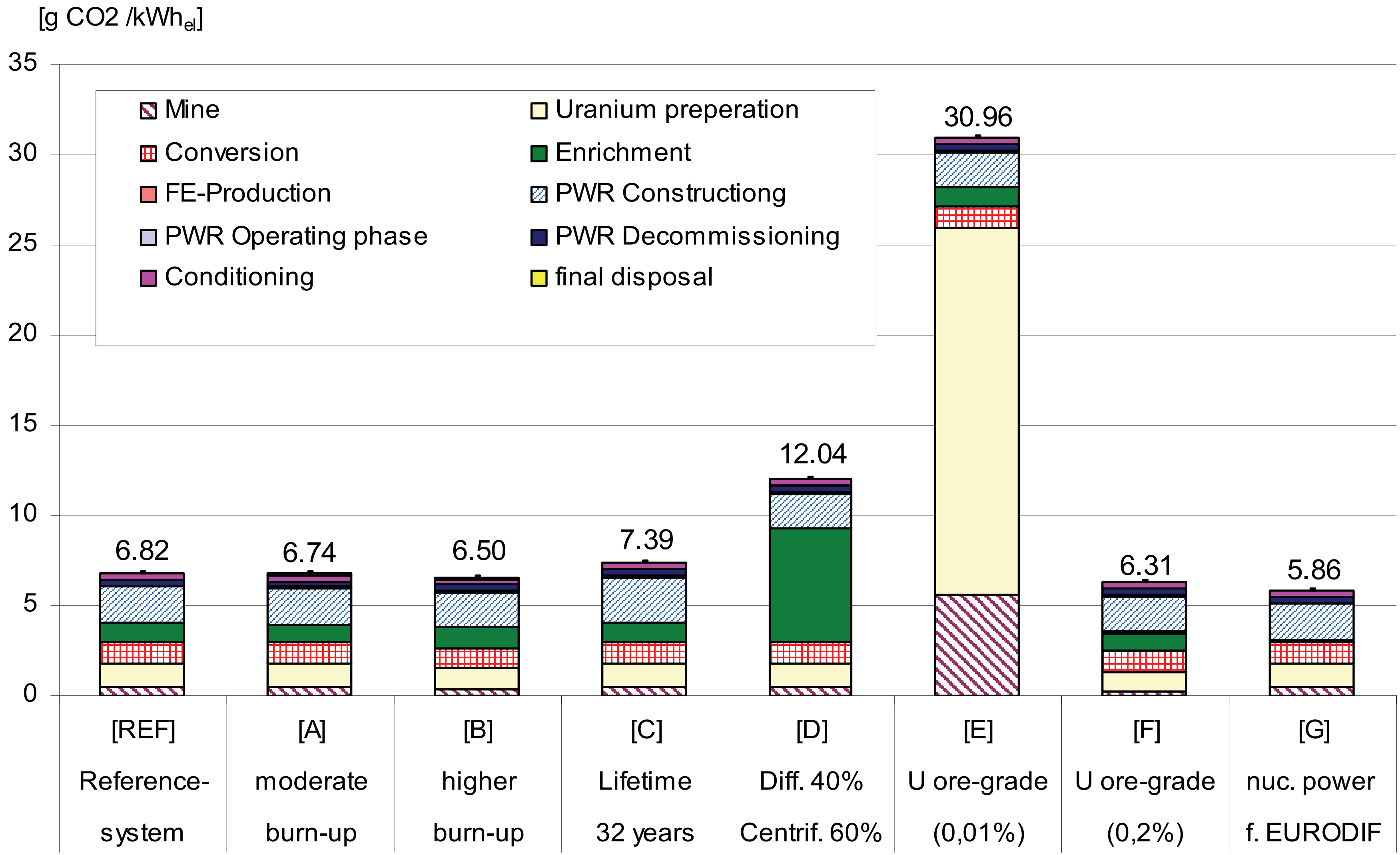


Sensitivity analysis

Following alternatives in comparison to the reference system were considered:

- Insertion of fuel element with a higher and a lower burn-up
  - A: Higher burn-up: 63,7 MWd_{th}/kg U
  - B: Lower burn-up: 45,6 MWd_{th}/kg U
- Operating time of nuclear power plant
  - C: Lifetime: 32 years, according the Germans phase out
- Variation of the amount of centrifugation and diffusion enrichment plants
  - D: Enrichment: Diffusion 40% and Centrifugation 60%
- Ore grade of the uranium mines (open-pit and underground)
  - E: Uranium ore-grade: 0.01%
  - F: Uranium ore-grade: 0,2%
- Choice of the background electricity mix
  - G: French electricity mix and gaseous diffusion plant

Sensitivity analysis of the reference system



Classification of the results

Reference	Reactor Power	Operating time Reactor	CO_2	Comment
	[MW_{el}]	[Years]	[g CO_2/kWh_{el}]	
Van den Vate J.F., 2002	1030	40	**3,27**	35 % of the CO_2 emissions from uranium mining/milling and uranium preparation Uranium production: 42 % open-pit (0,03 % U_3O_8), 37 % underground (0,06 % U_3O_8), 21 % in-situ leaching Enrichment: 80 % centrifugation
AEA Technology, 2005	625	40	**5,05**	36 % of the CO_2 emissions from uranium mining/milling and uranium preparation Enrichment: 100 % centrifugation
Wissel, Mayer-Spohn, 2008	1000	40	**6,82**	Reference process chain for Germany, uranium production: open-pit and underground mining
Vattenfall, 2005	1000	40	**8,88**	26 % of the CO_2 emissions from uranium mining/milling and uranium preparation Enrichment: 10 % centrifugation Electricity mix: Swiss
Dones R., 2004	1000	40	**10,70**	60 % of the CO_2 emissions from uranium enrichment Enrichment: 76 % centrifugation Electricity mix: German Using of MOX-Fuel elements
White S. W., 2000	1000	30	**15,00**	59 % of the CO_2 emissions from uranium preparation, 3 % mining, 3 % enrichment Enrichment: 100 % centrifugation

Summary and Conclusions

- Sensitivity analysis illustrate that uncertainities in the grade of the uranium ore and the enrichment technology major influence the CO_2-emissions of nuclear systems

  ⇒ result of the process chain analysis of Germans nuclear fuel cycle is 6,82 g CO_2/kWhel
- Advanced reactor concepts improve fuel utilization
- Effect of uranium with low-grade on CO_2-emissions is negligible in contrast to fossil power systems

  ⇒ From a Greenhouse Gas perspective nuclear power is very attractive

Thank you

for your attention!