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MATERIAL INPUT OF NUCLEAR FUEL IN PROPORTION TO THE GENERATED ELECTRICITY

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HISTORY OF MATERIAL FLOW STUDIES

- Introduced in 1960's, when the concern was the sufficiency of natural resources. .
- At the end of 1980's, in connection of pursuit of sustainable development the material flow studies were found attractive again.
- Vision that the global environmental impacts depend on the amount of materials utilized by the economy.
- In1992 German professor Friedrich Schmidt-Bleek of Wuppertal Instituutin introduced the new indicator (meter) of ecological efficiency, MIPS.

STUDY METHOD (page 1)

$$MIPS = \frac{MI}{S} = \frac{\text{material input}}{\text{service performance}} = \frac{\text{mass of product} + \text{mass of its 'ecological rucksack'}}{\text{utility of product}}$$

- Ecological rucksack means the mass of natural materials moved from their original location in the natural ecosystem – which mass is required by the (final) product in addition to its own weight during its whole lifecycle.

$$\text{MI-coefficient or MIC} = \frac{\text{material input}}{\text{mass of product}}$$

STUDY METHOD (page 2)

- Simple and clear, but it does not take into account the harmfulness of materials nor the way how the residual material is processed.

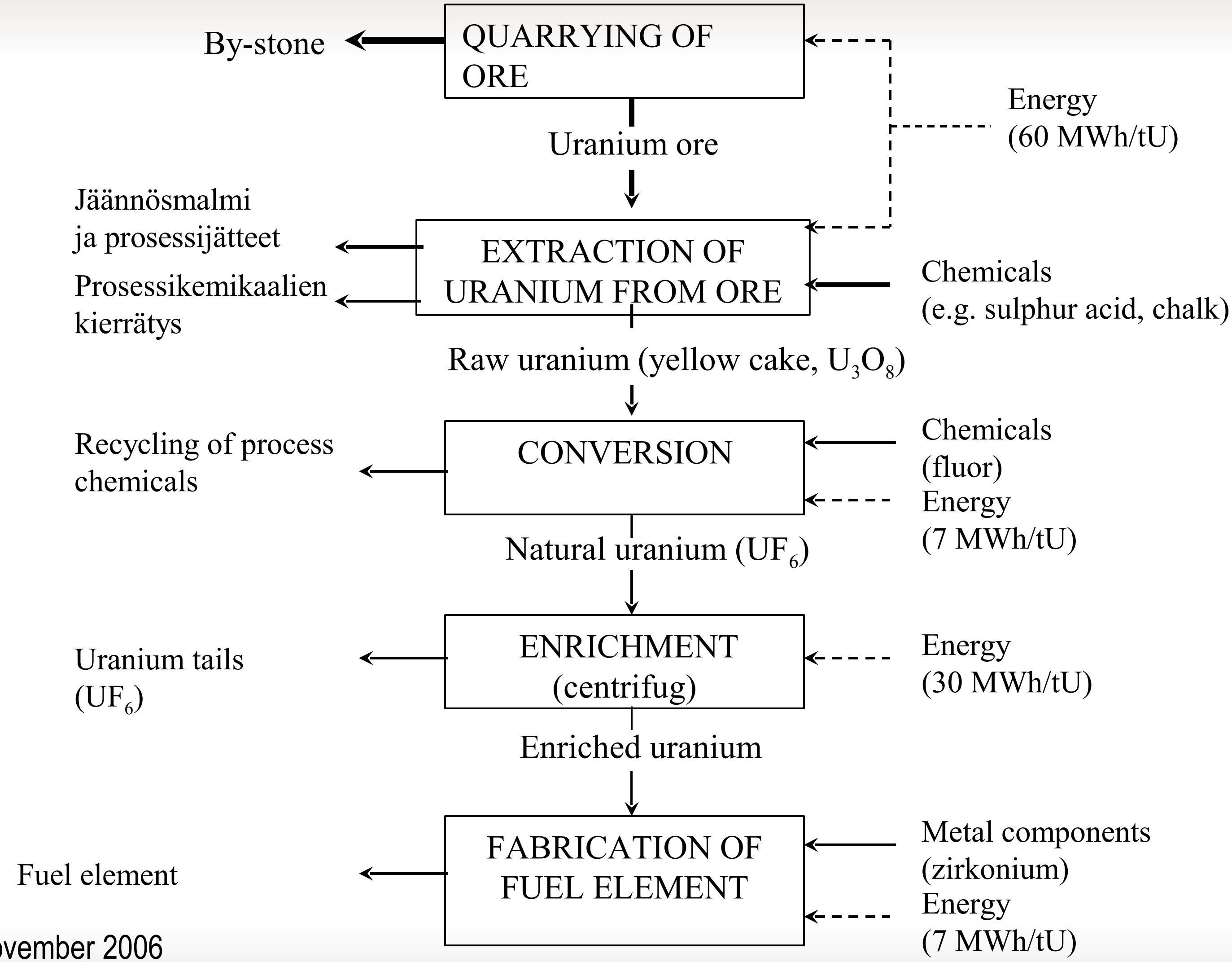
⇒ It does not as such express the amount of environmental impacts.

- The method is, however, considered suitable for measuring the sustainable development as one indicative (rough) indicator.

BASIC DEFINITIONS

- Only non-renewable materials are included in the ecological rucksack. These materials consist of the use of land material of the ore deposit as well as direct and indirect use of material in the various stages of the fabrication chain.
- The used water and air are not included in the rucksack nor the raw materials needed for the construction of the fabrication machinery of the product. Furthermore, the material use for the waste management is excluded in the examination.
- These basic definitions (”boundary conditions”) correspond to those used in the material input calculations for other energy sources, such as coal and natural gas.

NUCLEAR FUEL CHAIN



CALCULATION OF THE MATERIAL INPUT COEFFICIENT FOR NUCLEAR FUEL (page 1)

- Väkevöidyn uraanin The material input coefficient of enriched uranium is calculated as the sum of mineral, chemical and energy coefficient.

$$MIC_{VU} = \frac{m_{TM}}{m_{VU}} = k_M + k_K + k_E$$

MIC_{VU}	=	material input coefficient of enriched uranium
m_{TM}	=	mass of total material use,
m_{VU}	=	mass of enriched uranium,
k_K	=	chemical coefficient,
k_E	=	energy coefficient
k_M	=	mineral coefficient,

CALCULATION OF THE MATERIAL INPUT COEFFICIENT FOR NUCLEAR FUEL (page 2)

- Material input coefficient of uranium oxide is calculated by multiplying MIC_{VU} with the ratio of the molecyl mass of uranium and uranium dioxide

$$MIC_{UO_2} = 0{,}8815 \times MIC_{VU}$$

where

MIC_{UO2} = material input coefficient of enriched uranium dioxide.

- Supposing that 65 % of weight of the nuclear fuel element is uranium dioxide (UO_2) and 35 % zirconium, the material input coefficient of nuclear fuel, MIC_{YP}, can be calculated:

$$MIC_{YP} = 0{,}65 \times MIC_{UO_2} + 0{,}35 \times MIC_{Zr}$$

MIX OF URANIUM FROM VARIOUS SOURCES

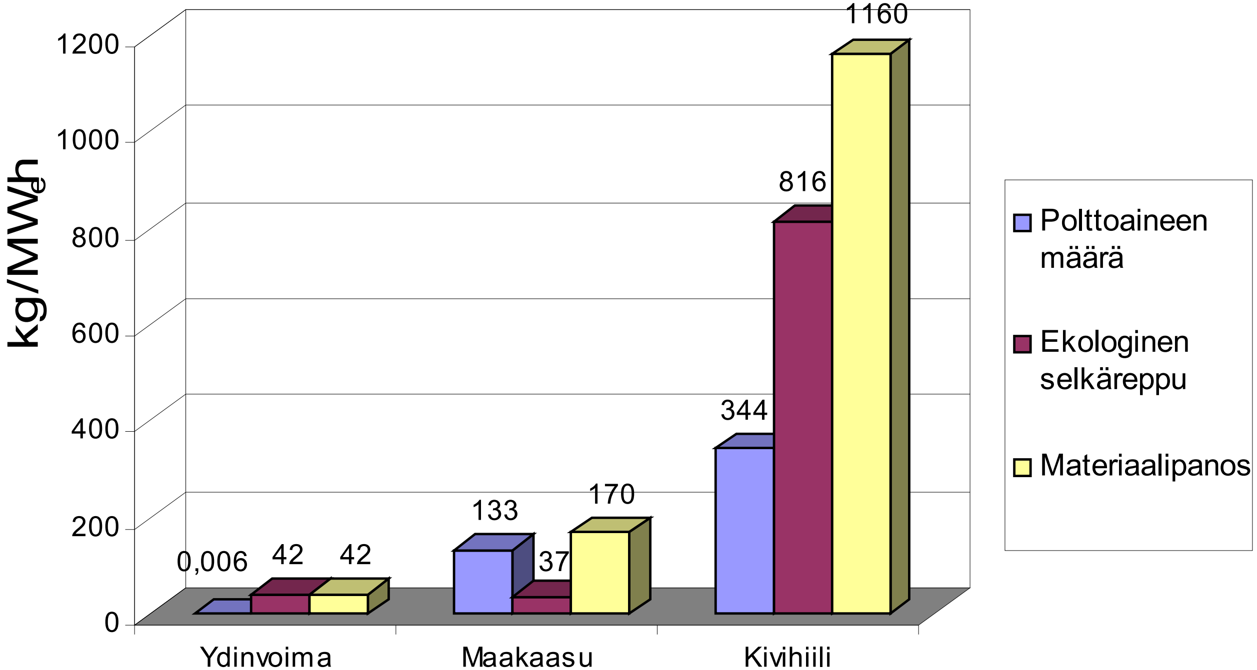
Source	**Amount**	**Average uranium content of the ore**	**Share of utilization (%)**	**By-stone coefficient (k_s)**	**MI coeff. of enriched U (MIC_{VU})**	**MI coeff. of nuclear fuel (MIC_{YP})**	**MI coeff. Of nuclear fuel without by-stone**
1	**80 t (25,0 %)**	4 %	97 %	2	1600	**920**	800
2	**60 t (18,8 %)**	-	-	-	1210	**700**	700
3	**50 t (15,6 %)**	(0,05 %)	(70 %)	-	1690	**970**	970
4	**30 t (9,38 %)**	0,29 %	70 %	31	120100	**68820**	2890
Recycled Uranium	**100 t (31,3 %)**	-	-	-	280	**160**	160
Total	**320 t (100 %)**	Weighted average			12200	**7000**	800

RESULTS (page 1)

	MATERIAALI-PANOS	POLTTOAINEEN MÄÄRÄ	**SÄHKÖN TUOTANTOMÄÄRÄ**	PÄÄSTÖT ILMAAN	KIINTEÄT TUOTOKSET
KIVIHIILI	1160 kg ← 3,38 ×	344 kg ←	**1 MWh** →	830 kg CO_2 0,87 kg SO_2 0,57 kg NO_x 48 g hiukkasia →	41,2 kg tuhkaa 12,8 kg $CaSO_4$ (rikinpoistotuote)
MAAKAASU	170 kg ← 1,28 ×	133 kg (= 182 m^3) ←	**1 MWh** →	367 kg CO_2 0,39 kg NO_x 7,8 g hiukkasia	0
YDINVOIMA	42 kg ← 7000 ×	3,86 g (UO_2) + 2,08 g (Zr) ←	**1 MWh** →	0,026 MBq jalokaasuja 2,1 Bq jodia →	2,2 g huoltojätettä 5,3 g matala-aktiivista jätettä 2,6 g keskiaktiivista jätettä 6,0 g käytettyä ydinpolttoainetta

RESULTS (page 2)

AMOUNT OF FUEL, ECOLOGICAL RUCKSACKS AND MATERIAL INPUTS OF NUCLEAR, GAS AND COAL ELECTRICITY



CONCLUSIONS

- The material input of nuclear electricity is clearly the smallest with the example mix of uranium sources
- The material input coefficient of nuclear fuel is highly dependent of the mining technology, the uranium content of the ore and other characteristics of the mine.

- The materil input, MIPS, of nuclear electricity is 42 kg/MWh with the example mix of sources

- Material inputs do not alone express the rate of environmental impacts. Also other indicators and methods should be used.