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TOTAL POLLUTION INCLUDING "GREY" POLLUTION: LIFE CYCLE ANALYSIS FOR THE ASSESSMENT OF ENERGY OPTIONS

POLLUTION TOTALE Y COMPRISE POLLUTION "GRISE": ANALYSE INTÉGRALE POUR L' ÉVALUATION DE SYSTEMES ENERGÉTIQUES

CONTAMINACION TOTAL INCLUSO LA CONTAMINACION "GRISA": ANALISIS INTEGRAL PARA LA EVALUACION DE SISTEMAS ENERGÉTICOS

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Photovoltaic plant
Installation photovoltaïque
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Renewable energy systems like photovoltaic plants are nowadays very expensive, when they are compared with existing fossil fuel power plants. External costs aren't included in present prices and nobody can say how high they are. Photovoltaic plants are called environmental friendly and some experts think even, that photovoltaics will solve our energy and environmental problems.

Some experts and a large part of critics of photovoltaic plants say, that more energy is needed for the production of cells and infrastructure, than the plant can deliver during life-time. While this might be true for some applications in space technology, many studies in the last years have shown, that cells for conventional power plants need less energy than they produce (e.g.<Hagedorn et al 1989>).

In two studies a large 500kW plant installed in the Swiss Jura region was analysed <Häne et al 1991>, <Schmocker et al 1991>. In a first step the energy needs for the production of cells, carrier and electronics were calculated. Secondly the associated environmental impact was analysed. This is motivated by the fact that overall energy savings do not necessarily mean an overall reduction of environmental pollution as we have shown in the example about low-energy housing (Section 3.2)

The power plant consists of 10'560 monocristalline modules installed on 110 carriers with normal efficiency of 12.5%. The peak power DC is 560kW while the expected AC-power is 500kW. Over one year the net electricity production is calculated to be 676.8 MWh.

Figure 3.3 shows the production steps of a photovoltaic module and shows the energy balance in primary energy units. On the left side are shown electricity inputs and on the right side thermal energy inputs for transportation, production of commodities and plant operation. About 90% of the whole energy demand is covered by electrical energy. For one module with 36 monocristalline cells (without frame) 2.6 GJ primary energy are required. Wafer production is not the only energy intensive step (33% of energy input). Other steps are energy intensive too. The material use efficiency is not very high especially in relation to MG-silicium. This is true also for the energy contained in this material.

For the production of the whole power plant including all infrastructure about 40 TJ primary energy are needed (Figure 3.4). 65% are used to produce the photovoltaic modules. 27% to produce and construct the carriers (incl. all construction work). Electronic components and infrastructure need only about 10% of total energy. Electronic components are difficult to calculate, because of lack of data from manufacturers.

The resulting energy payback time is 6.6 years, if it is assumed that it needs 2.59 kWh primary energy to produce 1 kWh electricity. For a photovoltaic plant a life-time of twenty to thirty years can be assumed, which means, that a photovoltaic plant produces about three to four times its construction energy. In future, when the production of cells will increase (in 1990 the worldwide production was about 50 MW), the production energy will decrease. Other technologies like multicristalline or amorphe cells already in use need less production energy. The energy demand for carrier, electronic and construction work will be minimized in future. Parts of the components will be reused after the life-time of the plant. This means that the energy payback time will be reduced considerably within the next ten years.

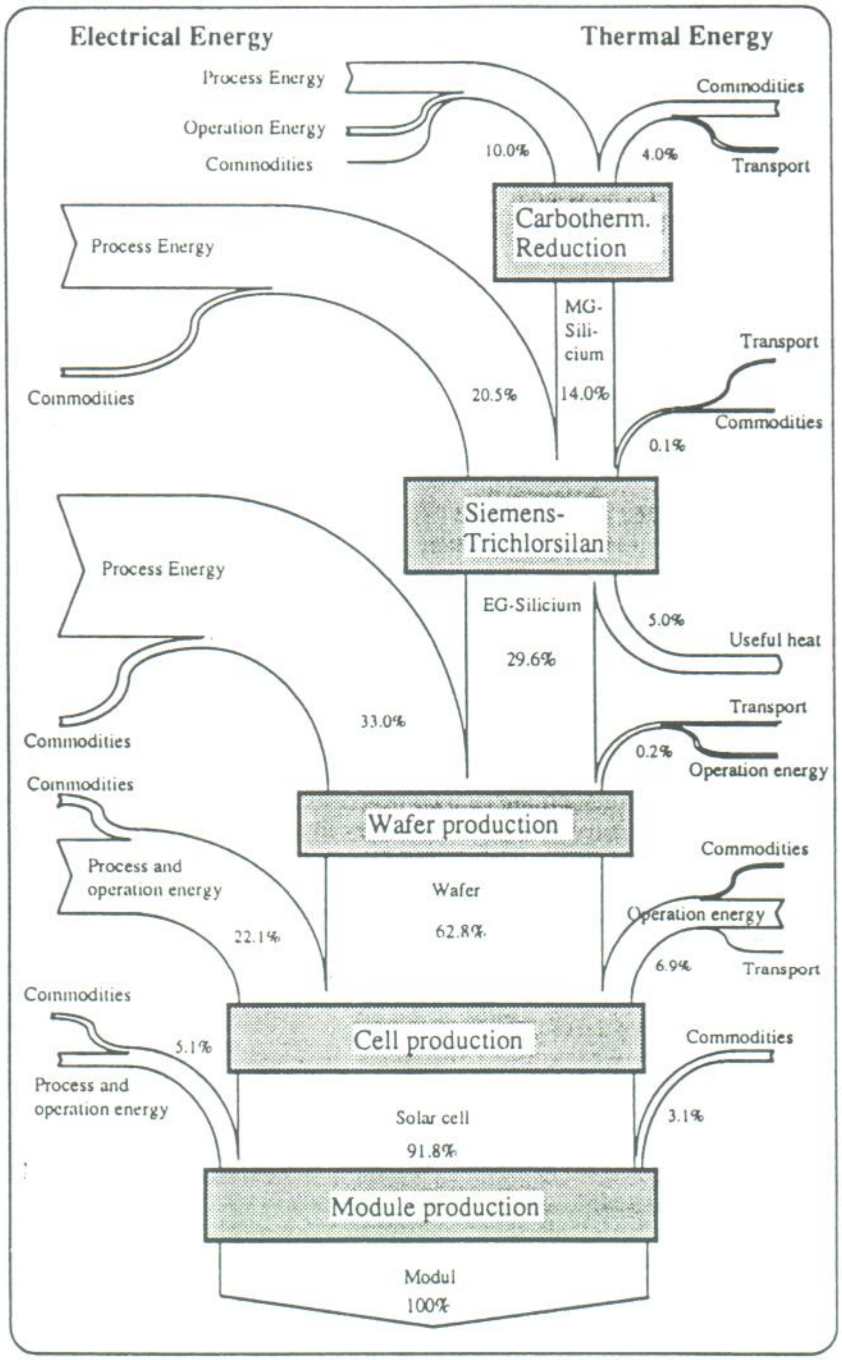

Fig. 3.3: Main production steps for a monocristalline photovoltaic module with indication of the energy flows. "Commodities" stands for energy requirements for the production of commodities. One module with 36 cells needs about 2.6 GJ primary energy <Häne et al 1991>.

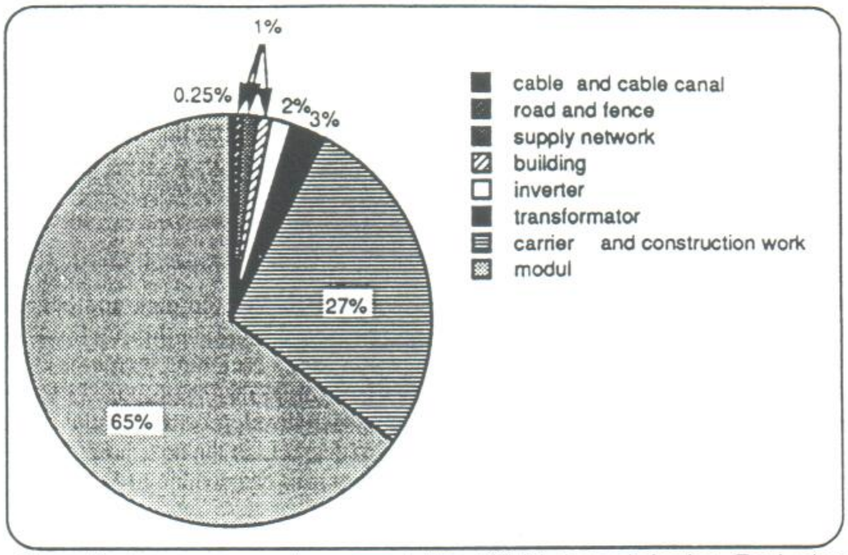

Fig. 3.4: Share of primary energy requirements to build a 500kW photovoltaic plant. Total primary energy demand is about 40 TJ or about 80 GJ per kWpeak <Schmocker et al 1991>.

We now consider the environmental impacts of photovoltaic plants. For this reason the whole production process of the modules and infrastructure, taking care of about 30 air pollutants, 30 water pollutants, waste volume and energy demand was analysed. Because of incomplete data for water pollution and waste production only the air pollution is discussed. For the decommissioning of photovoltaic modules no satisfying concepts exist, so that the environmental impact of module-waste treatment couldn't be studied. Producers should consider this at the stage of development.

Supposing, that the plant will produce 676.8 MWh each year for the estimated life-span (20 or 30 years) the emission factors per produced kWh of electricity can be calculated. In Table 3.5 the results are given for a few selected air pollutants. The uncertainty of this data is about 30% updated to the end of the 1980's. <Fritsche et al 1989> give much lower figures, because of an incomplete material list and special infrastructure. The emission factors of electricity produced by the solar plant lie just below those for conventional power plants. This data should not be used to oppose further development and installation of photovoltaic plants. <Strese et al 1988> showed the large cost and energy reduction potential of multicristalline cell production. The potential of development of photovoltaic modules is still very large.

Selected air pollutant	Life-span 20 years [g/kWhe]	Life-span 30 years [g/kWhe]
carbon dioxide (CO2)	190	130
sulphur dioxide (SO2)	0.8	0.56
nitrous oxide (NOx)	0.6	0.4
NMVOC	0.7	0.44
particle	0.6	0.4

Table 3.5: Resulting emission factors of a few selected air pollutants for a life-span of the photovoltaic plant of 20 and 30 years.

If the air pollutants are aggregated with the concept of weighting by immission standards, traditional pollutants like NO_X, SO_2, NMVOC and particles have the biggest share in the pollution index. For the calculation of the air-emission payback time (AEPBT) the air pollution index for the production of the whole plant has to be divided through the air pollution index, which can be saved due to the electricity delivered to the grid. A medium European electricity mix was assumed.

$$AEPBT = \frac{863 \text{ Exp } 10^9 m^3 \text{ polluted air}}{50 \text{ Exp } 10^9 m^3/a \text{ polluted air}} = 17 \text{ years}$$

The uncertanity of this result is large because of missing or old data and because of the aggregation method, which can't depict the environment. Using another method <BUWAL 1990> based on the concept of environmental scarcity the pay back time increases even more to 24 years. The payback times are in the same order of magnitude as the proposed life-span of the plant. Larger production capacities in the future and a high development potential mean that the emission factors of photovoltaic plants are expected to decrease in the next years.

More studies for other types of cells and other plants will be carried out at ETH to compare the results and to draw saver conclusions.