Solar Energy: from perennial promise to competitive alternative

- final report -

Project number: 2562

Written on the commission of:

Greenpeace Nederland

KPMG Bureau voor Economische Argumentatie
Steins Bisschop Meijburg & Co Advocaten

kpmg Bureau voor Economische Argumentatie

Hoofddorp, August 1999

Contents

Summary

Introduction

Solar energy is a promise for the future. It is a clean and sustainable source of energy that can provide a significant share of our energy needs. It is not only from an environmental point of view that solar energy has a future: from an economic perspective prospects abound. Large multinationals such as Shell, BP and Siemens are focusing their efforts in the field of sustainable energy, most particularly on photovoltaic solar energy. They are doing this primarily because they expect that solar energy will offer their companies good economic prospects, rather than through environmental concern.

However, solar energy appears to be developing into a perennial promise. The big breakthrough is long in coming. The predominant reason for this is price. Solar energy is much more expensive than conventional energy, and as long as this remains the case, solar energy will remain an unrealised promise.

As part of its drive to see fossil fuels phased out in favour of renewable sources of energy, it is very important to the environmental organisation Greenpeace that solar energy become widely accepted and widely used. The extent to which market mechanisms could be used to rapidly produce a competitive price for solar power via economies of scale[1] is a question which Greenpeace would like to resolve.

For this reason Greenpeace has commissioned KPMG Bureau voor Economische Argumentatie (Economic Research and Policy Consulting) to conduct a study into the feasibility of producing solar panels[2] on a large scale. The question was formulated as follows:

> Can the large-scale production of solar panels lower the price of solar energy to such an extent that solar energy can compete economically with conventional forms of energy?
> And if it can, what action is necessary on the part of government, customers and industry to break through the current impasse?

Note: In the original Dutch language version of this report we have concentrated on the Netherlands as a case study and included specific policy options pertinent to the Dutch situation. In this international version of the report we present the findings which are of international relevance. The specifically Dutch policy proposals are set out in an appendix.

---

1 And linked to this, the large-scale production of the necessary inverters and cables and the large-scale installation of the panels.

2 In this study we speak simply about solar panels, by which we mean PV systems.

In summary we have reached the following conclusions.

The current market: The chicken and egg problem

Even in a relatively small, cloudy and rainy country such as the Netherlands, there is an enormous market potential for solar panels. If this entire potential were utilised, solar energy could provide three quarters of the Netherlands' electricity needs.

The size of the current market for solar panels stands in stark contrast to the potential of solar energy. Up to the present only a fraction of the possibilities have been utilised. The most significant reason for this is the fact that the price of solar energy is much higher than the price of conventional energy. In the Netherlands the price difference is up to a factor four to five. The predominant reason for this is that the demand for solar energy and solar panels is small and the associated prices are high. It comes down to a classic chicken/egg problem: as long as demand is small, production of solar energy will remain small-scale and expensive, and as long as the production is small-scale and expensive, the price will remain high and the demand small: catch 22.

How to make PV competitive

Three factors can influence the price of PV-systems:

- technological developments;
- subsidies;
- the scale of production.

Technology: Solar cell technology has still not reached the end of its development, as indicated by the research on many new technologies. Currently it is not yet possible to say when producers will be able to use these new technologies on a large scale and to what extent they will contribute to lowering the price and increasing the acceptance of solar energy.

Subsidy: Under current incentives, solar energy’s share in the total supply of energy cannot be expected to grow rapidly in the foreseeable future. In the Dutch case study, generating a mass market for PV would require a quadrupling of the current level of subsidies

Up-scaling: According to the results of the Music-FM study, the large-scale production of photovoltaic solar panels is feasible using current technology, and would reduce the price of solar panels by 60 to 80%. This would make solar energy a competitive alternative to conventional energy, at least for the small-scale end-user of energy[3]. Our research

3 Since solar PV panels can be placed at the ‘point of use’ of electricity, they compete against the delivered price of energy rather than the generation price, i.e. the price a household pays per unit of electricity rather than the price at which conventional power plant produces the energy.

reveals that the scale of production needed to achieve this reduction is 500 MWp per year. This would take a plant that could supply three times the current world production of solar panels and that is 25 times larger than the largest plant now operational. However, in relation to the potential market for solar energy, even this plant is a very modest size. To realise the full potential in the Netherlands for solar energy, every year there would have to be seven 500 MWp plants in operation.

Of the three possibilities, upscaling offers the best prospects to achieve a substantial lowering of the price of solar panels in the short term.

The chicken and egg of market development

The market for solar energy will not spontaneously develop to the extent that will justify such a large plant. We have reached an impasse: (potential) buyers are waiting for the price of solar panels to fall and producers are waiting for the demand for solar panels to grow: catch 22.

It is clear that someone will have to bite the bullet and act. This could be:

- Industry could build the contemplated mega-plant in the hope that the price reduction this would achieve will bring about a market development that is large enough to justify (in hindsight) the construction of that plant;
- The government could, through high subsidies, convince potential buyers to use solar panels on a much larger scale in the hope that the growth in demand would lead to a scale-up of production, which would gradually make the subsidies unnecessary.
- The buyers of solar energy could achieve this change in a scenario where government uses its authority to regulate the large-scale installation of solar panels.

Conclusion

The answer to the question posed to us by Greenpeace is as follows:

Scaling up the production of solar panels is technologically feasible using current technology. To achieve a reduction in the price to the level of conventional energy, production needs to be scaled up to 500 MWp per year. There are costs involved in creating the required market size, and either the industry, or the government, or the users of energy will have to pick up the cost of transition.

1. Introduction

1.1. Reason and assignment

Solar energy is a sustainable and clean source of energy. Solar energy also holds promise for the future of electricity production, however the use of solar energy in contrast to the use of conventional energy is still very limited. The predominant reason for this is that the demand for solar energy and solar energy panels[4] is small and the associated prices are high. It comes down to a classic chicken/egg problem: as long as demand is small, production of solar energy will remain small-scale and expensive, and as long as the production is small-scale and expensive, the price will remain high and the demand small.

The environmental organisation Greenpeace has pondered the question of how this impasse in the market for solar panels can be broken. As part of its drive to see fossil fuels phased out in favour of renewable energies, it is very important to Greenpeace that solar energy gain wide acceptance and is widely used. It therefore wants to force a breakthrough. For Greenpeace environmental considerations are the primary motivation. The extent to which market mechanisms could be used to rapidly produce a competitive price for solar power via economies of scale is a question which Greenpeace would like to resolve.

For this reason, Greenpeace has commissioned KPMG Bureau voor Economische Argumentatie (Economic Research and Policy Consulting) in the Netherlands to conduct a study into the feasibility of a large-scale production of solar panels. The question posed by the study has been formulated as follows:

> Can the large-scale production of solar panels lower the price of solar energy to such an extent that solar energy can compete economically with conventional forms of energy?
>
> If it can, what actions are necessary on the part of government, customers and industry to break through the current impasse?

In this report we will present our findings.

4 In this report we use the term solar panels, by which we mean PV-systems.

1.2. Procedure and Report Structure

We have based this report to a significant degree on existing studies. We have analysed and updated this data based on information obtained from a number of discussions with experts who were interviewed about solar energy. The goal of these interviews was to gain insight into the uncertainties we had and to fill in the blanks in the published information, as well as to test our own ideas and assumptions.

The report is structured as follows.

- In chapter 2 we have described the market, both supply and demand, for solar panels and made an analysis of the potential of solar energy in the Netherlands.
- Chapter 3 delves deeper into the question of the extent to which there is an impasse and describes the possibilities for breaking through this impasse.
- In chapter 4 we examine more closely the possibilities for breaking through the impasse by employing large-scale production.
- In appendices to the report we analyse in more detail the policy options in the special case of the Netherlands, including a memo from Steins Bisschop Meijburg & Co Advocaten in which the legal aspects of possible policy measures are discussed.
- In the other appendices we have listed the suppositions that underlie and form the basis of our calculations. We also provide an overview of the people interviewed, the literature consulted and the acronyms used .

2. The Market for Solar Panels

In this chapter we investigate the use of solar energy. Taking the Netherlands as a sample case study we describe the market for solar panels, we compare the price of solar energy with the price of conventional energy and we analyse the market potential for solar panels in the Netherlands. The calculations in this chapter are based on the Dutch situation, but comparable calculations can be made for any national situation based on the analysis presented herein.

2.1. The sun as a sustainable source of energy

The lion's share (almost 95% in 1998) of the Netherlands' electricity supply[5] is generated from fossil fuels. The stocks of fossil fuels are limited and the use of these fuels will reduce their availability in the long term. Also the conversion of fossil fuels to electricity is accompanied by the emission of CO_2

In this respect solar energy has an advantage over conventional forms of energy. Solar energy is both sustainable and clean. The sun will not be depleted if solar energy is used on the earth and the conversion of sunlight to usable energy does not produce any damaging emissions.

There appears to be common agreement that the great advantages solar energy provides make the sun one of the most important sources of energy in the 21st century. However, we are not there yet. At this point, solar energy still has a significant disadvantage: The sun rises for free, but the panels that are necessary to convert sunlight into usable energy are expensive. This is the primary reason that solar energy's share of the total market for the generation of energy is still so small.

The energy that comes from the sun can be converted into energy that can be used by people in two ways. The first way is by converting solar energy into heat. In this case we are speaking of thermal solar energy: an example of this is the solar hot water boilers. The second way to make use of solar energy is by converting the energy into electricity. This can be achieved directly using photovoltaic (PV) solar panels. In this study the conversion of solar energy through the use of photovoltaic solar panels is the focus.

Photovoltaic solar panels are built from a number of solar cells[6]. A silicon layer forms the core of these cells[7]. When sunlight falls on the silicon layer, an electric current is created.

---

5 Coal, gas and crude oil provide almost 95% of Netherlands' source of electricity (Novem, *Energiegids,* 1998).

6 The size of solar cells is generally 10cmx10cm or 12.5cmx12.5cm. The surface area of most solar panels is approx. 1 m^2.

In a solar panel the individual solar cells are linked and the panel in this way supplies an amount of direct current. To convert this direct current into alternating current an inverter is needed.

The direct current can be used in three ways:

- The first possibility is to use the current directly by connecting electrical equipment to it.
- The second possibility is to store the energy in a battery and to use it at a later stage.

These two possibilities are called stand-alone systems and are often used in locations where there is no readily available connection to the electricity grid. This is often the case in developing countries, but also in outer space and on the ocean.

- A third possibility is to connect the solar panels to the electricity grid. In this case we speak of grid-connected PV systems. To do this the direct current must first be converted into alternating current.

In the last option the generation of solar energy for consumers represents a reduction of the energy used from the grid. This even goes to the extent that the electricity meter runs backwards at those moments when more energy is generated than is consumed, in which case the excess electricity that is supplied to the grid is at that moment used by other electricity consumers. Thus, in the last case the grid functions as a battery for the owner of the solar panels, if you will.

2.2. The market for solar panels: current situation and prospects

The market for solar panels: current status

Despite the fact that solar energy is a sustainable and clean source of energy, the market for solar panels is still very small. In 1996 in the Netherlands a surface area of only approximately 41,000 m^2 of photovoltaic solar panels had been installed with a combined capacity of 3.3 MWp[8] [9]. The contribution of solar energy to the total electricity supply therefore amounted to approximately 2.6 GWh. That is roughly 0.003% of the total consumption of electricity in the Netherlands.

The supply side of the market

7 Although other materials are also suitable, most cells are currently made of silicon.

8 Because this pertains to both recent and old models, the capacity is calculated at 80 Wp per m^2, although the current panels have a capacity of approx. 100 Wp per m^2.

9 Ministry of Economic Affairs and others, *PV Introduction Plan, (appendix 1 of the PV Covenant),* 1997.

Producers from the United States, Japan and the E.U. dominate the supply side of the world market for PV systems. The producers in the USA and Japan held approximately two-thirds of the world market in 1997[10]. Table 2.1 shows the international distribution of the production of PV systems.

Table 2.1. World production of PV systems in MWp

	1991	1992	1993	1994	1995	1996	1997
U.S.A	17.1	18.1	22.4	25.6	34.7	28.8	51.0
Japan	19.9	18.8	16.7	16.5	16.4	21.2	35.0
Europe	13.4	16.4	16.5	21.7	20.1	18.8	30.4
Other	5.0	4.6	4.4	5.6	6.3	9.7	9.4
Total	55.4	57.9	60.1	69.4	77.6	88.6	125.8

Source: Maycock

Development of the market: demand side

The Dutch Ministry of Economic Affairs (E.A.) expects the installed capacity in the Netherlands to increase sharply in the coming years. This ministry is striving for an installed capacity of 1,450 MWp by the year 2020[11]. This will enable 1,160 GWh of electricity to be produced annually. The share of solar energy as a percentage of the total electricity consumed would thus grow to 1.5%. Table 2.2 shows the projected development of the installed capacity.

Table 2.2. Development of the installed PV systems in the Netherlands

	Capacity (MWp)	Electricity saved (GWh)	Share of the total electricity consumed*
1995	2.5	2.0	0.003%
1996	3.3	2.6	0.004%
2000	12.5	10.0	0.01%
2007	119.0	95.2	0.1%
2020	1,450.0	1,160.0	1.5%

Source: Ministry of Economic Affairs, *Sustainable energy on the move, Action Programme 1997-2000.*

* Based on the electricity consumed in 1997

An increased use of solar energy is coupled with an increased demand for solar panels. The Ministry of Economic Affairs projects that by 2020 in the Netherlands 180 MWp of solar panels will be sold annually. The Dutch market will thus form 1% of the total world

10 Maycock, P., *Photovoltaic Technology, performance, cost and market, (1975-2010), version seven,* 1998.

11 Ministry of Economic Affairs, *Sustainable energy on the move, Action programme 1997-2000.*

market. The development of the world market and the Dutch market are shown in table 2.3.

Table 2.3. Development of PV in the world market and in the Dutch market

	World market (MWp per year)	Dutch market (MWp per year)
1995	84	0.45
1996	97	0.75
2000	169	3.80
2007	1,000	30.00
2020	18,000	180.00

Source: Ministry of Economic Affairs, *Sustainable energy on the move, Action Programme 1997-2000*

This development assumes an average annual growth of approximately 26%. Although this is a very sharp rise, it would bring the market share of solar energy in the total electricity demand in 2020 to only 1.5%. Some prognoses that reach far into the next century estimate that solar energy's world market share of the electricity production will be 20% or more by the year 2040[12].

2.3. The price of solar energy in the Netherlands

The primary explanation for the limited use of solar energy is the high price attached to solar panels. Despite technological developments which have lowered the price of solar panels in recent years, the price of electricity generated from solar energy is still significantly higher than current domestic electricity rates. And for solar energy to be considered as a competitive product, the price of this electricity will have to be brought to a competitive level. An initial question that has to be answered: how much more expensive is solar energy in reality?

The price of the electricity from solar panels

The price of electricity generated from solar energy is determined by the following factors:

- the costs of the solar panel itself;
- the costs of installing the solar panel and the costs of the inverter and the cabling (referred to together as Balance of System costs (BOS));
- the life span of the panel and the interest rate;
- the amount of energy provided by the sun;
- the efficiency of the panel, or the ratio between the energy that the sun provides and the amount of electricity that the panel supplies.

12 Shell, *Weltenergieverbrauch bis 2060, szenario: nachhaltiges Wachstum*, 1998.

In the box below the price of a kilowatt hour (kWh) generated by a solar panel in the Netherlands is calculated on the basis of a number of assumptions (see appendix 1).

Calculation of kWh-price from solar panels[13]*:*

The current costs of a solar panel are expressed in Wp-prices. A solar cell of 10x10cm supplies approximately 1 Wp. The costs of a solar panel with a capacity of 100 Wp now amount to approximately Eur 3.95 per Wp[14]. The costs of installation, the cabling and the inverter amount, on top of this, to approximately Eur 2.27 per Wp. This brings the system costs to approximately Eur 6.22 per Wp. One Wp supplies 800 Wh annually in the Netherlands.[15] If we assume a life span of 20 years and an interest rate of 3%, the kWh price comes to Eur 0.52 (=fl 1.14) excl. VAT. Including VAT, this amount comes to Eur 0.61 (=fl 1.34).

The current electricity rates for small-scale consumers

To compare the electricity price of solar energy with the current electricity rates, we will use the electricity rates charged by the power distribution companies to small-scale consumers (including households) as a yardstick. We do so because small-scale consumers will be important future purchasers of solar panels. The current electricity rates for end users depend on a number of factors, such as:

- the variable electricity rate charged by the distribution company;
- the fixed rate charged by the distribution company for a connection;
- the type of meter that is installed.
- the amount of electricity used. This is not only a yardstick for the cost structure of fixed and variable costs, but is also indicative of the variable rates or taxation related to the amount of electricity consumed.

In the following box it is calculated what the average electricity rate (per kWh) is for an average Dutch household. In the calculation and the comparison with the electricity rate of solar panels, we leave the fixed costs of connection as charged by the distribution company outside consideration[16]. We therefore only include the variable costs in the calculation. In the Dutch example we include the regulatory energy taxation (RET) in its entirety in the price of conventional electricity.

13 The kWh-price is an estimate based on a number of assumptions. The assumptions made are mentioned in appendix 2. The figures presented should therefore be used with a modicum of caution.

14 Novem, *PV Introduction Plan,* 1997.

15 This factor is significantly higher in countries that are close to the equator.

16 We assume that the power distribution companies will also charge households with solar panels a type of fixed rate because the solar panels connected to the electricity grid also use the grid and the household will still often purchase electricity via the distribution company.

Calculating kWh-price via the distribution company in the Netherlands:
The average[17] variable electricity rates amount to Eur 0.089 (excluding VAT and RET) in 1999 for small-scale consumers (incl. households).[18] Including VAT, this comes to a rate of Eur 0.105. Finally, on top of this comes the RET tax of 4.95ct (Eur 0.022) per kWh, on which Value Added Tax (VAT) is also owed. This means that another Eur 0.026 is added to the RET-tax. This brings the end-user rate per kWh (excl. fixed connection costs) in the Netherlands to Eur 0.13 per kWh.

Conclusion of comparison of the different electricity rates

On the basis of the above comparison of the rates for electricity generated via solar energy with the rates that are currently being charged by the power distribution companies, we can conclude the following:

Electricity generated with the help of solar panels is for the end user approximately a factor of 4 to 5 times more expensive than electricity generated by conventional sources and is currently not competitive economically.

2.4. The market potential of solar panels

As stated in paragraph 2.2, the current sales of solar panels in the Netherlands are limited. In this paragraph we describe the market potential for solar panels in order to be able to make an estimate of the demand that could be created by a substantial fall in the price.

The potential demand for solar panels in the Netherlands is determined by two factors: the energy consumption and the usable roof surface. Here we assume that households will not install more solar panels than are necessary to cover their energy consumption and that it is not possible, of course, to install more panels than there is space available for such in the Netherlands[19]. In 1996 small-scale consumers in the Netherlands used 30,000 GWh of electricity[20]. To produce such an amount of electricity one needs 380 million m^2 of solar panels[21].

In this section we focus our attention primarily on the placement possibilities for solar panels. The data is taken from a study that the Department of Natural Science and Symbiosis at the University of Utrecht conducted under the commission of the Ministry of

17 Average for the different distribution companies for the single kWh-rate.
18 EnergieNed, *Overview of energy rates*, 1999.
19 In time it is possible that households will generate more energy than they use.
20 EnergieNed, *Energy distribution in the Netherlands 1997*, 1998.
21 Assuming there are power-grid-linked systems and the surplus electricity produced is channelled back to the power grid and then used elsewhere.

Economic Affairs into the possibilities for solar energy[22]. On the basis of this data, we calculate the Dutch market potential for solar panels and for solar energy. The figures in this chapter are meant to be an indication of the market potential and therefore, should not be considered a forecast of the market size that will actually be achieved.

The University of Utrecht has come up with the following categories of locations for solar panels:

1. dwellings;
2. non-residential buildings;
3. in places other than on roofs.

1. Dwellings

In 1992 (the year of the study at the University of Utrecht) the Netherlands had 5.8 million dwellings, 4.0 million of which were single-family dwellings and 1.8 million multiple-family dwellings. The total roof surface of these dwellings amounted to 288 km^2, 79 km^2 of which was flat and 209 km^2 sloping[23]. According to the calculations of the University of Utrecht, this roof surface area provides room for solar panels with a combined peak capacity of 15.9 GWp.

According to data from the CBS, the housing supply has since grown to 6.4 million dwellings. If the total roof surface area increased proportionally, it would come to 321 km^2. The peak capacity of the panels that could be placed in this amount of space comes to 17.7 GWp. If the full potential were used, then 14,121 GWh of electricity could be generated annually by solar panels on the roofs of dwellings. This represents more than two-thirds of the total electricity consumed by households in the Netherlands.

2. Non-residential Buildings

The University of Utrecht estimates the total roof surface area of office buildings and non-residential buildings at 87 km^2. Since 1992, employment has increased by approximately 11%. If we assume that the roof surface area in this sector has kept pace with the increase in employment, then the roof surface area in this sector will have increased to 96 km^2. On this surface area 8.8 GWp of solar panels can be installed, good for an annual electricity production of 7,015 GWh[24].

---

22 Alsema, E.A. and van Brummelen, M. , *Less CO_2 through PV. Study into the maximum feasible energy generation and CO_2-emisson reduction using solar cell systems in the Netherlands up to 2020*, University of Utrecht, Dept. Natural Science and Symbiosis, November 1992.

23 Solar panels can also be placed on outside walls, although this is less effective due to the angle of inclination. This segment was not included in the study of the University.

24 University of Utrecht study of the employed for roofs on dwellings, roofs on non-residential buildings and 'other than roofs' different yield ratios per surface area (GWh/m^2). The reason for this are the different uses for surface areas in the three categories mentioned. For

Together, dwellings and non-residential buildings could provide an annual electricity production of 21,136 GWh. That is more than two-thirds of the total small-scale consumption in the Netherlands.

From a policy point of view it is interesting to make a separate inventory, within the office building and non-residential buildings sector, of all government buildings, because the government in these locations has control over the placement of solar panels. The government could act as the active customer in the market for solar panels for these buildings.

The government and semi-governmental buildings can be divided into three categories:
- national government buildings;
- educational institutions and care organisations;
- buildings of lower-level governments and buildings in the semi-governmental domain.

National Government buildings

Belonging to the category of national government buildings are the ministries and the buildings of the field organisations of the ministries, such as courts, prisons, barracks, palaces and national museums. The Netherlands has approximately 3,000 national government buildings with an average roof surface area of approximately 1,000 m^2[25]. The total roof surface area of national government buildings is therefore 3 km^2.

Buildings in the educational and care sectors

Schools and institutions in the care sector (hospitals, nursing homes, rest homes and so forth) are an important part of the buildings resting in the hands of the government and semi-governmental organisations. It is estimated that this comes to approximately 16,000 buildings[26]. If we assume that each of these roofs (just as those of the national government buildings) has a surface area of 1,000 m^2, then we are talking about a total surface area of 16 km^2.

Other government and public buildings

By other government and public buildings we mean the buildings of lower levels of government (city halls, provincial buildings, libraries, swimming pools, sports halls, police stations and fire stations). There is little information available on the roof surface area of these buildings. A rough estimate of this roof surface area comes to 4 km^2.

---

example, solar panels can be placed more efficiently (e.g. with respect to position and angle) on flat roofs of non-residential buildings than on the usually sloped roofs of houses.

25 Rijksgebouwendienst, VROM.

26 CBS 1999.

In total there are 23 km^2 of roof surface area available on government buildings. The capacity of the solar panels that can be placed on these roofs amounts to approximately 2.1 GWp, and the annual production amounts to 1,675 GWh.

3. Other places besides roofs

Besides roofs and outside walls, solar panels can also be installed in other places. The University of Utrecht names, for example, old farmland that will no longer be used for agriculture, fallow land, industrial and harbour areas, and land adjacent to airports, sound screens next to highways and railway lines. That is to say, the land that is no longer used for agricultural purposes offers enormous potential for the placement of solar panels. The use of these locations for solar energy instead of other forms of sustainable energy is efficient from the standpoint of power supply . Photovoltaic solar energy provides almost 20 times more energy per hectare than biomass.[27]

According to the University of Utrecht this type of surface provides a total of 221 km^2, on which (under a number of estimates concerning the use of the available land) panels could be placed with a total capacity of 45.8 GWp and an annual production of 36,600 GWh.

However, it should be noted that placing PV panels at locations where they are not at the ‘point of use’ of electricity, means that they are effectively acting as a power station supplying the grid. This is presents different economic conditions and competition for the solar supply, as they are then competing with other primary generators.

Total potential

The total potential for solar panels in the Netherlands is large (see table 2.4). In total, roofs and disused land offer room for the placement of panels with a combined peak capacity of 72.2 GWp and a total annual production of 57,736 GWh. This would provide three-quarters of the electricity consumed in the Netherlands[28]. If we only consider the roof potential on dwellings and non-residential buildings, then more than a quarter of the energy consumed in the Netherlands could be generated by solar panels.

27 From a spatial or architectonic viewpoint the consideration can be different.

28 This pertains to the current consumption of electricity and to the current output of solar panels. It is expected that both shall increase in the future. It is also assumed here that the electricity can be rechanneled to the power grid without problems and also that the 'other' surfaces are provided with solar panels.

Table 2.4. Total potential for solar panels

	Total GWp	electricity saved (GWh)	Share in the total electricity consumption*
Potential of dwellings	17.6	14,121	18%
Potential of non-residential buildings and offices	8.8	7,015	9%
Potential of other surfaces	45.8	36,600	47%
Total potential	72.2	57,736	74%

* based on the consumption in 1997

3. The chicken and the egg of market development

Even a cloudy and rainy country such as the Netherlands provides a significant market for solar energy. As outlined in the previous chapter, it is possible to provide three quarters of the country's total electricity needs through solar energy, and one quarter through PV on buildings. To make this economically attractive the price of solar energy will have to be lowered sharply. In this chapter we will discuss three factors that can influence the price of PV-systems:

- technological developments;
- subsidies;
- the scale of production.

3.1. Lowering the price through technological development

The development of solar panels is still in its infancy. Although it was possible as early as the end of last century to convert solar energy into electricity, the development of solar cells and solar panels has only really made large strides in the last two decades. During this period the price of solar energy fell sharply. In the future the price will undoubtedly fall further as a result of new technologies. This however is a slow process.

Solar cell technology is nowhere near the end of its development. The production of solar panels is at present being done according to the 'crystalline silicon' technology. This technology results in large, rigid silicon-based panels. At present a new technology is under intense development, the thin film technology. This technology also uses silicon as a basis[29], but offers the possibility of making flexible panels that can be manufactured on a roll. This provides advantages for production, storage, transport and installation. Another important advantage of this technology is that these panels require only 1 percent of the silicon now used in the crystalline silicon panels. The costs of the silicon used forms 40-60% of the total costs of a solar panel. Savings gained in the use of silicon can therefore make a significant cost reduction possible[30].

Most producers of solar panels still use the crystalline silicon technology, since thin film technology is not yet suitable for large-scale production. This will undoubtedly change in the future. Other promising technologies for the future are thin film technologies that are not based on silicon as a raw material, but that are based on other alloys such as copper-indium diselenide and gallium arsenide. New technologies do not necessarily make all ‘old’ technologies obsolete. A number of technologies can exist side by side because the technologies' area of application can differ.

---

29 But other alloys can also be used.

30 Though other costs replace these costs.

The moment at which new technologies will be applied and the degree to which these technologies will contribute to lowering the price and increasing the acceptance of solar energy is not yet clear. It can be said that the technological development will accelerate significantly when the market volume increases. In this event, both the resources and the importance of the technological developments for producers will increase enormously.

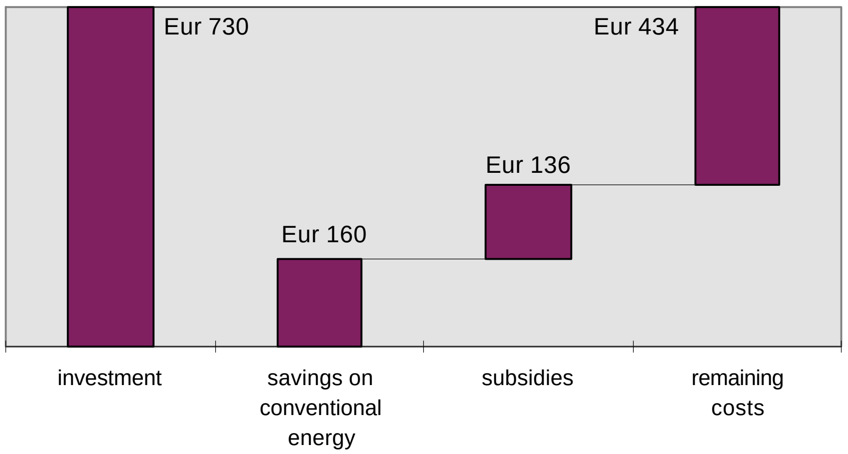
> Solar cell technology has still not reached the end of its development. The experiments with many new technologies indicate this. It is not yet possible to say when producers will be able to use these new technologies on a large scale and to what extent they will contribute to lowering the price and increasing the acceptance of solar energy.

3.2. Lowering the price through subsidies

In the Dutch case study, the current policy for the promotion of sustainable energy of the Dutch Ministry of Economic Affairs (EA) is two-tracked. The first track is aimed at technological development. It pertains to subsidies for research and development in the area of sustainable energy. The second track is aimed at promoting the use of solar energy by households.

The effect of the existing subsidy schemes on the price of solar energy is illustrated in figure 3.1. The bar on the left of the figure indicates the price of a solar panel. Next to it is the cash value of the amount saved on the electricity bill that can be achieved by the installation of solar panels. With the current price ratio between solar energy and conventional energy this comes to approximately one-fifth of the total price of the solar panels. Adjacent to this is the effect that current subsidy schemes have on the price of solar panels. The right-hand bar shows the extra costs that the consumer must incur to use solar energy instead of conventional energy.

Figure 3.1. Ratio between costs and returns of 1 m^2 of solar panel



With current technology and the current scale of production a solar panel of 1 m^2 with a capacity of 100 Wp will cost a private individual Eur 730 (incl. VAT)[31]. The energy output of such a panel amounts to 80 kWh per year. At an energy price of Eur 0.13 per kWh the saving comes to Eur 10.40 a year. With a depreciation period of 20 years and a discount rate of 3%, the cash value of the saving achieved comes to Eur 160.

In the Netherlands, the private individual can receive a subsidy for the placement of a solar panel amounting to Eur 1.36 per Wp, or Eur 136 per m^2. Even for private individuals that make use of this subsidy scheme, the price of solar energy is still high compared with the price of conventional energy. On a panel of 1m^2 the consumer still pay Eur 434. In conclusion we can therefore say:

> Under current incentive measures, the share of solar energy in the total supply of energy cannot be expected to grow rapidly in the foreseeable future. Generating a mass market for PV would require a quadrupling of the current level of Dutch subsidies.

3.3. Lowering the price through economies of scale

Besides subsidies and technological development, there is a third way to lower the price of solar energy, i.e. through enlarging the scale of production. Enlarging the scale of solar panel production provides a number of advantages. The most important of them are:

- a more efficient use of production equipment, both in terms of a more intense use of the machines and in terms of a higher throughput speed;

31 Novem, *Guide for PV-projects*, 1997.

- an improvement of the production process. By employing new work processes coupled with extensive automation of the process, a more efficient production can be achieved;
- technological innovations can be utilised on a larger scale and therefore have greater impact. Also certain innovations can only be used with large-scale operations;
- the relative size of the overhead costs can, in relation to the direct production costs, be reduced.

The prices currently charged for panels are based primarily on production from plants with an annual capacity of approximately 5-20 MWp. Although the largest producers are continually expanding production, the scale still does not exceed a capacity of 20 MWp.

Among the studies that focus on the possibilities for enlarging the production capacity there is one that, with respect to ambition, leaves the others far behind. This is the MUSIC FM-study[32] that researched the technical capacity of a plant of 500 MWp and the possible consequences for the final price of the panels. This study was conducted on behalf of the Commission of the European Union by a group of experts led by T.M. Bruton of BP Solar. The conclusions of this study indicate that, with a production capacity of this size and the necessary innovations, solar energy could be a competitive alternative to the conventional sources of energy. In the next chapter we shall discuss this research at greater length.

A 500 MWp plant produces 5 km^2 of solar panels, enough to provide 100,000 houses with a year's supply of solar energy. The production of such a plant is therefore more than 3 times larger than the current world production (in 1998 the world production came to approx. 150MW) and some 25 times larger than the largest plant that is currently in operation.

According to the results of the MUSIC-FM study, the necessary price reduction for solar panels by more than a *factor of 4* can be achieved by enlarging the production scale by a *factor of 25* compared to the largest plant now in operation.

Conclusion

Of the three possibilities that we have covered in the previous paragraphs, scale enlargement offers the best prospects to achieve a substantial lowering of the price in the short term. Technological developments can offer a solution in the future, but in the short term no enormous price reduction can be expected from this direction. Subsidies on solar panels can

32 Bruton, T.M. and others, *Multi-Megawatt Scale-up of Silicon and Thin Film Solar Cell and module manufacturing (MUSIC FM)*, 1996.

only be effective at a high cost, because of the big price difference between solar energy and conventional energy in the current situation.

4. Large-scale production of solar panels: possibilities and risks

In this chapter we take a look at the technical feasibility of a sharp scale-up in the production of PV systems. We will base our investigation on the MUSIC FM-study that was conducted on behalf of the Commission of the European Union. In this study research was conducted into the technical capacity of a 500 MWp plant and into the consequences that the economies of scale in production could have for the price of the solar panels. We will compare the results of the study with those of a number of other studies in this area. These studies pertain to plants of a much smaller size (10 and 20 MWp respectively).

4.1. The MUSIC-FM study

The MUSIC-FM study was carried out by a group of European experts under the leadership of T. Bruton from BP Solar for the Commission of the European Union. The objective of the study was to investigate whether it is technologically feasible in the short term to set up a 500 MWp plant, what investment would be required to do this and what the consequences would be for the cost price per Wp. The study initially focused on the market for solar panels in developing countries, but can just as well be projected onto the European market. In addition to the MUSIC-FM study, two other related studies analysed the possibilities of installing the panels in developing countries and the possible avenues for the financing.

The MUSIC-FM study has the following structure:

- at each step in the production process of the solar panels an analysis was undertaken into which technologies are available;
- next the technical capacity of these technologies was analysed on a similar scale, including the different technologies for producing crystalline silicon solar panels and the different thin film technologies[33];
- finally, it was determined what investments would be necessary to build such a plant.

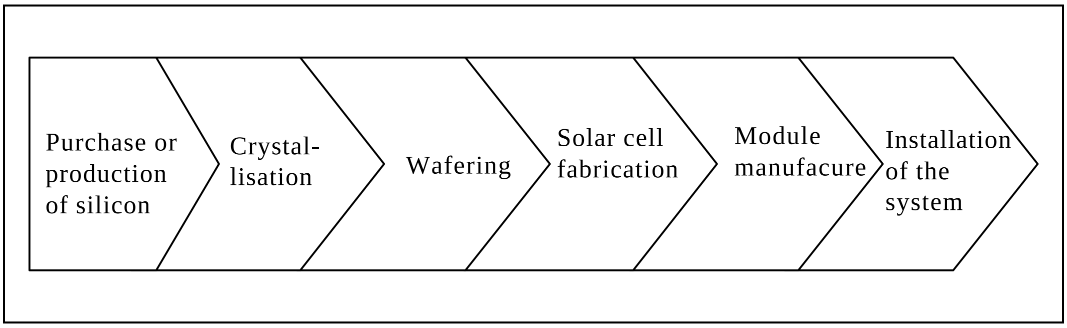
Because the MUSIC-FM study did not consider the BOS costs, which are an actual part of the total system costs, we have made an estimate of these costs ourselves. We will discuss this at the end of this section.

Figure 4.1 shows the different steps, in the form of a value chain, in the process for the production and installation of crystalline silicon solar panels. The last step in the value chain, the final installation, was not part of the study, but because these costs contribute to

33 For the thin film technology the study focused on a 60 MW plant.

part of the final price of solar energy, we have made our own projections of the installation costs.

Figure 4.1. Value chain for the production of PV systems



The study concluded that with the current status of technology it is possible to produce solar panels on a large scale in a relatively short term according to the crystalline silicon technology. The thin film technology is not yet sufficiently developed to begin production on a large scale. It is not possible to create a 500 MWp plant at a single go, not even with crystalline silicon technology. Such a plant will have to be scaled up in a number of steps.
The study concludes that if the best, most reliable and available technologies are used the cost price (ex-factory) of the solar panels will come to Eur 0.91 per Wp[34]. Use of other available technologies would result in a price of Eur 1.16 to 1.78 per Wp. The use of Edge-defined Film Growth ((EFG) could even cause the cost price of a crystalline silicon panel to fall to Eur 0.71 per Wp. It is still uncertain to what extent the necessary process improvements for the scale enlargement with the EFG-technology can be realised.

Table 4.1 provides an overview of the costs of the panel for the most reliable technology, divided into the different steps of the production process and different cost categories.

34 *Screen printed cells on wafers* based on *directional solidification* and *wire sawing*.

Table 4.1. Structure of the cost price per Wp of a 500 MWp plant[35]

Cost categories	*Cost price in Euros*	*Share in costs*	*Steps in the production process*	*Cost price in Euros*
Debt servicing charges	0.07	8%	Crystallisation of silicon*	0.28
Labour costs	0.10	11%	Wafering	0.22
Material costs	0.66	73%	Solar cell fabrication	0.11
Overhead costs	0.05	5%	Module manufacture	0.30
Other costs	0.03	3%		
Cost price	0.91	100%		0.91

* Including in-house production of cell grade silicon.
Source: MUSIC-FM

In-house production of silicon

For the production of solar panels at the current scale, silicon that is available as a by-product of the semiconductor industry can be used. For production of crystalline silicon solar panels at a scale of 500 MWp, this is no longer an option. The most reliable estimates indicate that 10% of the raw materials for the semiconductor industry is available for the PV industry. This is on the order of 1,000 to 1,200 tons a year. For a plant with a scale of 500 MWp, 5,000 tons is needed. That means that a separate plant has to be set up for the production of *solar grade* silicon, which will produce 5000 tons of silicon a year. The MUSIC-FM study calculates that the investment needed for the plant would amount to Eur 150 million, with production costs of Eur 20 per kg. These costs are (substantially) higher than the costs of silicon available as a by-product on the open market, whose price also fluctuates considerably. The price of silicon fluctuated over the last five years from approximately Eur 8 to Eur 16 per kg. These sharp fluctuations in the price are a result of the cyclical fluctuations in the semiconductor industry. Apart from the assurance gained concerning supply, in-house production also leads to greater price stability. Even with the substantially higher production costs, the final panel prices per Wp would still remain under 1 Euro.

Necessary investments

The investment that is needed to build a 500 MWp plant is estimated by the study at Eur 479 million. On top of this comes the investment of Eur 150 million needed to build the plant for the production of solar grade silicon. The plant would employ approximately 2,000 people. The investment cost per job, according to Bruton, is Eur 231,000, “which compares favourably with many projects such as the European fighter project where the cost per job created is Eur 1 million.”

Translation of the costs ex factory to the costs for the end user

35 With a straight-line depreciation over 10 years and own production of raw materials and a Return on Investment of approx. 15% which is included in the different costs categories.

The panel costs calculated in the MUSIC-FM study are the costs ex factory and therefore exclude the Balance Of System costs (BOS-costs). Within BOS fall the labour costs, capital costs (for the end user of the panels) and the costs for the *inverter* that converts the direct current of the panel into alternating current suitable for the electricity grid, as well as the costs for the cabling. The BOS costs make up approximately 40% of the final consumer price of solar energy.[36] For a comparison of the price of solar energy with the price of conventional electricity, the BOS costs must therefore be included in the calculations.

We assume that in large-scale production the BOS costs will fall a little less quickly than the panel costs. This assumption is based on the fact that the labour factor attached to the installation costs on roofs will not fall very much with an enlargement of scale[37]. This would mean that the trend of recent years would continue. In recent years the BOS price has fallen less sharply than the panel price (30% as compared with 45%). In 2000, according to Novem, a panel price of Eur 3.27 and a BOS price of Eur 2.09 will remain.

Table 4.2. Total system price per Wp divided between the panel price and the BOS price[38]

	1995	1996	1997	1998	1999	2000	relative fall ‘95-‘00
panel price	66%	64%	64%	63%	63%	61%	-/- 45%
BOS-price	34%	36%	36%	37%	37%	39%	-/- 30%
system price	100%	100%	100%	100%	100%	100%	-/- 40%

Source: Novem, Guide for PV-projects, 1998, edited by KPMG BEA

In our calculations we assume (in accordance with the results of the MUSIC FM-study) that the panel price with a production scale of 500 MWp could fall from Eur 3.27 to Eur 0.91. This is a reduction by a factor of 3.6.

If the costs of the inverter also fall by a factor of 3.6 and the other BOS costs (labour and cabling) fall by a factor of 2.4[39], then the total BOS costs will fall from Eur 2.09 to Eur 0.78[40].

36 Source: Novem, ECN.

37 If in the future solar panels begin to be integrated with the manufacture of roofs, then the installation costs could fall by the same and perhaps even a larger amount than the costs of the panels in large-scale production.

38 With a return rising from 13% in 1995 to 15% in the year 2000.

39 The fall in the other BOS costs will particularly be realised in new buildings. In new construction the installation of the solar panels on the roof is only one of the activities that is carried out during the construction of the roof and, in new construction, roof tiles can be saved (opportunity costs). With the integration of the panels in roofs ex factory, even larger savings can be realised.

As a result, the total system costs will come to Eur 1.69 per Wp.

Note: In calculating the system costs, no consideration was given to a margin or a profit margin for the secondary links in the chain (e.g. the distributors); this depends on the degree of vertical integration of the supply companies and depending on the number of links, the amount should be corrected here.

The price of solar panels for the end user at a 500 MWp production capacity

At a system price of Eur 1.69 per Wp, an annual output of 800 Wh per Wp, a life span of 20 years and an interest rate of 3%, the kWh price for the end user amounts to Eur 0.14 (exc. VAT). Including VAT the price comes to Eur 0.167 per kWh

In such a case the price of solar energy comes very close to the price of conventional electricity in the Netherlands, which currently amounts to Eur 0.13. Given the developments moving towards an increase in the tax on the use of conventional sources of energy (such as an increase in RET) it is possible that this difference will disappear entirely.

Conclusion

Technologically a 500 MWp-plant for solar panels can be built. Such a scale size in production will result in a rate for solar energy of Eur 0.16 per kWh. This brings the price of solar energy close to the price of conventional electricity for small scale consumers, which in the Netherlands is Eur 0.13 per kWh.

4.3. Comparison of 'Scale-Up' feasibility studies

To put the MUSIC-FM study into perspective with respect to other (cost price) studies that have been conducted into solar panel plants, we have placed the results of the MUSIC-FM study next to the results of other studies. In table 4.3 the results of the 500 MWp plant are compared with the calculations of Maycock[41] on a 10MWp plant and with the study of Greenpeace[42] on a 20 MWp plant.

Table 4.3. Costs per Wp of panels in Euros[43]

	Maycock (10MW)	Greenpeace	MUSIC FM (500

40 Under the assumption that 30% of the BOS costs consist of the costs of the inverter and the remaining 70% are the costs of labour and other costs.

41 Maycock, P., *Photovoltaic Technology, performance, cost and market, (1975-2010), version seven,* 1998; 'Proposed Cell Line for a New 10 MW Plant'.

42 Greenpeace, *Was kostet der Solar-Einstieg, Konzept für die Solarfabrik '96*, 1996.

43 Based on the conversion rate: 1 Euro = fl 2.20, 1 dollar = fl 1.90 and 1 DM is fl 1.10.

		(20 MW)[44]	MW)[45]
Debt servicing charges	0.20	0.44	0.07
Labour costs	0.10	0.70	0.10
Material costs	0.59	0.91	0.66
Overhead costs	0.32	*	0.05
Other costs, margin	0.43	0.16*	0.03
Cost price/Wp	1.64	2.21	0.91
Investment amount	17.4 m	39.1 m	500 m

* including overhead

44 The in-house production of wafers and when building a new plant.

45 In the MUSIC-FM study an indirect look was taken at the scale effects and cost reductions for a 100MWp plant. According to Mr Bruton, for such a plant the panel price came to between Eur 2.0 and Eur 2.4.

A relative comparison of the studies provides the following picture:

Table 4.4. Relative share of the cost components in the total cost price

	Maycock (10MW)	Greenpeace (20 MW)	MUSIC FM (500 MW)
Debt servicing charges	12%	20%	8%
Labour costs	6%	32%	11%
Material costs	36%	41%	73%
Overhead costs	20%	-	5%
Other costs, ROI	26%	7%	3%
Cost price/Wp	100%	100%	100%

The relative size of the various cost components varies widely between the studies. On comparison, a number of matters come to light:

- the debt servicing charges are considerably higher in the Greenpeace study than in the other studies;
- there is an even greater difference in the labour costs;
- it is noteworthy that the material costs, despite a much larger scale, in the MUSIC-FM study make up a much larger part of the cost price than in both other studies;
- the other costs are much higher in the Maycock study than in both other studies.

First conclusion

An initial cautious conclusion drawn from the tables above is that economies of scale primarily arise in the debt servicing charges, in the overhead items and in the other costs. Comparing the results of the different studies is very difficult, as is clear when we place several of the principles adhered to in each study next to one another (see table 4.5).

From a comparison of the assumptions shown it appears that:

- *the years as well as the countries in which the studies were conducted differ*. This creates price differences, for instance with respect to the costs of raw materials, which in 1996 were different than to those in 1998, or with respect to the labour costs, which differ between Germany and the United States for instance. Also the different years of the studies have an effect on the expected efficiency possibilities provided by the technologies used. This is reinforced by the fact that different technologies were used on components;
- *a difference in the supply of raw materials*. The MUSIC-FM study is based on an in-house production of silicon, the costs of which, Euro 20 per kg, were far above the then market price of silicon. This explains the relatively high material costs in the MUSIC-FM study in comparison with the two other studies in table 4.3;

- *not all studies include the same costs in the calculation of the cost price.* The different studies maintain different margins, rates for employees and costs for overhead.

Table 4.5. Comparison of several assumptions and principles in the three studies

	MUSIC-FM	**Greenpeace**	**Maycock**
Year of study	1996	1995/1996	1998
Technology	multi-crystalline, directional solidification, multi-wire sawing, screen printing, soldering & EVA lamination	multi-crystalline, EFG instead of directional solidification	Multi-crystalline, idem MUSIC-FM
Raw material supply	Own production of silicon at the cost of Eur 20 per kg (wafer production 12.5 x 12.5 cm)	Own production of wafers (12.5 x 12.5 cm) for Euro 1.79	Own production and purchasing of wafers (10x10 cm) based on current situation at several large producers
Depreciation	Straight-line over 10 years	Building 20 year straight-line Prod. Equipment 5 years straight-line	-
Overhead	An average of 25% (in part in the different steps	25%	30% of manufacturing costs
factory rental	not available	1000 per m2	-
Installation & maintenance charges	not available	3500 per m2	-
Labour rates (x 1000)	not available	- worker: E 32.5 - mechanic: E 45 - technician: E 50 - engineer: E 80	- worker: E 21.5 - engineering: E 86 - research: E 86 - marketing: E 43 - management: E 86
Other costs	Only costs of maintenance, ROI 15% a margin of approx. 20% in the different steps	Maintenance and such 6% on plant investment, including a margin of 5% on manufacturing costs and the costs of overhead	Energy costs, failure and 20% for yield loss

Potential economies of scale of large-scale production in theory

On the economies of scale that can be realised through enlarging the production capacity of solar panels there are several theoretical views. These correspond with the expected economies of scale in a scale enlargement of industrial production companies in general terms. The most important are the following:

- *scale effects in the primary process*: a larger scale size offers better possibilities to utilise the production machinery as intensively and thus as optimally as possible (efficiency in breadth). Scale enlargement can also optimise the throughput time of the production process[46] (efficiency in length);
- *scale effects in the support domain*: with a larger scale there is more freedom to co-ordinate the ratio between direct and indirect personnel (overhead) as optimally as possible. Also with a larger scale, the debt servicing charges can fall relative to the investment in the production machinery[47].

Reaction to the MUSIC-FM studies

The reactions of people interviewed and the written reactions to the MUSIC-FM are, in general, of an approving nature. Most respondents endorse the conclusion that the large-scale production of solar panels, provided it is introduced in phases, is technologically feasible. They also endorse the conclusion that considerable economies of scale can be realised, although not everyone agrees entirely with the manner in which the Euro/Wp 0.91 cost of a solar panel is calculated.

Conclusion

The findings of the MUSIC-FM study are difficult to compare with other studies, both with respect to the level of ambition in scale size and to the assumptions made and principles adhered to. We can establish from the studies that, especially in the area of overhead costs and the debt servicing charges, considerable economies of scale can be achieved through an enlargement of production capacity.

The costs that are recorded as other costs differ in each study to such a degree that a comparison in this area is not possible. The MUSIC-FM study in this instance appears to have taken fewer costs into account than the two other studies. Although this can have the effect of raising the cost price, this will not affect the general outline of the conclusions from the MUSIC-FM study.

---

46 Provided there is no under-capacity of the production machinery.

47 For example lower intrest rates.

4.4. Risks and consequences of large-scale production

Scaling up production to a level of 500 MWp brings different risks. We can group these risks in the following categories:

- the technological risk;
- the production risk;
- risks attached to the installation of panels;
- other practical risks;
- the market risk.

The technological risk

Part of the investment decision for large-scale production is the decision concerning which technology to use. Because of continuing technological development, it is possible that a few years after construction a technological breakthrough could occur which would make the technology currently invested in out-of-date, relatively speaking. In the market there are a range of different opinions on the significance of this risk. The general expectation is that the different technologies will be given different applications, such that they can exist side by side for a relatively long time. This means that the technological risk is limited.

The production risk

The most prominent production risk is the lack of practical experience with a large-scale production process. Although on paper it appears to be technically possible to produce panels on this scale, there are no practical examples to underpin the findings. In practice, therefore, practical problems can arise. A wide array of large and small problems can arise in the production process that make large-scale production impossible, or not possible with the expected economies of scale. The drafters of the MUSIC FM-study therefore also express the expectation that a plant of this scale size will not be built at one time, but will come about through a gradual scale-up. With such a gradual scale-up, according to the experts spoken to in the context of the study, no other or larger problems can be expected outside those problems that could be expected with the construction of other large plants.

Risks attached to the installation

With respect to the installation of the panels there is the risk, among others, posed by the fact that the necessary installation capacity has to be able to be adjusted to the output of the plant. There is the chance then that the installation activities cannot in the short term seamlessly grow along with this sharp rise in the supply of panels. The people interviewed have established that there is a market for the installation of panels and that this market can and will develop at lightning speed. A larger risk is that the installation of PV systems is still an 'add-on' operation, instead of being integrated into the building activities. To the degree that the use of solar panels starts to grow more rapidly, this integration can be expected to occur more and more.

Other practical risks

In addition, practical problems can appear in the area of:

- *logistics problems of storage and transport*: the plant has an annual production of 5 km^2 of panels. This places a great emphasis on good logistical handling of the panels and on good co-ordination and planning;
- *the effect of substitution on the end users' price*: the 500 MWp production of solar energy on a yearly basis has a number of consequences for conventional sources of energy. This can lead to a still larger over-capacity in the existing electricity grids. In view of the relatively high share of the fixed costs attached to the production and distribution of electricity, the costs for each end user will rise. This is a risk for the user of conventional energy, but also offers chances for an accelerated acceptance of solar energy;
- *the effect of supplying electricity to the electricity grid and grid integration:* the large-scale resupply of electricity to the grid can mean that the production or distribution companies, at certain times during the year, receive a volume of current back that exceeds demand. This will mean that this power will have to be stored, which at the present time is not possible on this scale.
- *the effect of substitution on the freedom of resupply*: a production of 500 MWp carries the risk that power distribution companies, because of the enormous generation of electricity via the panels, will decide to ban the resupply of electricity or to attach a higher price to it.

The market risk

The most significant risk attached to the building of a large-scale plant for solar panels is that the unconfirmed market for these panels. This view is confirmed by the people we have interviewed in the context of the study[48]. The size of the investment is not scaring away the current producers, which are subsidiaries of large multinationals. The risks and possible technological problems that are attached to large-scale production can all be overcome.

Our study confirms the most important conclusion of the MUSIC FM-study: "…by increasing the market size, the price of photovoltaic modules will fall. Indeed the study shows that it is market size which is the key driver in cost reduction."

48 In appendix 3 an overview is given of the people interviewed.

5. Conclusion

The Objective of the Report

Greenpeace commissioned KPMG Bureau voor Economische Argumentatie (Economic Research and Policy Consulting) in the Netherlands) to conduct a study into the feasibility of producing solar panels on a large scale. The question posed by the study has been formulated as follows:

> Can the large-scale production of solar panels lower the price of solar energy to such an extent that solar energy can compete economically with conventional forms of energy?
> And if it can, what action is necessary on the part of government, customers and industry to break through the current impasse?

This report is an international version of the original Dutch report which has focused on the Netherlands as a case study.

The Current Market

Solar energy is a sustainable and clean source of energy. Solar energy also holds promise for the future of electricity production, however the use of solar energy in contrast to the use of conventional energy is still very limited. The predominant reason for this is that the demand for solar energy and solar energy panels is small and the attached prices are high. The PV-market is in a classic chicken/egg impasse: as long as demand is small, production of solar energy will remain small-scale and expensive, and as long as the production is small-scale and expensive, the price will remain high and the demand small. Catch 22.

> Electricity generated using of solar panels is for the end user approximately 4 to 5 times more expensive than electricity generated by conventional sources and is currently not economically competitive.

How to Make PV Competitive : The Chicken and Egg Problem.

Even a cloudy and rainy country such as the Netherlands is an important market for solar energy. It is possible to provide three quarters of the country's total electricity needs through solar energy, and one quarter through PV on buildings. To make this attractive economically the price of solar energy will have to be lowered sharply. Three factors can influence the price of PV-systems:

- technological developments;
- subsidies;
- the scale of production.

Technology: Solar cell technology has still not reached the end of its development. The experiments with many new technologies indicate this. Currently it is not yet possible to say when producers will be able to use these new technologies on a large scale and to what extent they will contribute to lowering the price and increasing the acceptance of solar energy.

Subsidy: Under the current incentive measures, the share of solar energy in the total supply of energy cannot be expected to grow rapidly in the foreseeable future. In the Dutch case study, generating a mass market for PV would require a quadrupling of the current level of subsidies

Up-scaling: According to the results of the MUSIC-FM study, the necessary price reduction for solar panels by more than a *factor of 4* can be achieved by enlarging the production scale by a *factor of 25* compared to the largest plant now in operation.

Of the three possibilities that we have covered in our study, exploiting large economies of scale in manufacturing solar panels offers the best prospects to achieve a substantial lowering of the price in the short term. Technological developments can offer a solution in the future, but in the short term no enormous price reduction can be expected from this direction. Subsidies on solar panels can only be effective at a high cost, because of the big price difference between solar energy and conventional energy in the current situation.

Large Scale Production : Possibilities and Risks

Our study confirms that technologically, a 500 MWp-plant for solar panels can be built. Manufacture on this scale would bring the price of solar energy into the range of conventional electricity for small scale consumers. In the Netherlands such a scale size in production will result in a rate for solar energy of Eur 0.16 per kWh. This brings the price of solar energy close to the price of conventional electricity for small scale consumers, which in the Netherlands is Eur 0.13 per kWh.

Major Conclusions

- Scaling up the production of solar panels is technologically feasible using current technology.

- To achieve a reduction in price to the level of conventional energy, production needs to be scaled up to 500 MWp per year.

- There are costs involved in creating the required market size, and either the industry, or the government, or the users of energy will have to pick up the cost of transition.

-0-0-0-

Appendix 1: Policy options for the Netherlands

1.1. Current Dutch subsidies for PV-systems

The current policy for the promotion of sustainable energy of the Ministry of Economic Affairs (EA) is two-tracked. The first track is aimed at technological development. It pertains to subsidies for research and development in the area of sustainable energy. The second track is aimed at promoting the use of solar energy by households.

In the *Action Programme Sustainable Energy on the Move,* the Ministry of Economic Affairs has laid down a number of policy resolutions to promote the use of solar energy. This primarily concerns fiscal instruments and subsidy schemes to promote the use of solar energy and other forms of sustainable energy. These instruments and their significance are explained below. In addition, the EA has entered into an agreement in which the use of solar energy is promoted through collaboration with a number of market parties. This collaboration is formally established in the PV-Covenant and dated 14 April 1997. The participating parties are power distribution companies, EnergieNed, PV-companies, construction companies, ECN and Novem.

In the context of the PV Covenant, the EA has drafted a Multiple Year Programme NOZ-PV 1996-2000[49] whose goal is to:

- improve the price/performance ratio by 30% by the year 2000;
- gain solid industrial support for and a scaling up of PV-technology;
- create a healthy market for autonomous PV-systems;
- gain knowledge of PV-applications in the urban environment;
- garner wide social support.

The budget for supporting solar energy amounts to *ƒ*34.3 million (Eur 15.6 million) per year. The money will be spent, among other things, on research and subsidies for market-introduction projects for PV on a small scale.

A number of schemes to promote the use of sustainable energy are listed below. The fiscal schemes and the subsidy schemes are all aimed at promoting sustainable energy use in general. With schemes that are directly important for the promotion of PV, it is indicated what the contents of the scheme are and what financial advantage the scheme provides.

- General incentive scheme for energy conservation of the power company 1999, conducted by local power companies[50]. The scheme can be applied to dwellings

49 Ministry of Economic Affairs*, Multiple Year Programme - the Netherlands research programme solar energy-pv*, 1996.

and non-residential buildings. The subsidies vary per power company, but a very common investment subsidy is ƒ3.- (Eur 1.36) per Wp. This allowance can run up to ƒ7.50 (Eur 3.41) per Wp;

- Energy investment deduction (EIA). The scheme is carried out by Senter. Each company that invests in an operating asset that meets a certain energy conservation norm is eligible for the EIA. The measure pertains to investments in solar panels. These investments provide an extra deductible item on the Vpb varying from 40 to 52% of the invested amount. This corresponds with a government contribution of 14.5 to 18.5% of the investment amount;
- Subsidy scheme energy supplies in the non-profit and special sectors, such as foundations, religious communities, etc.: EINP. This scheme is comparable to the EIA, but is applicable to the non-profit sector. It is carried out by Senter. The subsidy varies from 14.5 to 18.5% of the invested amount. To be eligible the investments should amount to at least ƒ10,000 (Eur 4,545).
- Scheme for general write-offs of Environmental investments for companies (VAMIL). Investments in operating assets that, in the interest of the environment and the efficient use of energy, can be written off.
- Energy conservation fund (EBF), for non-household energy users that pay a MAP charge. This scheme is carried out by the power companies. Money can be borrowed for energy conservation measures at an interest rate that is at least 3% lower than the market interest rate. This pertains to an initial investment amount or an extra investment and depends on the depreciation period. The investment should amount to at least ƒ20,000 (Eur 9,091). A maximum of ƒ300,000 (Eur 136,364) in credit is advanced. This concerns ƒ85.- (Eur 38.6) to 4 GJ and ƒ25.- (Eur 11.36) for each extra GJ. A combination with EIA and VAMIL is permitted.
- Educational program PV in the urban environment (PV-GO!)[51]. Subsidising of demonstration projects that demonstrate a successful engineering, architectural and urban development integration of PV in combination with active management and financing forms. The maximum subsidy amounts to 25% and depends on the degree of innovation and the interest in the contribution of the submitter. The percentage can rise to 40% for demonstration project components and up to 50% for innovative components.

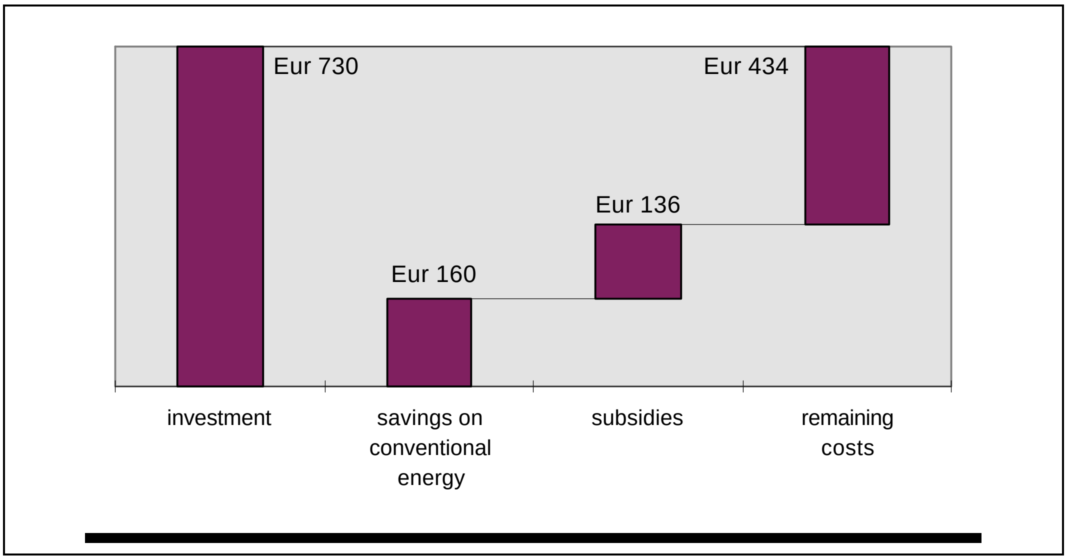
The effect of the existing subsidy schemes on the price of solar energy is illustrated in figure 3.1. At the left in the figure stands the price of a solar panel. Next to it is the cash value of the amount saved on the electricity bill that can be achieved by the installation of solar panels. With the current price ratio between solar energy and conventional energy this comes to approximately one-fifth of the total price of the solar panels. Adjacent to this is the effect that the subsidy schemes have on the price of solar panels. The left-hand bar

50 EnergieNed, Overview of implementation of *General incentive scheme for energy conservation of the power company*, 1999.

51 Novem, *Guide for PV-projects*, 1997.

shows the extra costs that the consumer must incur to use solar energy instead of conventional energy.

Figure 3.1. Ratio between costs and returns of 1 m² of solar panel



With current technology and the current scale of production a solar panel of 1 m^2 with a capacity of 100 Wp will cost a private individual Eur 730 (incl. VAT)[52]. The energy output of such a panel amounts to 80 kWh per year. At an energy price of Eur 0.13 per kWh the saving comes to Eur 10.40 a year. With a depreciation period of 20 years and a discount rate of 3%, the cash value of the saving achieved comes to Eur 160.

On the basis of the Power Company Incentive Scheme, the private individual can receive a subsidy for the placement of a solar panel amounting to Eur 1.36 per Wp, or Eur 136 per m^2. Even for private individuals that make use of this subsidy scheme, the price of solar energy is still high compared with the price of conventional energy. On a panel of 1m^2 the consumer must add an amount of Eur 434. In conclusion we can therefore say:

> Under the current incentive measures, the share of solar energy in the total supply of energy cannot be expected to grow rapidly in the foreseeable future. Effective subsidising requires a quadrupling of the current level of subsidies.

1.2. Policy options for a breakthrough

In the main text of this report we discussed the possibilities for the large-scale use of solar energy in the Netherlands. In this appendix we will look into the possibilities there are to develop the market for PV systems. We will discuss both the measures that will stimulate

52 Novem, *Guide for PV-projects*, 1997.

the supply of PV systems and the measures that will help to stimulate demand. In the final section we will take a look at the speed at which the measures will have effect, both on the use of solar energy and on the price of solar panels.

In our study we have established that there is no lack of surface space on which to place solar panels. The scale of production that will be required to fully utilise that surface area requires heavy investments, but does not come up against insurmountable technical problems. With such a production scale, enormous economies of scale can be realised. It may also be expected that with large-scale production the importance of innovations will increase, through which the technological development of PV systems can accelerate quickly. The production costs can, as a result, fall to a level that would bring solar energy down to a price that could compete with conventional energy.

The bottleneck for a large-scale production of PV systems and a large-scale use of solar energy lies in the market. The large-scale production of PV systems will only occur if there is a large demand for these systems. And a large demand for solar panels cannot be expected as long as the price of PV systems is not brought down to a competitive level by large-scale production.

In chapter 3 of this report we explored three avenues by which the price of solar energy could be brought down:

- through technological development;
- through subsidies;
- through enlarging the scale of production.

In the long term the price of PV systems will fall further under the influence of technological development. With the current production volume and the current size of the market this will take a long time.

Subsidies will help bring the price of solar energy down, but the current subsidy schemes bridge only a small part of the gap between the price of solar energy and the price of conventional fuels. To make solar energy an actual competitive alternative, much larger subsidies are required that, with an increase in the use of solar energy in the long term, could lead to a large burden on public finances. An enlargement of scale in production, in combination with market development, for this reason appears to be the most promising path to lowering the price of PV systems and a massive use of solar energy. From the MUSIC FM-study that was carried out by a number of experts for the European Commission it appears that scale enlargement up to a level of 500 MWp could lower the price of PV systems by 60 to 80%.

Large-scale production and large-scale use of solar energy in the Netherlands is not impeded by a lack of space. According to the study of the University of Utrecht's study discussed in chapter 2, in the Netherlands there is room for approximately 70 GWp of solar panels. If the PV systems have a life span of 20 years, then this potential corresponds with an annual production of approximately 3,500 MWp per year. If the Netherlands were to use only 10% of this potential, it would give enough of a boost to the scale-up in the production of PV systems.

A role for government

It is clear that this market size will not be achieved by itself in the foreseeable future. As long as the sales of PV systems remain uncertain, no company will build a 500 MWp-plant, and at the current price of solar panels the sale of panels will not quickly justify the construction of a 500 MWp plant. An important question to ask is whether a role has been identified for the government in promoting the development of the market for solar energy. It is clear that there is a collective interest served by the use of sustainable energy. The government has set itself goals with respect to the reduction of CO_2-emissions and the introduction of sustainable energy that can only be achieved through a heavy deployment of sustainable energy. The importance of reducing emissions presents an argument for government intervention, even when there are drawbacks to this from the standpoint of market forces.

Given the character of the problems in the market for PV systems, arguments can also be put forward in favour of government measures to serve the interests of market forces. The potential buyers of PV systems are faced with a dilemma: they would be happy to buy PV systems for a reasonable price, but not one of them wants to be one of the 'early adopters' who will bear the burden of the expenses of market development.

In fact, the market for solar energy is comparable to the market for conventional energy, which was pushed into development through active government intervention. The construction of the electricity grid required large investments that could only be recouped over the long term. Had the construction of the electricity grid at the time been left to the market, these facilities would probably have never got off the ground. In this case the 'early adopters' of the new technology would have had to pay a high price for the construction of the basic infrastructure. The latecomers in the market could then have gained a connection to the grid at a much lower cost.

The government broke through this dilemma for the customers at the time by assuming a role in the construction of the infrastructure. In fact all customers were forced to connect to the electricity grid, which immediately created the critical mass needed to make the construction of the grids profitable. PV systems are now faced with a similar dilemma. A critical mass is needed to push the market into development, and it appears that this critical mass can only be achieved within the foreseeable future through an active stance taken by the government.

Scaling up supply

There are different ways conceivable that the government could move the supply of solar panels to a higher level. It is unlikely that the government itself will build a large plant for PV systems, but it could make a special contribution to limiting the risk of an investment in a large-scale plant.

This can be done in two ways:

- the government can offer the investor the possibility of a general depreciation allowance for taxes on the investment in a plant;
- the government can grant a subsidy for part of the investment amount or (e.g. via the industrial credit facility) provide risk-bearing loans for the building of a plant.

It is improbable that through these types of measures the government will convince companies to make investments that they would not have made anyway due to their assessment of the market. In general we are also not talking about companies that have insufficient resources to make investments on the order of this magnitude. For energy concerns such as Shell and BP, and for other multinationals such as Siemens, an amount of Eur 650 million is a mid-sized investment. There are also a number of drawbacks to offer-related measures from a competitive point of view. When the government offers one company support with an investment in a 500 MWp plant, they create an enormous competitive edge for this plant over other (potential) suppliers of PV systems. This not only has economic drawbacks, but would also lead to legal objections and would quickly be in violation of the European ban on State support. In an appendix to this report, the legal aspects of a policy aimed at scaling up the supply are discussed.

Scaling up demand

In the energy sector the market size is seen as the bottleneck holding back further development of solar energy. This view is confirmed in the MUSIC FM study and by the discussion we have held in the context of our study. The current producers of solar energy are not waiting around for support from government for their investments, they are waiting for the demand for solar panels to justify a much larger scale of production and supply.

The deployment of financial instruments (i.e. subsidies) offers insufficient encouragement. Under the current price relationships heavy subsidies are needed for solar energy to compete in price with conventional energy, and there is insufficient certainty that, as a result of these subsidies, a substantial increase in the demand for solar panels will be created.

An alternative is for the government to intervene in the market for solar panels through legislation. In principle there are two conceivable ways in which the government can further development in the market for PV-systems:

- prescribe the use of sustainable energy;

- prescribed the installation of PV systems in all new buildings and in buildings being renovated.

Prescribing the use of sustainable energy

An alternative to (directly or indirectly) prescribing the installation of PV systems in new buildings, requirements can be set for the use of sustainable energy. As a result of the liberalisation and internationalisation of the energy sector, the government increasingly has fewer possibilities to prescribe how the energy used in the Netherlands is produced. The government can require customers to purchase or produce part of the energy in the form of sustainable energy. The customers can meet this requirement by producing sustainable energy or by buying it from production companies.

The Dutch energy companies are already working with a system of Green Labels, which separates the extra value of sustainable energy from the actual supply of energy and makes it separately marketable. In this system producers of sustainable energy are given Green Labels that they can sell to the energy companies. The energy companies have an incentive to use these Green Labels because they are required to show that a certain share of the energy they supply to their customers comes from sustainable sources. To show this they have to submit Green Labels.

The energy companies have pledged to purchase or to produce 1700 GWh of sustainable energy in the year 2000. After 2000 the system of Green Labels will be replaced by a system of green certificates. This system will be set up by the Ministry of Economic Affairs.

Small-scale Consumers that, with the help of PV systems, generate electricity are in principle not eligible for green certificates because with their PV systems they do not supply any electricity to the electricity grid but instead avoid purchasing electricity from the grid. This is also a more attractive option for them because the electricity that they would take from the electricity grid is considerably more expensive than the electricity they would supply to the grid.

Indirectly, small-scale consumers with PV systems benefit from the system of green certificates because the requirement to procure part of the electricity from sustainable sources raises the price of electricity supplied via the grid. This effect is surpassed many times over by the expected increase in the Regulatory Energy Tax, now 5 cents per kWh, to 11 cents in the future. However, this price rise for electricity from the grid is still insufficient at the current scale of production of PV systems to make solar energy a competitive alternative.

Prescribing the installation of PV systems

Prescribing the installation of PV systems could be done in the Netherlands via the Building Decree. Here different variants are conceivable:

- the requirement can be imposed in the Building Decree itself;
- the installation of PV systems can be compelled through a further tightening of the energy performance norm;
- the installation of PV systems can be compelled through a newly formulated energy production norm.

The Building Decree

In the Building Decree a regulation could be included for the installation of PV systems which is comparable to the existing requirement stating that dwellings and residential buildings must be connected to the power distribution grid. The Building Decree is an obvious vehicle for such a regulation, but the regulation could also be given form as a separate piece of legislation.

A direct regulation requiring PV systems to be installed in new buildings fits very poorly with the development of the building regulations, as means-prescribing regulations are increasingly making way in this legislation for goal-prescribing regulations. The government is prescribing increasingly less *how* certain results have to be achieved and increasing more *which* results must be achieved. The government leaves it up to the builders to choose the way they wish to achieve these results. .

The Energy Performance Norm

In the Energy Performance Norm (EPN) is laid down which energy performance requirements new buildings must meet. The energy performance requirements pertain to the use of conventional energy in the normal use of a building. The requirements can be met by taking measures that relate to energy conservation (insulation, high efficiency boilers and similar things) and by taking measures that pertain to energy production (the use of solar energy and such like).

The builder is free to choose the way in which he achieves the prescribed energy performance. This energy performance is calculated on the basis of norms set down by the Netherlands Standardisation Institute.

The Energy Performance Norm was introduced in 1995. The norm for residences was tightened on 1 January 1998. A new tightening is planned before the year 2000. Another tightening of norms has since been announced for non-residential buildings. But these norms are not so tight that companies cannot get out from under the installation of PV systems.

An Energy Production Norm

A more direct way to promote the installation of PV systems is through the introduction of an Energy Production Norm in which requirements are set with respect to the local production of (sustainable) energy. In such an energy production norm it could be established that each building must itself provide a part of its own energy needs.

Effect of regulations

Even a tight government policy in which a requirement is imposed for the installation of PV systems in new buildings is in fact a very gradual approach. In the short term this is connected with the necessity of introducing the measures gradually. Firstly, a transitional period is needed to give the building sector the opportunity to adjust to the measure. Secondly, a transitional period is necessary because it will take several years to scale up the production from the current level to the level at which the calculated economies of scale can be achieved. In the long term the introduction will remain gradual because the installation of PV systems is only prescribed for new buildings and buildings undergoing renovation, which means that annually only 2% of total housing will be outfitted with PV systems.

It will therefore take at least 50 years before the full potential can be enjoyed. This tight government policy does mean a substantial acceleration in comparison with a situation in which market development is left to market forces.

With an annual percentage of new buildings and renovated buildings coming to 2% of existing buildings (residences and non-residential buildings), as calculated in chapter 2, such a regulation would in a relatively short time lead to a structural yearly demand for PV systems of over 500 MWp. This structural demand will increase further when the life span of the PV systems first installed has expired and a replacement demand gets underway. The replacement demand will also increase gradually as more buildings are provided with PV systems, bringing the annual demand finally above 1,000 MWp.

Prescribing the installation of solar panels in new buildings and in renovated buildings would be enough for a 500 MWp plant. It is more probable that a number of different suppliers will appear on the market, such that not all the economies of scale that, according to the MUSIC FM study are possible, will be realised. However, because of such a measure there will be a significant fall in the price of PV systems. Part of the production can be used for export.

The effect of a regulation on the price of PV systems depends on different factors. One crucial factor is technological development. When the market for PV systems begins to develop to a serious degree, the significance of research and development will increase. The costs of research and development play a smaller role because they can be spread over a much larger scale of production. The efforts in research will, on the one hand, be aimed at the development of inexpensive systems. On the other hand we can expect the development of production methods through which, even on a small production scale, economies of scale can be realised that now only appear available for a production scale of 500 MWp. Unavoidably, the ‘early adopters’ will still pay the price for market development. In a fast development of the market forced by regulations, this price would be considerably lower than it would be if market development was left entirely to market forces.

Summary

Scaling up the production of PV systems is the most effective and fastest way to bring the price to a level at which solar energy can compete with conventional energy. The bottleneck for this scale-up lies on the side of market demand. There are good arguments for the government to play a role in the development of the market for PV systems. Firstly, the use of PV systems will contribute to achieving the policy objectives with respect to the introduction of sustainable energy. Secondly, there is an impasse in the market: the potential buyers of PV systems are waiting for a price breakthrough that is not appearing because they are all waiting for it.

A government policy to promote the use of solar energy must therefore intervene on the demand side of the market. To achieve the use of PV systems on a large scale, prescribing the installation of solar panels is the most obvious path. This can be done in an indirect manner by tightening the energy performance norm or by introducing an energy production norm. But it can also be done in a direct manner by prescribing the installation of PV systems in new buildings and in buildings being renovated within the Building Decree or in separate legislation.

Prescribing the installation of PV systems is also a gradual approach. Firstly, a transitional period is necessary in the regulations to enable the building sector and the PV producers to adjust themselves to the new rules. Secondly, the measure pertains only to new buildings and will therefore take 50 years before the full potential of PV systems is fully achieved. The measure will in a much shorter period ensure that the production volume of PV systems increases to such an extent that the price will gradually fall to the level of the price small-scale consumers pay for conventional energy. It will also ensure that the market will reach the critical point.

Appendix 2. Definitions and assumptions

Capacity of a solar panel (Wp). The capacity of a solar panel is usually expressed in Watt-peak (Wp). This is the capacity (in Watts) of a solar cell in the full sunlight. The capacity of the solar panel per m^2 differs. A solar panel with a surface area of 1 m^2 has a capacity of 100 to 150 Wp. This study is based on the supposition that: a solar panel with a surface area of 1m^2 has a capacity of 100 Wp. A megaWp (MWp) is one million Wp, a gigaWp (GWp) is 1000 million Wp.

System outputs. The output of an installed solar panel depends, among other things, on the number of hours of sunlight and the efficiency (yield and losses) of the system. The annual energy that a 1 KWp-panel installed provides in the Netherlands is roughly *800 kWh/kWp/year*[53]*.* A panel of 1 m^2 in the Netherlands annually provides 80 kWh of electricity.

Average roof surface area for solar panels. An average household uses 3,200 kWh of electricity annually[54]. To be able to provide for its total electricity needs the average Dutch household would have to place 40 m^2 of panels on its roof.

Regulatory energy tax (RET). A Dutch tax on the consumption of conventional energy. The tax rate is currently 4.95 ct (Eur 0.022) per kWh.

Interest rate for the consumer. In the study we made calculations using an interest rate of 3% for consumers. This estimate is based on an average market interest rate of 6%. The interest payments on mortgages are tax deductible in the Netherlands. Assuming an expected tax deduction in the 50%-tax bracket, the net interest would amount to 3%.

Depreciation period for panels. In this study we have assumed a depreciation period for solar panels of 20 years.

Balance of system (BOS). The costs of installation and peripheral equipment (inverters, cables).

System and panel price 1999. The bases for the system and panel prices (excl. VAT) for 1999 are as follows[55]:

Panel price	Eur/Wp 3.95
BOS costs	Eur/Wp 2.27
Total	Eur/Wp 6.22

---

53 Novem, *Guide for PV-projects*, 1997.

54 Novem, *Energiegids,* 1998, the data pertains to 1996.

55 Novem, Guide for PV-projects, 1997.

Appendix 3. Overview of the interviewed persons

Mr. W.C. Sinke	Energieonderzoek Centrum Nederland
Mr. P. van der Vleuten	Free Energy Europe
Mr. B. Wiersma	Sunergy
Mr. T.M. Bruton	BP Solar (by telephone)
Mr. G. Boxhoorn	Shell Solar
Mr. S. Hogan	Spire Corporation USA (by telephone)

Appendix 4. Overview of literature consulted

Alsema, E.A. and van Brummelen, M. , *Minder CO_2 door PV (Less CO_2 through PV). A study into the maximum feasible generation of energy and CO_2-emission reduction with the help of solar cell systems in the Netherlands up to 2020*, University of Utrecht, Department of Natural Sciences and Symbiosis, November 1992.

Bruton, T.M. and others, *Multi-Megawatt Upscaling of Silicon and Thin Film Solar Cell and module manufacturing (MUSIC FM),* 1996.

EnergieNed, *Energiedistributie in Nederland 1997 (Energy Distribution in the Netherlands)*, 1998

EnergieNed, *Overzicht van energietarieven (Overview of Energy Rates)*, 1999.

Greenpeace, *Was kostet der Solar-Einstieg, Konzept für die Solarfabrik '96*, 1996.

Maycock, P., *Photovoltaic Technology, performance, cost and market, (1975-2010), version seven,* 1998.

Ministry of Economic Affairs, *Duurzame energie in opmars, Actieprogramma 1997-2000 (Sustainable Energy on the Move, Action Programme 1997-2000).*

Ministry of Economic Affairs*, Meerjarenprogramma Nederlands onderzoeksprogramma zonnestroom-pv (Multiple year programme for Dutch research programme for solar energy PV)*, 1996.

Novem, *Elektriciteit uit zonlicht (Electricity from sunlight),* 1995.

Novem, *Energiegids (Energy Guide),* 1998.

Novem, *Leidraad PV-projecten (Guide for PV projects)*, 1997

Novem, *PV Introductieplan (PV Introduction Plan),* 1997.

Renewable Energy Policy Project, *Expanding Markets for Photovoltaics,* 1998.

Appendix 5. Acronyms

Appendix 6. Legal aspects

Memo Steins Bisschop Meijburg & Co Advocaten

This memo starts with an introduction as to the applicable rules in relation with the four questions mentioned on page 4 of the draft proposal for a Solar Energy research project dated 8 March 1999 (“Proposal”). Thereafter the four questions from the Proposal will be briefly addressed.

Introduction

1 If the Dutch government initiates a large scale production factory for photovoltaics, invests in such a factory, or acts as a large scale buyer of photovoltaics, it should operate within the boundaries of European and Dutch competition rules. In particular are relevant the articles 82 (ex 86), 86 (ex 90) and 87 (ex 92) of the EC treaty, articles 24 and 25 of the Dutch Competition Act (“DCA”) and EC Directives on public procurement.

2. Article 82 EC Treaty and 24 DCA prohibit the abuse of a dominant position by enterprises. Article 86 EC Treaty and 25 DCA contain an exception to that prohibition if the activity is pursued by a company in the general economic interest. Article 87 EC Treaty prohibits state aid without explicit consent of the European Community.

3. The EC Directives on Government Procurement are applicable to government assignments regarding the supply of goods, services and construction. All European Directives have been implemented in the Netherlands. Most likely to be applicable to the Proposal is EC Directive 93/36 regarding the supply of goods.

4. Also should be mentioned the Dutch Electricity Act 1998 (hereafter: “Electricity Act”). The Electricity Act addresses primarily the *producer* and the *distributor* of *electricity* (solar energy included), this legislation has no direct impact on the options as mentioned in the proposal. After all, these options are aimed at stimulating large scale production of *components* used by the production of solar energy, either by creating demand or by initiating a factory.
However, the Electricity Act contains a set of rules aimed at the promotion of green energy. First, there is a provision enabling the production of energy, for instance by using photovoltaics, for personal use or for use of a limited group of owners, without being licensed. Second, there is a possibility to deliver back self produced green energy to a electricity supplier. Third, the Electricity Act includes a certification system that is to be used in the near future by the Dutch government in order to stimulate the production of green energy by electricity firms. Under this system, every producer must obtain a certain number of (negotiable) certificates. Every certificate stands for a certain quantity.

The four questions

Question 1: Can the Dutch government create a large scale demand by acting as a large scale buyer of photovoltaics ?

5. Whenever the Dutch government wants to buy goods on a large scale the freedom to choose a supplier is limited pursuant to EC Procurement Directive 93/36, hereafter “the Procurement Directive”. As soon as the buying entity falls within the definition of “government” (state, local government and also certain types of government controlled private entities with public interest), and the total sum exceeds a certain minimum, there must be an open competition for all interested parties.

6. For orders that do not exceed this minimum amount, there are no such restrictions. Government can grant the order to whomever she wants, unless government has committed herself to a more restrictive procurement policy. Since the Netherlands signed the WTO Agreement on Government Procurement, the minimum amount is 130.000 SDR or fl. 288.643,00 for central government, 200.000 SDR or fl. 444.067,00 for local government, and 200.000 Euro or fl. 431.087,00 for agreements that are not covered by the WTO Agreement.

7. For orders that do exceed the amounts mentioned before, government must create an open competition in accordance with the detailed rules of the Procurement Directive. This will be a complication if the option of stimulating demand is combined with the option of initiating a large scale production factory, for it would be a natural choice to grant all government orders to this new plant.

8. Alternatively, it *might* be a solution, to form a new factory in such a way that this factory itself would fall within the definition of “government bodies” that have to follow the rules of government procurement (we refer to recent Dutch case law, such as the ARA/BFI case). However, this possibility, is highly disputable and can only be assessed in a more concrete situation. What would be needed in the first place is a concession or exclusive right, granted by law, for the production of photovoltaics. This concession or exclusive right should not be in conflict with competition law. Secondly, it must be argued that this plant is in the public’s interest and does not merely serve an industrial or commercial goal. Besides that, this plant must be government controlled or financed for more than 50%. It should also be noted that the specific article the case law mentioned before is based upon, does not *explicitly* occur in the EC Directive with regard tot the supply of goods, while it does occur in all other EC Directives on government procurement. This means, it remains to be

seen whether these types of constructions to avoid public procurement, have any basis in the applicable Procurement Directive at all.

9. The argument of large scale production in the interest of assessing economical or technical feasibility or for covering expenses of research, is explicitly excluded by the Directive as a valid argument for not having to cope with the normal, extensive, rules of public procurement.

10. From a *government procurement* point of view, it can be concluded that the stimulation of demand by government by acting as a large scale buyer does not raise serious questions, as long as such is not combined in such a way that government automatically will grant her orders to a specific government owned large scale factory. Of course, there are also other aspects of competition law that should be taken into consideration.

Question 2: Can the Dutch government create a large scale demand by prescribing the installation of photovoltaics on the roofs of new buildings e.g. on VINEX locations?

11. In itself there is no legal impediment to prescribe the installation of photovoltaics at the roofs of new houses built at certain sites, provided that the prescription is properly done according to law and properly notified as a technical requirement under EC Directive 83/189 to the European Commission.

12. However, since the costs of the legal provision probably will be shared by the consumer, the seller, and (at least initially) the government, here also the government may tend to introduce requirements either for the products to be used or for the way they must be installed. If these requirements in any way exclude certain photovoltaics produced in another country than the Netherlands, which are legally at the market in the European Community, the provision may be in jeopardy, unless the requirements can be considered justified for reasons of general interest.

Question 3: Can the Dutch government subsidise, provide tax relief, grant low interest loans in relation with the building of a large scale factory for photovoltaics?

13. If the Dutch government chooses to subsidise (either through subsidies in the narrow sense or through tax-relief, low interest loans or other financial incentives) the factories already producing photovoltaics, according to article 87 EC Treaty, the measure should be notified to the European Commission as state-aid. State-aid is prohibited, unless the Treaty itself or the Commission declares it compatible with the internal market.

14. The question of how the Commission would react in this particular case is uncertain. In itself, a

policy in which investments in enterprises producing one particular product are central to national policy, is seldomly received well by the Commission. Also the ‘Community Guidelines on State Aid for Environmental Protection’ [56], which provide criteria for the acceptability of state-aid if it serves an environmental goal, do not endorse this particular form. Article 87(3b) EC Treaty which provides that the aid which may be considered compatible with the internal market includes ‘aid to promote the execution of an important project of common European interest’ may provide for an opportunity. This article in combination with the provisions laid down in the Guidelines mentioned above, and more in particular article 3.7 of said guidelines, could fit the situation.The guiding principle is that the beneficial effects of measures containing state aid must outweigh the distorting effects of competition. It can be argued that a non-discriminatory subsidy to the branch as a whole adheres to this principle.

The conditions under which the guidelines may be applied are, however, quite circumscribed. Firstly the aid must be essential (in the sense that no other measure is deemed feasible) to achieve the goal of the project; the project has to meet concrete and accurate specifications; it must be important with respect to quality and it must provide for a exemplary and clearly provable contribution to the common European interest. The Commission applies these criteria meticulously and does not easily derogate from article 87(1).

This can be seen in Decision 97/542 on tax exemptions for biofuels. In this case, the French government invoked article 87(3b) EC-treaty in connotation to two Community laws[57] favouring renewable energy. Unfortunately, because of infringements of other secundary Community law, the outcome of the case cannot be considered conclusive for the case of photovoltaic[58]s. However, the Commission also detailed its hesitations to apply article 87(3b) since the producers were not the ‘experiment’ the French government claimed them to be, but appeared to be fully fledged (and competing) operations. With this reasoning, the Commission is not claiming that it only rewards experiments under article 87(3b), but appears to require accurate information as to the status of aided enterprises. So even while the case is not conclusive, it urges member states inclined to invoke the article to be very accurate in their claims.The above leads to the conclusion that member states should be extremely cautious when they decide to subsidise enterpreneurs whether it is through investments or tax exemptions for specific products. Not just notification to the Commission but advance consultation so as to avoid unwelcome decisions is advisable.

---

56 OJ 1994, C 72/3

57 *Dir. 91/81 on the structures of excise duties on mineral oils and Council Decision 93/500 concerning the promotion of renewable energy sources in the Community.*

58 *The Commission decided that the article could not be applicable because the exemption was granted only to biofuels derived from product from set aside lands. With that the French measure infringed other EC-rules and thus could not fall within the scope of article 87(3b).*

14a. Instead of subsidising by the government as such, subsidising by private or semiprivate initiative may be a feasible alternative. In the Netherlands the Dutch Investment Bank (NIB), the ministry of Economic Affairs, certain insurance companies and organisations controlling pension schemes collaborated to introduce a specific credit convenience (named: *Industrie-faciliteit*) to stimulate investments in innovating developments in Dutch industry. The organisations provide for a non-guaranteed and marketconform credit for enterprises in the form of a non-preferential loan or a participation in the enterprise by said organisations. The scheme only facilitates enterprises as a whole: there is no facilitating stand alone enterprising or projectfinancing. Credits to be granted range from a minimum of NLG 10 million to a maximum of NGL 50 million per company or group of companies.

Because of the commercial character of the *Industrie-faciliteit* the legal hazards with regard to state aid seem to be avoided, even though the government is participant in the scheme. The role of the ministry is no more than a co-financing institution of the fund from which credits may be drawn; since it does not provide for any more support than just that, state-aid does not seem to be the question[59]. In other words the *Industrie-faciliteit* is nothing more than a commercial credit which may be provided for activities the normal banks do not (yet) deem commercially interesting enough. Because of its commercial character there has been made little use of it.

To be eligible for the use of the *Industrie-faciliteit* an enterprise has to fall within the criteria of the scheme which focus primarily on the activities of the enterprise as a whole, the innovating and commercial character of the activities concerned. This innovating character may include investments in environmentally friendly products. An investment in a factory producing photovoltaics might be feasible, depending on the adherence tot the other, named, criteria of the scheme. The question of whether the *Industrie-faciliteit* in itself would be able to stimulate large scale production seems dubious since the factory should be commercially and legally sound. As appears from above, the *Industrie-faciliteit* cannot be used to horizontally subsidise the production of photovoltaics because it is a credit convenience to an enterprise and not to production-lines.

15. Instead of the government initiating factories or subsidising them, stimulation of the production of photovoltaics could also take place by *subsidising the consumer*. To do so several alternatives exist. One could think of tax-relief with regard to the energy-levy for those who buy (or better) install photovoltaics. Another measure could be the non discriminatory subsidising of each separate product, or the provision of a subsidy to every buyer of a panel which is actually installed. There is also the possibility to add products to the 'VAMIL'list. The VAMIL-regulation is a Ministerial

---

59 Whether the arrangement could violate other provisions of the EC-treaty will not be discussed here.

Decree based on the Income Tax Law 1964, which allows businesses to write-off certain environmental-friendly means of production at will instead according to the rules of said Law. The products concerned are explicitly mentioned in the VAMIL-Decree.

The Decree offers a tax-advantage following from the opportunity provided to the users of said products to write of the products when it is most effective for them. Thus the Decree offers a horizontal subsidy in the form of tax-relief. Since the subsidy is horizontal and does not favour specific producers over others, the measure is assumed to be compatible with article 87. Since the coming into force of Council Regulation 994/98[60] this kind of horizontal aid is exempted from notification. Photovoltaics itself have already been added to the VAMIL list.The question of whether the means of production with which photovoltaics are produced could be included in the VAMIL list is an interesting one, but not one which can be answered by lawyers. It depends on the question of whether these means of production are environmentally friendly themselves. If so, this might be an interesting avenue to explore.

16. If the consumers are subsidised, either through tax relief or subsidies, the measure may be eligible for notification under article 87 EC Treaty. Since consumers tend to buy close to home, especially when installing of the photovoltaics may be required, the measure may assume a state aid character, because the products of a member state may be favoured by the increased sales. Even though the measure would have a good chance to be declared compatible with the internal market under 87(3c), one cannot be completely certain[61].

17. The subsidy must be non discriminatory: every panel from whichever origin should be equally treated. Here a warning is appropriate: governments who subsidise products, in whichever form, have a tendency to require certain qualities from those products, because otherwise they feel they are subsidising inferior products (aside from a certain tendency to protect the domestic market). If the photovoltaics do have to fulfil certain requirements to be eligible for a financial incentive, problems with article 28 (ex 30) EC-treaty arise.

18. Despite the reservation given above, the subsidising of either consumers or the individual products may be promising.

Question 4 Can the Dutch government invest venture capital in a large scale factory for

---

[60] OJ 1998, L 142/1

[61] When some ten years ago a tax relief was proposed for cars with a catalisator, the Commission made a huge fuss about its state aid character. Eventually the case did not go to Court, so a final decision has not been taken.

photovoltaics?

19. If the government initiates a factory as a private party (which is for several reasons not regarded as acceptable under Dutch law and may even be prohibited once the Lex Cohen is adopted[62]), the factory would be required to adhere to article 82 EC-treaty. Since the government would be the main investor, chances are extremely high that the factory is regarded as being in a dominant position. This may be even more so if the government is prepared to lower the prices of photovoltaics to a level that might increase popular demand. If so, the government-financed factory would unfairly compete with the other players in the field and thus abuse its position. Since it could only attain that position through government financing, its actions would be prohibited. In other words: a factory initiated by the government only acting as owner or investor is not allowed to act any different from other factories and for example to lower prices unilaterally. Thus, the production and sale of photovoltaics would not be stimulated.

Proclaiming the production of photovoltaics a service of public interest

20. Article 86 contains an exception to the rule mentioned above for public undertakings and undertakings entrusted with the operation of services of general economic interest. The article absolves those undertakings from adhering to the competitions rules in so far as these rules could obstruct the performance of those particular tasks.

21. To make use of this article for a government-initiated large scale factory two requirements should be fulfilled. The first is that either the factory or the production of photovoltaics should get a statutory basis. This means that a law must pass Parliament which not only allocates the production of photovoltaics to one (or a few) particular plant, but also prohibits or limits (for example through the requirement of a concession) other factories producing them. Moreover, the law should contain a system in which all consumers would be facilitated to obtain photovoltaics at a (with regard to their individual income) reasonable price either through fixed pricing and subsidising by the government or a tax-related measure.

22. If such a law would be politically feasible, the next challenge would be the acceptance of such a scheme by the European Community. Since this option would lead to collectivisation of commercial enterprise and (undoubtedly, since necessary to finance the scheme)to restriction in trade between the member states, it would be up to the government of the member state to convince the European Institutions that the service performed is indeed in the public interest as such, and additionally that

62 The Lex Cohen is a statute the Dutch government intends to introduce, which will either prohibit or severely circumscribe all economic activities by the public authorities.

measure is necessary and the least restrictive to achieve the required goal. According to current case-law (especially the Höfner/Macotron) case, chances are slim that the Institutions would be convinced.

* * *