Roadmap for implementing bioenergy in the Netherlands

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Summary

Bioenergy could make a significant contribution to the provision of renewable energy in the Netherlands in an active climate-friendly policy, which includes an ecotax. The quantities of biomass available in the Netherlands could then increase from the current 116 PJ to 235 PJ in 2020. Based on an inventory of the available biomass and waste flows, and the technologies and its potential development in the future a roadmap has been developed. Electricity would be produced, in the first decade of the century, in particular by means of co-firing in existing coal or natural gas-fired power stations.

After this, there will be scope for new technologies. From a business economic perspective, fluidised bed combustion plants will become increasingly evident while from the perspective of maximal renewable energy production, this will be the case with fluidised bed gasifiers and waste pyrolysis. Also the use of biomass for liquid fuels could be ready-to-market following a series of demonstrations. In order to achieve the Dutch goal of 10% renewable energy in 2020 it will, however, be necessary to import renewable energy or, alternatively, biomass that can be used to produce renewable energy.

Introduction

The Dutch government has the ambitious objective of raising the contribution of renewable energy from the current 1.4% to 5% in 2010 and 10% in 2020. Wind energy and bioenergy will both make a major contribution to achieving this goal.

An initial indication is that this could amount to more than 40% for bioenergy, but the actual realisation will take place in a competitive renewable energy market where the domestic production via wind, solar energy and biomass will compete with renewable energy imported from other countries.

The additional costs incurred in the production of renewable energy will be met by a sophisticated taxation system. Renewable energy will be financed by a tax being imposed on electricity from fossil sources (ecotax) . [1]

Bioenergy is defined, in the Netherlands, as energy from all biogenic materials of non-fossil origin. Also energy from the biogenic portion of waste is counted as renewable energy. Recently, in June 2001, the European parliament approved this same definition on a European level, with the proviso that the financial stimulation of this form of renewable energy does not impede the re-use of materials. With also the biogenic portion of waste being considered renewable, optimal use is made of the contribution of biomass to sustainable development. For, first solar energy captured by the biomass is used in products, cattle feed or foodstuffs, and then residue flows or waste flows can be re-used or used for generating renewable energy. The sequence of this cascade results in an optimal utilisation of the biomass and, in turn, in a reduction in CO2 emission.

In the Netherlands, a large number of biomass flows are found in the waste, agrarian, and forestry sectors. Each flow has its specific alternative processing or use which determines its current market value. At the same time, as far as composition and characteristics are concerned, the flows are of a very diverse nature and each one requires a specific processing technology for energy generation.

This is the background to Novem, in 2000, commissioning a study to be carried out by the consortium PriceWaterhouse Coopers, ECN and TNO. The study concentrated on developing roadmaps for realising renewable energy from biomass with the flows and technologies available in the Netherlands. The context of the study was the Energy from Waste and Biomass (EWAB) programme, conducted by the

Netherlands Ministry of Economic Affairs between 1992 and 2000. This paper is based on the results of the report which rounded off the study.

Roadmaps

Roadmaps are not predictions. The objective is:

- To draw up recommendations and an accompanying analysis in respect of the R,D&D policy.
- To invite market parties to participate in a dialogue on priorities. The roadmaps present "the best" options in a stylized world, based on a stylized perspective.
- Indicate links for any further policy focussed on achieving the goals of economising on fossil fuels by the use of biomass and waste.

A **roadmap** as set out in this paper describes the use of biomass and waste for generating electricity and heat over the next twenty years. The technologies invested in and the waste and biomass flows converted into those technologies are indicated per 5-year period.

Each set of roadmaps is developed from two **perspectives** for 3 scenarios:

1. In the **business-economic perspective**, for each period for each waste and biomass flow, the technology with the highest score is selected. This is a weighted average of the Net Cash Value (NCV) per guilder investment. It is assumed that all subsidy and stimulation measures which apply in 2001 will continue in force[2]. It is further assumed that the deductible REB discount and any Green Electricity compensation will together amount to around 5 Euroct/kWh[1]. If, for a particular flow, there is no technology with a positive score available, the flow will not be exploited. According to this business-economic perspective, the roadmap represents what is likely to happen.

2. In the **government perspective**, for each period the technology for each waste and biomass flow is selected on the basis of what achieves the greatest cutback in fossil fuels. A precondition is that the investment in the relevant technology has a payback period of not more than 15 years. According to this government perspective, the roadmaps indicate what is desirable based on the objectives relating to renewable energy.

Scenarios

1: A free world
In this scenario, the starting point is an entirely free market for energy, waste, biomass and agriculture, with resulting low prices. Moreover, there is only a very limited global climate policy, with the consequence that the energy price continues at the current level or may even fall. World energy consumption increases by 2% per annum.
2: A free and climate-active world
The markets for energy, waste, biomass and agriculture are not regulated by government legislation. Internationally, however, there are far-reaching agreements designed to counter the greenhouse effect. By means of levies, the energy price is increased by 50% compared to the current level. Technology transfer takes place by multinationals in respect of production systems and by governments in respect of CO_2-reduction options. The consumers have a sharp awareness of the global environment.
3: A regulated and climate-active world
With so much attention being paid to the greenhouse effect, many governments are once again introducing strict regulations for the energy, waste and agricultural markets. This has resulted in the forming of trading blocks at continental level. Relatively little transfer of technology is taking place. New regulations have the direct and indirect consequence of a doubling of the price of fossil energy compared to the current level. The average consumer behaves in an environmentally conscious manner and is willing to co-operate in reducing the effects of the environmental problem, in particular in avoiding local consequences.
As far the method is concerned, it has been decided to opt for scenario 2 as the basic path for developing the availability and roadmaps since this is most closely aligned to the international treaties. Certain

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[1] Implicitly it is assumed that the flow produced is sold to small consumers as a green electricity, with the advantage of not having to pay the REB (3.5 Euro ct/kWh) being for the benefit of the producer. It is also assumed that the demand for green electricity is sufficiently large.

questions still have to be answered, however: on the one hand the proposed energy price (1.5 x the current energy price) is considered to be on the high side. On the other hand, the fact that the Netherlands has signed the Kyoto protocol and will have to achieve a considerable reduction in CO_2 emission means that the climate levies are in line with the expectations.

Goal and Methodology

The objectives set for energy generation from waste and biomass, as presented in Table 1, are based on the goal of 5% renewable energy in 2010 and 10% in 2020, with 44% of this from biomass and waste (see: Third Energy Memo)[3]. The absolute values are far higher than when the Third Energy Memo was issued (1995)[3] since a higher energy consumption is now predicted for the future.

Table 1 *Goal set for energy generation from biomass and waste (PJs saved)*

	2010	2020
Portion of biomass and waste in the target for renewable energy	79	170
Energy generation from waste, with 50% as biomass crops	45	45
Total (first row plus half the second row)	101	192

The quantities of saved fuels are, in principle, calculated according to the Protocol Monitoring Renewable Energy method. This means that the electricity and heat produced via reference yields for heat and electricity are calculated according to the fossil input. In the case of co-firing options, this is deviated from; here a calculation is made of the quantity of coal or gas that is replaced in the co-firing of biomass of waste. The reference yield for electricity (being the average yield of Dutch power stations taken as a whole) will rise from 46.5% in 2000 to 51% in 2020. The reference yield for heat will rise from 90% in 2000 to 94% in 2020.

An important starting point is also Dutch power stations taken as a whole. Currently, around 50% electricity is generated with coal-fired power stations (pulverised coal) and 50% by means of natural gas. In this study, it is assumed that between 2010 and 2015 these coal-fired power stations will be written off and replaced, giving the opportunity for investment in new technologies. The same applies to the 11 very modern and clean waste incineration plants (grate-oven) which will need to be replaced between 2010 and 2015.

Availability of biomass and waste flows

Twenty-nine different flows have been identified which could be used for energy generation. The current production of these flows when converted amounts to ca. 222 PJ calorific value on a wet basis, but the true availability for energy generation is limited to ca. 116 PJ due to functional competition, ecological aspects, societal acceptance, organisation, logistics and infrastructure, and government policy. Currently ca. 65 PJ of this is used, contributing to a saving of 40.2 PJ on fossil energy carriers. In future, a number of developments are possible. Table 2.

A division and analysis of the various flows show that the increase in the basic path (scenario 2), with no technical limitations, could be achieved in particular in the case of separate waste flows and the forestry and agricultural flows. In cases in which the availability of waste is decreasing from 78 to 50 PJ, the separate waste flows will increase, by means of improved separation and generating techniques, from 10 PJ to 64 PJ. An increase from 37 PJ to 57 PJ is expected in forestry and agriculture.

Table 2 Availability of waste and biomass for energy generation in 2020 based on scenario 2, and a maximum availability with no technological limitations.

	according to scenario 2		**maximum** available	
	available (kton wet)	assumed price (Euro/ton)	available (kton wet)	assumed price (NLG/ton)
Forestry by-products	550	0	1,000	20
Straw (grain)	-	100	708	150
Rape straw	-	100	15	150
Hemp and flax, fibres and pit	-	0	5	0
Hay from grass seeds	-	60	138	100
Cattle manure and pig manure	-	-11	74,000	0
Swill	146	-30	216	0
Foodstuff- and luxury goods industry	1,500	5	9,564	120
Sep. Collect. Veg.Fruit Gard. Waste	-	-30	1,500	-30
Sep. Collect. Old paper and board	2,100	-16	3.100	-16
Sep. Collect. Artificial fibres/plastic	600	-100	1,000	-100
Sep. Collect. Textile	100	-50	400	0
Other	10.808		10.808	
Total (kton wet)	20,907		107,557	
Total (kton dry)	13,879		24,865	
Biomass (PJ), excluding wet manure	87		146	
Fossil origin (artif. fibres) (PJ)	21		34	
Mixed origin (PJ)	56		55	
Total (PJ)	164		235	

Role of import of biomass is crucial for achieving target

In view of the conclusion that domestic availability is insufficient for achieving the targets set, the amount of biomass that can be imported for an acceptable price is of crucial importance. In the study, two tranches are assumed. The first tranche is 30 PJ in 2020 and costs 7.5 NLG/GJ (at the gate of the power station). The second tranche is 200 PJ in 2020 and costs 12 NLG/GJ. In order to achieve the target, also the second tranche needs to be addressed.

Import of biomass requires a far broader assessment than merely being based on the Dutch energy-objective for biomass. It naturally refers also to the role of biomass in the country of origin, nature conservation, biodiversity, etc.

Technologies

Based on current developments in the Netherlands and other countries, a list has been made of conversion technologies which, over the next 20 years are, or could be, available for practical application in the production of electricity of heat. See Table 3.

The list includes the following technologies:

- large-scale gasification with the help of a circulating fluidised bed (CFB)
- small-scale gasification with the help of a circulating fluidised bed or a fixed bed-gasifier (FB);
- large-scale combustion in a fluidised bed or a grate installation;
- small-scale combustion;
- co-firing in existing coal-fired and gas-fired electricity power stations (STEG)
- pyrolysis with the help of flash pyrolysis, the Pyrovac procedure or the Gybros procedure
- Hydrothermal conversion according to the HTU process

In addition, attention has been paid to the possibility of producing fuel from waste which does not need to be incinerated in a conventional waste incineration plant.

This list of conversion technologies has been elaborated to a list of conversion systems with also one or more scale dimensions linked to the technology in a manner which is representative for the potential application(s) of the relevant process.

Table 3: The technologies looked at in the Roadmap with investment costs in 2000 and expected reductions in cost price and rise in efficiency in 2020. The overall efficiency, including the utilisation of waste heat, is between brackets.

		Available after	**Investment costs**	**Costs of development**	**Yield of Development**	
	Scale		2000	2000-2020	2000	2020
CFB-gasification - gas engine,	3 MW_e	2005	7500 kNLG/MW_e	-25 %	27 % (+34%)	30 % (+31%)
CFB-gasification-STEG	30 MW_e	2005	6000 kNLG/MW_e	-10 %	38 %	42 %
CFB-gasification- STEG,	150 MW_e	2010	4300 kNLG/MW_e	- 10 %	43 %	46 %
BFB-gasification-turbine with/without heat delivery	10 MW_e	2005	6500 kNLG/MW_e	- 20 %	27 %/ 22% (+34%)	30 % 26 % (+31%)
FB-gas engine	1 MW_e	2002	4500 kNLG/MW_e	- 25 %	20 % (+ 30 %)	23 % (+30%)
Combustion, fluidised bed, biomass	25 MW_e	2000	1050 kNLG/MW_{th}	- 10%	30 %	30 %
Incineration, grate oven, waste	40 MW_e	2000	5000 kNLG/MW_{th}	+ 20 %	22 %	30 %
Flash pyrolysis (for co-firing)	20 MW_{th}	2010	750 kƒ/MW_{th}	- 10 %	75 %	75 %
Pyrolysis-co-firing coal clean/dirty	100 MW_{th}	2010	2800 kNLG/MW_e/ 4500 kNLG/MW_e	- 10 %	35 %/ 31 %	35 % 31 %
Pyrolysis gas engine/ steam turbine	8 MW_e	2005	10000 kƒ/MW_e	- 20 %	31 % 27 %(+28 %)	34 % 30 % (+26%)
Pyrolysis STEG	30 MW_e	2005	8000 kƒ/MW_e	- 15 %	36 %	39 %
HTU	130 kton dry matter/year	2010	500 ƒ/ton dry matter/a	- 30 %	80-87 %	85 - 87 %
Wet fermentation (manure)	30 kW_e farm	2000	11,000/ kW_e	- 10%	22 kWh_e/ton	22 kWh_e/ton
Dry fermentation (VFG, ONF) Thermophilic fermentation (ONF)	40.000 ton/year 90.000 ton/year	2000	VFG: 600 ƒ/ton/a ONF 550 ƒ/ton/a excluding E-portion	- 10 %	100 kWh_e/ton	100 kWh_e/ton
Direct co-firing in coal –fired power station	120 MW_e (= 20 % co-firing)	2000	65 kƒ/MW_e	-	39,5 %	39,5 %
Indirect co-firing in coal-fired power station	120 MW_e (= 20 % co-firing)	2000	855 kƒ/MW_e	-	38 %	38,0 %
Co-firing in coal-fired power station via gasifier: Clean Dirty	120 MW_e (= 20 % co-firing)	2000	 810 kƒ/MW_e 2000 kNLG/MWe	 - 10 % - 10 %	 38 % 35 %	 38 % 35 %
CFB co-firing in natural gas gas-STEG	30 MW_e(= 10 % co-firing)	2005	2250 kƒ/MW_e	- 10 %	42,5% %	45 %
Co-firing in KV/STEG	25 MW_e(= 10 % co-firing)	2005	1300 kƒ/MW_e	- 20 %	41 %	41 %
Direct co-firing in KV/STEG	10% co-firing	2000	105 kNLG/MWe	-	42,5%	42,5%
Integration coal/gas steam side	20 MWe (= 3,5 %)	2000	2050 kƒ/MW_e	-	38,5 %	38,5 %
Small-scale combustion	0,5 - 1 MW_{th}	2000	1000 kƒ /MW_{th} (+20 % with higher emission standards)	-10 %	80 %	80 %

The roadmaps

Based on the data concerning the availability of 22 flows and 23 technologies, 252 relevant combinations have been calculated and selected. Based on the economic and energy criteria, the optimal technologies that could be used have been selected.

Seen from this angle, the savings on fossil fuels as a consequence of the use of biomass and waste for electricity generation in 2020, varies, in the roadmaps, from 42 PJ to 192 PJ. The lower limit occurs in the roadmap in which it is assumed that no active climate policy is pursued in Europe or in the Netherlands, with the (presumed) consequence of in a lower availability of waste and biomass and the cancellation of the stimulation policy (ecotax, Green Electricity). The amount of savings on fossil fuels would then not be much higher than the current level. The upper limit occurs in the roadmap in which the current stimulation policy is maintained, the availability of domestic biomass and waste flows increases and biomass is imported in order to reach the set target. Without that import, the savings in fossil fuels is 136 PJ in this roadmap. With a maximum heat delivery in the case of stand-alone installations, this could be raised to more than 158 PJ.

In the case of the continuation of the current stimulation policy, no withdrawal of biomass and waste flows for the benefit of other applications and no import of biomass (the basic path, business economic perspective), it is estimated that 100 PJ fossil fuels will be saved in 2020. If the government can implement a policy which ensures that the technologies with high savings on fossil fuels are selected (as long as the payback period of the relevant technologies is less than 15 years), the 100 PJ can grow to 115-130 PJ (the upper limit is with the maximum heat delivery with stand-alone installations).

In Table 4, a summary is presented of the results of the roadmaps in terms of cutbacks in fossil fuels. Availability of waste and biomass play a role equal to the savings in fossil fuels in 2020: in the case of two scenarios (lack of urgency concerning the climate policy and the regulating of the agricultural sector and waste sector at European level) availability is such that the targets set could in no way be reached.

Table 4 *Results availability roadmaps for the year 2020*

Roadmap Scenario	Business economic perspective [PJ cutback]	Government perspective [PJ cutback]	Government perspective met maximum CBH with stand-alone installations [PJ cutback]
Withdrawal of stimulation policy	42	46	51
Regulating of agriculture sector and waste sector	60	67	77
BASIC PATH (current policy)	*97*	*114*	*132*
Basic path with extra domestic availability	121	136	158
Basic path with extra domestic availability and import	141	192	N.a.

In Figure 1 and Figure 2 it is shown which technologies are selected in the basic path, according to both perspectives. It is here exclusively a question of new projects. Existing and already planned energy generation from waste and biomass is therefore not included in these graphs.

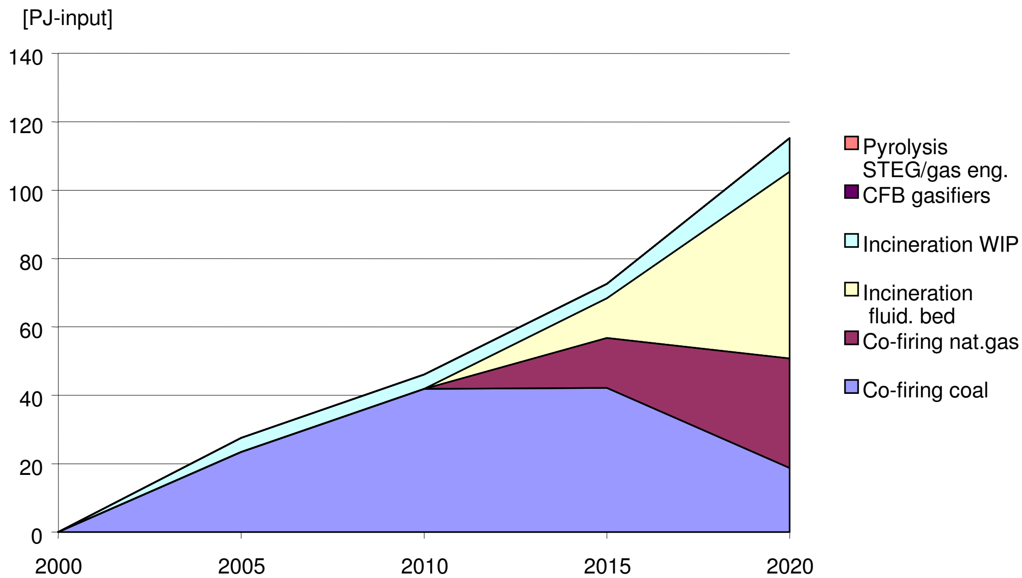

Figure S.1 *Technology option in the basic path according to the business economic perspective*

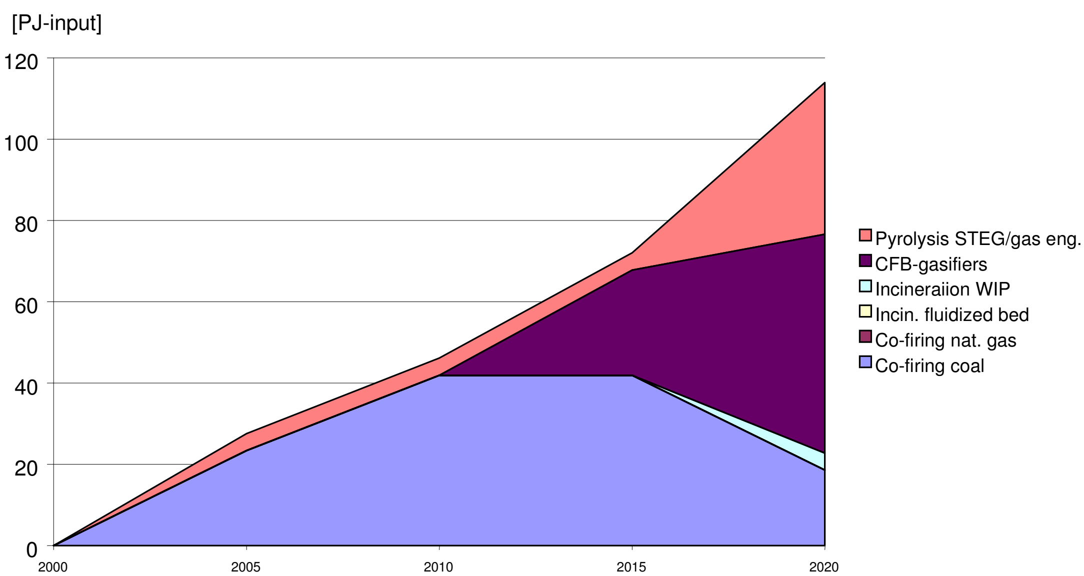

Figure S.2 *Technology options in the basic path according to the government perspective*

Conclusions

1. Co-firing will play a dominant role in the short term

Co-firing in coal-fired power stations clearly emerges as the most attractive technology. Co-firing in gas-fired power stations will also play a very important role in the roadmaps.

In the business economic perspective, co-firing options in coal-fired power stations would appear by far the most profitable option, followed by co-firing in gas-fired power stations. In the government perspective, too, this is co-firing option which, during the next ten years, would result in the greatest saving on fossil fuels. Depending on the calculation method used, it is a question of co-firing in coal-fired power stations or co-firing in gas-fired power stations.

In the calculations it is assumed that also in the case of co-firing in coal-fired power stations Green Electricity compensation applies to a number of biomass flows. In the case that the flow generated by means of co-firing in *coal-fired power stat*ion is not sold as Green Electricity (and does not profit therefore from the zero tariff), in most cases co-firing in a *natural gas-fired* power station (or steam- side integration) would be the most attractive technology. In addition, the head start in terms of profitability compared to the stand-alone options (in particular fluidised bed combustion) is much reduced, though it continues to exist

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2. CFB-gasification of biomass and pyrolysis of waste are the most promising new technologies for the longer term

Of the 'new' stand-alone technologies, only the pyrolysis options (for waste processing) and de CFB-gasifier-STEG (for clean biomass and separately collected waste flows) make a significant contribution to the roadmaps, from both the business economic perspective and the government perspective. From the point of view of business economics, the competitive position of CFB-gasifiers compared to fluidised bed combustion is very sensitive to the estimates of the investment costs.

3. Alternative processing of waste would appear attractive from the point of view of business economics and savings

As far as waste processing is concerned, it would appear that a considerable business economic profit can be achieved with co-firing or with fluidised bed combustion (possibly with. steam-side integration in coal or gas-fired power stations) of fuel made from the residue fraction of office, shop and services waste and household waste. Fluidised bed combustion, possibly in combination with steam-side integration in gas-fired power stations, then remains as the technology which plays a major role in business economic terms. From the point of view of a maximum saving on fossil fuels, it is in particular the pyrolysis options which would appear most promising for obtaining far more energy from waste that has been achieved to date with the WIPs.

4. Technology choice appears 'robust'

Sensitivity analyses indicate that the co-firing options are robust: even if the costs of co-firing are higher than expected and the costs of other options turn out to be lower, the profitability of co-firing continues to be higher than that of the competing technologies. The reverse would appear to be true for the small-scale (gas engine) options: even with favourable assumptions, profitability is lower than that of the competitors. If the electricity from co-firing options in *coal-fired power stat*ions is not sold as Green Electricity, the co-firing options in *natural gas-fired* power stations take the lead as far as profitability is concerned.

5. Major influence of life span of coal-fired power stations and WIPs (Waste Incinerators)

The limited 'availability' of coal-fired power stations influences the content of the roadmaps considerably[2]. An extension of the life of current power stations or those to be built would be accompanied by a far greater emphasis on co-firing in coal-fired power stations. This would result,

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[2] It has been assumed that the current coal-fired power stations have a lifespan of around 30 years and will be taken out of operation between 2010 – 2015.

however, in a higher consumption of coal and - unless additional requirements are set for CO_2-emissions of coal-fired power stations - to higher CO_2-emissions.

In the study, it is assumed that existing WIPs will be withdrawn from operation before 2020 while a number of plans for new WIPs are not yet definite. If the existing WIPs continue in operation for a longer period and/or all current plans are realised, there is no room for new technology in the processing of waste. From the viewpoint of energy saving, this has considerable consequences, since it is precisely with energy generation from waste that the greatest advantages would appear obtainable (see above).

Considerable influence of the maximum co-firing factor

In the study, a maximum co-firing factor 30% (on energy basis) has been used for coal-fired power stations and 10% for gas-fired power stations. In view of the fact that the availability of co-firing capacity is a limiting factor in the roadmaps, it is obvious that research needs to be done into the possibilities of raising the co-firing factor. One of the claims of HTU, for example, is that with the fuel that is produced a far higher co-firing factor can be achieved.

Biomass versus natural gas

In most energy scenarios up to 2020, the number of power stations in the Netherlands will expand further, in particular the natural gas-fired power stations, often in the form of heat/power installations. The question can be raised of whether a number of these installations couldn't be biomass-fired. For the flows with a negative or slightly positive price, it would seem that, in particular, fluidised bed combustion does indeed have a higher NCW/inv than both natural gas-STEG and natural gas-STEG including conversion. The far higher investment costs are compensated for by lower fuel costs, the REB (Energy Saving) subsidy and Green Electricity compensation. However, as long as existing STEGs or coal-fired power stations are still available, co-firing continues to be a more profitable use of biomass flows than stand-alone options.

Diverse picture

(Fluidised bed) combustion, gasification and pyrolysis all play an important role in the roadmaps. HTU plays a less significant role (in particular since it is assumed that HTU will be available only after 2010), but the differences in profitability between HTU and the other co-firing options are not very great. Fermentation does not occur in the roadmaps, although manure fermentation, in particular, would appear promising if it can be mixed with other flows.

No opportunity for small-scale options?

The small-scale stand-alone technologies do not appear to have any chance in the roadmaps, with the exception of the pyrolysis-gas engine option for (small) waste flows. It needs to be studied whether the logistical advantages (including contractability of inputs) in the case of small installations have been underestimated in this study and whether the 'economies of scale' of large installations have been overestimated. Moreover, small-scale technology can form an essential step towards large-scale installations.

Competition with other options

In respect of the 'competition' with other options for CO_2 reduction, it can be stated that co-firing options as far as costs are concerned fit within the range of the basic package of Part 1 of the Implementation Memo Climate Policy [5]. With the prices cited for import (7.5 and 12 NLG/GJ, from the power station gate), this option is at the higher end of that range.
Compared to transport fuels from biomass, as studied in the framework of the GAVE project [6], it can be said that the co-firing options are cheaper and that the cheaper stand-alone options are comparable in terms of costs per ton CO_2.

As far as other renewable options for electricity generation are concerned, the relevant comparison is with offshore wind. In general, it can be said that co-firing options result in a lower kWh-price than offshore wind. Stand-alone options, in particular for biomass flows with a positive price, have in general a higher kWh-price than offshore wind.

Some Remaining Questions:

Change in prices for waste and biomass?

In this study no account has been taken of the impact on the prices of biomass and waste as a consequence of being used for energy generation. The current negative price of many flows make a significant contribution to economic profitability. Any rise in prices could therefore have major consequences, particularly since this could also influence contractability.

Changes in the stimulation policy for renewable energy

The current tax stimulation of renewable energy has great influence on the profitability of the options considered. The complete freeing of the Dutch market for renewable energy or (later on) of the European market, could have consequences for the degree of tax support. The current Dutch stimulation policy matches the effect of a European levy of more than 50 Euro per ton CO_2. It is very unlikely that a European levy could reach such a level. If it fails to do so, the profitability of the options studied in this report will decline. Furthermore, greater competition could arise between the various renewable options. Co-firing would appear to be able to cope with the competition of offshore wind without too much difficulty. For the stand-alone options, this will be far more difficult..

Residue products

In the calculations, no account has been taken of the costs and revenue of selling/processing residue products such as ash. The relationship between the characteristics of the ash and the value of it has not been included in the specifications of this study. It is implicitly assumed, therefore, that this problem has no influence on the selection of technologies. This problem deserves full attention, in particular as far as the various processing routes for the waste residue fractions are concerned.

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