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Groene Grondstoffen

Biomass in the Dutch Energy Infrastructure in 2030

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Preface

In April 2005 the “Platform Biobased Raw Materials” (Platform Groene Grondstoffen, PGG) was established within the framework of the energy transition policy of the Dutch government. The Platform aims to promote a switch from the consumption of fossil fuels to renewable or “green” raw materials. This makes the Netherlands less dependant on raw materials which are finite and on the supply from politically less stable regions. Furthermore, the switch will contribute for an important part to the decrease of the Dutch greenhouse gas emissions. The changeover will also lead to opportunities for Dutch industries. Especially the sectors agro, food, chemical and harbour/logistics could further strengthen their positions.

The “Platform Biobased Raw Materials“ has developed a vision, in which 30% of the fossil raw materials will be replaced by green raw materials. The degree of replacement varies amongst the different end-uses in the following way:

- 60% replacement of transportation fuels,
- 25% replacement for the production of chemicals and materials,
- 17% replacement in the heat production,
- 25% replacement in the electricity production.

The Platform assumes a scenario in which energy savings play a central role. The Platform realises that The Netherlands have a limited agricultural area and a limited amount of by-products and that at least 60-80% of the necessary biobased raw materials will have to be imported.

To gain a better insight in the requirements to realise this ambitious vision, the Platform has asked ECN and WUR to perform an analysis of the current raw material consumption for the Dutch energy supply and the expected energy supply in 2030, the fit of biobased raw materials in the energy supply and insight in the availability of biomass to realise this vision.

According to the Platform this report provides a structured and sound insight in the current and future raw material consumption. The fact that the estimations of ECN and WUR of the use of biobased raw materials in certain sectors differ from the ambition of the Platform, is for the Platform a motivation for further discussions. Are the bottlenecks which have been identified by ECN and WUR recognized by other experts? Can these bottlenecks be removed with directed interventions? From this point forward the Platform Biobased Raw Materials will continue. The working groups within the Platform will start with the formulation of an implementation agenda and with an investigation of the bottlenecks in the feasibility of the ambitions. This report offers a good basis for further discussion; if you would like to contribute you are invited to respond to groenegrondstoffen@senternovem.nl.

Paul Hamm
President Platform Biobased Raw Materials (Platform Groene Grondstoffen)

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Summary

This study has been executed by ECN (Netherlands Energy Research Centre) and WUR (Wageningen University & Research Centre) on the instruction of the "Platform Biobased Raw Materials" (Platform Groene Grondstoffen, PGG). The goal of this study is to evaluate the ambition of the Platform to replace 30% of the fossil energy carriers by biomass in the Netherlands in 2030. Starting points are the total annual consumption of primary energy carriers of 3000 PJ by 2030 and contributions of biomass of 60% in transportation, 25% in electricity production, 20% in raw materials for chemicals, materials and products and 17% in heat production.

The study provides a review of the current Dutch energy balance, with the role of different energy carriers, based on data for the year 2000 and estimates for the year 2030. For the situation in 2030, an analysis is made of the possible role of biomass.

The study also provides a review of the Dutch import, export and production of biomass in 2000 and an estimation of the developments until 2030.

The following conclusions can be drawn form the analysis of the energy consumption and the possible role of biomass:

- A total consumption of primary energy of 3000 PJ in 2030 is less than can be expected on the basis of current developments. Extra efforts will be needed to reach that level.
- An important restriction of the possibilities to use biomass is the inertia of the infrastructure. The infrastructure cannot be completely written off between now and 2030 and is currently totally tuned to fossil fuels.
- A 60% share of biomass in transportation is very ambitious, considering the policy to minimize energy consumption by transportation. A 40% share puts the necessary effort more in tune with those for other applications.
- A 25% share of biomass in the production of electricity is only possible at complete replacement of a number of base-load power plants based on coal or natural gas by biomass plants. Through co-firing the share is limited to approximately 10%. This share can be larger if the role of wind energy will be much smaller than has been envisioned thus far.
- A 25%, or even somewhat higher, share of biomass in raw materials for chemicals, materials and products is possible, but still needs much development, more than with other applications.
- A 17% share of biomass in heat requires the development of technology and the construction of installations for large scale production of "SNG" (synthetic natural gas). In that case a larger contribution than 17% would be possible.
- For some sectors the technology is readily available, or has been developed, that with increasing development this will be the case amply before 2030. Especially in the field of raw materials for chemicals, materials and products much research and development is needed.
- In the chemical industry several options exist to replace raw materials from fossil energy carriers. Bio-synthesis gas could replace synthesis gas ($CO + H_2$) from natural gas or could be used as raw material for the Fischer-Tropsch process. Bio-ethanol could be used as raw material for ethylene production. Through bio-refinery, it is possible to separate components from biomass from which functionalised chemicals could be produced. The last two options could lead, next to savings in raw materials, to extra savings because of a lower need for process energy. ECN estimates these extra savings to be maximally 20 PJ, WUR estimates 40 PJ to 80 PJ.

- Based on the division given by the Platform, the share of biomass in the Dutch energy balance would amount to 28.4%. If also the savings in process energy in refineries and industry are included, the total would amount to 30%.
- According to the present analysis the share of biomass in the Dutch energy balance would be restricted to 21.4%. Including savings on process energy this will be 23%. This lower result is due to a diminished share in transportation fuels from 60% to 40% and to a share of only 10% instead of 25% in electricity.
- Extra input of biomass for heat, in the form of process energy or SNG, is a relatively simple way to bring the share of biomass in the Dutch energy balance closer to 30%.
- A biomass share of 23% requires over 900PJ of biomass, which is equal to about 60 million tons dry matter. For a share of 30%, about 1200 PJ of biomass are required, which is equal to about 80 million tons dry matter.

The analysis of the biomass supply leads to the following conclusions:

- The gross consumption of biomass (all short-cyclic organic streams) in the Netherlands, calculated from import – export + domestic primary production, was equal to 32.8 – 21.5 + 31.0 = 42.3 Mtons in 2000. Expressed in energy terms this amounts to 620 – 405 + 527 = 742 PJ. Which equals to 24% of the Dutch consumption of primary energy. Only a part of these organic streams will be actually available for energy and raw materials for chemicals, materials and products.
- In 2030 some 6 million tons dry matter of primary by-products will become available in The Netherlands, which is equal to about 100 PJ.
- In 2030 some 12 million tons of dry matter from secondary and tertiary by-products will become available In the Netherlands, which is equal to 200 PJ.
- In order to realise these contributions, specific attention is needed for the establishment of an efficient infrastructure. For primary by-products this is even more relevant than for secondary and tertiary by-products. It is of great importance to find a synergy with efficient recycling of nutrients and landscape conservation.
- Through specific crop production for energy and raw materials up to 9 million tons dry matter could become available, which is equal to about 150 PJ. This contribution is very uncertain and strongly depends on government policies. Apart from specific energy cultivation the production of multi-functional crops, from which by means of bio-refinery food components and various non-food raw materials are being produced, offers options to open up this potential.
- The maximum domestic availability of biomass is 450 PJ. Extra import of at least 450 PJ in biomass are required to realise a biomass share of 23%. This amounts to 30 million tons.

1 Introduction

The target of the Platform Biobased Raw Materials (Platform Groene Grondstoffen) is to initiate and demonstrate increased sustainability of raw materials use in the Netherlands. The Platform consists of representatives of the government, trade and industry and research centres. An important part of the activities of the Platform is to develop a vision on the future utilisation of biobased raw materials as a substitution of fossil raw materials and to define transition paths to reach that utilisation.

The members of the Platform would like to gain insight in current and future flow of organic raw materials and products in the Netherlands. This leads to an insight in the potential availability and application of biomass in the Netherlands for energy and chemistry for the current situation and for the situation in 2030.

The Platform has assigned ECN and WUR Agrotechnology and Food Innovations B.V. to describe the situation for the year 2000 and to make a prognosis for the situation in 2030. The main question is to analyse how realistic the stated ambitions are to substitute 30% of the fossil fuels and raw materials in the Netherlands with alternatives based on biomass in 2030.

The main goal of this study is to answer the questions how much biomass is needed, how much is available, and if such a large contribution of biomass could be fitted into the Dutch energy infrastructure in 2030. Sustainability and economic feasibility will only be discussed indirectly. Under current conditions the replacement of fossil energy carriers with biomass is not, or hardly, economically feasible. Because the Dutch and European governments acknowledge the importance of the development towards a sustainable energy supply, they stimulate the use of biomass and other forms of sustainable energy through subsidies and regulations. This way the transition is initiated, which should result in an independent role for biomass and other forms of sustainable energy in the energy supply in 2030.

The above-mentioned ambition level, to substitute 30% of the fossil energy carriers by biomass, is based on the following contributions in different applications:

- 60% bio-fuels (50% bioethanol and 50% FT-biodiesel)
- 20% chemicals/materials/products (white biotechnology / bioprocess technology, production of fine chemicals and functionalised compounds)
- 25% electricity (mainly decentralised combined heat and power from biomass (bioCHP), co-firing is limited)
- 17% heat (residual heat from bioCHP, total demand of heating will diminish)

As a pre-condition, it is assumed that for the prognosis for 2030 the consumption of primary energy will be limited to 3000 PJ per year, by improved efficiency and savings. This is about the average over the period from 1995 to 2000. This energy consumption is at least 20% lower than the consumption that follows from scenarios that extrapolate trends from the recent history to the future. Measures which are being considered in view of additional policies (to reduce greenhouse gas emissions), should be able to reduce the difference, but may not be sufficient to achieve the target.

2 Energy infrastructure in the Netherlands, situation in 2000

This chapter is based on information from National Bureau for Statistics (Centraal Bureau voor de Statistiek", CBS, http://statline.cbs.nl). According to the Energy Balance the Dutch consumption of primary energy in 2000 amounted to 3065 PJ. The total imports and exports were, respectively, 2.5 and 2 times as large[1]. Figure 1 shows the routes in PJ/year which energy carriers follow in and through the Dutch energy infrastructure.

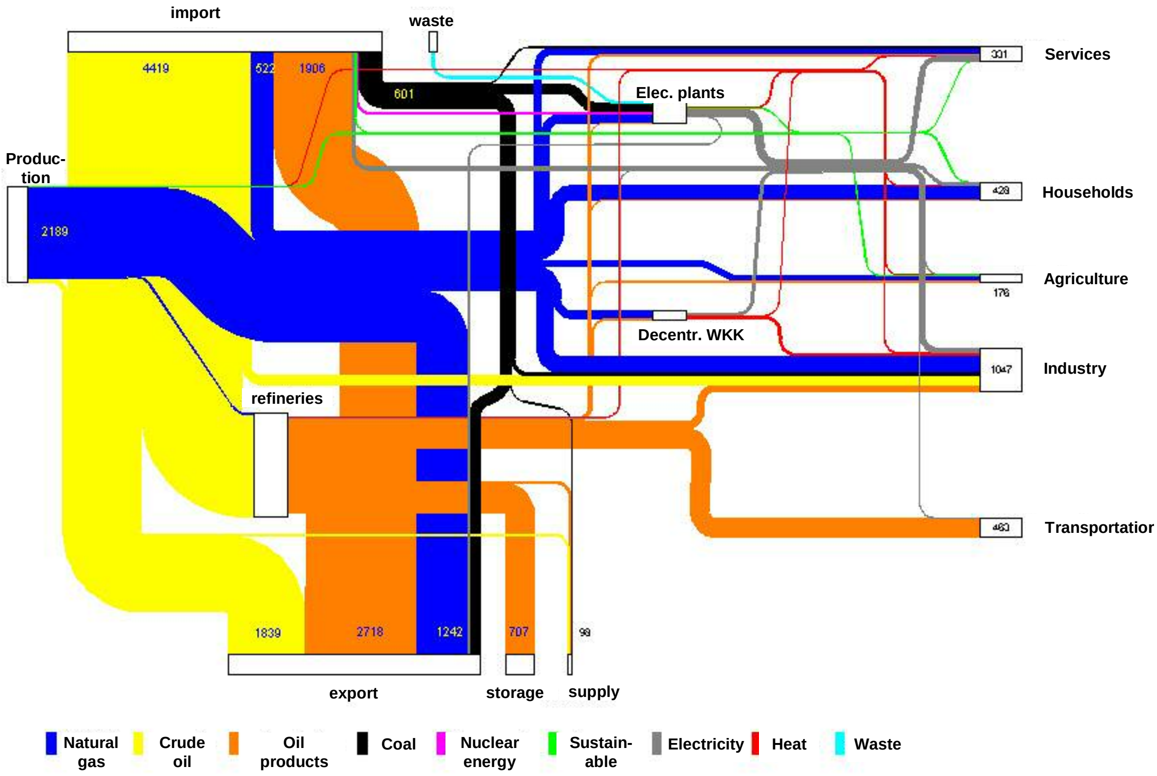

Figure 1 *Sankey diagram of energy carriers in the Netherlands. The width of the blocks is a measure of the energy value of a certain stream in PJ/year.*

Below follow the energy balance and a review of the total consumption by the most important users per energy carrier. At the end of this chapter a separate review of the non-energetic consumption of energy carriers follows. Aside from fermentation gas, biomass has not been implemented into the energy balance as such, but into steam and heat. The role of biomass as energy carrier can be found in the CBS statistics on sustainable energy. Biomass is discussed more extensively in the chapters 3, 5, and 6.

2.1 Natural gas

In 2000 the import was 522 PJ, the production 2189 PJ and the export 1242 PJ. Herewith the domestic consumption amounted to 1469 PJ. These amounts correspond with 16.5 billion m^3 import, 69.2 billion m^3 production, 39.2 billion m^3 export and 46.4 billion m^3 domestic consumption. Table 1 shows the input of natural gas in different sectors.

[1] For the conversion from PJ to weight or volume or reversed please refer to Attachment A.

Table 1 *Consumption of natural gas in the Netherlands in 2000. The domestic consumption equals over 46 billion m^3 natural gas from Groningen.*

	Natural gas [PJ]
Refineries	33
Production companies	34
Energy companies	341
WPI (waste incineration)	2
Distribution companies	34
Industry	410
Transportation	
Households	334
Services and agriculture	281
Domestic consumption*	1469

* Domestic consumption = Production + Import - Export

2.2 Petroleum and petroleum products

As shown in table 2, in 2000 the total import of petroleum raw materials and petroleum products was 6324 PJ, the production 102 PJ and the export 4557 PJ. These amounts correspond with 148.7 Mton import, 2.4 Mton production and 107.1 Mton export.

A large amount of the petroleum products is going to storage. This is the quantity which is being used for international transport in the Netherlands by shipping and aviation, by both Dutch and international consumers. This consumption is not charged to the Netherlands and is also excluded by, for instance, the Kyoto Treaty[2]. There is also a small item "mutations stock". In 2000 this post was negative, which means that an addition was made to the stock. After settlement of these items, the domestic consumption amounted to 1073 PJ. This corresponds with 25.0 Mton. In this figure neither the storage nor the petroleum products, which are being refined in the Netherlands and exported thereafter, are included. The energy losses which are involved with the refinery process are, however, included.

Table 2 *Energy balance of petroleum in the Netherlands in 2000. The total annual import, export and domestic consumption equal about 149 Mton, 107 Mton and 25 Mton.*

	Petroleum raw materials [PJ]	Petroleum products [PJ]	Total [PJ]
Import	4419	1906	6324
Production	102		102
Mutations stock	-34	-57	-91
Export	1839	2718	4557
Storage		705	705
Domestic consumption*	2647	-1574	1073

* Domestic consumption = Import + Production + Mutations stock - Export - Storage

[2] The Kyoto Treaty does describe through which organisations the negotiations about the reduction of this contribution have to be made.

Table 3 shows the input of petroleum and petroleum products in different sectors. After 1998 the statistics have been adjusted, due to which approximately 180 PJ input has been moved from refineries to the basic chemistry. In the reference estimates energy and emissions 2005-2020 (van Dril, 2005), the consumption in the sector services and agriculture is 45 PJ lower and those for the industry the same amount higher. This is probably due to a somewhat different division of sectors[3].

Table 3 *Consumption of petroleum in the Netherlands in 2000. The total domestic consumption of 1073 PJ equals 25 Mton.*

	Petroleum raw materials [PJ]	Petroleum products [PJ]	Total [PJ]
Refineries	2445	-2290	156
E and H companies		34	34
Distribution companies		1	1
Industry	202	166	367
Transportation (excl. bunkers)		457	457
Households		4	4
Services and agriculture		55	55
Domestic consumption	2647	-1574	1073

2.3 Coal and coal products

Table 4 shows that in 2000 the import of coal and coal products was 598 PJ and the export 262 PJ. These amounts correspond with 23.2 Mton and 10.1 Mton. After settlement of the item “mutations stock” the domestic consumption amounted to 329 PJ, which is 12,7 Mton. Table 5 shows the input in different sectors. This shows that, next to the electricity sector, the cokes factories and the steel industry (both in IJmuiden), are large consumers.

Table 4 *Energy balance for coal in the Netherlands in 2000. The total annual import, export and domestic consumption equal about 23 Mton, 10 Mton and 13 Mton.*

	Coal and lignite [PJ]	Coal products [PJ]	Total [PJ]
Import	580	17	598
Mutations stock	-5	-2	-7
Export	246	16	262
Domestic consumption*	329	-1	329

* Consumption = Import + Mutations stock – Export.

[3] The sector services serves as closing item, data from the CBS for this sector are therefore relative inaccurate.

Table 5 *Consumption of coal in the Netherlands in 2000. The total domestic consumption of 329 PJ equals about 13 Mton.*

	Coal and lignite [PJ]	Coal products [PJ]	Total [PJ]
E & H companies	209	23	232
Cokes factories	86	-74	12
Industry	32	48	81
Services and agriculture	1	2	3
Domestic consumption	329	-1	329

2.4 Electricity

In 2000 the total import of electricity was 83 PJ (23 billion kWh) and the export 15 PJ (4 billion kWh). The net import amounted to 17% of the total consumption. Furthermore, amply over 4 PJ (1.2 billion kWh) was produced from other sources such as wind, sun and water. However, it is hard to interpret statistics for electricity, because it is not a primary source of energy, maybe with the exception of the 4 PJ which is being produced from wind, water and sun. Table 6 shows a review of the production and the consumption. Negative figures for the amount of consumption show that electricity is being supplied to others.

Table 6 *Production and consumption of electricity in the Netherlands in 2000. The total consumption of 390 PJ equals 108 billion kWh.*

	Production PJ_e		Consumption balance PJ_e		Consumption PJ_e	
Refineries	10		-1		9	
E & H companies	258		-248		10	
WPI	9		-7		2	
Distribution companies	12		6		18	
Sum energy companies		289		-248		41
Industry	22		121		143	
Services and agriculture	7		115		122	
Transportation			6		6	
Households			79		79	
Sum energy consumers		29		321		350
Production		4				
Balance import-export		68				
Total		390				390

2.5 Other energy carriers

Other energy carriers have been included into the collective item “others”. This is mostly steam and heat. Steam from refineries, E and H companies and distribution companies only concerns steam that has been delivered to other users. The domestic consumption corresponds with the production of 122 PJ from various sources. The main sources are nuclear power (40 PJ) and waste (51 PJ with WPI). The contribution of biomass through co-firing in power plants corresponds with almost 2 PJ primary energy. The contribution through wood stoves and other combustion corresponds to with 10 PJ and the contribution through fermentation and landfill gas to considerably over 5 PJ.

Consumers are E and H companies, industry, households and services and agriculture. The WPI have been using steam for the production of 2000 GWh of electricity. From the resulting primary energy contribution, 9 PJ is attributed to the share of biomass in waste. Furthermore, the WPI delivered heat, of which 4 PJ is due to biomass. This brings the total contribution of biomass in the energy infrastructure to almost 29 PJ.

2.6 Summary consumption

Table 7 shows a review of the total consumption of the main energy carriers per sector. Table 8 provides a further division for the consumption in the industry for separate sectors. The contributions of petroleum raw materials and products have been summed up in the category petroleum and those of coal, lignite and coal products under the category coal. For electricity, steam and heat the consumption balances have been stated.

Table 7 *Total energetic and non-energetic consumption of energy carriers in the Netherlands in 2000.*

	Natural gas [PJ]	Petroleum [PJ]	Coal [PJ]	Electricity* [PJ]	Other# [PJ]	Total [PJ]
Refineries	33	156		-1	-8	180
Production companies	34					35
E & H companies	341	34	232	-248	-63	297
Cokes factories			12			12
WPI	2			-7	46	41
Distribution companies	34	1		6	-6	35
Industry	410	367	81	121	95	1075
Transportation (excl. storage)		457		6		462
Households	334	4		79	16	432
Services and agriculture	281	55	3	115	41	496
Domestic consumption	1469	1073	329	73	122	3065

* Negative means electricity production, positive consumption. The total balance of 72 PJ comes from import (68 PJ) and solar, wind and water production (4 PJ).
# Mainly steam and heat, plus 5 PJ gas from fermentation .

Table 8 *Total energetic and non-energetic consumption of energy carriers in the different sectors of the Dutch industry in 2000.*

Industry branch	Natural gas [PJ]	Petroleum [PJ]	Coal [PJ]	Electricity [PJ]	Other [PJ]	Total [PJ]
Fertiliser	109			1	2	112
Organic base chemistry	60	318	4	9	56	447
Base chemistry + fibres	36	1		6	8	52
Other anor. base chemistry	12	15	4	12	9	52
Chemical end products	14	3		3	2	22
Glass, ceramics, cement	26	2	2	6		37
Base ferro metal (steel)	14		69	9		91
Base non-ferro metal	4	4		21	1	31
Metal products	22	16		16		54
Others	113	8	2	38	17	177

Total	410	367	81	121	95	1075

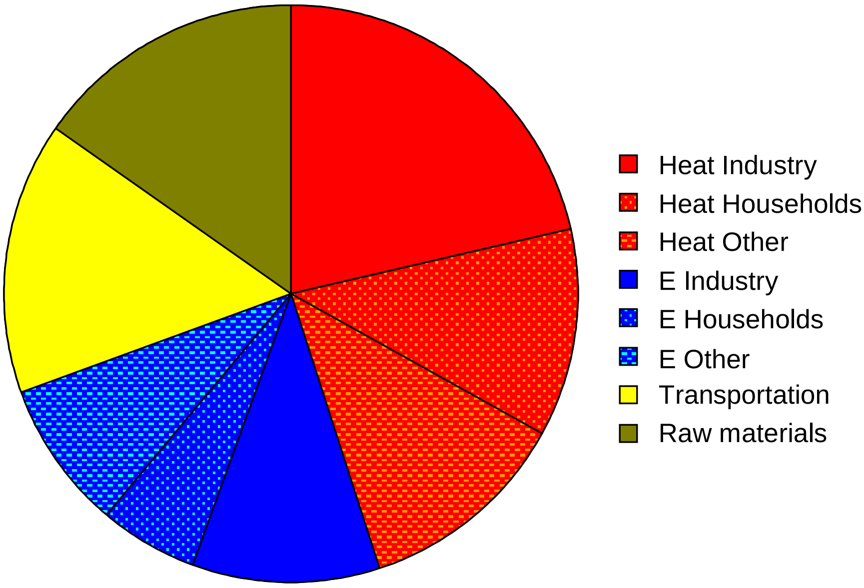

Figure 2 *Distribution of the total Dutch consumption of 3065 PJ of primary energy in 2000 over all applications and users. Oil refinery and cokes production are included in industry.*

The total consumption of energy carriers can be distributed into four fields of application: heat, electricity, transport and raw materials. Figure 2 shows the result. The division is to some extent arbitrary and only serves as indication. In this report, the following choices have been made:

- Losses in conversion in the domestic production of electricity, in combination with the production of heat or not, have totally been ascribed to electricity and been divided over the consumers pro rata of their total electricity consumption[4].
- Electricity consumption by E and H companies, WPI and distribution companies have been accounted as losses in conversion in the production of electricity.
- Consumption of electricity for heat production has not been included in the application heat.
- Consumption of electricity for transportation has been integrated under transportation and not with “other” electricity.
- Non-energetic consumption of electricity has been mentioned as electricity and is not integrated in the application raw materials.
- Conversion losses in production processes and in the production of steam have been ascribed to heat.
- Energy consumption through production companies has been ascribed to heat.
- Energy consumption for the production of petroleum and coal products, which are being used for transportation or as raw material, has not been assigned to those applications. That consumption is included in the consumption of electricity and heat in the industry. For petroleum products this consumption is on average 8% of the energy value of the products[5].

[4] Conversion losses in the production of foreign electricity are not included in the Dutch energy balance.
[5] The energy consumption of the refineries is 180 PJ for a production of 2290 PJ in oil products.

- Energy consumption for the production of chemicals, materials and products is part of the consumption of heat and electricity in the industry. It is estimated that this consumption is 50% to 60% of the non-energetic consumption. (Please refer to the next paragraph).

Based on these choices, the division of the total consumption of 3065 PJ of energy carriers over the applications in 2000 was as follows:

Heat	45%
Electricity	25%
Transport	15%
Raw materials	15%

The next paragraph will elaborate the application of energy carriers as raw materials for chemicals, materials and products.

2.7 Non-energetic final consumption of energy carriers

Non-energetic final consumption is the part which is being incorporated in the final product. In that case it concerns final products which are not being used as energy carrier, so no products like petrol, diesel or cokes. The tables 1 through 7 show the sum of energetic and non-energetic consumption.

In 2000 the non-energetic consumption amounted to 493 PJ. That included 27 PJ electricity, for instance for the production of aluminium. The remaining part here has been added to the application raw materials. Because of the fact that biomass has yet not been included in the Energy Balance by the CBS, this figure does not include a contribution of the input of wood or wood products in construction or at the production of furniture and paper. This is also true for fibres like cotton, wool, jute and linen. Table 9 shows the non-energetic consumption of all energy carriers. Table 10 shows a further division of the category petroleum products.

Table 9 *Non-energetic final consumption of energy carriers in the Netherlands in 2000. Contributions smaller than 1 PJ are not separately mentioned, but are included in the total.*

Industry branch	Natural gas [PJ]	Petroleum products [PJ]	Coal, lignite [PJ]	Cokes, others [PJ]	Electricity [PJ]	Total [PJ]
Fertiliser	77					77
Organic base chemistry	15	250		2		267
Base chemistry + fibres	8					8
Other anor. base chemistry	1	9		2	8	20
Chemical end products	1	3				4
Glass, ceramics, cement		1				1
Base ferro metal (steal)			19	32		50
Base non-ferro metal		3			18	22
Metal products		15				15
Non-specified		7				7
Transportation		3				3
Services and construction		17		2	1	20
Total	102	307	19	39	27	493

Table 10 *Non-energetic final consumption of petroleum products in the Netherlands in 2000. Contributions smaller than 1 PJ are not separately mentioned, but are included in the total.*

Industry branch	LPG propane butane [PJ]	Naph-tha [PJ]	Aro-matics [PJ]	Light oils [PJ]	Lubricants Fats bitumen [PJ]	Others [PJ]	Total [PJ]
Organic base chemistry	61	17	70	44		56	250
Other anor. base chemistry						9	9
Chemical end products	3						3
Glass, ceramics, cement						1	1
Base non-ferro metal							3
Metal products						15	15
Non-specified					2	4	7
Transportation					3		3
Services and construction					14	3	17
Total	64	17	70	44	20	90	307

The non-energetic final consumption of natural gas in the fertiliser industry concerns the production of hydrogen from natural gas by steam reforming. Next, the hydrogen is transformed with nitrogen into ammonia. The non-energetic final consumption of natural gas in the organic base chemistry is for the production of methanol. This also takes place through steam reforming, but in this case through a catalytic process in which the synthesis gas is being transformed into methanol.

The non-energetic final consumption of coal and cokes in the steel industry is for the reduction of iron-ore.

The non-energetic final consumption of petroleum products in the organic chemistry mainly concerns olefins (ethylene, propylene, butadiene) which are being produced from LPG, naphtha and light oil fractions. Besides this, it concerns a large amount of aromatics (benzene, toluene, ethyl benzene, xylenes).

From figures in table 8 and 9 it becomes clear that the relation total consumption/non-energetic consumption in the sector fertiliser emerges at 145%, in the organic base chemistry at 167% and in basic ferro metal at 182%. Because in these sectors the production process is responsible for the largest part of the energetic consumption, it can be concluded that in 2000 process energy for the production of chemicals, materials and products amounted from 50% up to 60_of the non-energetic consumption. With a total non-energetic consumption of 493 PJ, the corresponding energetic consumption is about 250 PJ up to 300 PJ.

3. Biomass, situation in the Netherlands in 2000

In the previous chapter the contribution of biomass in the Dutch Energy infrastructure was presented. It has been estimated by CBS (Statistical Bureau) for the year 2000 to be equal to 29 PJ avoided primary energy. In 2004 the contribution was 41 PJ. This includes only the contributions from steam and heat production and from fermentation gas. Data from CBS do not provide insight in the non-energetic consumption of biomass. Also, contributions from alcohol and vegetable oils as transportation fuels are not included. In 2000, these contributions were negligible, but within a few years, these could be considerable, if the Netherlands comply with the EU-guideline 2003/30/EC for transportation fuels.

This chapter provides an overview of the total production, import, export and use of biomass in the Netherlands. This provides insight in the possibilities to use currently existing organic streams partly as raw materials for energy production and chemistry. The amounts are expressed in PJ, next to the in agriculture and forestry commonly used unit kton, to provide insight in the gross biomass potential at present.

3.1 Gross availability of biomass in the Netherlands

CBS does not keep track of statistics of the gross biomass import, export and local production and the corresponding stream diagram as it does for petroleum, total energy, nitrogen, phosphate and also potassium. A similar exercise for agricultural streams has been performed for 1989 data (Boons, 1996).

To calculate the gross availability of biomass an analysis is made, analogous to the CBS energy streams, of biomass import, export and production (figure 1). Tables 11 and 12 show the Dutch import and export of biomass in 2000 [Van Galen, 2002]. Based on the estimation of the dry matter content (DM) the import and export are respectively 32.8 and 21.5 Mton DM per year. The large spread in composition, ash and moisture content, makes an exact translation to energy content difficult. Based on the combustion values in tables 11 and 12, the import and export are respectively 620 PJ and 405 PJ.

Table 13 provides an estimation of the total Dutch primary production of biomass on the basis of land use data according to the Statistical Yearbook of the CBS. 90% of the total production of 31 Mtons (527 PJ) originates from agriculture. 2.3 million ha is used for that purpose, which is two-thirds of the total Dutch land surface.

Table 11 *Dutch import of organic materials (biomass) in 2000*[6].

	Total mass [kton]	Fraction dry matter	Mass dry matter [kton]	Energy content [GJ/ton]	Total energy [PJ]
Living animals	200	0.2	40	20	0.8
Meat, fish and dairy	2,995	0.2	599	20	12.0
Living plants	307	0.1	31	16	0.5
Vegetables and fruits	6,381	0.1	638	16	10.2
Grains	6,413	0.85	5,451	18	98.1
Products from the flour industry	654	0.9	589	18	10.6
Oil containing seeds	7,133	0.95	6,776	20	135.5
Fats and oils	2,279	1.0	2,279	30	68.4
Sugar and cocoa	1,926	1.0	1,926	20	38.5
Food preparation	1,952	0.5	976	18	17.6
Waste and by-products of the food industry	8,946	0.3	2,684	16	42.9
Fertiliser (Animal and plant)#	200	0.95	190	10	1.9
Wood and pulp	7,010	0.9	6,309	18	113.6
Paper and cardboard	4,092	0.9	3,683	16	58.9
Other biomass	1,308	0.5	654	16	10.5
Total *	51,796	n/a	32,824	n/a	620.0

* Total organic products, excluding rubber and beverages, including paper and cardboard.

Undefined composition.

Table 12 *Dutch export of organic materials (biomass) in 2000.*

	Total mass [kton]	Fraction dry matter	Mass dry matter [kton]	Energy content [GJ/ton]	Total energy [PJ]
Living animals	398	0.2	80	20	1.6
Meat, fish and dairy	5,028	0.2	1,006	20	20.1
Living plants	1,761	0.1	176	16	2.8
Vegetables and fruits	5,861	0.1	586	16	9.4
Grains	630	0.85	536	18	9.6
Products from the flour industry	1,275	0.9	1,148	18	20.7
Oil containing seeds	1,845	0.95	1,753	20	35.1
Fats and oils	2,237	1.0	2,237	30	67.1
Sugar and cocoa	1,856	1.0	1,856	20	37.1
Food preparation	3,065	0.5	1,533	18	27.6
Waste and by-products of the food industry	9,310	0.3	2,793	16	44.7
Fertiliser (Animal and plant)#	271	0.95	257	10	2.6
Wood and pulp	3,462	0.9	3,116	18	56.1
Paper and cardboard	3,880	0.9	3,492	16	55.9
Other biomass	1,871	0.5	936	16	15.0
Total *	42,750	--	21,502	--	405.0

* Total organic products, excluding rubber and beverages, including paper and cardboard.

Undefined composition.

[6] Data from [van Galen, 2002]. Chemicals are not included because composition and possible biological origin are unclear.

Table 13 *Estimation of Dutch primary biomass production, which is in principle renewable, based on the land use in 2000.*

Category	Surface [10^3 ha]*	Biomass production [tons DM/ha.yr] #	Yield dry matter [ktons/yr]	Energy content [GJ/ton]	Energy yield [PJ/yr]
Transport	113	3	339	17	5.8
Built-up area	318	1	318	17	5.4
Semi-built area	49	2	98	17	1.7
Recreation	89	3	267	17	4.5
Agriculture	2,326	12	27,912	17	474.5
Forest & nature	483	3.5	1,691	17	28.7
Inland waterway	357	1	357	17	6.1
Off shore	417	0	0	17	0.0
Total	4,153	n/a	30,982	17	526.7

* CBS, Statistic yearbook 2005.
# This is an estimation of all biomass dry matter production, which is yearly harvestable and transportable.

Explanation of the biomass production estimates
The gross total harvestable agriculture production is estimated to be 12 tons/ha dry matter. This is the total biomass, including by-products, which can be realistically removed. The most important crops are:

- Wheat: 130,000 ha, average grain yield: 8.4 tons/ha (dry material is 10 to 15% lower) over the last 5 years [Statline]. The estimation of the amount available straw is about 5 tons/ha. This results in a total yield of 12 to 13.4 ton/ha (depending on water content).
- Sugar beets: 100,000 ha, 60 tons/ha beets over the last 5 years. One ton of beets can produce 140 kg sugar, 58 kg dry pulp, 40 kg molasses, 15 kg beet-ends and 600 kg beet-tops and leaves. In total this is roughly 140 + 50 + 30 + 100 = 320 DM/ton x 60 ton = 19.2 tons DM/ha.
- Potatoes: 160,000 ha, 44 tons/ha. At 25% dry matter this gives 11 tons DM/ha potatoes. Plus an estimated 2,5 to 3 tons DM/ha leaves. This makes 13.5 to 14 tons DM/ha.
- Corn: 200,000 ha at 14.2 tons/ha DM averaged over 2000 to 2004.
- Grass: 1 million ha, 12 tons/ha DM.

There are smaller crops like rapeseed and seed-potato which have lower DM proceeds. Furthermore, the CBS provides the gross surface, which should be compensated for.

3.2 Dutch biomass flux and consumption in 2000

The biomass flux is the total of import and primary production. This value is 32.8 + 31.0 = 63.8 Mton biomass, which results in 15.4 tons per ha. The number provides an indication for the biomass density of the Netherlands. It shows the theoretical opportunities for converting biomass into energy and products.

The gross consumption of biomass in the Netherlands is calculated from import – export + domestic primary production. The result of the year 2000 is on a dry matter basis:

32.8 – 21.5 + 31.0 = 42.3 Mtons per year

The result on the basis of the energy content is:

620 – 405 + 527 = 742 PJ per year

The gross biomass consumption of 742 PJ equals 24% of the Dutch consumption of primary energy in 2000. This exceeds by far the 29 PJ contribution of biomass according to the data of CBS in 2000 or the prognosis of 57 PJ for 2005. The 742 PJ of biomass, which are consumed per year in the Netherlands, are of course largely unavailable as energy carrier or raw material. The main part is after all a raw material for the food industry and for cattle feed. To get an impression of the part that is potentially available for energy and non-food, it is necessary to have an impression of the utilisation rate of these streams. This determines whether biomass can be made available for energy and products.

It is plausible that a large part of the biomass that is being produced is not used and could be available for energy and products. Table 13, for example, shows that 3.5 tons/ha biomass are produced in forests and nature but this is only partly used. It is known that only half of the yearly growth of the Dutch forests is being used. Moreover, there are streams like tree tops and branch wood and natural grass which could be used, but have no application. The “Grass oil” project by “Staatsbosbeheer” (Dutch National Forestry) and partners focuses on these unused grass streams [Innovation network, 2005]. Also in agriculture there are many primary biomass streams which are not being used, but have a potential application (See comments on figure 3 below). Also biomass originating from roadside maintenance, from built-up areas and maintenance of waterways has limited use. Most of the biomass is left behind. Furthermore, the efficiency of the usage is usually low. In compost production, for example, process heat is lost.

In figure 3 the flow chart of organic carbon in the Dutch agriculture is shown for 1989. It shows that only 3,307 ktons C (equivalent to about 8.9 Mtons biomass) of a total supply (import and vegetable production) of 20,534 ktons C (equivalent to about 55 Mtons biomass) end up in end-products. The yield of agricultural raw materials is therefore currently about 16%. This means, that only 16% of a primary product ends up in the end product and 84% is essentially lost. Losses are, amongst other things, manure production, unused crop residues, CO_2 and methane emissions. The efficiency of raw material use in the food industry is not taken into account here.

It is clear that there are many unavoidable losses, but there are also many opportunities to increase the efficiency in the conversion of raw materials into end-products. A possibility could be better cattle feed, which could be converted with higher efficiency to animal products. For this end, it is probably necessary to refine the raw materials, which results in higher quality cattle feed and a stream which can be used for energy production. By-products, which are produced in agriculture, are often not used or used inefficiently.

By-products are indicated in red in figure 3. These are often not used, like the 3,744 ktons C (about 9 Mtons dry mass) in manure and the 2,095 ktons C (more than 5 Mtons DM) in vegetable by-products that are not removed from the field. Also the 321 ktons C in animal by-products (700 ktons DM) are currently not used anymore in mix cattle feed. Due to changes in regulation these streams are largely available for non-food and non-feed use. An example is bone meal that is currently used for energy production. Animal fats are more and more used for greenhouse heating and biodiesel. Furthermore, there are 1,168 ktons C present in waste water (almost 3 Mtons DM).

These calculations show that in agriculture there is more than 18 Mtons DM of biomass present that could be used for biomass scenarios. This amount would represent about 300 PJ. It should be taken into account, that these are data from 1989 and not even with technology of 2030 all of this by-product potential can be made available in an economically viable way. Table 13 does not show opportunities to grow energy crops or to bio-refine plants and to used these for food/feed and non-food.

The question, how large the biomass consumption in 2030 could be and what part is available for raw materials for energy and chemical production, will be discussed in chapter 6.

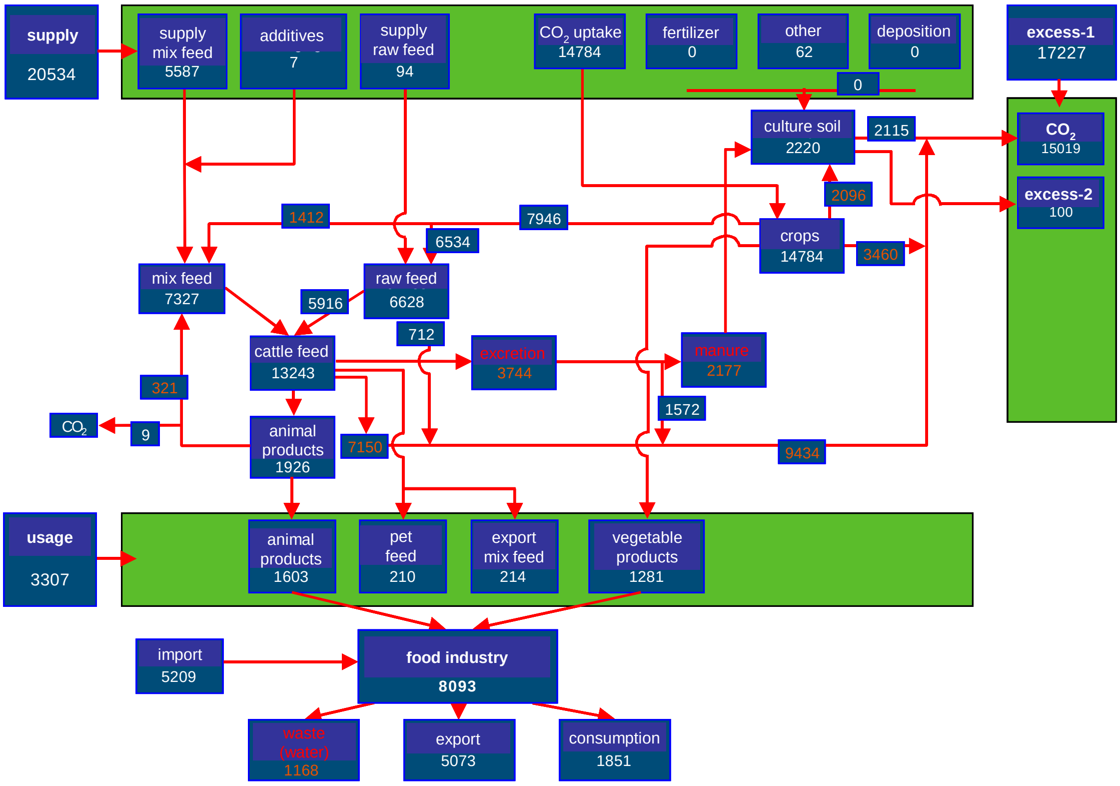

Figure 3 *Carbon flow chart for the Dutch agriculture in 1989 [Boons, 1996] Amounts are in kton/year.*

4. Energy balance in the Netherlands, prognosis for 2030

In recent years multiple studies have been performed, which show, based on different assumptions and scenarios, different results; the energy demand in the Netherlands in the next 20 to 40 years could decrease to 1700 PJ or could increase to 4500 PJ [Seebregts, 2002]. In this report, the values of the most recent report "Referentieramingen energie en emissies 2005-2020" [van Dril, 2005] are used. In his report, two scenarios are described, of which the SE-scenario (Strong Europe) corresponds best with the transition policy, which assumes a strong growth in the contribution of biomass. The SE-scenario corresponds with the B1 scenario, which is applied by the IPCC (Intergovernmental Panel on Climate Change). Characteristics of these scenarios are international cooperation and public responsibility.

The SE-scenario assumes a growth of the Gross Domestic Product of 1.7% per year. The estimate provides growth percentages of the separate sectors for the years 2000-2010 and 2010-2020. It is expected, that the energy consumption between 2000 and 2010 will increase with 0.9% per year and between 2010 and 2020 with 0.7% per year. This results in a total demand in 2020 of 3550 PJ. The department of Economic Affairs has proposed an additional policy, which could lead to the decrease of the demand of 214 PJ[7] [Brinkhorst, 2005].

On request of the Platform the starting-point for the demand in 2030 is set to 3000 PJ. This is the average over the period 1995-2000. This is clearly lower than what is to be expected on the basis of the references, even with an additional policy. This starting-point is therefore not really based on a scenario, but more on an ambition level.

To reach the consumption of 3000 PJ in 2030, the economic growth is assumed a little lower than in the reference estimations. Furthermore, it is assumed that drastic energy savings and increase in efficiency will lower the demand. Below a summary is given of the expected developments of the separate sectors. Initially this is based on the conventional energy carriers, with contributions of sun, wind and water. The next chapter will go explicitly into the possibilities to replace the fossil fuels by biomass.

4.1 Households

According to the medium version of the CBS prognosis the Dutch population will increase from 15.9 million in 2000 to 17.9 million in 2030. The number of households will increase from 6.8 million to 8.3 million. Most of the residences in 2030 have been constructed before 2000 and will therefore be heated with natural gas. The average consumption per residence will decrease because of the demolition or renovation of old houses and because of energy-saving new houses. The demand will also decrease, because more heat will be released by increasing consumption of electricity.

The consumption of warm tap water per person will remain the same and will decrease per residence. A part of the growth, which results from a growing population, can be met by a growing use of sun collectors.

The average lower heat demand per house, certainly in new houses, will decrease the economic advantages of district heating. The contribution of district heating will therefore stay more or less equal. By stimulation of the consumption of residual heat

[7] This will be saved compared to the GE-scenario (Global Economy), which will lead, without supplementary policy, to a consumption of 3867 PJ in 2020.

and a larger contribution of heat through solar panels and heat pumps, the total consumption of electricity and heat will increase to 25 PJ. The demand of natural gas will decrease from 334 PJ in 2000 to 230 PJ in 2030.

The electricity demand is already increasing for years by the increasing number of electrical devices in the houses. It is expected that the growth will decrease because of saturation. Increasing use of audio and video equipment will lead, however, to a further growth. The increasing use of cooling has a limited effect. The total electricity consumption will increase from 78 PJ in 2000 to 115 PJ in 2030.

4.2 Services and agriculture

The largest part of the energy consumption in the services sector is used for room heating, cooling and electrical equipment. The development in the consumption is comparable to the households, but larger savings are possible. The natural gas consumption will decrease from 180 PJ in 2000 to 110 PJ in 2030. The consumption of oil derivates will decrease by 50%. This is mainly the result of the European Legislation on Energy Performance of Buildings[8] for existing buildings and the Energy Performance Standard for new buildings. The electricity and heat consumption will stay equal at 25 PJ. A part of this will be obtained from sun and environment. The electricity consumption will continue to increase, starting from 105 PJ in 2000 to 120 PJ in 2030. From this, 10 PJ comes from own production.

In the agricultural sector, the greenhouse horticulture dominates the energy consumption. Precisely in this sector, economic growth is expected, in contrast to shrinkage in the cattle breeding and low growth in the agriculture. According to the Covenant Greenhouse Cultivation and Environment, the energy efficiency has to increase considerably before 2010. The natural gas consumption will decrease from 110 PJ in 2000 to 80 PJ in 2030, whereas the consumption of steam and heat will increase from 15 PJ in 2000 to 20 PJ in 2030. The consumption of oil will decrease with almost 50% and the consumption of electricity will remain the same at 15 PJ. Of this, 5 PJ will be out of own production.

4.3 Transportation

According to the traffic prognosis, which is used in the estimates, the number of vehicle kilometres will increase from 125 billion kilometres in 2000 to 175 billion kilometres in 2020. Especially in this sector a new policy should lead to a substantial reduction. This is the reason that the assumption is made that the number of vehicle kilometres in 2030 will be 170 billion kilometres. The average fuel consumption per kilometre has decreased from 1991 to 1997 with 4%. This is partly because of the increase in number of cars with relatively economical diesel engines and partly because of technological improvements. Between 2000 and 2030 the specific fuel consumption could decrease with 15%. This will result in an increase in the total fuel consumption of 457 PJ in 2000 to 530 PJ in 2030. The non-energetic consumption will increase from 3 PJ to 4 PJ. The consumption of electricity for transportation will increase because new railroad connections are put into use and higher speeds are achieved.

4.4 Refineries

During the last years the refineries have operated at maximum capacity. Until 2010 no large expansions are foreseen. Also in the following years no large expansions are

[8] The Netherlands have informed the EU that it will not implement this legislation. It has been assumed here, that the Netherlands will take measures to achieve the same effect.

expected. This is subject to change if a large installation is built that will convert biomass into transport fuels. For now it is assumed that the capacity will increase only slightly because of small adjustments, from 2450 PJ in 2000 to 2700 PJ in 2030. Savings by increasing efficiency will be cancelled out by the increasing demand for hydrogen for desulfuring, particularly if this will also be performed for storage oil. The refinery consumption will increase for this reason from 180 PJ in 2000 to 200 PJ in 2030. The contribution of natural gas in this consumption will increase to 40% and of oil will decrease to 60%.

The small increase in capacity is possibly just sufficient to cancel out the increase in domestic consumption and storage. A shift between separate products from refining, import and export is, however, necessary. Independent of the capacity of the refineries import and export could grow because of a higher throughput of notably petroleum derivates.

4.5 Industry

The industry plays an important role to reduce the energy demand. The easiest option is the relocation of energy-intensive industry to foreign countries [Jeeninga, 2002]. There are signs that this is in some form already occurring as a response to the high price of energy. The estimates are expecting, however, a relatively strong growth of the chemical industry. This industry is responsible for the largest part of the non-energetic consumption of energy carriers. Also for the base metal industry, the main consumer of non-energetic usage of coals, the expected growth is larger than average. This growth will be largely compensated by energy savings.

The electricity consumption will increase from 140 PJ in 2000 to 160 PJ in 2030, of which 30 PJ is due to own production. The non-energetic use of the energy carriers, not including electricity, will increase from 444 PJ in 2000 to 530 PJ in 2030. On the other hand, there will be a large saving on energy for heat production. The total energy consumption will increase from 1075 PJ in 2000 to 1110 PJ in 2030.

4.6 E and H companies

In the SE-scenario the total electricity consumption will grow from 390 PJ in 2000 to 500 PJ in 2020. New policy has to restrict this already to 440 PJ. Hereby it is assumed, that the consumption in 2030 will result in 462 PJ. Import and export will be more balanced, but the net import of the Netherlands will be necessary to balance variations in the production by wind turbines. It is assumed that the import balance will decrease from almost 70 PJ in 2000 to 30 PJ in 2030.

The contribution of wind energy is based on the intention to construct 6000 MW offshore and 1500 MW on land. This capacity is originally planned for 2020 and can definitely be realised in 2030. If the average yield will result in 35% of the maximum possible production, wind energy will supply 83 PJ. This is equal to over 16% of the expected consumption in 2030. The contributions of sun and water will add 7 PJ for a total yield of 90 PJ from wind, sun and water.

According to the SE-scenario the share of coal power plants in the electricity production will decrease from 25% in 2000 to 16% in 2020. This is concluded from the expectation that the oldest coal-fired power plants will be closed down and that no new coal-based power plants will be built. Considering the recent plans for a new large coal power plant, however, it seems more realistic to assume that the production of energy from coal will remain the same or will even increase. The share in the total production will result in that case in 20% from 215 PJ from coal power plants. Larger throughput and higher yields will increase the share of WPI in the electricity production from 9 PJ to 15 PJ. The WPI will consume 60 PJ of steam for this purpose.

The production of gas fuelled Combined Heat and Power units (CHP) in industry, services and agriculture will increase about 50%. The heat production of CHP-units hardly increases, because older units will be replaced by new ones with a lower H/P-ratio.

It is assumed that nuclear power will not contribute to the electricity production and the usage of oil decreases to zero. For the production of 165 PJ of electricity and 95 PJ of Heat the E and H companies will use 400 PJ of natural gas . Table 14 provides an overview of the total production and consumption of electricity.

Table 14 *Production and consumption of electricity in the Netherlands in 2030.*

	Production PJ_e		Consumption balance PJ_e		Consumption PJ_e	
Refineries	10		0		10	
E and H companies	257		-246		11	
WPI	15		-12		3	
Distribution companies	15		5		20	
Sum energy companies		297		-253		44
Industry	30		130		160	
Services and agriculture	15		120		135	
Transportation			8		8	
Households			115		115	
Sum energy consumers		45		373		418
Production		90				
Balance import-export		30				
Total		462				462

4.7 Energy balance

Table 15 provides an overview of the energy balance in 2030 based on the considerations described above. The contribution of biomass is not included, apart from the contribution through WPI and the existing small contributions in the category “others” in 2000. For a comparison please also refer to table 7.

Table 15 *Total energetic and non-energetic consumption of energy carriers in the Netherlands in 2030.*

	Nat. gas [PJ]	Petroleum [PJ]	Coal [PJ]	Electricity* [PJ]	Others* [PJ]	Total [PJ]
Refineries	80	130			-10	200
Production companies	25					25
E & H companies	400		215	-246	-95	274
Cokes factories			15			15
WPI	2			-12	60	50
Distribution companies	33			5	-5	33
Industry	380	420	85	130	95	1110[#]
Transport(excl. storage)		530		8		538
Households	230			115	25	370
Services and agriculture	190	30		120	45	385

Domestic consumption	1340	1110	315	120	115	3000

* For clarification please refer to the comments in the paragraph of table 7.
# Of which about 50% for non-energetic usage.

In a similar manner as for the situation in 2000 the total consumption of energy carriers can be distributed over four application areas; heat, electricity, transportation, and raw materials. Figure 4 provides the result for 2030.

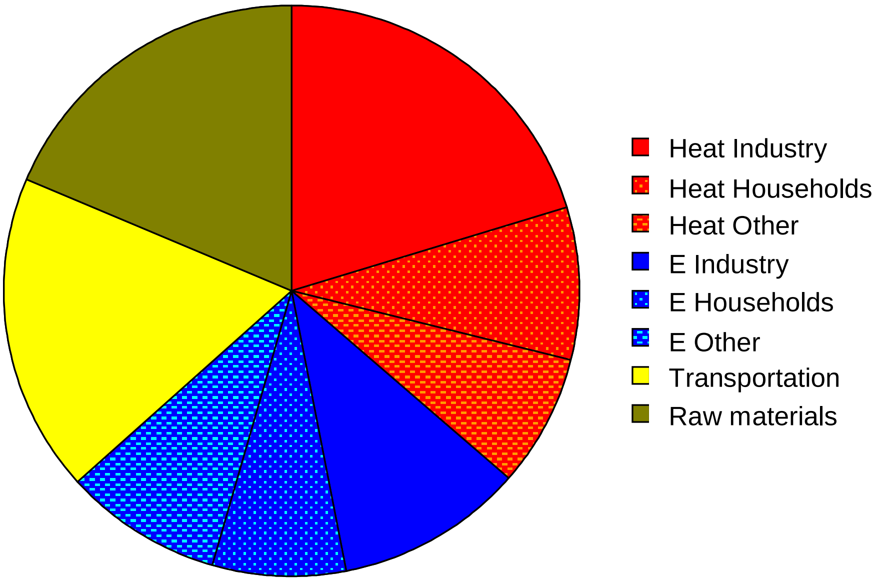

Figure 4 *Distribution of the total Dutch consumption of 3000 PJ of primary energy in 2030 over all applications and users. Oil refinery and cokes production are included in industry.*

Based on the choices[9] described in chapter 2 for the distribution of the separate items, the total consumption of 3000 PJ of energy carriers can be divided a follows:

Heat	37%
Electricity	27%
Transportation	18%
Raw materials	19%

Based on this distribution and the ambition level, which is determined by the Platform, the contribution of biomass per application can be calculated. Table 16 shows the results. At the indicated percentages per application biomass will yield in total a contribution of 28.4 %. This is a little below the desirable share of 30%. This is mainly the result of the large role of the heat demand in 2030 and the relatively low contribution of biomass in this application. An increase in this share for heat production from 17% to 24% will lead to the desired result of 30% of the total. The next chapter will elaborate on the contribution of biomass in 2030.

[9] This means, amongst other things, that the energy consumption in refineries and the process energy in the industry are ascribed to heat. If a proportional share in the consumption in refineries would be ascribed to transportation, its share would increase to 19%. In raw materials the share would increase to about 26%, if besides a proportional share in the consumption in refineries, also the process energy for production is taken into account.

Table 16 *Desired contribution of biomass per application in 2030.*

Application	Consumption [PJ]	Replacement [%]	Replacement fossil energy carriers [PJ]
Heat	1090	17	185
Electricity	810	25	203
Transportation	540	60	324
Raw materials	560	25	140
Total	3000		852

5 The contribution of biomass in the Netherlands in 2030

The Platform has estimated that in 2030, a 30% contribution of biobased raw materials and fuels could be a realistic target. More specifically, shares of 60% in the transport fuels, 20% in the chemicals, 25% in electricity production and 17% in heat production were assumed. An analysis of the feasibility of these figures is made below.

5.1 Electricity and heat

Central input

In all sectors natural gas can be replaced by SNG, synthetic natural gas that is produced from biomass through gasification, with an energetic efficiency of about 70%. SNG can also be produced through fermentation of wet biomass. For 2030 the contribution of SNG is estimated to be 9% of the total natural gas consumption, which is almost 18% of the amount of natural gas which is not being used as raw material or for the production of electricity.

Biomass can be converted into electricity and used in all sectors. The yield of electricity production can be 40% to 45% through combustion and 50% through gasification with usage in STEGs (Steam and Gasturbine).

Co-firing of biomass in coal plants could make a contribution of 4% in the total production at 20% replacement of coal. If the replacement percentage will be raised to 30%, or if an exclusively biomass fired 400 MWe plant would be built, the share in the production will increase to 6%. Instead of one large plant, also smaller plants could be constructed, which will deliver both electricity and heat. In the energy balance a 6% contribution means the replacement of 65 PJ of coal through 65 PJ in the category “others”. Because of the somewhat lower output 70 PJ biomass is required. Additionally, biomass through the WPI provides a contribution of 30 PJ.

Liquid fuels from biomass can be co-fired in gas turbines in order to save natural gas. This already takes place at two natural gas fired plants. This option has not been taken into account here because of the expected competition in the application “transportation”.

In this way biomass could be transformed centrally and at large scale into SNG or electricity and be used de-centrally, using the existing infrastructure, such as the gas network and the electricity network. Existing technology for coal provides a good starting point for the development for technology for biomass. In the import, central conversion provides large savings in expenses for transportation and distribution.

De-centralised use.

Direct conversion of biomass into heat can be possible with a yield that is comparable to other fuels. In this way houses and buildings can be heated by central heating appliances using wood pellets. In the industry biomass can be used for production of process heat. De-central combustion of biomass has as the important disadvantage of higher emissions of dust and acidic gases (like in the past with de-central usage of coal). These emissions could be reduced, but with small installations this would lead to higher costs. For this reason, biomass use for households through SNG is more attractive.

At specific applications problems could evolve, which could hinder the replacement of fossil fuels by biomass or make it unpractical. Also the adjustability of the combustion process is a lot more difficult with biomass than with natural gas or oil. The combustion temperature of biomass is also lower, which is a disadvantage in processes which require heat at high temperature.

De-central combined production of heat and electricity is possible mainly in the sector services and agriculture, with the usage of locally available biomass rest streams or specially grown biomass. The biomass will, partly through methanation or gasification, be transformed into gas, for the application in gas engines, and partly be burnt to produce steam for steam turbines.

Biomass contribution

The demand of heat is about 36% of the total consumption of primary energy, which is 1090 PJ. The biomass contribution consists of a mixture of heat from small biomass-CHP, supply of heat by plants with biomass co-firing and WPIs, direct combustion of biomass and of SNG. This heat will be used in the industry, households and services and the horticulture sector.

The total input of biomass for electricity and heat amounts to 355 PJ. This amount has been calculated from the following contributions:

Central electricity production	70 PJ =>	28 PJ_e	
WPI	30 PJ =>	7 PJ_e +	3 PJ_{th}
Small-scale CHP	35 PJ =>	12 PJ_e +	14 PJ_{th}
Direct combustion	48 PJ =>	0 PJ_e +	41 PJ_{th}
SNG[10]	172 PJ =>	0 PJ_e +	120 PJ_{th}
Total	355 PJ =>	47 PJ_e +	178 PJ_{th}

According to these figures biomass supplies 10% of the total electricity consumption. The contribution of 47 PJ_e corresponds with savings of 98 PJ of fossil fuels. This is much lower that the target of the Platform. The share of biomass is limited by the assumed large share of wind. The electricity production by wind turbines, on an average 16% of the consumption in 2030, could theoretically vary from 0% to 50% of the average demand. During off-peak hours the share could even be larger. As compensation, good and fast adjustable production capacity is needed, while plants based on coal or biomass are better fitted for base loads. This means that variations in the production by wind turbines have to be taken care of by natural gas plants.

A larger role for biomass in the production of electricity can be realised by replacement of natural gas by oil from biomass, or by complete replacement of a coal plant by a biomass plant. At this moment only vegetable oil can be used in gas turbines. The quality of pyrolysis oil is not satisfactory for this application at the moment. If this will change, there could be much more supply of oil as replacement of natural gas.

A biomass contribution of 178 PJ to heat leads to 184 PJ of savings on fossil fuels (120 PJ through SNG and 64 PJ through heat). This is 17% of the demand, which satisfies the goals of the Platform.

[10] SNG replaces natural gas without differences in yield for applications. Heat replaces natural gas, which is used for the production of heat with an average yield of 90%. For the direct production of heat from biomass the yield of 85% is assumed.

A larger share of biomass in the production of heat can be realised by a higher usage of biomass in the small-scale CHP or by direct combustion. It is important to notice, that a contribution of 1 PJ comes down to an industrial installation of 40 MW that is in service for 7000 hours per year, or to 35,000 households with district heating. Especially for households the extra production of SNG from biomass is an alternative.

In total, the input of 355 PJ biomass in the sector electricity and heat saves 282 PJ on fossil fuels according to this analysis. In these figures it is not taken into account that raw materials and new process routes based on biomass can contribute to a lower consumption of electricity and heat in the industry. This will be discussed in paragraph 5.3 and attachment B.

5.2 Transport and refineries

The EU have stated an objective of 2% for 2005 and 5.75% for 2010 in their “Biofuels Directive”. In the proposal for the Directive also a contribution of 8% for 2020 has been anticipated. In a research project for the European Committee, the “Alternative Fuels Contact Group” concluded at the end of 2003 that 15% will be possible in 2020 as the second-generation biofuels have a higher output per hectare. However, in this study and also in comparable studies the biomass potential in Europe is always considered a restrictive factor. If also import from outside is taken into account, a higher potential is possible. Other factors can still limit the share of biofuels, as is being explained next.

Although research on new drive systems is performed,, in 2030 the combustion-engines on the basis of diesel and petrol will still play a dominant role in transportation. For both types of engines alternative biofuels exist already at present (biodiesel and conventional bio-ethanol). In addition, around 2010 the formerly mentioned second-generation biofuels will come on the market. For diesel engines Fischer-Tropsch diesel from biomass could be used, in pure form of mixed with fossil diesel. For petrol engines bio-ethanol from cellulose can be used. Bio-ethanol can be mixed in small quantities with petrol. For the consumption of large quantities of ethanol, flexi-fuel vehicles are needed, which can drive on ethanol/petrol mixtures with a maximum of 85% ethanol. These vehicles are already on the market in a number of countries.

The mixture of biofuels that will come on the market has to be such that the relation between fossil diesel and petrol will stay somewhat equal. So it is not possible to bring just ethanol in large quantities on the market without also bringing a diesel substitute on the market. The reason is that oil refineries produce a fixed proportion of diesel and petrol. Only at the construction of a new refinery the choice can be made for a certain proportion between diesel and petrol, thereafter it can hardly be changed.

A limiting factor for the share of biofuels comes from the present oil refining capacity. Not using the full capacity, and at the same time the production of biofuels, actually means the destruction of capital. As the European refineries are currently being used at maximum capacity, in principle every increase in the demand of fuel by biofuels can be met by the building of new production capacity and/or by import. Between 2000 and 2030 the demand of transport fuels is increasing with 73 PJ, which is 16%. Moreover, part of the present oil refinery capacity has to be replaced before 2030. The life of oil refineries is relatively long, but the life of the several parts is about 25 years on average.

In order to meet the aim of 60% biofuels, 318 PJ of biofuels are needed[11], which means that besides the 73 PJ of new capacity or import, 245 PJ are required. This is more than half of the oil refinery capacity used for Dutch transport fuels in 2000. This seems too much to have been substituted already by 2030. As the refinery capacity in the Netherlands is much larger than the Dutch market (see table 3), the substitution will be possible but not likely if the Netherlands want to keep pace with other countries in Europe with the introduction of transport fuels from biomass. In European context the ambition for 2030 is about 20%.

Moreover, it has to be taken into account that oil refineries are also producing many oil products for the chemical industry. If the oil refinery capacity decreases, also the available amount of base chemicals from oil products for the chemical industry will decrease. In that case alternative raw materials (biomass) and production processes for the chemical industry have to be made available. Where substitution of present transport fuels from petroleum by biofuels is concerned, the oil refinery and the chemical industry have to be considered as one organic part.

The transportation sector offers good possibilities to introduce biomass at a large scale. The technology is rather well developed. This means that a large contribution of biomass will be possible in 2030. On the basis of the above mentioned considerations, it seems more realistic after all to aim at 40% for 2030. This amounts to 212 PJ. At an average yield of 60% from biomass to fuel, 353 PJ of biomass are required[12]. The production of transport fuels from biomass could lead to savings corresponding to an additional contribution of 17 PJ. As conversion losses and energy consumption for refinery have been added to the consumption of heat in the industry, the savings have to be booked to that item as well.

The above estimated contribution of biomass in transportation is significantly lower than the target set by the Platform. In this case the difference is largely caused by a different estimation of the feasibility, partly based on economics and partly based on the developments in other European countries.

5.3 Industry and cokes factories

The sector industry is responsible for 95% of the non-energetic consumption of energy carriers. This is the consumption of energy carriers as raw materials for chemicals, materials and products. Apart from this the industry is also consuming energy in the production processes. This consumption is assigned to the applications electricity and heat. Where the use of biomass as a raw material consumes clearly less energy, the savings of the process energy can also be assigned to the application raw materials. Below those contributions are described separately.

In the fertiliser industry, the non-energetic consumption of natural gas (92 PJ in 2030) for the production of ammonia can be substituted partly by the use of hydrogen which can be produced from biomass. In the organic base chemistry the consumption of natural gas in 2030 has been estimated to be 31 PJ. For the production of methanol synthesis gas from biomass gasification can be used. Under the recent economic conditions this is only a theoretical possibility. For a contribution of 30% in both

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[11] Here a share of 60% is calculated over the share of 530 PJ from petroleum. For the 8 PJ from electricity the share for the production thereof applies.

[12] In the production of bio-ethanol a rest product remains, which can be used in the production of electricity and heat, of which a part is needed in the process itself. Also the production of diesel through the Fischer-Tropsch process yields an excess of electricity. The excess of electricity is included in the calculations for the average yield of 60% [Tampier, 2004; Ahlvik, 2001].

sectors, 44 PJ of biomass is required, with an estimated substitution yield of 85%. A larger contribution, or a lower biomass requirement, are possible through direct production of nitrogen compounds from biomass (see Attachment B).

In the steel industry, coal and cokes can be substituted by biomass. In non-energetic consumption (65 PJ in 2030) it mainly concerns the substitution of coke by charcoal. Technically, a contribution of 50% seems certainly attainable. Substitution of 33 PJ coke requires 47 PJ of biomass[13]. If substitution of cokes by charcoal leads to a lower coke production, the heat demand of coke factories will diminish. That contribution, about 6 PJ, has been neglected here.

The non-energetic consumption of petroleum products in the organic base chemistry (315 PJ in 2030), mainly consists of olefins (ethylene, propylene, butadiene) which are produced from LPG, naphtha and light oil fractions. Besides, large quantities of aromatics (benzene, toluene, ethyl benzene, xylenes) are being consumed. Momentarily there are no possibilities to replace these base chemicals by biomass products. There are, however, different possibilities for the future. Roughly 5 routes can be identified. These routes fit increasingly in the concept “bio-refinery”, in which the biomass structure is kept intact and used as much as possible.

1. Synthesis gas
Through gasification at high temperature, biomass can be transformed into synthetic gas, with as main components CO and H_2. This synthesis gas can, amongst others, be used in the Fischer-Tropsch process for the production of hydrocarbons. This process provides, apart from the diesel fraction, which can be used as bio-fuel, also other fractions, just like a refinery. These other fractions can be used to produce base chemicals, such as olefins. However, the Fischer-Tropsch process produces much less aromatics than a refinery.

2. Gasification at middle-high temperature
At relatively low temperature (about 700-900 C), gasification of biomass provides a gas, which apart from the usual synthesis gas components also contains methane, ethylene, benzene and other hydrocarbons. With efficient separation techniques which still have to be developed, components such as ethylene and benzene could be separated. These could be used in the base organic chemistry just like how it is currently done. The BTG pyrolysis process and the HTU process can be counted to this route too. These processes provide a mixture of oil and water which contains different components suitable for application in chemistry.

3. Staged gasification
This is an even more subtle approach, in which biomass is gasified at still lower temperatures (from 200ºC) in the absence of oxygen. By this procedure, interesting basic chemicals are produced, such as methanol and acetic acid. The application of catalysers in different processes can maximise the output of specific desired products. This is, however, a field of research from which some parts have been studied already, but for which the total potential will not be known for a considerable time.

4. Fermentation, microbial and enzymatic transformations
Through isolation of components from vegetable material, as well by fermentation on the basis of sugars, (base) chemicals can be produced, by which fossil raw materials can be saved. Examples of the production of existing chemicals are the ABE process (acetone-butanol-ethanol fermentation process) and biological hydrogen production. Moreover,

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[13] The 30% conversion loss of biomass to charcoal is taken into account. If the conversion takes place outside the Netherlands, this loss will not be included in the Dutch energy balance.

also new chemicals can be produced, or intermediate products for this purpose. At this moment particularly in the USA fermentation processes have been developed for functionalised compounds, such as 1,3-propanediol and (poly) lactic acid[14]. It is to be expected that this development leads to a large amount of compounds and new materials.

5. Specific production of chemicals in plants
In this concept chemicals (or raw materials) in plants are being produced and won by separation. Examples of this are the production of amino acids or peptides which can easily be isolated and purified and which form good starting compounds for a number of existing (bulk) chemicals. An example is the peptide cyanofycine which can lead to the bulk chemicals 1,4-butanediamine, ureum and acrylonitril.

It is possible that developments in microbiological transformations and production of chemicals in plants will lead to a new class of functional chemicals and products which can partly replace existing products. An example is the use of (poly) lactic acid as replacement of polyethylene in some applications. Furthermore, it is also possible that new final products can be formed directly from raw materials without use of the existing routes and infrastructure. One example is the production and the usage of Solanyl®[15] as replacement of existing polymers in some applications.

By use of routes 4 and 5 it is possible to arrive at two types of concepts:
- Energy reduction by replacement of the non-functionalised raw material. Apart from (partial) replacement of the raw material, all other factors remain equal.
- Reduction of the energy demand by the usage of alternative raw materials for functionalised chemicals. In this case the demand for means of production and energy and the usage of reagents are limited.

These two concepts are more specifically explained in Attachment B.

Replacement of 25% of the non-energetic consumption of petroleum products amounts to 79 PJ. Just like with transportation fuels and cokes, an extra contribution for energy saving in refineries could be added. Here too that contribution has been neglected[16]. With routes 4 and 5 an extra saving on process energy is possible.

As estimated by ECN, this saving is 20 PJ at most. This result comes from the assumption that these routes provide half of the 79 PJ saving on non-energetic consumption of oil products and that the saving on process energy is again half of this[17]. Furthermore it is required that biomass provides all process energy for the new process.

As estimated by WUR, the saving can amount to 40 PJ up to 80 PJ. This result comes from the assumption that these routes provide the total 79 PJ saving on non-energetic consumption of oil products, as well as a part of the natural gas based production of ammonia. New routes have to be found mainly for processes at which the classic process requires above average process energy. Furthermore, it is required that biomass provides all process energy for the new process.

The yield of biomass to chemicals, materials and products can vary from less than 60% for gasification in combination with the Fischer-Tropsch process and upgrading to 90%

[14] Cargil-Dow, DuPont, Genecor.
[15] www.biopolymers.com
[16] Here the savings in the energy consumption in refineries for the production of raw materials from petroleum are meant. By a replacement of 79 PJ in raw materials this will be 6 PJ.
[17] In chapter 2 it has been stated that the process energy is 50% to 60% of the non-energetic consumption. Here it is assumed that in 2030 maximally 50% is still necessary.

for slow gasification and biochemical routes. With an average yield of 70%, 113 PJ of biomass are required. This input can save 79 PJ on petroleum products plus 20 PJ on process energy. A larger saving on process energy requires a larger input of biomass.

The possible non-energetic input of biomass in other industries is hard to estimate because of the diversity and has been neglected here. Non-energetic input of petroleum products in services and construction mainly concerns bitumen for asphalt. It has been assumed that in that case substitution by biomass is not possible.

On the basis of the above-mentioned, in 2030 the input of biomass for non-energetic consumption in the industry can save 149 PJ of fossil energy carriers. This amounts to almost 27% of the non-energetic consumption. This result is a little higher than the target of the Platform, mainly due to the high estimated potential in the steel industry. For this contribution 204 PJ of biomass are necessary. Apart from a direct saving in fossil raw materials the use of biomass can yield a saving in the process energy in the chemical industry and possibly some smaller contributions in the cokes factories and the refineries. According to ECN an extra saving in the chemical industry can yield at most 20 PJ. According to WUR 40 PJ to 80 PJ is achievable. The total of these extra contributions will result, in a cautious estimation, in 4.5% of the demand of heat and 1.6% in the total demand of primary energy.

It is recommended to aim firstly at the use of biomass, in which the required adaptations of the infrastructure are limited. Furthermore, the processes that lead to a lower consumption of the process energy should be promoted.

5.4 Biomass demand in 2030

Table 17 shows a review of the assumed contributions of biomass in various sectors and the corresponding required amount of biomass. The input of 912 PJ of biomass provides a saving of 643 PJ of fossil energy-carriers, which amounts to 21.4% of the total demand of primary energy. Including various savings in process energy the total comes down to 692 PJ, which results in 23 %. This is lower than the 30%, which the Platform has stated as ambition level. The difference is mainly due to significantly smaller contribution in electricity (-105 PJ) and transportation (-112 PJ).

Table 17 *Biomass contributions to the energy balance in the Netherlands and the necessary biomass in 2030.*

Sector		Energy demand [PJ]	Contribution biomass [%]	Savings fossil energy [PJ]	Necessary Biomass [PJ]
Heat		1090	17	184#	240
Electricity		810	12	98	115
Transportation		540	40*	212#	353
Raw materials	Metal industry	65	50	33#	47
	Chemistry natural gas	123	30	37	44
	Chemistry petroleum	315	25	79#	113
	Others	57			
Total		3000		643#	912

* The consumption of electricity for transportation is not included.
# The savings of energy consumption in oil refinery, in cokes production and for the process energy in the chemical industry are neglected. These savings could together lead to an extra contribution of 49 PJ in heat, which is 4.5% of the consumption for heat.

6. Biomass supply in 2030

In the previous chapter it has been shown, how biomass can lead to savings of 23% of the Dutch consumption of fossil energy carriers. To achieve this goal almost 900 PJ biomass is needed. This demand will have to be covered by domestically produced biomass and by imported biomass.

This chapter will deal with the question on how much biomass (and biofuels) can be made available in the Netherlands and through import and where this will be put into use. To achieve this, the Dutch land use in 2030 will be analysed. This will provide insight in the gross productivity and the type of biomass that can be released. Furthermore, an analysis will be made of existing studies, which have studied the availability of biomass in the Netherlands and in the world.

To gain more insight where and which streams could become available, a short analysis of 5 streams has been made. These streams are primary biomass, secondary biomass, tertiary biomass, cultivated biomass and imported biomass.

6.1 Dutch primary production

Table 18 gives an estimation of the Dutch primary biomass production in 2030, based on the expected land use. Table 18 shows that the total biomass production will increase from 31 Mton (527 PJ) to 36 Mton (627 PJ). The expected changes in land use as presented by Londo [Londo, 2002] have been used. Our assumption is that agricultural production will increase from 12 ton/ha DM in 2010 to 16 ton/ha DM in 2030. This corresponds to an increase of 1% per year. This improvement in yield has taken place in the past years for a number of crops, like potatoes and sugar beets.

Table 18 *Estimation of the Dutch primary biomass production in 2030, which in principle can be used in a sustainable way, based on the estimated land use in 2030 [Londo, 2002].*

Category	Surface in 2000 [10^3 ha]	Surface in 2030 [10^3 ha]	Biomass production [ton DM/ha.yr]	Yield dry matter [kton/yr]	Energy content [GJ/ton]	Energy yield [PJ/jr]
Transport, built-up and semi-built-up area	480	524	1,6	838	17	14,3
Recreation	89	130	3,5	456	17	7,8
Agriculture	2.326	2.004	16,0	32.064	17	545,1
Forest and nature	483	579	4,0	2.315	17	39,4
Inland waterways	357	498	1,0	498	17	8,5
Off shore	417	417	0,0	0	17	0,0
Total	4.152	4.152	nvt	36.172	17	627,8

An increase of the yield to 16 ton/ha DM in 30 years is possible by breeding and improvements in agronomic practice, a longer growing season because of climate change and a higher CO_2 content in the air. Furthermore, it is expected that the less productive agricultural areas will be converted to forest and natural areas and recreational areas. It can be assumed, that also larger changes will take place, like the cultivation of more productive crops. An example would be the introduction of fodder beet for bio-refinery (sugar + protein + fibre). This can result in a 30% higher yield than the cultivation of sugar beet. Similar yield differences exist between conventional maize and energy maize. The latter is produced especially for fermentation (biogas).

6.2 Biomass sources

The appearance of biomass and the sources of biomass are very diverse. The type of biomass that is available will partly determine how the bio-based economy will look like. The biomass sources in the Netherlands can be divided into 5 categories:

- Primary by-products, these are by-products which are released at the source. These include crop residues like sugar beet tops and leaves, straw, verge grass, greenhouse waste, wood thinnings, etc.
- Secondary by-products, are by-products that are released later in the production chain like potato peels, beet pulp, sawdust, C-starch, brewers grain, etc.
- Tertiary by-products are by-products that already have had a function and become available again like discarded frying oil, manure, animal grease, most household organic waste, recycled paper, demolition wood.
- Specific crops, like hemp, flax, *Miscanthus*, switchgrass, short rotation coppice, sugar beets for ethanol, etc.
- Import of biomass in the form of crops, primary and secondary (by-) products or intermediates.

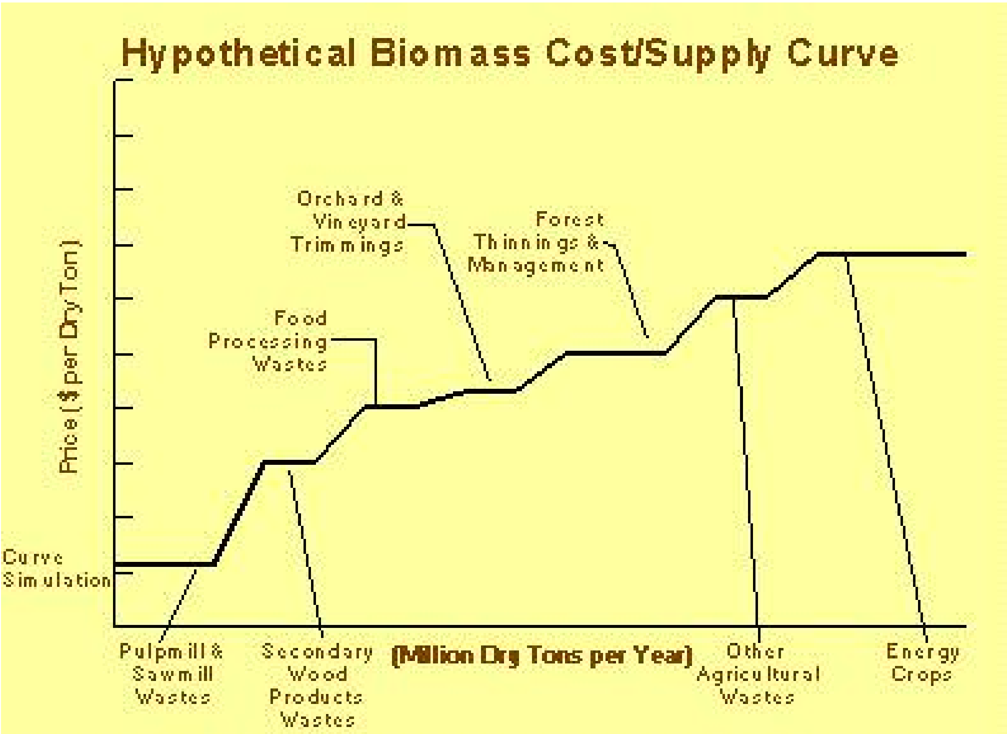

Figure 5 *Typical biomass supply curve for a wood-burning installation [Tumbull, 1994]. Secondary and tertiary by-products are the cheapest, followed by primary by-products and specifically grown crops.*

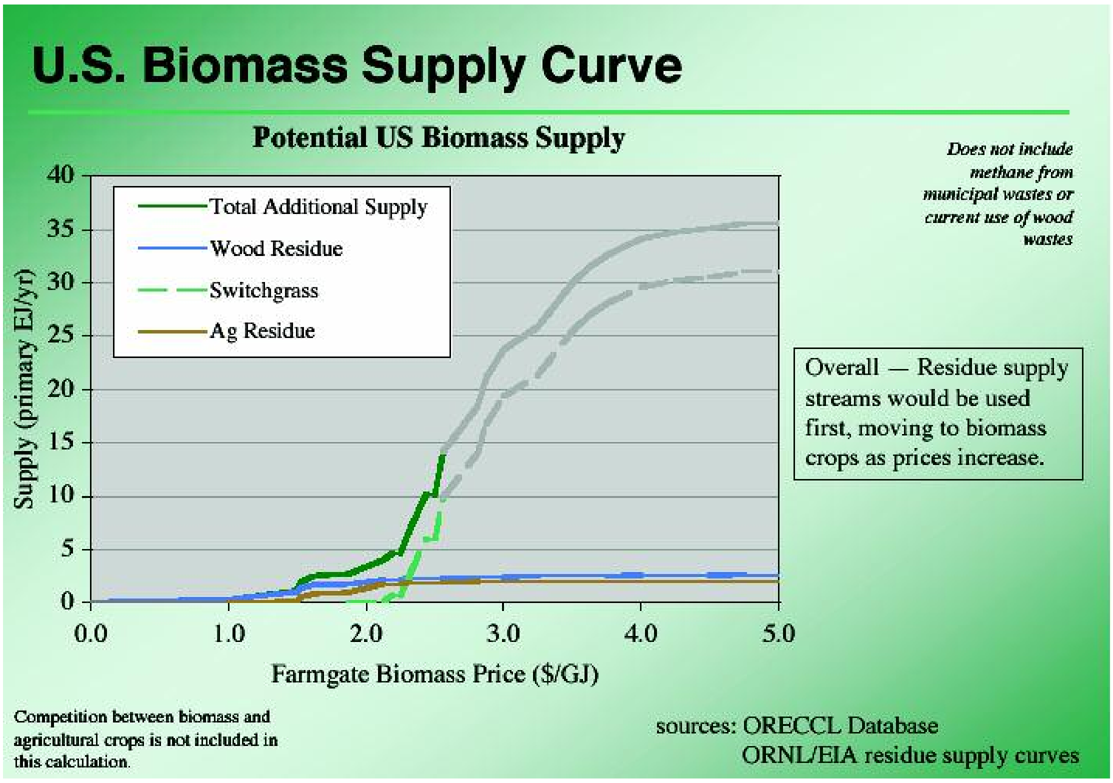

Figure 6 *Biomass supply curve for the US of wood residues, agricultural residues and the energy crop switchgrass [Smith, 2004].*

Figure 5 and 6 present some general biomass supply curves. These illustrate that first, secondary and tertiary by-products are supplied, followed by primary by-products and finally especially cultivated crops. Each type of biomass with the accompanying conversion system has, of course, a different supply curve.

In studies on the availability of biomass for energy production, mainly secondary and tertiary by-products come to the front. This is illustrated by table 18, in which the expected supply of biomass streams in 2010 is shown [Koppejan, 2005]. This study mainly focussed on biomass for electricity and heat. In the literature it is hard to discriminate between primary and secondary by-products. These are treated collectively from now on.

6.3 Biomass developments

Traditionally, primary by-products don't have many applications and are often being left behind in the field or in the forest. There is, however, often an interest to find a (more) sustainable and, preferably, financially attractive outlet. Drivers are, amongst others, the wish to remove nutrients which may otherwise run off. This is the case for verge grass and grass that is cut to maintain natural open areas. As an efficient infrastructure develops to utilise these types of biomass, many of these biomass streams could start contributing to the production of sustainable energy, transportation fuels and chemistry. Conversion technologies which could be used for this purpose, are fermentation, bio-refinery [Zwart, 2004] and pyrolysis [Innovation Network, 2005]. Crop residues often do have a role for supplying soilcarbon and nutrients, but in the Netherlands this should not be a real obstacle for the use for energy [Verhagen, 2004]. Furthermore, the removal and use of agro residues could contribute to a lower run-off of nitrate after the harvest [Zwart, 2004].

Table 19 *Expected supply of biomass in 2010 [Koppejan, 2005].*

Nr.	Biomass type	Supply in the Netherlands [kton/year]	Energy-content [GJ/ton]	Energy-content [PJ/year]	Price [Euro/ton supplied]	Price [Euro/GJ supplied]
1a	Fresh residue wood, woodblocks	500	10.2	5.1	10	1.0
1b	Fresh residue wood, shredded wood	540	10.2	5.5	18	1.8
2	Energy crops	2	10.2	~0	80	7.8
3a	Clean residue wood (sawdust/curls)	270	15.6	4.2	n.v.t.	0 – 0.6
3b	Wood pellets	100	17.5	1.8	90	5.2
3c	Clean wood resudues,	250	15.6	3.9	10	1.0
4	Separate collected wood, A quality	500	15.4	7.7	16	1.0
5	Separate collected wood, B quality	700	15.4	10.8	6	0.4
6	Separate collected wood, C quality	50	15.4	0.8	-74	-4.8
7	Grains	0	-	0	-	-
8	Grain straw	0	13.3	0	41	3.1
9	Verge grass	450	5.3	2.4	-44	-8.3
10	Grass hay	140	12.7	1.8	76	6.0
11	Hemp, flax	5	11.3	~0	6	0.5
12	Energy cop (Miscanthus)	0,5	13.2	~0	80	6.1
13	Vegetable oil	4	38	~0	705	18.6
14	Straw	15	13.6	~0	41	3.0
15 a	Peals	100	16.5	1.7	80	4.8
15 b	Oil seed residues	100	15	1.5	150	10
16a	Discarded frying oil	60	38	2.3	200	5.3
16b	Residues from oil hardening Residues from oil hydrogenation (bleek aarde)l	12	10	0	-	-
16c	Fatty acids	60	38	2.3	45-125	2.0
16d	Residue greases	0	30	0	-	-
16e	Dry food processing residues	100	18	1.8	55-80	3.2
16f	Bone meal	50	22	1.1	0	0
16g	Animal fats	200	25	5	250	10
17	Swill	215	3.4	0.7	-34	-10
18	Organic household waste	2.280	3.4	7.8	-31	-9.1
19	Waste	10.200	8.4	40	-100	-11.9
20	Used paper and cardboard	-	-	0	-	-
21	Textile	-	-	0	-	-
22	Shredded waste	0	-	0	-	-
23	Municipal wastes	0	-	0	-	-
24	Chicken manure	1.000	6.6	6.6	~0	~0
25	Cow and pig manure	15.000	-1	0	-16	-
26	Watertreatment sludge (RWZI)	1.400	1.5	2.1	-	-20 tot -40
27	Compost fractions	50	10.2	0.5	-	~0
28	Assorted wood from waste streams	500	15.4	7.7	10	0.6
29	Papers sludge	1.000	1.6	1.6	-	~0
30	Paper/plastic pellets (SRF)	2.500	13-20	42	10	0.6
Total *		17 Mton		150	-	-
Primary by-product (direct from the field)				4.4		
Secondary en tertiary (by-product or waste)				143		
Crops				0.03		
Import				1.9		

Organic household waste consists of primary as well as secondary and tertiary by-products and is included here in the last type.

* Cow and pig manure are not included in the total. Of waste and paper/plastic pallets only the biomass share is included.

Crop residues forms a substantial part of the total agriculture production in the Netherlands. The amounts per ha are variable. For 11 filed vegetable crops the estimated amount of crop residues is more than 3 ton DM/ha, while for arable farming crops more than 2,5 ton DM/ha of residues are available [Zwart, 2004]. For sugar beets it is even more than 4 ton DM/ha. This means that in the Netherlands some 3 x 100.000 ha = 0,3 Mton DM horticultural by-products are available, and that from arable farming 2,5 x 800.000 ha = 2 Mton DM biomass is available. About 2.3 Mton DM was available in principle from arable crops and horticulture, with optimalisation this could be higher. By-products from greenhouses have not been included here. For 2030 an even larger availability may be expected. We assume that 3 Mton DM of crop residues will be available by then.

Furthermore, the so-called fertiliser crops, like rape, form an attractive biomass source. These crops are being grown later in the season, after the main crops, like wheat, in order to retain nutrients, mainly nitrogen. At this moment these fertiliser crops are being ploughed under. The release of nutrients is being postponed leading to less run-off and , eutrophication of surface water. The following crops can then use the nutrients. The crops can also be used as raw material for bio-refinery and/or biogas production. After which nutrients can be recycled more efficiently. The yield of these crops strongly dependent on the time of sowing but can amount to 5 tons DM/ha. At this moment some ten thousands hectares are being grown in The Netherlands.

The analysis shows that some 3 Mton DM of primary by-products from agriculture can be removed at this moment. This seems a reasonable estimation compared to the gross analysis in chapter 3, where some 5 Mton DM crop residues could be identified.

Apart from agriculture, products originating from landscape maintenance, such as verge grass, tree prunings and wood thinnings form an attractive biomass source which can be almost totally used for energy. Leaving behind of wood in the forest can be a specific part of landscape management (as is often the case with "Stichting Natuurmonumenten"). Probably a large part of these streams could in principle be used. However, at the moment practical objections, such as the cost of logistics and the absence of a processing infrastructure, do exist, but these can be brided by 2030. In principle some 1.4 Mton DM could be made available of these biomass streams on the basis of 2000 figures. For 2030 this should be a lagre amount because of a higher productivity and a larger projected area for nature, woods and recreation. In table 18 a gross potential of 4 Mton for these streams is given. We assume that some 3 Mton DM could be made available.

Overall, the exercise shows that some about 3 Mton primary by-products from agriculture and 3 Mton primary biomass from outside agriculture can be found. In total this could amount to about 6 Mton DM, which equals to 100 PJ.

The opening up of these streams requires an investment in an infrastructure which can process various kinds of biomass, from dry to wet, which are generally produced in peaks over the year. The utilisation of these biomass streams often coincides with specific advantages for landscape management and it can support the efficient recycling of nutrients [Zwart, 2004].

Secondary and tertiary by-products are released, respectively, in the processing of agricultural and forestry products and after usage (manure, demolition wood, organic household waste, etc.). In the Netherlands in recent years a shift has taken place in the application of by-products from the food and beverage industry, globally 10 Mton [Koppejan, 2005]. Traditional applications have been in mostly in animal feed (77%). This has been under pressure because of the following reasons:

- Because of feed incidents (see BSE, hormones, etc) it has been prohibited to use many by-products in animal feed.

- Animal diseases (swine pest, bird flu, foot and mouth disease) have led to interruptions in removal of by-products from production sites, which has led to high costs.
- The expected decline of livestock in The Netherlands, to 50% in 2030, as indicated in the fourth “National Environment Policy Plan” (NMP4), is already taking place. Hence there is less possibility to depose of by-products in the direction of feed.

If regulations or market changes lead to problems in the sale of by-product as feed, the value will diminish considerably. Companies and the authorities welcome alternative processing options. Industries often need to have an alternative output of by-products and are actively looking for this. This applies to slaughterhouse wastes, but also to non-animal by-products such as potato peals, brewers grains, beet pulp, etc. [Elbersen, 2002; Rabobank, 2001; Vaals 2003]. The potential supply of these secondary and tertiary streams is 143 PJ (see table 19). The utilisation for energy production of part of these biomass streams is expected to lead to 88 PJ avoided fossil fuel utilisation in 2010 [Koppejan, 2005].

For the developments between 2010 and 2030 we have to make some assumptions. Thus we expect that the above-mentioned supply will not decrease and that a number of biomass streams may actually increase. A biomass stream like cattle and pig manure, was not yet been included in the 2010 estimate, but is expected to contribute to electricity and heat production in the coming years. Furthermore, streams which are now being composted will also be used for energy applications. We assume that this development can result in a supply of at least 200 PJ in 2030. These types of (secondary and tertiary) streams are already being utilised and will be somewhat easier to mobilise for energy than primary by-products, but they also require further investments in an appropriate infrastructure.

<u>Specific cultivation</u> of biomass crops is slowly starting in the Netherlands. See rape seed [Janssens, 2005] and specific biogas crops, but also existing industrial non-food crops like hemp, flax and starch potatoes. Developments untill 2030 are difficult to predict. They are strongly dependent on the changes in the Common Agricultural Policy (CAP) of the EU, as this determines which crop is attractive for farmers to produce. A disconnection will take place between subsidies and production, while sustainability will be rewarded. This could offer chances for production of biomass raw materials.

Studies into the possibilities for energy growth [Londo, 2002; Janssens, 2005] are surrounded by large uncertainties, especially for the longer term untill 2030. An analysis by Londo shows that up to 10% of the Dutch agricultural area could be dedicated to energy crops. This would give a potential of 200.000 ha x 16 ton DM/ha = 3,2 Mton DM biomass (equivalent to 54 PJ primary energy).

At this moment several commercial energy crop initiatives exist, which focus on rape-seed oil for bio-diesel (Groningen, Achterhoek and Limburg), wheat for ethanol production (e.g. Zeeland) and energy corn for biogas. Moreover, changes in EU sugar regulations could induce the combined production of sugar and ethanol (from sugar beets). This shows that energy crop production for biofuels (and also for chemistry) will probably also be an option in 2030. As said before, the real potential will strongly depend on the CAP and the competition with other crops, claims on land, etc. Multi-functional energy crops, in which energy crop cultivation is combined with other land use functions, is also an option that can have an impact before 2030 [Eker, 1999; Londo, 2002], which cannot be quantified immediately.

Apart from arable crops, there are also opportunities in the Netherlands to use grass lands for biomass production. There is a trend towards a decrease in livestock, as mentioned above and optimisation of management practices. In the peat grassland regions of The Netherlands measures are being implemented to increase the water table leading to the production of large quantities of low grade grass (which have less value for cows and may be used for energy production) All these trends will probably lead to the need for an alternative output for of grass. The (partial) utilisation as a raw material for energy and chemistry through bio-refinery concepts is likely [de Jong, 2005; Rabbinge, 2005]. Globally, the Dutch grass production is now 12 Mton DM. When 30% could be extracted through bio-refinery and used for non-food applications in 2030, this would amount to be 3 Mton DM (50 PJ).

So we can assume that several forms of energy crop cultivation could contribute between 0 and 150 PJ in 2030.

Import of biomass will have to cover the largest part of the Dutch requirements in 2030. Potential studies show that the gross potential is sufficient [Lysen, 2000]. World-wide, the net available biomass is estimated to be 200 to 700 EJ per year. The Netherlands are already active on this developing biomass world market (see the import of pellets, cacao shells, etc.).

The challenges seem to lie mostly in the sustainable supply of this biomass. As the recent discussion about palm oil import for electricity production illustrates. Solutions are being sought for in certification and the demand for sustainability requirements to get subsidies on sustainable electricity production. This will also have to be applicable to transportation fuels and chemicals. Various initiatives exist to realise this in the coming years. See for instance the “Fair Bio-trade Initiative”[18] which explores potentials, quantifies performance of supply and lays down plans for certification.

So the import of biomass is not so much determined by the potential biomass availability, as by the possibilities for sustainable supply and the associated price.

[18] http://www.fairbiotrade.org/otherreportspublications/fairbiotradeproject20012004/

7. Conclusions

The Platform Biobased Raw Materials has expressed the ambition to substitute 30% of the fossil energy-carriers by biomass in the Netherlands by 2030. This ambition has been based on a total consumption of primary energy-carriers of 3000 PJ. The contributions of biomass for different applications have been set at 60% in transportation, 25% in electricity production, 25% in raw materials for chemicals, materials and products and 17% in heat production.

This study reviews the Dutch energy balance, with the role of different energy carriers, based on figures for the year 2000 and estimations for the year 2030. The study also shows an overview of the Dutch import, export and production of biomass in 2000 and an estimation of the developments in these fields up to 2030. Moreover, the study analyses the possible role of biomass in 2030.

The following conclusions can be drawn form the analysis of the energy consumption and the possible role of biomass:

- A total consumption of primary energy of 3000 PJ in 2030 is less than can be expected on the basis of current developments. Extra efforts will be needed to reach that level.
- An important restriction of the possibilities to use biomass is the inertia of the infrastructure. The infrastructure cannot be completely written off between now and 2030 and is currently totally tuned to fossil fuels.
- A 60% share of biomass in transportation is very ambitious, considering the policy to minimize energy consumption by transportation. A 40% share puts the necessary effort more in tune with those for other applications.
- A 25% share of biomass in the production of electricity is only possible at complete replacement of a number of base-load power plants based on coal or natural gas by biomass plants. Through co-firing the share is limited to approximately 10%. This share can be larger if the role of wind energy will be much smaller than has been envisioned thus far.
- A 25%, or even somewhat higher, share of biomass in raw materials for chemicals, materials and products is possible, but still needs much development, more than with other applications.
- A 17% share of biomass in heat requires the development of technology and the construction of installations for large scale production of “SNG” (synthetic natural gas). In that case a larger contribution than 17% would be possible.
- For some sectors the technology is readily available, or has been developed, that with increasing development this will be the case amply before 2030. Especially in the field of raw materials for chemicals, materials and products much research and development is needed.
- In the chemical industry several options exist to replace raw materials from fossil energy carriers. Bio-synthesis gas could replace synthesis gas ($CO + H_2$) from natural gas or could be used as raw material for the Fischer-Tropsch process. Bio-ethanol could be used as raw material for ethylene production. Through bio-refinery, it is possible to separate components from biomass from which functionalised chemicals could be produced. The last two options could lead, next to savings in raw materials, to extra savings because of a lower need for process energy. ECN estimates these extra savings to be maximally 20 PJ, WUR estimates 40 PJ to 80 PJ.
- Based on the division given by the Platform, the share of biomass in the Dutch energy balance would amount to 28.4%. If also the savings in process energy in refineries and industry are included, the total would amount to 30%.

- According to the present analysis the share of biomass in the Dutch energy balance would be restricted to 21.4%. Including savings on process energy this will be 23%. This lower result is due to a diminished share in transportation fuels from 60% to 40% and to a share of only 10% instead of 25% in electricity.
- Extra input of biomass for heat, in the form of process energy or SNG, is a relatively simple way to bring the share of biomass in the Dutch energy balance closer to 30%.
- A biomass share of 23% requires over 900PJ of biomass, which is equal to about 60 million tons dry matter. For a share of 30%, about 1200 PJ of biomass are required, which is equal to about 80 million tons dry matter.

The analysis of the biomass supply leads to the following conclusions:

- The gross consumption of biomass (all short-cyclic organic streams) in the Netherlands, calculated from import – export + domestic primary production, was equal to 32.8 – 21.5 + 31.0 = 42.3 Mtons in 2000. Expressed in energy therms this amounts to 620 – 405 + 527 = 742 PJ. Which equals to 24% of the Dutch consumption of primary energy. Only a part of these organic streams will be actually available for energy and raw materials for chemicals, materials and products.
- In 2030 some 6 million tons dry matter of primary by-products will become available in The Netherlands, which is equal to about 100 PJ.
- In 2030 some 12 million tons of dry matter from secondary and tertiary by-products will become available In the Netherlands, which is equal to 200 PJ.
- In order to realise these contributions, specific attention is needed for the establishment of an efficient infrastructure. For primary by-products this is even more relevant than for secondary and tertiary by-products. It is of great importance to find a synergy with efficient recycling of nutrients and landscape conservation.
- Through specific crop production for energy and raw materials up to 9 million tons dry matter could become available, which is equal to about 150 PJ. This contribution is very uncertain and strongly depends on government policies. Apart from specific energy cultivation the production of multi-functional crops, from which by means of bio-refinery food components and various non-food raw materials are being produced, offers options to open up this potential.
- The maximum domestic availability of biomass is 450 PJ. Extra import of at least 450 PJ in biomass are required to realise a biomass share of 23%. This amounts to 30 million tons.

Finally, the authors would like to recommend, that the statistical bureau (CBS) should monitor organic (biomass) streams in the Netherlands, as they do for fossil energy-carriers and nutrients N, P and K. In this way the efficiency of biomass consumption and opportunities to utilise biomass could be monitored.

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Systeeminnovatierapport, Praktijkonderzoek Plant & Omgeving, Sector Akkerbouw, Groene Ruimte en Vollegrondsgroenten, PPO nr 530133, 2004.

Attachment A: Caloric value energy carriers

Table A1 shows the average lower heating value[19] for a number of energy carriers. Mainly for coal, lignite and biomass, a large variation of values is possible, by variations in composition and in the content of ashes and moisture. In this report the lower heating value for biomass is based on the amount of dry matter. In the case of wet matter this is not completely correct; the heat, which is released during the heating of the dry matter, is partly needed to evaporate the attached water.

Figure A1 shows that for biomass with less than 50% moisture, the amount of dry material is a good measure for the lower heating value. At a higher percentage of moisture some caution is required. The lower heating value per kg dry matter is diminishing quickly, because an increasing larger share of the heating value is required to evaporate water. If the percentage of moisture can be lowered down to less than 50% through mechanical drainage (pressing or screening), the amount of dry matter still shows a reasonable estimation of the lower heating value. Also with evaporation by air or evaporation with unused residual heat, the lower heating value on the basis of dry matter gives a good image.

Some wet biomass can be used for fermentation. Herewith about half of the organic material is being transformed into a mixture of methane and carbon dioxide. For that part the output is almost equal to the lower heating value of dry material. In such a way material with less than 12% dry matter, which according to figure A1 has no combustion value, can supply an output of 9 MJ/kg dry material. If the residue can be dehydrated mechanically, also that part can supply a contribution. The lower heating value of the total amount of dry matter shows a reasonable image.

Table A1 *Conversion factors for energy carriers.*

	Combustion value	1 PJ =	1000 kton =
Petroleum	42.7 MJ/kg	23.4 kton	42.7 PJ
Gasoline	44.0 MJ/kg	22.7 kton	44.0 PJ
Diesel	42.7 MJ/kg	23.4 kton	42.7 PJ
LPG	45.2 MJ/kg	22.1 kton	45.2 PJ
Natural gas	31.7 MJ/m_n^3	31.5 million m_n^3	1 billion m_n^3 = 31.7 PJ
Coal	26.6 MJ/kg	37.6 kton	26.6 PJ
Lignite	20.0 MJ/kg	50.0 kton	20.0 PJ
Cokes	28.7 MJ/kg	34.8 kton	28.7 PJ
Biomass solid	15.1 MJ/kg	66.2 kton	15.1 PJ

[19] Combustion value or lower heating value (LHV) is the heat which is released at combustion, when attached and during combustion formed water remain in vapour phase. The higher heating value (HHV) is the sum of the combustion value and the heat that is released during the condensation of the water.

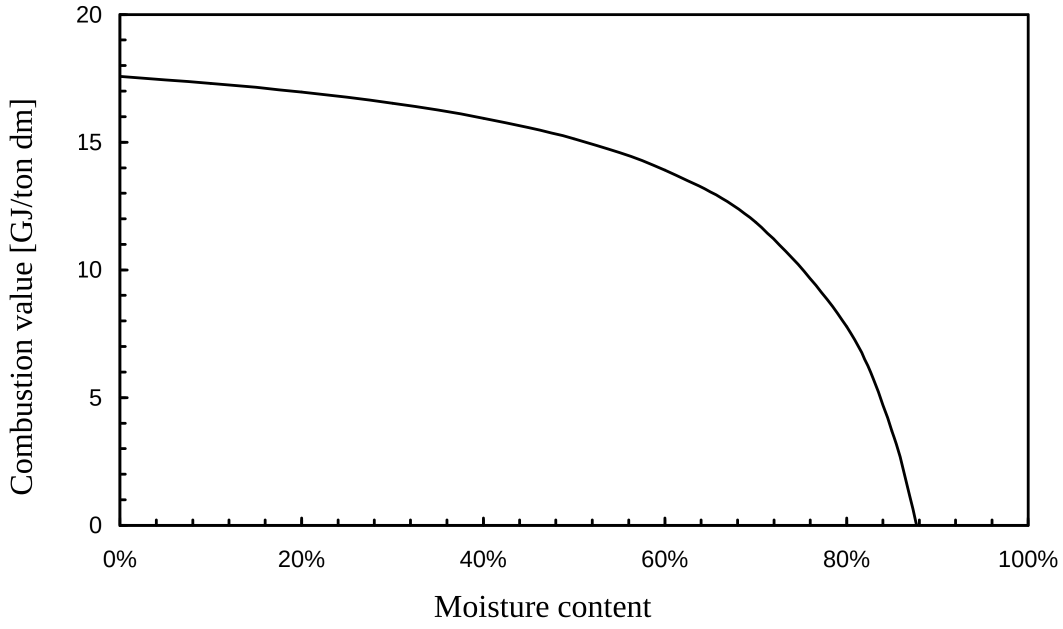


Figure A1 *Net heat of combustion in GJ per ton dry matter as a function of the moisture content for biomass with 5% ash.*

Attachment B: Potential biomass substitution in the chemical industry

Introduction

In 2000, the Netherlands used (according to data from the CBS) 3065 PJ of primary energy (see par. 2.6). Of this 1075 PJ was used by the industrial sector. More specifically, 685 PJ of energy was used in the chemical industry. This is divided over the various sectors as follows:

- fertiliser industry 112 PJ
- organic base chemistry 447 PJ
- inorganic and other base chemistry 52 PJ
- chemical end-products 22 PJ
- plastics, rubber and other industries 52 PJ

Table 9 shows that the chemical industry uses ca. 260 PJ of petroleum based raw materials. The refineries also use energy to produce those raw materials. The total energy consumption of the refineries was 180 PJ. Based on the schematic representation in figure B1, it can be seen that ca.15% (27 PJ) is allocated to products which are used as raw material in the chemical industry. However, out of the total production of 12 Mton (about 500 PJ) of raw materials, only 72% is being used in the Dutch chemical industry.

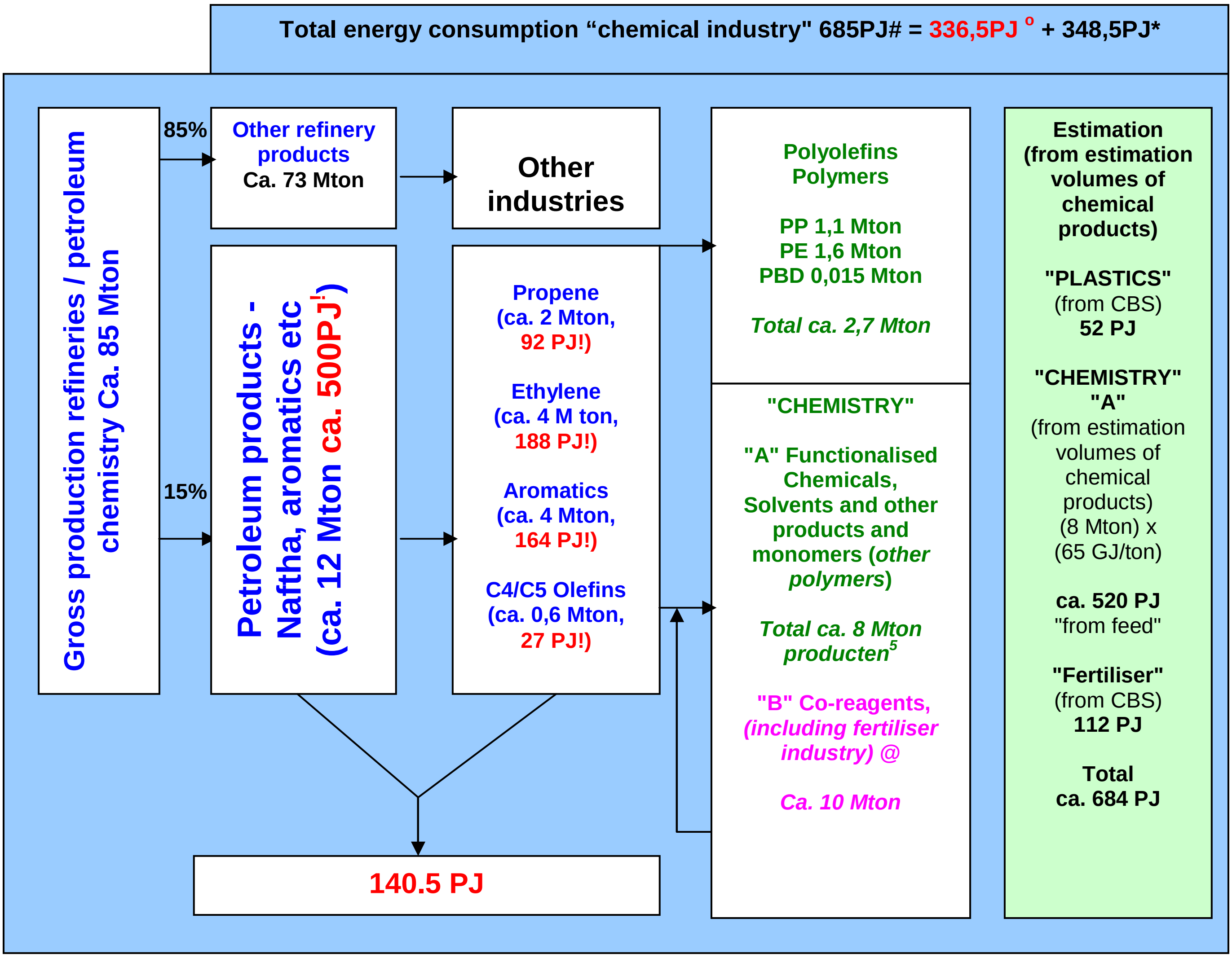
The total energy consumption in the chemical industry consists of three parts:

1. Fossil energy carriers, which have been used as raw materials.
2. Energy, in the form of heat, steam and electricity, which is required to perform chemical processes.
3. Energy for the composition of products and for heating, cooling and lighting of buildings and grounds.

If we leave out the fertiliser industry, then the first term in the chemical industry is responsible for ca. 50% of the energy consumption (see table 8 and 9). With a 20% growth in production and less growth of the total energy consumption, in 2030 that share will grow to 55%-60%. The second and third term are not specifically mentioned in the statistics and therefore are difficult to separate. Here we assume that process energy is a maximum 60% of the non-energetic consumption, and thus ca. 30% of the total[20]. In 2030 the share of process energy will decrease to about 50%. The third term in this approach is responsible for 20% of the total in 2000 and 15% in 2030.

From the above it follows that with replacement of raw materials from fossil resources by raw materials from biomass, for each PJ of raw material in 2030, an average of 0.5 PJ of process energy can be saved. In reality, that extra saving will be lower, since processes basised on biomass also require some energy. For the first two routes, which have been discussed in chapter 5.3, the saving on process energy can probably be neglected. The last two routes offer more possibilities to save process energy. Two concepts will be discussed with the use of examples.

[20] In this approach the organic base chemistry would have consumed, by a non energetic consumption of 267 PJ, 160 PJ of process energy in 2000. The total energetic consumption in this sector was 180 PJ, which means that 20 PJ, or 4.5% of the energy consumption, was not process related.



Processes which take place in the port of Rotterdam.

Processes of which a large part take place in the port of Rotterdam and of which the other take place somewhere else in the Netherlands.

Processen which take place in the port of Rotterdam and on other places in the Netherlands. Exact contributions of individual processes/producers are unclear or unknown..

PJ!:	*Caloric value.*
PJ°:	*Contribution of the consumption of petroleum raw materials and products..*
PJ:*	*Contribution of energy sources to the total energy consumption.*
#:	*Fertiliser industry (112PJ*), organic base chemistry (318PJ°+129PJ*=447PJ), anorganic and other base chemistry (15PJ°+37PJ*=52PJ), chemical endproducts (3PJ°+19PJ*=22PJ), plastics, rubber and other industry (0,5PJ°+51,5PJ*=52PJ)*
@:	*It is unclear from this data which share of the production is used for e.g. other processes and which share is being exported.*

Figure B1 *Petrochemical industrial production chain.*

Concept A: non-functionalised raw materials

In chapter 5.3 it has already been stated that syn gas (CO and H_2) can be produced from biomass , from which hydrocarbon raw materials, such as methane, for chemical products can be made. These raw materials make use of existing technologies and infrastructure. Here a different concept is discussed, which focuses at the core of the chemical industry, at the start of the total production chain.

Example: ethylene production from bio-ethanol
A somewhat different approach for the synthesis of non-functionalised raw materials can for instance be by the use of bio-ethanol, which is produced by the fermentation of carbohydrates (biomass), as a potential alternative raw material for (partial) ethylene production and all products which are being produced or derived from ethylene.

In order to produce 1 Mton ethylene, on a stoichiometric basis about 1,7 Mton of bio-ethanol is required. The production of ethylene requires, via the conventional method, besides 47 PJ of raw material, 12 PJ of process energy per Mton. Through the “new” route, 49 PJ of bio-ethanol is required (47 PJ as raw material and 2 PJ which is released at the reaction as heat). At an average yield of 60% of biomass to ethanol, 81 PJ of biomass is required [Tampier, 2004]. In this yield of 60%, the process energy for the production of bio-ethanol has been included and a correction has been made for extra electricity which can be produced from residue compounds.

The current production in The Netherlands of bio-ethanol lies well below the amounts mentioned, although large quantities of bio-ethanol are (theoretically) available (e.g. in Brazil). This concept allows the usage of a large part of the existing infrastructure, but also requires energy in order to produce more (functionalised) products.

In The Netherlands in 2000, ca. 4 Mton of ethylene was produced. As mentioned before, a part of this was not consumed in The Netherlands. If we do make the assumption of 25% replacement of the total production of ethylene, this amounts to 1 Mton. For this an input of 81 PJ of biomass is required. This leads to a saving of 47 PJ on fossil raw material plus 12 PJ on process energy. Therefore, in this case the saving on process energy is equal to 25% of the saving on non-energetic consumption.

Concept B: production of functionalised chemicals

Here we are concerned with the most known chemicals, of which at least a proportion can be produced more efficiently from biomass than from oil. This concept means that alternative (“bio-based”) raw materials for functionalised chemical raw materials are used. In this concept the requirements for the means of production and the consumption of reagents will be reduced.

With the conversion of crude oil products, the primary products (propene, ethylene etc.) are used as raw materials. Conversion of these products into other chemicals or polymeric materials takes place with the aid of reagents, like ammonia or chlorine, in order to induce groups such as –NH2 and –COOH into the more simple structures of the primary products.

On the contrary, biomass (components) often already contain this type of groups. Therefore, it is potentially attractive to use these. In this way the use and preparation co-reagents, process steps and process energy may be avoided or reduced. Suitable biomass components are for example (non-food) proteins[21] and amino acids, but also organic acids, which are obtained by the fermentation of carbohydrates.

For instance, the energy consumption to build nitrogen into chemicals (in a specific process step), is in general within a range of ca. 3-10 GJ/ton product and synthesis ("from the feed") requires about 50-70 GJ/ton product. An average is about 65 GJ/ton, of which ca. 40 GJ/ton is fossil resources. It remains difficult to predict the total volume of nitrogen containing chemicals produced annually, but on the basis of figures an estimation of production in The Netherlands is ca. 0.5-1 million tonnes. This amounts to about 1.5-10 PJ only to incorporate nitrogen and about 32.5-65 PJ for synthesis "from feed" per year. So if the incorporation of nitrogen containing groups could take place in a crop based system, in the form of appropriate protein/amino acids precursor(s), this would correspond to a potentially large energy saving. A comparable analysis can be made for the functionalised chemicals.

Example: production of ethylene diamine from serine
By prudent choice of biomass precursors it may also be possible to avoid (or to reduce) the consumption of primary petrochemical raw materials, such as ethylene and reagents such as chlorine in the process. An example is the synthesis of 1,2-ethanediamine, see figure B2. Here the amino acid serine has been used to produce ethanolamine (which is then converted to 1,2-ethanediamine. Figure B3 shows an example of the energy that is required for the various steps in both processes.

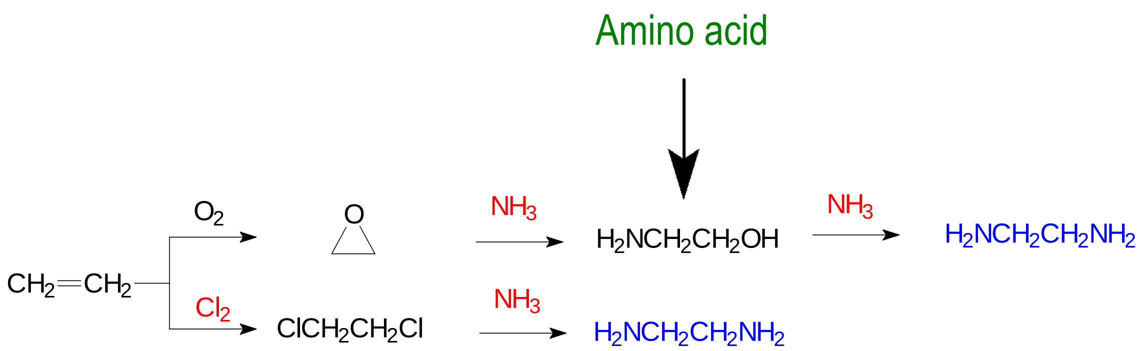


Figure B2 *The synthesis of 1,2-ethanediamine from ethylene oxide or ethylene dichloride.*

The current process consumes (47 + X + Y) GJ per ton. The values of X and Y are unknown, but probably lie between 2 and 10 GJ/ton. For the further analysis we assume 5 GJ/ton for both X and Y. For an estimation of the possible saving on process energy, it is required to divide the various items over non-energetic consumption and process energy. ECN and WUR differ in opinion on this. Table B1 compares both opinions.

[21] To obtain these proteins and amino acids one should also think of other, non-conventional sources, such as grass and other non-food crops. Furthermore, research should be performed in the production in non-food proteins and amino acids. This can be done by GMO of some non-food crops or through other microbiological techniques, such as the production of non-ribosomal proteins.

Table B1 *Distribution of energy consumption for production of 1,2-ethanediamine for the non-energetic consumption and process energy, according to ECN and WUR. All values are expressed in GJ/ton ethane diamine.*

	Non-energetic (ECN)	Process energy (ECN)	Non-energetic (WUR)	Process energy (WUR)
Ethylene	22.0	5.5	22.0	5.5
Step 1		2.5		2.5
NH_3 production	5.5	3.0		8.5
NH_3 addition		5.0		5.0
NH_3 production	5.5	3.0		8.5
NH_3 addition		5.0		5.0
Total	33.0	24.0	22.0	35.0

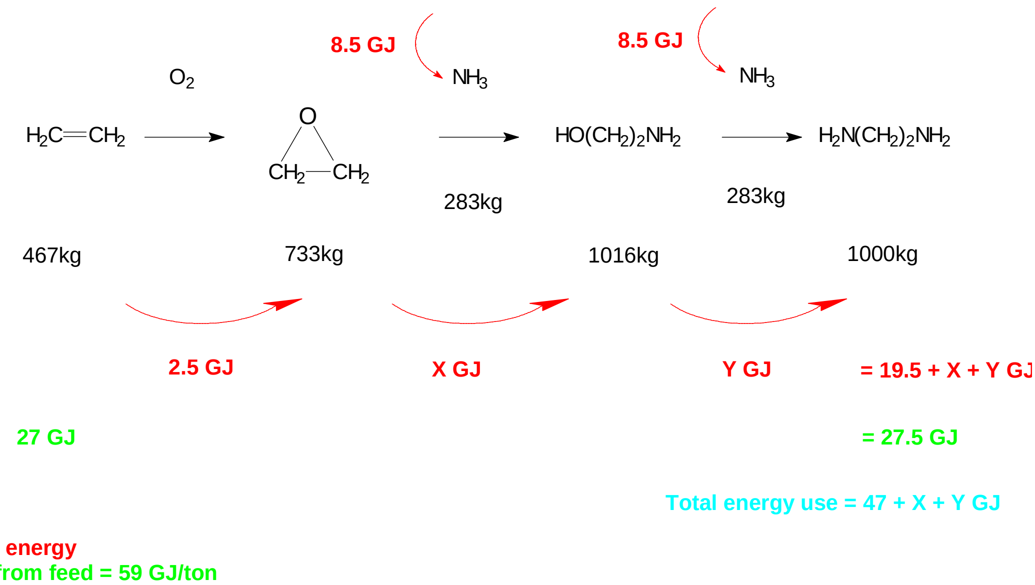


Figure B3 *Energy contributions in the current synthesis of 1,2-ethanediamine*[22].

By using serine to produce ethanolamine, different posts can be avoided. On a stoichiometric basis 1749 kg serine is required for the production of 1016 kg ethanolamine. The caloric value of that quantity of serine is approximately 26 GJ (on the basis of approx. 15 GJ/ton). Moreover, only half as much ammonia is required, after conversion of serine to ethanolamine ammonia is used in the last step to 1,2-ethanediamine. Table B2 shows the energy demand in various steps of the new process. The required energy for the production and isolation of serine and for the

[22] It is reasonable to assume that the value of X and Y lies between 2 and 10 GJ. The 59 GJ/ton energy from feed for ethylene contains 12 GJ/ton process energy. This means that for the 467 kg the indicated caloric value of 27.5 GJ consist of 22 GJ of raw materials and 5.5 GJ of process energy.

conversion to ethanolamine is unknown. It is assumed, that that energy can be won from the part of the biomass which remains after separation from serine.

Table B2 *Distribution of energy consumption for the new production process of ethane diamine for the non-energetic consumption and process energy, according to ECN and WUR. All values are expressed in GJ/ton ethane diamine.*

	Non-energetic (ECN)	Process energy (ECN)	Non-energetic (WUR)	Process energy (WUR)
Serine	26.0	?	26.0	?
Conversion serine		?		?
NH_3 production	5.5	3.0		8.5
NH_3 addition		5.0		5.0
Total	31.5	>8.0	26.0	>13.5

From the figures in tables B1 and B2 the savings can be calculated according to the opinions of ECN and WUR. Both assume that the production of NH_3 and the final process step also require energy from fossil sources in the new route. Totally the new process costs 39.5 GJ/ton of raw material and process energy, plus the energy for the production, isolation and conversion of serine. If those unknown steps require less energy, the total energy demand per tonne 1,2-ethanediamine can emerge lower than the 57 GJ/ton of the classic process. The total saving is equal, according to ECN and WUR, but the division over non-energetic consumption and process energy shows a large difference.

According to ECN, the input of 26 GJ serine per ton 1,2-ethanediamine saves 27.5 GJ of non-energetic consumption of fossil energy carriers and a maximum of 16 GJ of process energy. This means that the saving on process energy is 58% of the saving on non-energetic consumption.

According to WUR, the input of 26 GJ serine per ton 1,2-ethanediamine saves 22 GJ on non-energetic consumption of fossil energy carriers and a maximum of 21.5 GJ of process energy. This means that the saving on process energy is almost equal to the saving on non-energetic consumption.

Other examples of the usage of amino acids for the formation of other industrially interesting diamines, such as 1,4-butanediamine, as well as other N-containing chemicals, lsuch as ε-caprolactam and ureum, are also be possible. A similar approach to treat chemicals with O-containing groups, like e.g. 1,4-butanediol, is also predicted.

Conclusion

The above examples show, that the production of raw materials and functionalised compounds through new process routes, offer the possibility to save not only fossil raw materials (non-energetic consumption), but also process energy. On average the consumption on process energy is approximately 50% of the non-energetic consumption. The example of concept A shows a saving on process energy of 25% of the non-energetic consumption. Concept B allows a larger saving, in the given example 58% according to ECN and 98% according to WUR. Herewith it has been assumed that all process energy for the new processes can be produced from biomass.

Replacement of 25% of the non-energetic consumption of petroleum products in 2030 amounts to 79 PJ. If new process routes accounts for half of this , this amounts to 40 PJ. The extra saving on process energy amounts then to maximum 20 PJ, according to ECN. If these routes provide the total saving on non-energetic consumption of oil products, or are applied in processes with a higher than average demand on process energy, or if concept B can also be implemented for a part of the ammonia production (or of other co-reagents), the extra saving can amount to 40 PJ up to 80 PJ, according to WUR.

A new route on the basis of biomass can require less energy in total than the traditional production process. For only the raw material the required amount of biomass, on energy basis, can vary from approximately 100% up to 175% of the required fossil raw material. On mass basis this would amount to 2 - 5 tonnes biomass per tonne product. Thus only the fraction that is being used in the process has been included. If only a specific component can be used in the process, the total required amount of biomass can increase considerably. In principle the rest can be used for energy.

Further investigation is required to identify the most appropriate products and technologies for replacement and identification of the most suitable biomass raw materials. As well as this, research and development are required to discover (new and efficient) production in areas such as bio-refinery, (bio)technology, (new) separations technologies of biomass components. Changes in, or modification of, the infrastructure are also needed in this approach.