

Analysis of the Economic Impact of Large-Scale Deployment of Biomass Resources for Energy and Materials in the Netherlands

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1 INTRODUCTION

The transition to a more sustainable energy system leading to a strongly reduced dependency on fossil fuels and large Greenhouse Gas emission reductions is an unsurpassed challenge. In the Netherlands, this challenge is addressed by the 'Energy Transition', in which stakeholder platforms have formulated strategies and pathways for different key themes to realize the required changes. One of the platforms deals with 'Green Resources' (PGG, Platform Groene Grondstoffen), tackling the large scale and sustainable use of biomass for energy and material applications. As a longer term vision, the platform has targeted 30% replacement of fossil fuels by biomass resources (assuming a stabilized energy use), divided over: 17% of the heat demand, 25% of electricity demand, 25% of feedstock use for chemicals and 60% of transport fuels.

The main objective of this paper is defined as to provide quantitative insight in the macro-economic impacts of the large scale deployment of biomass based resources and related infrastructure and production capacity for the energy and material supply.

More specific, the sub-objectives are:

- Quantitative descriptions of scenarios for biomass use in the Netherlands in 2010 to 2030 under different premises of technological development and biomass trade. These descriptions include biomass resource availability, production and costs, main conversion options for energy and materials and are relative to a baseline scenario.
- A description of the impact of biomass use in the scenarios with regard to biomass use for energy and materials, fossil primary energy saving, total costs for biobased production and net costs and GHG emission reduction for fossil based substitution by biomass. These impacts are calculated using bottom-up information on technologies for biomass production and use taking into account future technological learning.
- A quantification of the macro-economic impact of large scale deployment of biomass in the Netherlands. GDP, employment, trade balances with an as detailed as possible (with current methods and data) breakdown of macro-economic impacts with respect to GDP impact, sectoral effects (e.g. agriculture, chemical industry, energy sector, etc.), employment effects and trade balance of biobased scenarios.

The focus on this study is on biobased production of electricity, liquid fuels for road transport and biobased chemicals. Biobased production of heat is only taken into account for industrial co-firing heat plants (CHP) in the energy and greenhouse gas balances. Stand alone

production of heat from biomass in industries and house holdings is not taken into account as the applied CGE model is not capable of modelling this commodity directly.

A limited selection of biomass conversion technologies is represented in this paper. For chemicals, the biobased production is aggregated and represented by three conversion options to represent for different chemical products. Direct production of functionalized chemicals from bio-refineries are not included here as of limitations to represent these multiple output options in the top-down CGE model and because of limited data available on the (economic) performance of these technologies.

The bottom-up scenarios are designed on a set of pre-defined technology portfolios for biomass conversion. No optimization modelling tools are used which implies that the outcome of this paper does not support information on economic, energetic or environmental optimal combinations of technologies or feedstocks. It should be noted that a full optimization analysis would also require a comparison of competing energy and GHG mitigation technologies such as wind or photovoltaic (PV), but also electric or fuel cell vehicles. This is beyond the scope of this study.¹

2 METHODOLOGICAL APPROACH

In order to quantify the impact of biomass for bioenergy and biobased materials in the Netherlands, this paper combines a bottom-up model with a top-down model. Detailed bottom-up technology projections of biomass conversion options in combination with an advanced multi-sector and multi-region macroeconomic computable general equilibrium (CGE) model, support understanding of both the impact on the macro-economy as the required technological development, fossil energy avoided and greenhouse gas emissions avoided.

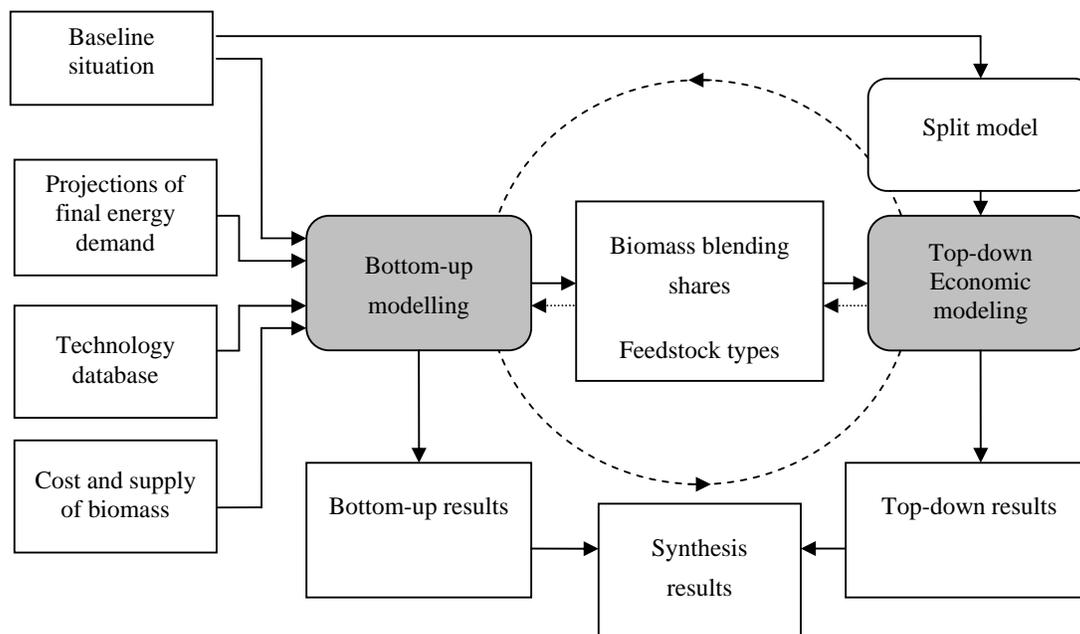
To address for change in biobased production sectors, the CGE model LEITAP is extended for bioenergy in the sectors electricity generation, petrol and bulk and specialty chemicals. The bottom-up model comprises scenarios of a biobased economy for the electricity, transport fuels and chemicals sectors in the Netherlands projected to 2030.² Figure 1 summarizes the approach and interaction between the bottom-up model and the top-down model.³ This paper presents the combined results where projections of final energy demand and biomass shares of the LEITAP model are used as input parameters for the bottom-up model.

¹ The results published here are based on a study commissioned by the Dutch Ministry of Agriculture, Nature protection and Food Quality (LNV). Further details of the bottom-up and top-down modelling results are documented in the individual reports which are available under http://www.lei.wur.nl/NL/nieuwsagenda/nieuws/Gevolgen_toename_biomassagebruik_op_de_economie

² For a description of the LEITAP model see, Banse et al. 2009.

³ A detailed description of the individual modelling approaches can be found under http://www.lei.wur.nl/NL/nieuwsagenda/nieuws/Gevolgen_toename_biomassagebruik_op_de_economie

Figure 1: Model system for macro-economic modelling using bottom-up input data for bioenergy and biobased chemicals



Remark: Figure is partly based on Schäfer et al. (2005).

The model interaction is essentially in one direction, i.e. the results of the bottom-up model are translated into biobased blending shares for the electricity, transport fuels and chemical sectors and applied to the LEITAP model as mandatory biobased blending shares in these sectors. Further model adjustments were based on comparing the final results of the bottom-up model and the top-down model, e.g. technology substitution. Finally, projections of final energy demand of the LEITAP model are used as input for the bottom-up model in order to generate the results of the synthesis report. This paper summarizes both the bottom-up results based on the WLO-projections (Janssen, Okker et al. 2006) and the results based on the LEITAP projections as presented in chapter 3.

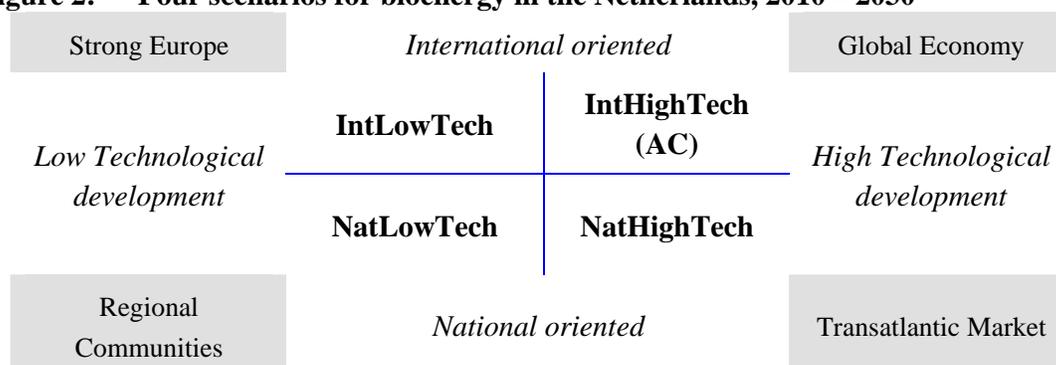
A bilateral and iterative exchange between the models, represented by the dotted lines in Figure 1, would improve consistency between the bottom-up and top-down models. These calibration steps are however not conducted due to time constraints. The discussion section deals with the differences between the outcomes of the bottom-up and top-down model and discusses possible further steps to improve the linkage between the models.

2.1 Bottom-up scenarios

Future projections of biomass for bioenergy and biobased materials to 2030 for the Netherlands are outlined in four different scenarios. Emphasis in these scenarios is on technological development of (biomass) conversion technologies and international cooperation including international trade of biomass (Figure 2). The two national oriented

scenarios include limited sources of biomass available from EU member states. The two international oriented scenarios include global biomass sources available for the Netherlands like palm oil and sugar cane. Other than international cooperation, the two national and international scenarios include one scenario with low technological development and one with high technological development. For the low-tech scenarios (NatLowTech and IntLowTech) we assume biomass conversion technologies to be used until 2030 that are already commercially available while for the high-tech scenario (NatHighTech and IntHighTech), we assume that advanced (2nd generation) technologies substitute current technologies from 2010 onwards. The IntHighTech scenario includes one projection with biobased synthesis gas in the chemical industry and one scenario with both biobased synthesis gas and substitution of bulk and specialty petrochemicals (IntHighTech AC)⁴. Projections of socio-economic change and final energy demands were derived from the WLO-scenarios (Welfare and Environment) (Janssen, Okker et al. 2006).

Figure 2: Four scenarios for bioenergy in the Netherlands, 2010 – 2030



Remark: The WLO-scenarios are displayed in the gray shaded areas.

A selection of biomass conversion technologies is projected to be deployed in the scenarios in order to substitute fossil energy and fossil based chemicals. The biomass conversion technologies in the scenarios differ on biomass feedstock types (availability of non-EU biomass in the international scenarios), technological development and availability. In all scenarios, wet organic waste and solid organic waste are assumed to be used for electricity generation by anaerobic digestion and incineration respectively.

The LowTech scenarios include technologies that are already used on commercial scale. For electricity generation, biomass are assumed to be co-fired in pulverized coal (PC) plants, bio-gasoline and biodiesel are assumed to be produced from fermentation of sugar and starch crops and transesterification of oil and fat residues and vegetable oils respectively. In the NatLowTech scenario, biodiesel and bio-gasoline are assumed to be made from EU rapeseed and EU starch respectively. In the IntLowTech scenario, imported sugar cane derived ethanol

⁴ The IntHighTech AC scenario is aimed to be more consistent with the goal of the PGG to substitute 25% of fossil based raw materials in the chemical industry with biomass. This scenario includes both bulk chemicals as well as specialty chemicals. Blending targets are derived from Rabou et al. (2006). It should be noted however that, different from Rabou et al., this study does not include biobased options with direct extraction and production of functionalized chemicals (bio-refinery concept).

is assumed to be used for transport fuels and for ethylene production via ethanol dehydration. Imported palm oil and jatropha oil are the major feedstock for biodiesel production in this scenario.

In the HighTech scenarios, advanced conversion options are assumed to be commercially available from 2010 onwards. Included are ethanol production from lignocellulosic biomass and synthesis gas production from biomass gasification. Synthesis gas is used for electricity generation (co-combustion in gas turbine combined cycle plants), biodiesel production via Fischer-Tropsch (FT) synthesis and for substitution of fossil based synthesis gas in the chemical industry. The latter option is only assumed to be available in the IntHighTech scenario. In the NatHighTech scenario, biobased caprolactam, a precursor for the production of nylon-6 is assumed to substitute fossil based caprolactam from 2020 onwards. Please note that, although 100% of caprolactam was assumed to be replaced by biomass, the total share of biobased production in the chemical industry will remain limited as of the production share of caprolactam in the chemical industry. In reality, a variety of chemicals will be substituted by biomass instead of substitution of one single product completely as assumed in the scenarios. Different from the IntHighTech scenario, the IntHighTech AC scenario includes all three chemical representative routes in order to substitute 25% of fossil raw materials in the chemical industry.

The bottom-up model is a simple excel spreadsheet model with exogenous inputs of final energy demand from existing scenarios, a detailed technology dataset for bioenergy and biobased materials and scenario dependent assumption on the use of biomass by these different technologies. Scenarios include cost estimates and supply potentials for fossil and biobased energy carriers.

2.1.1 Input data for bottom-up scenarios

The *baseline situation* includes a detailed assessment of current biomass use for bioenergy. It was not feasible to quantify the current use of biomass for biobased chemicals as these statistics are not reported. The baseline situation also includes information on the structure of the electricity sector (vintage). These data is used to model the replacement rate of retired capacities in the electricity generation sector.

Projections of *final energy demand* for electricity, transport fuels and chemicals are used to estimate the demand for primary fossil energy carriers and the substitution potential of biomass. The bottom-up projections include final energy demand projections from the WLO-scenarios (Janssen, Okker et al. 2006). The final energy demands in the LEITAP projections are modelled endogenously.

The *technology database* includes the technology characterization and aggregation per sector and commodity. A selection of representative technologies was made for the current situation and for the various scenarios until 2030. This implies that also technologies were considered that are not yet commercialized. Data on cost and performance of these technologies were collected from bottom-up engineering studies. Future projections of cost were made using economies of scale, technological learning and innovation factors. The bottom-up model

includes a detailed database of these technologies, but in order to assess the results for the data calibration process with the production functions in the top-down model, the technologies in this paper are aggregated to single commodity options.

For the bottom-up estimations of *cost and supply of biomass* in the scenarios, existing studies were used that estimate the cost and supply relations for biomass energy crops produced in the EU27+ region (Wit, Faaij et al. 2007) and the global supply potential (Hoogwijk, Faaij et al. 2005). Furthermore, domestic supply of primary, secondary and tertiary residues are taken into account. The projected supply of residues are based on PGG publications (Rabou, Deurwaarder et al. 2006; Kip, Lammers et al. 2007) and (Koppejan and Boer-Meulman 2005). For evaluation, the results are compared with the cost and supply of biomass that result from the top-down model outcomes.

2.1.2 Bottom-up biomass blending shares and model interaction

The amount of fossil energy that can be substituted by biomass depends mainly on cost and supply of biomass and the techno-economic performance of biomass conversion technologies. The blending targets, i.e. the fossil energy fractions of fossil resources that can be replaced by biomass, are different per scenario and are based on policy objectives and the performance on technologies in the different scenarios.

Table 1: Blending shares of biomass per scenario and sector (energy basis)

	NatLowTech	IntLowTech	NatHighTech	IntHighTech	IntHighTech AC					
<u>Electricity</u> (% energy output)										
2010	4%	4%	5%	5%	5%					
2020	6%	5%	9%	24%	20%					
2030	7%	6%	9%	29%	21%					
<u>Transport fuels</u> (% energy output)										
2010	5.75%	5.75%	5.75%	5.75%	5.75%					
2020	10%	10%	10%	25%	25%					
2030	10%	20%	20%	60%	60%					
<u>Biobased chemicals</u> (% energy for raw materials in the chemical industry)										
	<u>Bulk^a</u>	<u>Specialty^a</u>	<u>Bulk^b</u>	<u>Specialty</u>	<u>Bulk</u>	<u>Specialty^c</u>	<u>Bulk^d</u>	<u>Specialty^d</u>	<u>Bulk^e</u>	<u>Specialty^f</u>
2010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2020	N/A	N/A	4%	N/A	N/A	4%	9%	9%	13%	13%
2030	N/A	N/A	7%	N/A	N/A	7%	19%	19%	25%	25%

a) No biobased chemicals in the NatLowTech scenario

b) Biobased production of bulk chemicals, based on 10% and 20% replacement of fossil based ethylene by biobased ethylene in 2020 and 2030 respectively.

c) Biobased production of specialty chemicals, based on 50% and 100% replacement of fossil based caprolactam by biobased caprolactam in 2020 and 2030 respectively.

d) Biobased production of synthesis gas, replaces fossil based synthesis gas used for bulk and specialty chemicals. Note that the division between synthesis gas use for bulk and specialty chemicals is similar to the total use of fossil energy for chemicals (80% and 20%).

e) Bulk chemicals, based on biobased ethylene (25% substitution of petroleum products in 2030) and biobased synthesis gas (30% substitution of natural gas in 2030).

f) Biobased production of specialty chemicals, based on caprolactam (25% substitution of petroleum products in 2030) and synthesis gas (30% substitution of natural gas in 2030).

For electricity generation, the share of biomass was estimated by taking into account the structure of the Dutch electricity sector. In the low-tech scenarios, retired PC plants and new

capacities are met by new PC plants with a higher biomass co-firing share (20%). In the High-Tech scenario, retired PC and natural gas combined cycle (NGCC) plants and new required capacities are met by NGCC plants with co-gasification of biomass. Blending shares of biomass for transport fuels in the IntLowTech and NatHighTech scenario were based on the EU 2003 directive on biofuels. The blending share of biomass in the NatLowTech scenario was assumed to be more conservative as of limited biomass sources and low production efficiencies. The shares in the IntHighTech scenario were based on the PGG targets for biomass in the transport sector including global biomass resources and high production efficiencies. In this paper shares for biomass in the chemical industry were assumed to substitute one fossil based chemical product per scenario. The IntLowTech scenario includes biobased ethylene, the NatHighTech scenario includes biobased caprolactam and the IntHighTech scenario includes biobased synthesis gas. Please note that, although 100% of caprolactam was assumed to be replaced by biomass, the total share of biobased production in the chemical industry will remain limited as of the production share of caprolactam in the chemical industry. In reality, a variety of chemicals will be substituted by biomass instead of substitution of one single product completely as assumed in the scenarios. The IntHighTech AC includes all three chemical representative routes in order to substitute 25% of fossil raw materials in the chemical industry.

2.2 CGE modeling (top-down approach)

The implementation of biobased sectors builds on a modified version of the GTAP multi-sector multi-region CGE model (Hertel, 1997). This multi-region model allows the capture of inter-country effects, since the enhanced biofuel use influences demand and supply, and therefore prices on world markets and hence will affect trade flows, production, and GDP. The multi-sector dimension enables to study the link between energy, transport, and agricultural markets. The model is extended through the introduction of energy substitution into production by allowing energy and capital to be either substitutes or complements (GTAP-E; Burniaux and Truong, 2002). Compared to the standard presentation of production technology, the GTAP-E model aggregates all energy-related inputs for the biobased sectors in the nested structure under the value added side. For a more detailed presentation of the model see Banse et al. (2009).

2.2.1 Implementation of scenarios in the CGE model

In this modeling approach cross-price relations between fossil energy and biomass are the most important endogenous driver. Therefore, the output prices of the biobased industries will be, among other things, a function of fossil energy and biomass prices. The nested input demand structure implies that necessary variables of the demand for biomass are the relative price developments of fossil energy versus the development of agricultural prices. Also important is the initial share of biomass utilization in the biobased sectors.

In addition, prices for outputs of the biobased industries will depend on any subsidies/tax exemptions affecting the price ratio between fossil energy and biomass inputs. In case that the estimated amount of biomass utilisation is smaller than the optimal amount based on cost-minimizing behaviour of the industries, a subsidy is given to the bio-based industries to

achieve the specified biomass shares. This has also been implemented for the modelling of the EU Biofuels Directive which fixes the share of biofuels in transport fuel. It should be mentioned that the payment of subsidies on biomass inputs in the bio-based industries are modelled as so-called budget neutral from a government point of view. To achieve this in our model two policies were implemented: first, the biomass share in transport fuel, the bioenergy share in electricity and the biomass share in the fine chemicals are made exogenous and second, a subsidy on biomass inputs is made endogenous to achieve the specified biofuel share.

In case of low technologies and moderate fossil energy prices, the subsidies in the bio-based sectors are necessary to make the biomass inputs competitive with fossil energy. These policy instruments (input subsidies in the bio-based sectors on bioenergy inputs)⁵ are implemented as 'budget-neutral' subsidies counter-financed by an end user tax on petrol and electricity consumption.

Budget equations are introduced in the model in which end user tax receipts provide the income and the input subsidies the spending. In case of a mandatory blending the budget surpluses are made exogenous and put equal to zero. The end user tax on petrol and electricity are made endogenous to generate the necessary budget to finance the subsidy on inputs necessary to fulfil the mandatory blending. Due to the end user tax consumers pay for the mandatory blending and end user prices of blended petrol and electricity increase. The higher prices are the result of the use of more expensive bioenergy inputs relative to fossil energy inputs in the production of fuel and electricity.

It should, however, be mentioned that the LEITAP model is build upon the assumption that technical changes does not occur in a sudden shift from one technology to another, i.e. even under the HighTech scenario 2nd and 1st generation biomass inputs will be used in the bio-based industries. Substitution between one input (1st generation biomass) and another input (2nd generation biomass) is modelled as a continuous function. This approach differs from most analyses based on linear-programming or technology approaches with thresholds and sudden and drastic shifts in different technology options.

2.2.2 GTAP data used

Version 6 of the GTAP data for simulation experiments was used. Developments in the biofuel sector are extremely fast. Therefore, we updated the GTAP database to include the latest developments. The calibration of the utilisation of biomass in LEITAP is based mainly on sources published in F.O. Licht's World Ethanol and Biofuel Reports as well as the F.O. Licht Interactive Database for Ethanol and Biofuels (F.O. Licht 2007). Current uses of biomass for liquid biofuel production at EU member state level are derived from Eurostat and publications of the European Commission. For implementing 1st generation biomass crops

⁵ Please note that input subsidies are granted for cereals, oilseeds, woody crops and sugar-beets/cane in the petrol and the fine chemical sectors. In the electricity sector forestry inputs are assumed not to be eligible for subsidies while the woody crops inputs are eligible for subsidies. The use of forestry, however, is taken into account for the calculation of the bioenergy shares in the electricity sector.

the GTAP data base has been adjusted for the input demand for grain, sugar and oilseeds in the petroleum industry. Under the adjustment process the total intermediate use of these three agricultural products at national level has been kept constant while the input use in non-petroleum sectors has been adjusted in an endogenous procedure to reproduce 2005 biofuels shares in the petroleum sector (corrected for their energy contents).

For the extension of 2nd generation bio-energy crops the production and consumption data of the GTAP sector ‘other crops’ has been adjusted by the so-called ‘splitcom’ program which allows to divide the production and consumption data in GTAP according to defined shares. Here the information of the production of bioelectricity in the EU member states and the use of wood and wood wastes as published in the European Biomass Statistics 2007 (Kopetz et al., 2007).

In the original data base the chemical industry is presented as a single sector. To show the impact of growing biomass utilization in the fine chemical industry we applied also the splitcom program to separate the fine chemical industries from the rest of the chemical sector. Due to the limited information about the composition of the Dutch chemical industry (in value terms), we based our assumption for the disaggregation of the chemical sector on the quantity shares in the chemical industries.⁶

3 MODEL RESULTS

3.1 Integration of the LEITAP projections in the bottom-up model

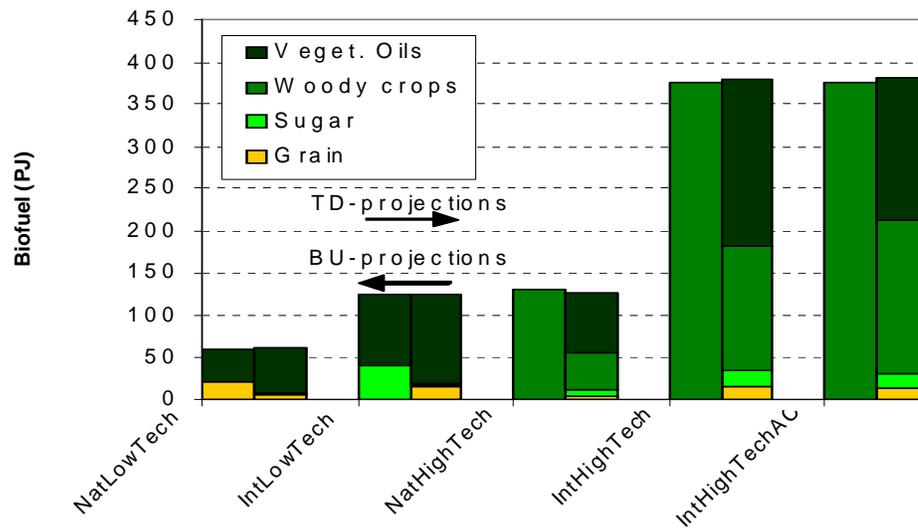
The results of the bottom-up analysis, as in the bottom-up reports includes projections of energy demand and growth in the chemical industry sectors based on the WLO-scenarios as displayed in figure 1. For this report, the projection results of the top-down LEITAP and translated into physical input parameters for the bottom-up model. This section describes how the data is translated from monetary outputs of the LEITAP model to physical input parameters. The results of the synthesis of both models are presented in the following paragraphs.

Transport fuels

Figure 3 displays the projections of biofuel per feedstock type. The right bars display the results of the LEITAP results - top-down (TD) projections -, the left bars display the results of the bottom-up (BU) results which are based on the WLO-projections for transport fuels.

⁶ Due to the lack of data we applied a share of 20% for fine and 80% for bulk chemicals similar to Wielen et al. (2006).

Figure 3: Biofuels in the bottom-up scenarios (left bars) and the top-down scenarios (right bars)

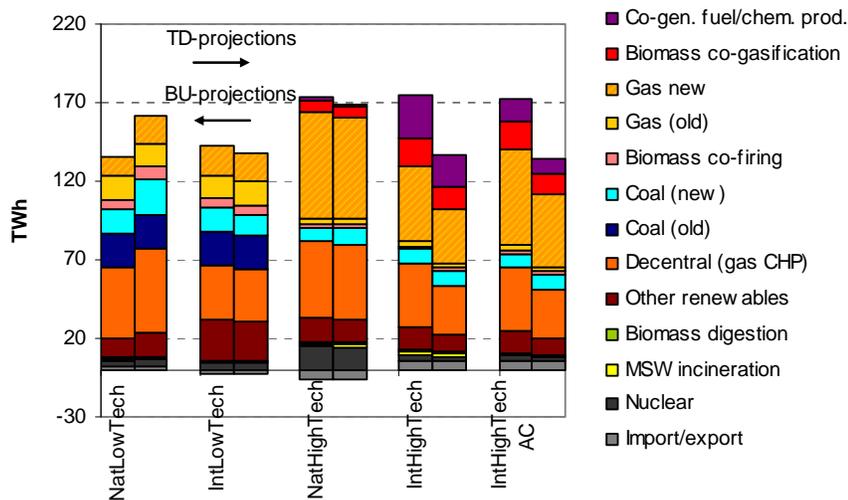


There are two important differences between these projections. The results of the high-tech scenarios of the bottom-up analysis, only include transport fuels from lignocellulosic feedstock whereas the LEITAP projections still include a large share of oil crops and some sugar and starch crops. Furthermore, the total production of biofuels in the low-tech scenarios and the NatHighTech scenarios is 14 to 35% higher in the LEITAP projections as a result of the higher demand for transport fuels relative to the WLO-projections used for the bottom-up results. For this report, both the final demand as the shares of crop types of the LEITAP results are integrated in the bottom-up model. All sugar crops are assumed to be sugar cane, the ratio for ethanol and FT-diesel from woody biomass is assumed to be similar to the initial bottom-up projections.

Electricity

Figure 4 presents the results of the bottom-up and LEITAP projections for electricity generation. Note that the results of the LEITAP projections are translated to physical units to make the results comparable. The replacement of retired existing capacities is assumed to be similar to the bottom-up scenarios. The final demand is based on projections of the LEITAP model and is, apart from the NatLowTech scenario, lower than the WLO projections which are used for the bottom-up results. Also co-production of electricity is slightly lower in the top-down projections as these scenarios include more 1st generation technologies for biofuel production without co-generation of electricity (Figure 3).

Figure 4: Electricity generation in the bottom-up scenarios (left bars) and the top-down scenarios (right bars).



Chemicals

For chemicals, the projected growth of the chemical industries is used to estimate the demand for energy and biomass in the scenarios.

Figure 5: Final energy demand of the chemical industry sectors in the bottom-up (left bars) and top-down (right bars) scenarios.

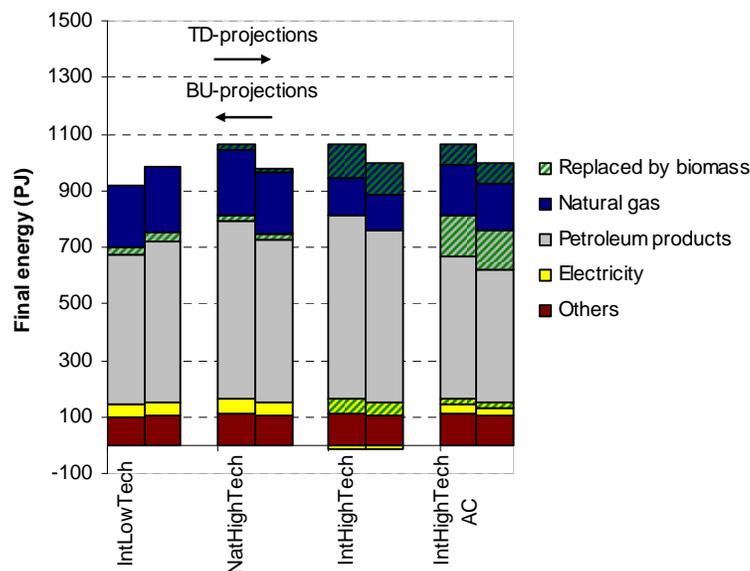


Figure 5 shows the size of the chemical industries as projected using the WLO-scenarios (left bars) and the LEITAP projections (right bars). The variation between the scenarios is much larger for the WLO-based bottom-up scenarios than the LEITAP projections. This is mainly

the result of efficiency improvements in the high-tech scenarios and different socio-economic assumptions⁷.

The projections of the LEITAP model for biofuels, electricity generation and chemicals (Figure 3 through Figure 5) are integrated in the bottom-up model. The initial results, based on the WLO-projections, are also included for reason of comparison.

3.2 LEITAP scenario results

To assess the impact of an increasing use of biomass in the bio-based industries, i.e. liquid petrol, chemicals, gas and electricity, we applied the estimated biomass blending shares as presented in table 1 above. As outlined in table 1, in addition to the four main scenarios that include single chemical representatives, an additional scenario (IntHighTechAC) is created that includes biobased production of natural gas and petroleum products and in both the specialty and bulk chemical industries. For all five scenarios calculated here the same assumptions on GDP and population growth have been applied. Apart from those coefficients which define the differences between the HighTech and the LowTech as well as the differences between the National and the International scenarios, all other parameters are kept constant over the scenarios.

The main difference between the HighTech and the LowTech scenario is the different degree of the substitutability between biomass and fossil inputs in the bio-based industries. We assume that under the LowTech scenario production of the bio-based industries is mainly based on current (1st generation biomass) technologies. Therefore, 1st generation biofuels than can be substituted with fossil fuels. However, especially under the LowTech scenarios the efficiency of biomass conversion is assumed to be low, i.e. at current level which leads to a relative low elasticity between fossil and biomass energy inputs. The values of the elasticity of substitution are taken from Birur *et al.* (2007).

To identify the effect of an enhanced use of biomass inputs we also run all four main scenarios without a mandatory blending obligation for biomass use in the bio-based industries, i.e. petrochemicals, electricity and chemicals. It should be mentioned that even without a mandatory blending the use of biomass inputs changes due to changes in relative prices (biomass crops vs. fossil fuel). Especially in the HighTech scenarios it can be assumed that the required subsidies for the biomass use will strongly decline due to the high technological progress we assume for these scenarios.

To illustrate the long-term development the results are presented for the initial period (2006), for 2010, 2020 and 2030.

3.3 Scenario Results

Under all scenarios calculated Dutch trade balance deteriorate significantly, figure 6. This decline is triggered by a strong increase in GDP and private income. In all scenarios Dutch

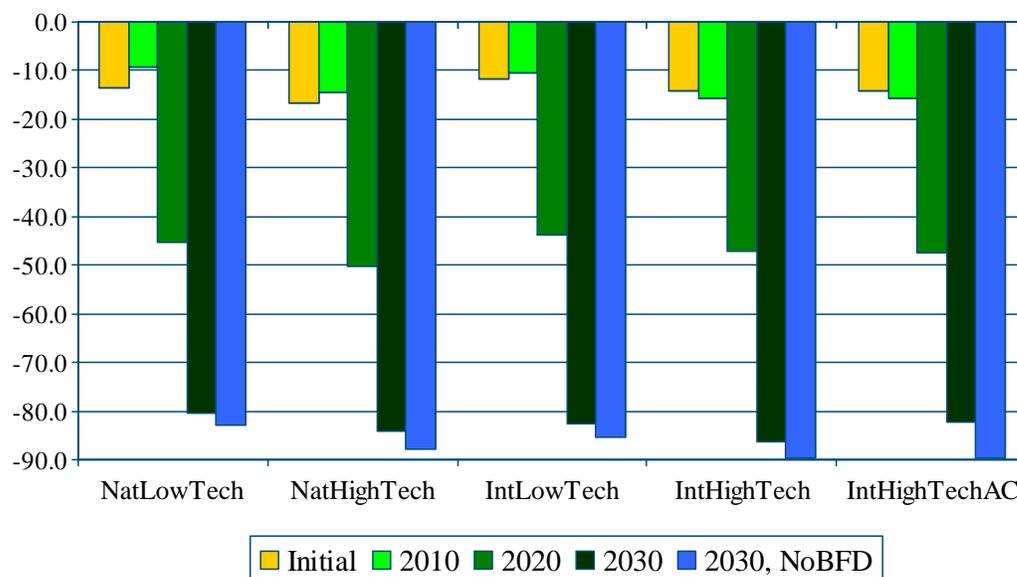
⁷ GDP and population growth are equal for all LEITAP scenario projections. In the WLO-scenarios, these parameters vary significantly over the four WLO-scenarios.

GDP is projected to increase by around 60% between the initial period (2006) and the final projection year, 2030. Imports increase at a similar rate while overall exports increase by 12% only. As a consequence of this general macro-economic development, which is not related to any specific tendency of the ‘bio-based economy’, Dutch trade balance becomes more and more negative.

With an enhanced biomass utilisation, however, the increasing trade deficit is partly compensated due to a substitution of imports of fossil energy with increasingly used biomass use in the bio-based industries. Under the IntHighTechAC scenario this effect is most visible. Under the scenarios where the use of biomass is not enforced (NoBFD) the resulting trade balance is projected to be more negative compared to the scenarios where biomass use is implemented as mandatory.

It should be mentioned that even without an enforced use of bio-energy crops through a mandatory blending the shares of bio-energy inputs in fuel consumption for transportation purposes and in electricity increase.

Figure 6: Balance in total trade, in billion € in the Netherlands

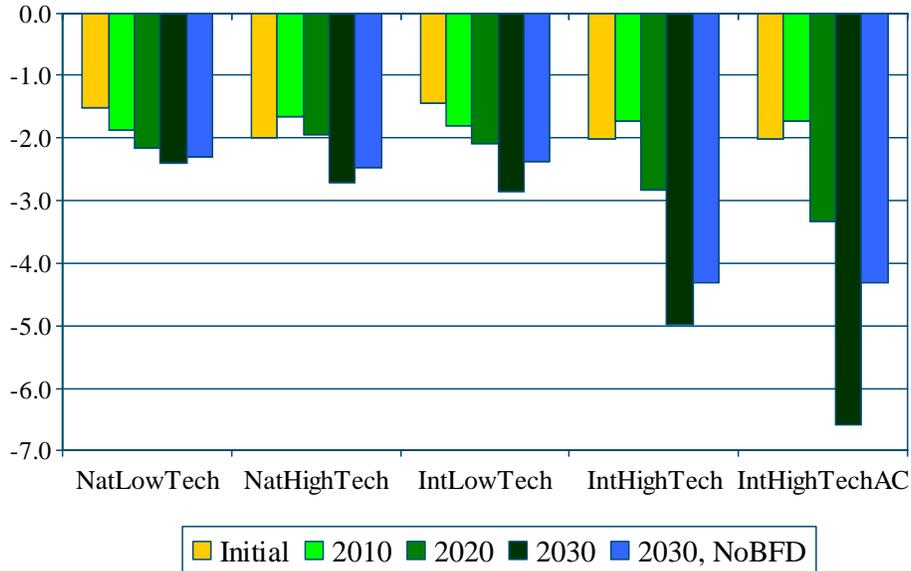


The Dutch balance in trade with biomass crops also declines, see figure 7. Figure 7 presents the development of the aggregated Dutch trade balance in biomass crops regardless whether these products are used for food, feed purposes or as inputs in the bio-based industries. Under the two ‘Int’ scenarios with open trade with all trading partners, Dutch biomass imports increase and the trade balance becomes more negative, especially in the IntHighTech scenario in which biomass use is high.

This strong increase is also due to relative high biomass blending shares modelled especially under the IntHighTech and IntHighTechAC scenarios. The lower trade deficit under the

‘NoBFD’, where biomass use is not modelled as mandatory, the imports are projected to be lower in all scenarios.

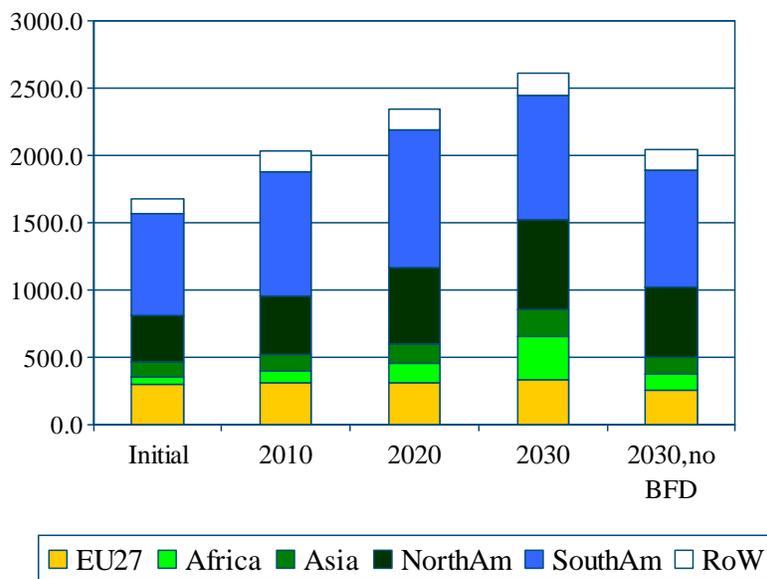
Figure 7: Trade balance in biomass crops, in billion € in the Netherlands



The regional composition of trade in biomass crops is presented in the following figures 8 and 9. Figure 8 presents the development under the NatLowTech scenario, which serves as a kind of reference scenario between the initial period and 2030. The projection indicates that the major part of biomass crop imports is coming from the other member states of the EU as well as North America and South America. With an increase in imports in biomass crops, the additional demand for biomass will come mainly from those regions with a relative large land reserve. Under all model scenarios the land reserve in EU-15 countries is rather limited, while in the North American countries land reserves are higher compared to the EU-15 member states. The largest reserve in agricultural land is projected for the countries in South America. Consequently additional demand for biomass crops imported to the Netherlands is projected to come from South American countries, especially Brazil.

Under the ‘International’ it is assumed that biomass imports come especially from the non-EU countries. Technically this assumption is implemented with higher trade elasticities for the ‘International’ scenarios than for the ‘National’ scenarios. Therefore, imports from outside EU are not restricted under the ‘National’ scenarios. Due to high trade elasticities under the ‘International’ scenarios producers strongly react to relative changes in domestic vs. world prices. This set-up also explains the strong increase in non-EU imports under the IntHighTech scenario.

Figure 8: Imports of biomass crops under NatLowTech, in million € in the Netherlands



While figure 8 shows the development of total biomass crop imports, the composition of the utilization of these crops within the Dutch economy significantly changes over time. In the initial situation biomass imports, as an input to the bio-based economy, contributes only to around 3% of total imports of these products. In 2030, however, almost half of the total biomass imports are used as an input to the bio-based sectors in the Netherlands.

The differences in biomass imports between the different scenarios, presented in figure 9, are due to the different blending shares in the scenarios calculated for this analysis. In the IntHighTech and IntHighTechAC scenarios, with blending shares of 60% and 75%⁸ in transportation fuels, respectively, imports of biomass is projected to increase to more than 7 billion €. Most of this additional imports is coming from South American countries, see figure 9.

⁸ The GTAP based model aggregates all petroleum products in one sector (Petrol). Because both transport fuels as chemical feedstocks are aggregated to one commodity, replacement of naphtha for ethylene production by biomass implies a higher biomass blending share in the Petrol sector. This is translated in an additional biobased blending share (15% points), i.e. demand for ethanol for transport fuels in the LEITAP model.

Figure 9: Imports of biomass crops in 2030 under different scenarios, in million € in the Netherlands

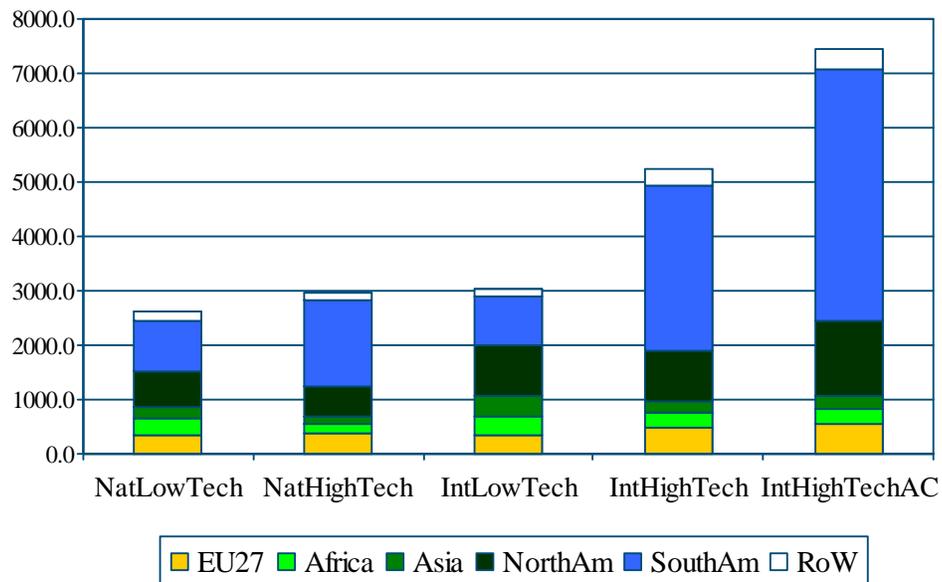


Figure 10 shows the development of the total production of biomass crops (grain, oilseeds and woody crops) regardless of final uses (food, feed, and biomass) under the four main scenarios. It becomes clear that even under high blending rates – projected under the IntHighTech scenarios, Dutch agriculture does not expand production at a high rate. This little expansion is due to restrictions on agricultural land use in the Netherlands. The higher biomass use under mandatory blending will lead to an additional crop production of around 150 million €. As already mentioned above the use of biomass crops in the bio-based industries increases even without mandatory blending. This endogenous development is due to the fact that until 2030 the development of *relative* prices is in favour for biomass crops, i.e. prices for biomass crops are projected to decline *relative* to fossil energy prices. Therefore, the use of biomass inputs as a substitute for fossil energy becomes more and more profitable.

Figure 11 – the right hand graph – presents the share of domestic crops used in the biobased industry in total domestic crops production. It should be mentioned that these numbers are relative to initial 2006 values. Showing the development relative to the initial situation presents both the autonomous trend to use more biomass and the enforced biomass use due to mandatory blending targets. As a general result: 2/3 of the biomass crop demand is related to mandatory targets while 1/3 is related to autonomous trends which occur also without mandatory blending targets.

Figure 10: Production of biomass crops, in billion € in the Netherlands

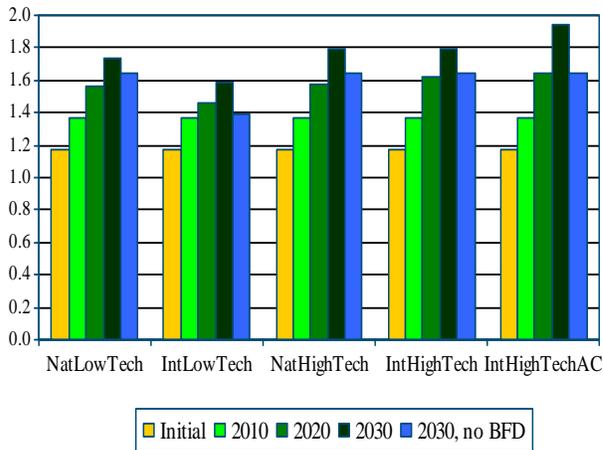
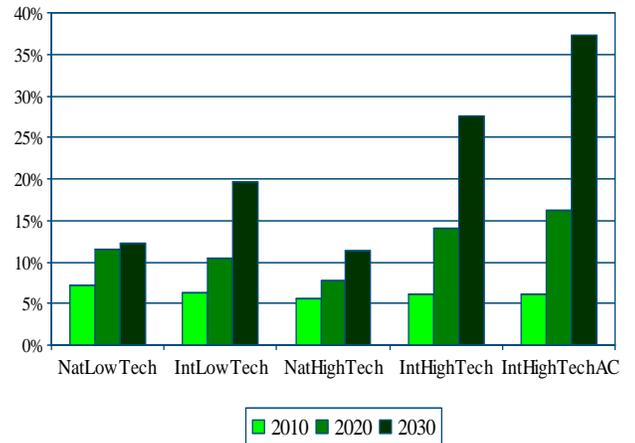


Figure 11: Share of biomass crops use for bio-based Industries, in %



The share of domestically produced biomass crops in total biomass crop production strongly depends on the assumed blending target. Under the IntHighTechAC scenario around 37% of total Dutch biomass crop production is projected to be used as inputs to the bio-based industry, Figure 11.

Figure 12: Income in bio-based industries, in million € in the Netherlands

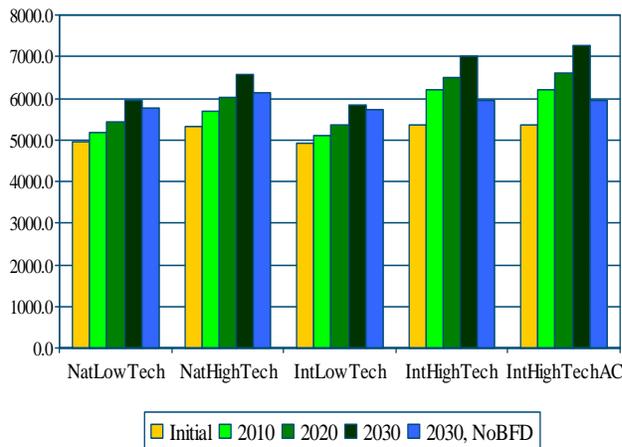
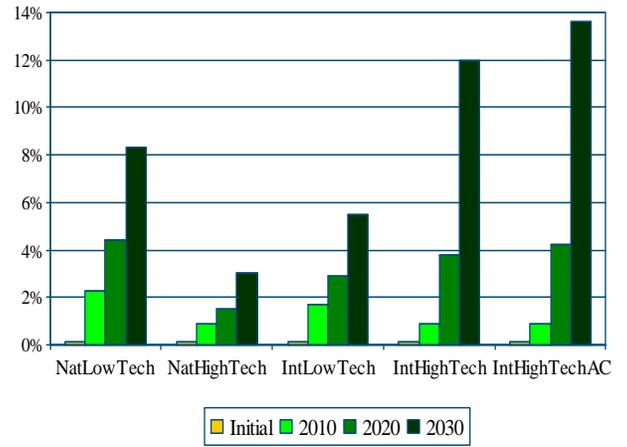


Figure 13: Share of employment in bio-based industries, in %



Under all scenarios the aggregated income in the petrol, electricity and the fine chemical industries is projected to increase, figure 12. This figure includes the income generated in both the ‘non bio-based’ and the bio-based part of the respective industries.⁹ Under the IntHighTech scenario 75% of the total income presented in figure 12 is allocated to the

⁹ Sectoral income is defined as the sum of all payments to factors employed in each sector. These payments include salaries, capital user costs and land rents which occur in agriculture only. Please note that installation and investments costs of new technologies are not included in these income figures, displayed here.

electricity sector, 24% for the petrol and 1% to the fine chemicals sector.¹⁰ In the IntHighTechAC scenario these share change and only 60% of total income is generated in the electricity sector, 30% in the petrol sector and 10% in the chemical sector.

Higher blending rates will lead to an increase in biomass inputs to the expense of fossil energy inputs. The questions remains: Will this development towards a more bio-based economy also lead to an increased income in the bio-based industries? The scenario results indicate that with a shift towards a more bio-based economy, total income in the bio-based sectors might be up to 1 billion € higher compared to scenarios without an enforced use of biomass, see figure 12. This strong income effect is projected only for the IntHighTech scenario which assumes very high utilisation of biomass in 2030 under very favourable conditions. Under a more conservative scenario assuming a low rate of technology development, such as the IntLowTech scenario, the projected additional income is only 100 million €. While, depending on the scenario 60 to 75% of total income is allocated to electricity, the additional income from enhanced bio-based activities industries is projected to be allocated differently. Of the 1 billion € **additional** income under the IntHighTech scenario 19% is created in the electricity production, 78.5% in petrol production and 2.5% in the (fine) chemicals industries. Under the IntHighTechAC scenario the shares are 11% in electricity, 76% in the petrol and 14% in the chemical sectors.¹¹ These numbers are different compared with the bottom-up analysis. The structure of employment in the bio-based sectors is also affected by the shift towards a more bio-based oriented economy. With high blending shares under the IntHighTech scenario, almost 12% of total employment in the petrol, fine chemical and electricity sector is working in the bio-based part of these industries, see figure 13. With 13.8% under the IntHighTechAC scenario, this share is even higher.

Similar developments are projected for the additional income for Dutch agriculture. Compared to the scenarios without enforced biomass use (NoBFD scenario), the enhanced biomass use generates an additional income between 50 and 140 million € in Dutch farming, see figure 14. This development is also mirrored by the share of agricultural employments in the production of biomass crops, see figure 15. Depending on the projected scenario, between 3% and 5% of agricultural employment will be related to the production of biomass crops used in the bio-based sectors.

It is important to mention that total agricultural employment is projected to decline strongly in all scenarios. Compared to current level employment in Dutch agriculture in 2030 is projected to be half of current level. This strong decline is mainly due to a high growth in labour productivity which boosts the structural change in Dutch farming. The projected

¹⁰ The high share in electricity is due to the fact that the electricity sector in the top-down model includes both electricity production and distribution.

¹¹ This lower share in the IntHighTechAC scenario (compared to the IntHighTech scenario) is related to the fact that the substitution of natural gas by syngas mainly affects the gas sector and not the chemical industries. Biobased synthesis gas requires high capital investments and skilled labour similar to 2nd generation biofuels. These results indicate that further research is required in order to address for these factors in the macro-economic model.

increasing share of employment for biomass crops the bio-based economy is not able to alter this trends but it will ease the burden of structural changes in Dutch agriculture.

Figure 14: Agricultural income in biomass production, in mill. € Netherlands

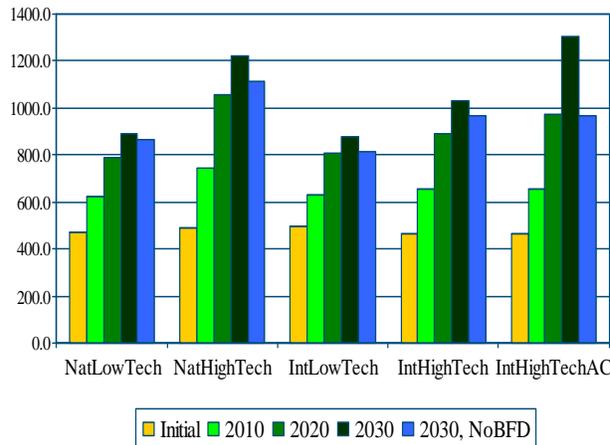
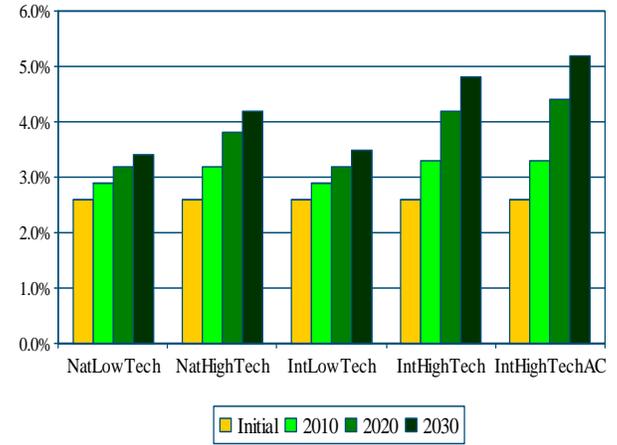
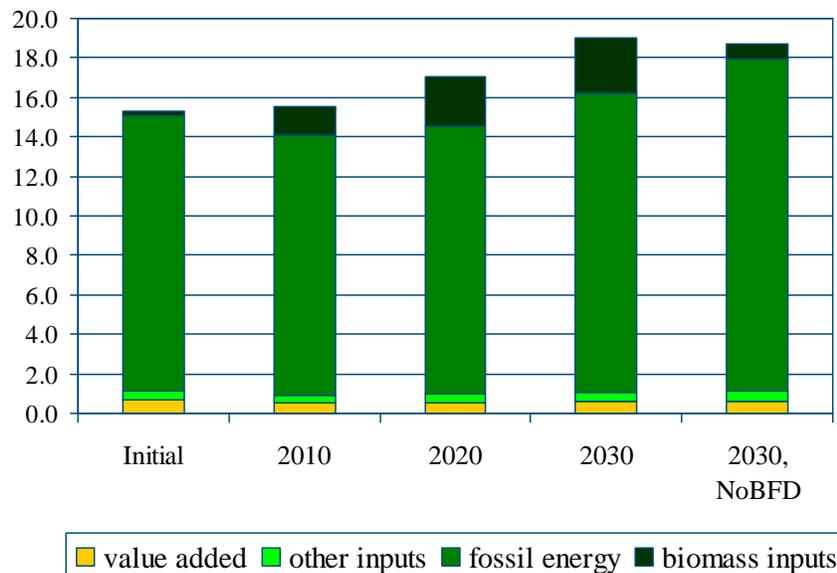


Figure 15: Share of employment in biomass production, in %



The development of the cost structure of the Dutch petrol industry under the NatLowTech scenario is presented in figure 16. This figure describes total production of the Dutch petrol industries, i.e. production for domestic use and for exportation. Please note that the blending shares are assumed for the entire EU and that exported petrol also fulfils the blending requirements.

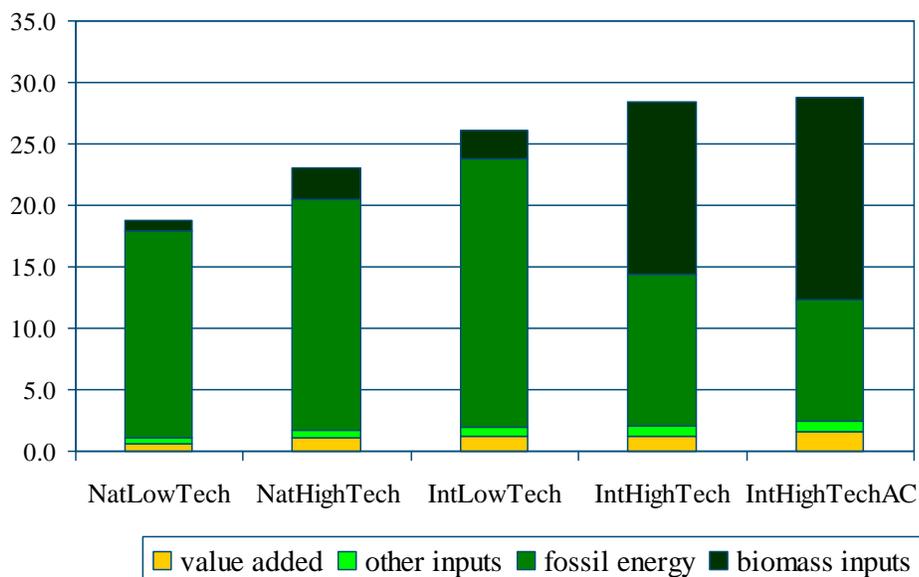
Figure 16: Cost structure in petrol sector, in billion €, in the Netherlands under NatLowTech scenario



While biomass use is relatively low in the initial situation the relative importance grows until 2030. Even without enforced biomass use the utilization of biomass increases due to the change in relative prices between biomass and fossil inputs. The question, whether petrol is mainly based on fossil energy inputs (as modelled in NoBFD scenarios with mandatory blending of biomass inputs) or produced with higher biomass shares has only limited impact on the total value added generated in the petrol sector, (compare last two columns in figure 16).

With relatively low blending shares under the NatLowTech scenario the share of biomass use significantly increases in different scenarios and under the IntHighTech (IntHighTechAC) scenario, 60% (75%) of transportation fuel is based on biomass inputs, figure 17. Please note that the shares presented in figures 16 and 17 refer to the value share of the respective inputs and not on the volume share.

Figure 17: Cost structure in petrol sector under different scenarios, in 2030 in billion € in the Netherlands



The Dutch petrol industry is highly integrated in the single European market and a large share of crude oil, which is imported, is processed in the Netherlands, but exported to other EU member states afterwards. The following two graphs illustrate the trade structure of the Dutch petrol sector under the NatLowTech scenario.

Figure 18: Trade in crude oil and petrol, in million €, Netherlands (NatLowTech scenario)

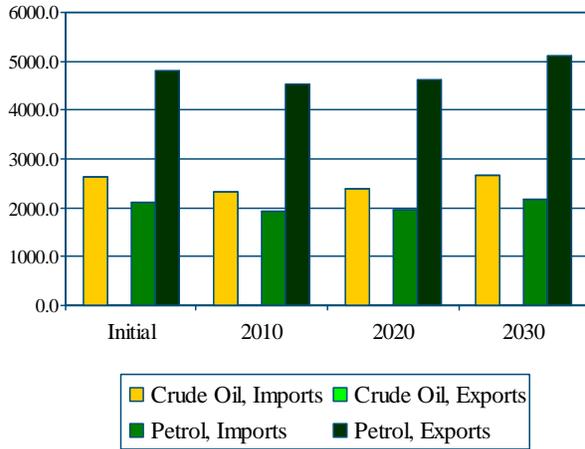


Figure 19: Production and exports in petrol, in mill. €, Netherlands (NatLowTech scenario)

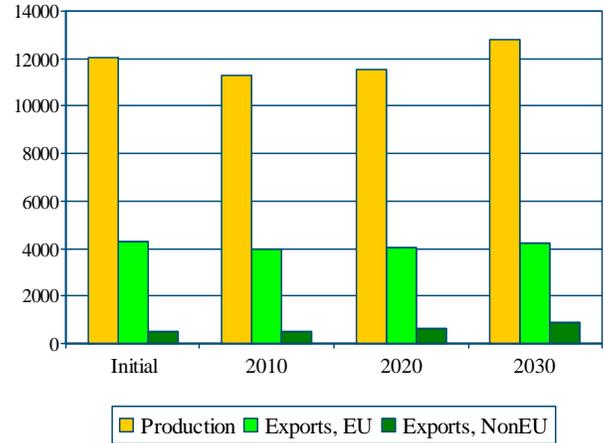


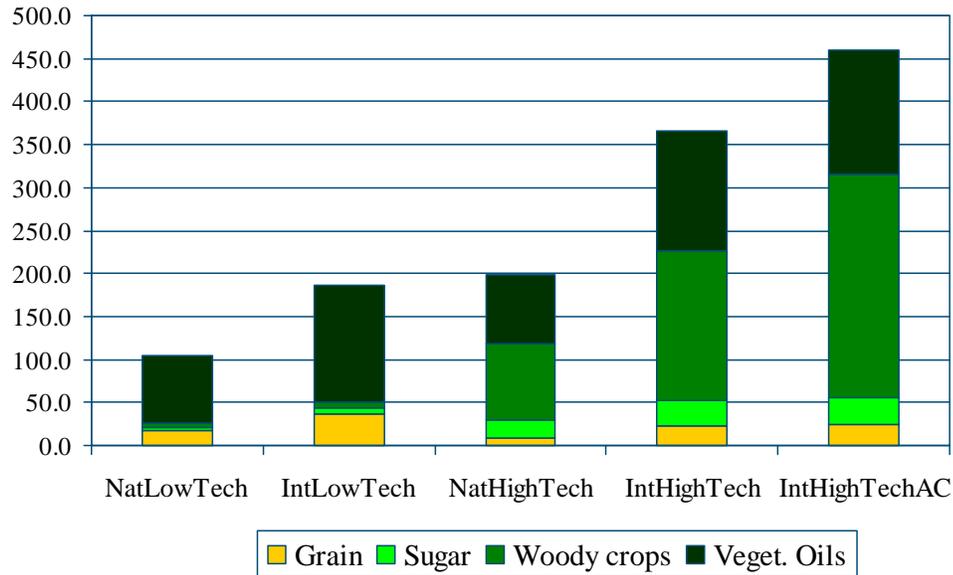
Figure 18 shows the large trade surplus in Dutch petrol trade. Around 50% of total Dutch petrol production is exported after processing, see figure 19. Figure 18 shows that imports and exports of oil and petroleum products increase at almost the same magnitude. Therefore the strong increase in the Dutch trade deficit, as described above, is not related to the petrol sector.

Figure 20 illustrates the composition of biomass inputs in the Dutch petrol sector in term of energy value of the various inputs. These numbers show how the estimated amount of biomass inputs from the bottom-up process are integrated in the macro-economic model. The total amount of biofuel crops is determined by two factors: a) the autonomous trend towards a bio-based economy and b) by an enforced biomass use due to blending targets of biomass use. The first effect is induced by the change in the relative prices between biomass and fossil energy.¹²

As outlined already in the report for the bottom-up approach, the composition is changing. Under the LowTech scenarios 1st generation biomass crops (domestic and imported) dominate the use of biomass crops, while under the HighTech Scenarios the share of 2nd generation biomass (woody-crops) becomes more important. These numbers are also reflected by the outcome of the macro-economic model; see first two columns in figure 21. Figures 22 and 23 show the composition of biomass inputs in the electricity and the fine chemical sectors, respectively.

¹² The average change in relative prices between (aggregated) biomass and fossil energy under the NoBFD scenarios is around -30% under the NatLowTech scenario.

Figure 20: Composition of biomass inputs in Dutch petrol sector, in 2030 in PJ



It should be noted that ethanol is not modelled as an individual product in the current version of LEITAP. Therefore, the increase use of sugar under both HighTech scenarios may be interpreted as a proxy for the increase in ethanol production based on 1st generation crops. Comparing the outcome of the macro-economic model with the estimate of the bottom-up approach one could expect a larger share of 2nd generation biomass, especially for the IntHighTech scenario. Under the IntHighTech scenario oilseeds still contribute a significant part to total biomass use in the petrol industry.

Figure 21: Composition of biomass inputs in electricity, in 2030 in PJ, in the Netherlands

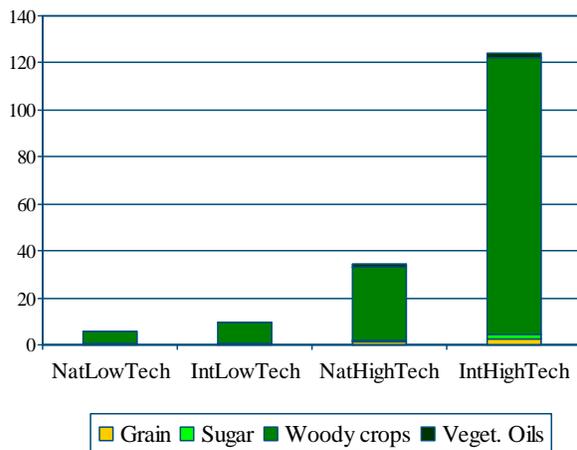
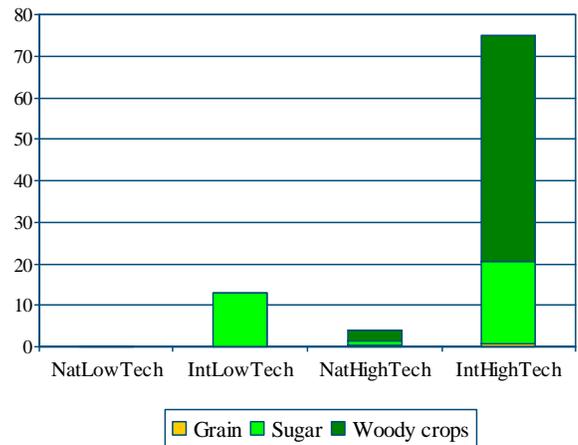


Figure 22: Composition of biomass inputs in fine chemicals, in 2030 in PJ, in the Netherlands

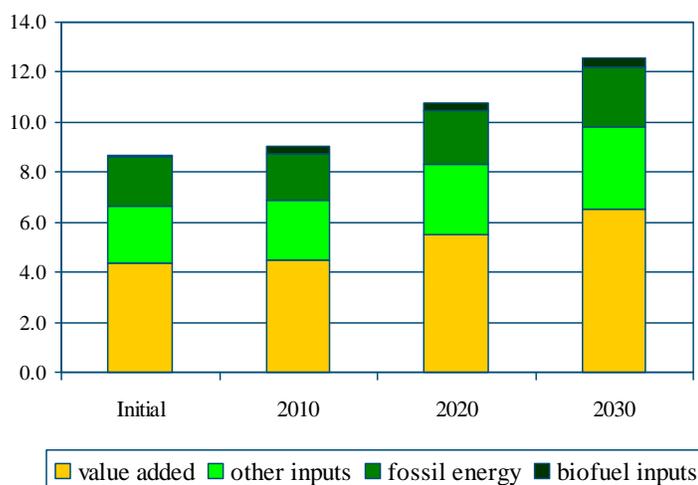


This outcome is explained by the underlying technology assumption of the LEITAP model. Due to the fact that technology changes follow a path of substituting an existing technology (based on 1st generation biomass) with a new and modern one (based on 2nd generation biomass) the model seems to react a bit ‘sticky’. Thus, LEITAP does not allow for drastic changes in the composition of the feedstock in the biomass sector.¹³ Thus, even in the IntHighTech scenario, 1st generation biomass crops such as oilseeds continue to contribute to biofuel production at a significant level. Based on the economic model applied in this analysis the achieved results indicate that an economy fully based on 2nd generation biomass inputs would require a longer time path for adjustment.

Due to the remaining use of 1st generation biomass crops even under the HighTech scenario some subsidies are still necessary to fulfil the blending target. The ‘persistent’ contribution of 1st generation biomass has also consequences for the calculation of tax burden of an enforced utilization of biomass crops in the bio-based industries, see following table 1. The composition biomass use in the two other biobased industries – electricity and fine chemicals – are more biased to a single input (woody crops) in electricity and a mix of sugar and woody crops in fine chemical industries.

Similar to the development of biomass use in the petrol sector (figure 20) the electricity sector uses only a small amount of biomass inputs under the NatLowTech scenario, see figure 23. In 2030 it is assumed that 5.7% of total energy inputs in the Dutch electricity production are based on biomass inputs. It should be also mentioned that the composition of the electricity sector differs significantly from the petrol sector. In the electricity sector value added has the largest cost shares with more than 50% in total costs which also contributes to the large share of electricity in the aggregated bio-based sectors.

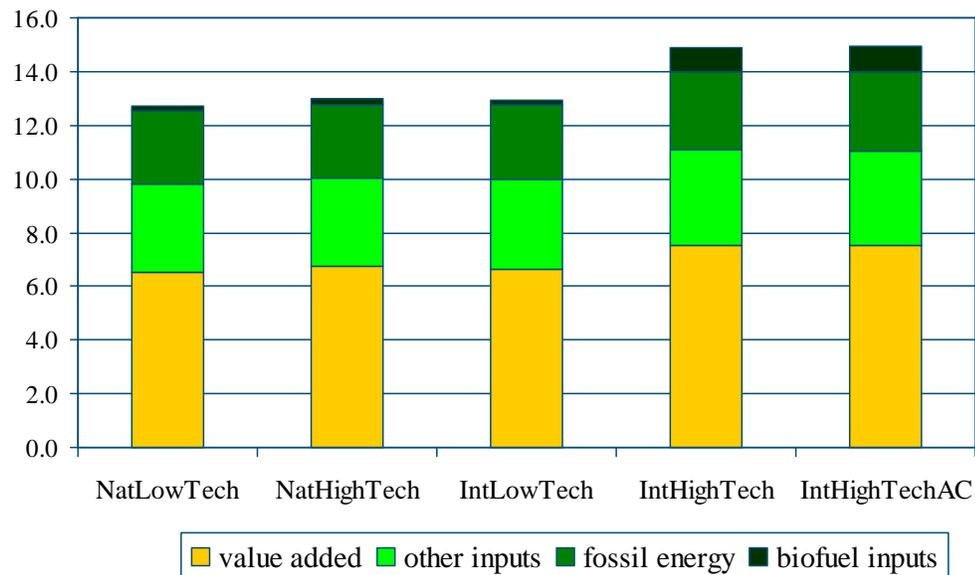
Figure 23: Cost structure in electricity sector, in billion € in the Netherlands under NatLowTech scenario



¹³ Other modelling approaches such as a linear-programming model would allow for these immediate shifts in the mix of 1st and 2nd generation biomass. However, these modeling approaches would neglect other important features such as the endogenous development of relative prices between different inputs.

For the other three scenarios biomass inputs will not dominate the demand of energy related inputs in the electricity sector, see figure 24. Under the IntHighTech scenario biomass inputs are assumed to contribute by almost 1/3 to total energy related input demand.

Figure 24: Cost structure in electricity sector under different scenarios, in 2030 in billion € in the Netherlands



The following table 2 presents the burden to tax payers of an enforced use of biomass in the Dutch petrol industry. With around 14 billion litres, the amount of total petrol consumed is very similar between the different scenarios and the differences are due to different prices for gasoline. However, with different blending rates the amount of biofuels (including the naphtha substitution) produced in 2030 varies from 1.4 billion in the NatLowTech to 8.6 billion litres in the IntHighTech scenario and 10.6 billion litres under the additional IntHighTechAC scenario.

Table 2: Tax burden of using biomass inputs for liquid petrol production, 2030 in the Netherlands

	NatLowTech	IntLowTech	NatHighTech	IntHighTech	IntHighTech AC
Fuel consumption (mill. litres)	14218	14035	14364	14286	14160
Substitution share in %	10	20	20	60	75
Amount of biofuel (mill. litres)	1422	2807	2873	8572	10620
Subsidies, million €	578	347	828	293	421
€/litre of biofuel	0.407	0.124	0.288	0.034	0.040

With these different volumes of biofuels produced also the absolute spending in subsidies is very different and depends on the assumed technology. The highest spending on subsidies to compensate petrol producers for the (otherwise) unprofitable is projected for the NatHighTech scenario where annual tax payers burden of biomass use in the petrol industry

is more than 800 million € To compare the costs across different scenarios we calculate the required subsidies of producing 1 litre of biofuel. The results show a strong decline in subsidies per litre of biofuel in moving from LowTech to HighTech scenarios and in moving from national to international scenarios. As discussed already for figure 20, under the IntHighTech scenario subsidies of 0.034 €/litre of biofuel are still required due to the (remaining but declining) use of 1st generation biomass crops. Similar results are for the IntHighTechAC scenario where blending rates are at 75% level. Here the required subsidy per litre of biofuel is 0.04 €/litre which is higher compared to the IntHighTech scenario. The questions, whether 2nd generation biomass crops still needs subsidies to be profitable compared to fossil energy strongly depends on the technology and the prices for fossil energy. Under the very optimistic assumptions of the IntHighTech scenario the scenario results indicate that 2nd generation biomass becomes competitive at the price level of 75 US\$/bbl (in 2006 US\$).

Results of the Sensitivity Analysis

Because the market for bioenergy and biobased materials is surrounded by uncertainties, the sensitivity analysis shows the impact of the most crucial assumption: The development of the world market price of fossil energy. Two additional scenarios have been calculated with regard to the development of world fossil energy prices. Under the scenarios IntHighTechHigh the increase in fossil energy prices 50 per cent (which is 112 USD/bbl, in 2006 USD) higher than in the reference IntHighTech scenario. Under the scenario IntHighTechLow fossil energy prices are assumed to be 25 percent lower compared to the IntHighTech scenario, which is 56 USD/bbl, in 2006 USD. To identify the impact of different developments of fossil energy prices in the IntHighTech scenario all other assumptions including the blending rates of biomass utilisation in the bio-based sectors are kept unchanged in the two sensitivity scenarios. In the following graphs only those results are presented which show a significant difference in the results of the two sensitivity scenarios compared with the IntHighTech scenario.

Figure 25: Sensitivity scenarios: Balance in total trade, in billion €, in the Netherlands

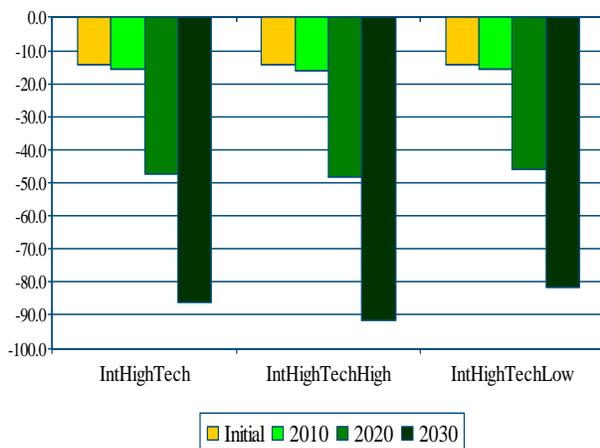
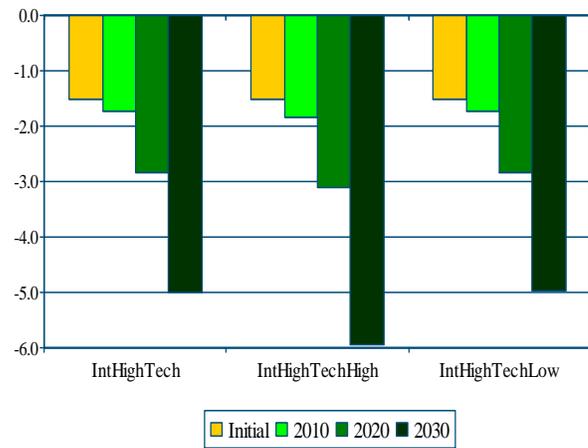


Figure 26: Sensitivity scenarios: Balance in biomass crop trade, in billion €, in the Netherlands

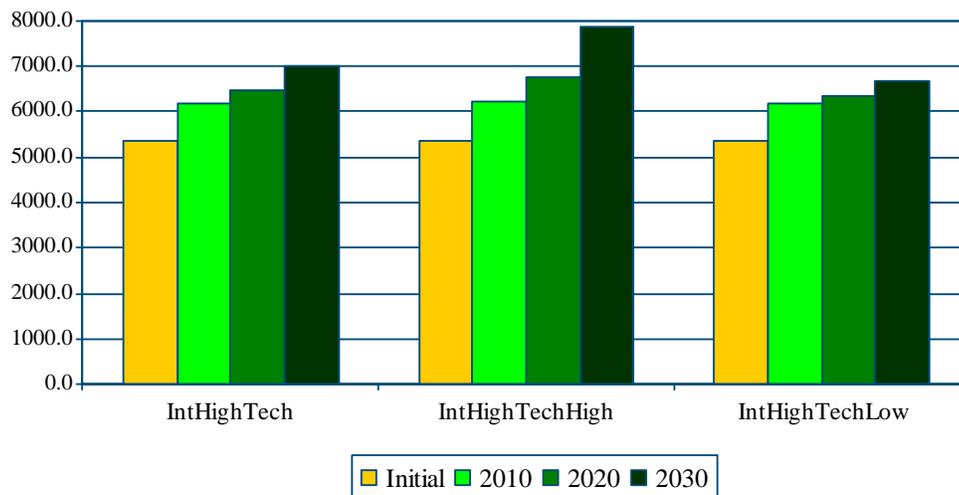


Under higher fossil energy prices the Dutch trade balance will further deteriorate due to higher expenses for energy import while lower energy prices will lower the Dutch trade deficit, see following figures 25 and 26.

Under the IntHighTechLow sensitivity scenario the Dutch balance in trade with biomass crops change only little relative to the IntHighTech scenario, see figure 26. However, under higher fossil oil prices more biomass crops will be used compared to the IntHighTech scenario, i.e. with higher fossil energy prices biomass use become more profitable. This result indicates that with lower fossil energy prices, the blending shares applied in the scenarios remain ‘binding’ constrains. The lower profitability of biomass crops – due to lower fossil energy prices – will lead to higher subsidies on biomass inputs, even under the IntHighTech scenario, see below.

Due to the limited availability of agricultural land, Dutch agriculture does not benefit from this increase in biomass demand in the bio-based sectors. The additional demand is covered almost completely by an increase in biomass imports, with South America as the most important origin of imports.

Figure 27: Sensitivity scenarios: Income in bio-based industries, in million €



The increase in demand of biomass crops in the biobased sectors positively affects income generated in those sectors, see figure 27. Under the IntHighTechHigh scenario, total income in the bio-based industries is around 800 million € higher compared to the IntHighTech scenario. Lower energy prices lower total income in the bio-based sector which is due to changes in the relative factor prices.

With a higher demand for biomass inputs in the bio-based industries the composition of biomass remains unchanged. However, the level of fossil energy prices determines the competitiveness of biomass inputs relative to fossil inputs in the bio-based sectors. The lower the fossil prices the more ‘costly’ is the use of biomass inputs. Without blending shares which are set as minimum blending requirements for the bio-based sectors less biomass would be used, i.e. additional subsidies are required to maintain the blending shares at their

minimum level. Higher fossil energy prices increase the relative competitiveness of biomass inputs. The sensitivity analysis shows that under the IntHighTech scenario with high fossil energy prices the required subsidies become very low, see following table 3.

Table 3: Sensitivity analysis: Tax burden of using biomass inputs for liquid petrol production, 2030 in the Netherlands

	IntHighTech	IntHighTechHigh	IntHighTechLow
Fuel consumption (mill. litres)	14286	13286	14786
Substitution share in %	60	62	60
Amount of biofuel (mill. litres)	8572	8237	8872
Subsidies, million €	293	121	521
€/litre of biofuel	0.034	0.015	0.059

The sensitivity analyses shows that the qualitative results are not fundamentally different, but the size of the effects can change substantially. The sensitivity analysis shows that, despite the ambitious biomass blending targets in the IntHighTech scenario, at crude oil prices of 112 USD/bbl, biomass becomes competitive and increases the demand for bioenergy crops. The results, i.e. biobased production, are however still in range with the baseline situation. The required subsidies for biobased substitution of fossil energy carriers are sensitive to fossil energy prices as displayed in table 3.

4 SUMMARY

The macro-economic analyses results cover impacts of the different bio-based scenarios on the Dutch trade balance, GDP, sectoral effects (in particular agriculture, energy and chemical), employment, all compared to the baseline development where only a low share of biomass use (mainly for energy) is included. To summarize the results of the quantitative analysis the following conclusions can be drawn:

- All bio-based scenarios have a positive effect on the trade balance of the Netherlands. In 2030 the net (positive) impact compared to the baseline developments simulated by LEITAP are about 2000 (LowTech scenario) to 4000 (HighTech scenario) million € per year.
- Imports of biomass (and biofuels, especially ethanol; depending on the scenario) are substantial, varying between over 2600 million € (NatLowTech) up to 7400 (IntHighTechAC) million € annually. Especially South America is a likely major supplier.
- The production of biomass used in the Dutch bio-based economy varies in value between some 180 Million € (IntLowTech) and almost 720 million € (IntHighTechAC). This is substantial, but also reflects the relatively modest role of national biomass resource production compared to imports.
- In terms of employment generated, the share of employers working in the bio-based ‘part’ of the bio-based sectors (fuel, electricity and fine chemicals), the total

employment in these three sectors remains relatively stable over the projected period, but the increasing share in employment in the ‘bio-based part’ indicates an growing importance of the bio-based economy for those sectors. The results show that with a shift towards a biobased economy agricultural employment will continue to decline. However, at growing demand for biomass will slightly dampen this structural change in agriculture.

- The macro-economic modelling results confirm the large shares of first generation biofuels for the LowTech scenarios as defined by the bottom-up approach. The use of lignocellulosic biomass (both for fuels and for biomaterials) covers over half the total demand for the HighTech scenarios in 2030.
 - This result, different from the bottom-up scenarios, where this share is even higher, is explained by the incorporation of continuous functions in the modelling framework that basically take into account the lifetime of investments and reasonable rates of change in production capacity over time.
 - With the base scenario assumptions, the share of lignocellulosic based biomass applications would increase further after 2030 and overall costs would go down. Furthermore, this share is sensitive to the rate of technological progress (learning) of new technologies. A more conservative progress would lead to lower shares and vice versa.
- Required support levels to ensure the realization of the projected shares of biofuel shares in the different scenario’s differ strongly between the scenarios (following data are all versus a reference oil price of 75 U\$/bbl (in 2006 US\$):
 - The NatLowTech scenario requires (for a modest share of 10%) a subsidy of about half a billion per year (and around 0.40 €/litre of biofuel).
 - IntLowTech this is reduced to 350 million € annually and 0.12 €/litre of biofuel for a 20% share (especially due to lower costs imports such as ethanol). Costs increase again for the NatHighTech scenario (due to higher feedstock costs).
 - IntHighTech achieves the 60% share of biofuels in 2030 with some 300 million € per year subsidies (and a low 0.034 €/litre biofuel subsidy). This subsidy is only required for the first generation biofuel part and to some extent for 2nd generation biodiesel; in this scenario competitive production costs are achieved for 2nd generation ethanol production given the technology assumptions and base oil price of 75U\$/bbl.
 - In addition to the IntHighTech scenario, the IntHighTechAC scenario includes biobased production of natural gas and petroleum products and in both the specialty and bulk chemical industries. Under the (extreme) high blending shares assumed under IntHighTechAC imports of biomass is projected to increase to more than 5 billion € with most of imports from South American

countries. Additional income and employment under the IntHighTechAC scenario is mainly created in the petrol sector; while around ¼ is generated in the in electricity and chemical sectors.

- These results are highly sensitive to the oil price; with lower oil prices, required support increases and vice versa. In addition, the scenarios assume a fixed (and high) diesel demand in the transport sector. When this could be replaced by 2nd generation bio-ethanol or cheaper synfuels than Fischer-Tropsch diesel (such as methanol or DME), costs would go down and be competitive at the 75 U\$/barrel reference oil price. This implies, however, also more adjustments investments in the transport sector (e.g. engine adjustments, fuel distribution).
- Shares of additional income across the bio-based industries in 2030 for the IntHighTech Scenario) due to biomass expansion amount 19% for electricity production using biomass, 78.5% for production of biofuels and, 2.5% due to the production of the assumed biomass derived chemicals.

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