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Assessment of biofuels supporting policies using the BioTrans model

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ABSTRACT

The introduction of advanced, 2nd generation biofuels is a difficult to forecast process. Policies may impact the timing of their introduction and the future biofuels mix. The least-cost optimization model BioTrans supports policy analyses on these issues. It includes costs for all parts of the supply chain, and endogenous learning for all biofuels technologies, including cost reductions through scale. BioTrans shows that there are significant lock-in effects favouring traditional biofuels, and that the optimal biofuels mix by 2030 is path dependent. The model captures important barriers for the introduction of emerging technologies, thereby providing valuable quantitative information that can be used in analyses of biofuels supporting policies. It is shown that biodiesel from oil crops will remain a cost effective way of producing biofuels in the medium term at moderate target levels. Aiming solely at least-cost biofuel production is in conflict with a longer term portfolio approach on biofuels, and the desire to come to biofuels with the lowest greenhouse gas emissions. Lowering the targets because of environmental constraints delays the development of 2nd generation biofuels, unless additional policy measures (such as specific sub targets for these fuels) are implemented.

1. Introduction

The introduction of 2nd generation biofuels is a difficult to forecast process. General biofuels supporting policies may impact the timing of the introduction and the future biofuels mix. The cost optimization model BioTrans supports policy analyses on these issues.

Developed for the VIEWLS project [1], the focus of BioTrans lays on ascertaining the economic viability of many different technologies to produce biofuels. BioTrans was used for cost assessment of biofuels production in Europe. Future cost reductions were taken into account as predefined rates of cost decline, so-called exogenous learning. Exogenous learning sufficed given the focus on biofuels in general. In the REFUEL project, the focus shifted towards the introduction of 2nd generation biofuels. The introduction of 2nd generation biofuels depends on the development of emerging technologies which have to overcome introduction barriers and which further market penetration heavily depends on learning. This focus on emerging technologies called for a different approach on costs reduction. The costs reduction should depend on the accumulated experience in the emerging technologies. The model BioTrans used for the REFUEL project includes endogenous learning.

A model that applies exogenous learning, takes future cost reductions as fixed input parameters. Thus, the production costs in the end year of the model run are known in the beginning. A model that applies endogenous learning,

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computes the cost reductions based on model outcome like cumulative production or installed capacity. The costs in the end year of the latter model depend on the events of the intermediate years. A more thorough discussion on exogenous versus endogenous learning can be found in Junginger et al. [2].

This paper assesses biofuels supporting policies, in order to identify no-regret measures and the dos and don'ts of biofuels policies in general. It identifies to what extent specific measures contribute to the market introduction of 2nd generation biofuels, and whether or not a point of no return will be passed, e.g. by the break-through of a new technology. For this, the mid-term years (2015–2020) are important, both in reality as well as in modelling sense. If new technologies are to emerge in the market, the investment hurdle has to be overcome in the intermediate years. The time of emergence might also be a potential point of divergence in the model. The modifications made to BioTrans in the context of the REFUEL project, serve to improve the modelling and understanding of events in these intermediate years.

The structure of this paper is as follows. Section 2 describes the model. Section 3 describes the dynamic behaviour of the model, thereby validating the use of the BioTrans model for the mentioned purpose of biofuels policy assessment. Section 4 interprets the main results in terms of policy impactions. Section 5 concludes with a general discussion.

2. BioTrans characteristics

2.1. *Description of the model and data used*

BioTrans computes the optimal biofuel mix, given an externally defined biofuels consumption target. One could classify BioTrans as a myopic cost optimization model. Given the yearly defined consumption target, the least-cost biofuel mix is computed. The model has no foresight, in order to better capture lock-in effects. The model architecture resembles that of a network flow model. The biomass flows follow a route over several nodes, from biomass cultivation or collection to biomass conversion into biofuels, biofuels distribution and biofuel use. The nodes have specific costs associated with them, and transport costs are associated with the routes. The model is spatially differentiated in the 27 member states of the EU, and Ukraine. Transfer of biomass flows from one country to another is possible, at the expense of international transport costs [3].

The cost structure of modelled biofuel use follows the production chain. For the feedstock of energy crops, a cost-supply curve per country is created [4]. Every element of the cost-supply curve represents a NUTS2 region. The competition for land by the different energy crops takes place only within a NUTS2 region. The feedstock is the only data that is specified on a sub country level. The other data is country-based. Therefore, BioTrans doesn't see a difference between crop harvesting in, e.g. northern Italy or southern Italy with respect to geography. Within each NUTS2 region, each of the five crop categories has a supply potential against certain production costs [4,5]. Only for greenhouse gas emission

Table 1 – BioTrans assumptions on start-up scale and typical costs for different conversion technologies.

Technology	Typical (start-up) scale	Conversion costs 2005	Technological learning mechanism
	$MW_{th\ input}$	€ GJ_{fuel}^{-1}	
First generation technologies			
Oil extraction + Transesterification (oil seeds)	134	2.77	Endogenous
Ethanol from sugars	54	7.32	
Ethanol from starch	54	10.36	
Second generation technologies			
Lignocellulose ethanol	200	15.79 (19.02[a])	Endogenous and exogenous
Fischer–Tropsch diesel	200	14.54 (15.33[a])	

a Excluding an electricity reimbursement 47.7 € MW h^{-1}.

Table 2 – BioTrans assumptions on transport costs [1].

Country	Inland transport	International transport			
	Road (€ tkm^{-1})	Handling costs (€ t^{-1})	Road (€ tkm^{-1})	Ship (€ tkm^{-1})	Rail (€ tkm^{-1})
AT	0.07	3	0.05	0.006	0.04
BE	0.08	3	0.06	0.006	0.05
BG	0.01	3	0.01	0.005	0.01
CH	0.10	3	0.08	n/a	0.06
CY	0.07	3	n/a	0.005	n/a
CZ	0.02	3	0.01	0.005	0.01
DE	0.07	3	0.06	0.006	0.05
DK	0.05	3	0.06	0.006	0.05
EE	0.01	3	0.01	0.005	0.01
EL	0.07	3	0.07	0.006	0.06
ES	0.08	3	0.06	0.006	0.06
FI	0.07	3	0.05	0.006	0.04
FR	0.08	3	0.06	0.006	0.05
HU	0.01	3	0.01	0.005	0.01
IE	0.06	3	0.08	0.006	0.05
IT	0.07	3	0.06	0.006	0.05
LT	0.01	3	0.01	0.005	0.01
LU	0.08	3	0.06	n/a	0.05
LV	0.01	3	0.01	0.005	0.01
MT	0.07	3	n/a	0.005	n/a
NL	0.08	3	0.06	0.006	0.05
NO	0.08	3	0.06	0.006	0.05
PL	0.01	3	0.01	0.005	0.01
PT	0.07	3	0.05	0.006	0.06
RO	0.01	3	0.01	0.005	0.01
SE	0.07	3	0.05	0.006	0.05
SI	0.03	3	0.02	0.005	0.02
SK	0.02	3	0.01	0.005	0.01
UA	0.01	3	0.01	0.005	0.01
UK	0.07	3	0.07	0.006	0.06

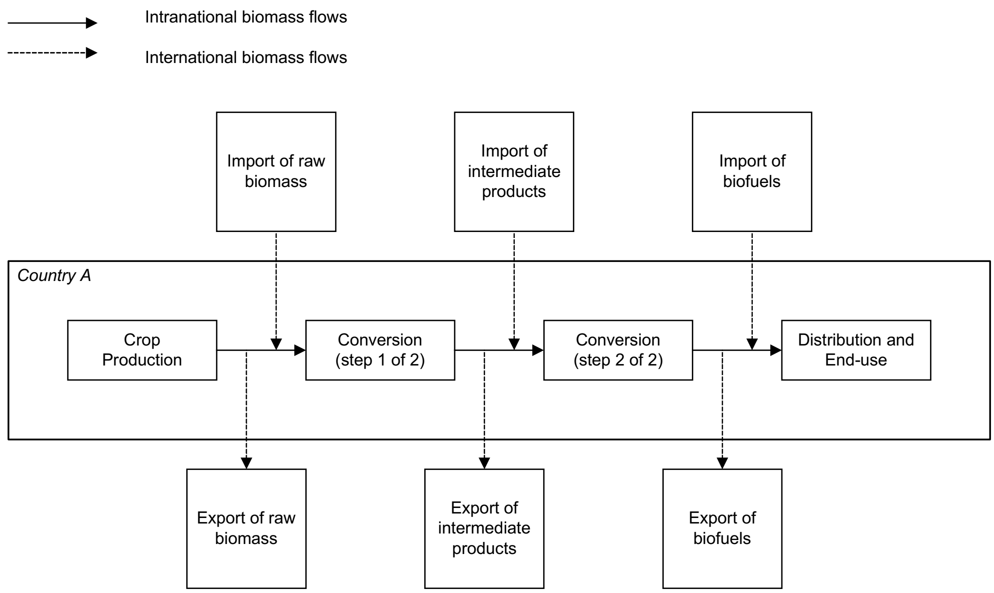

Fig. 1 – Material flows, including the import and export flows.

calculations (part of the model but not discussed in detail in this paper), the model takes the dominant crop per crop category per region into account. Otherwise, the specific crop does not matter. The cost and potential for biomass wastes and residues, liquid manure, agricultural residues, used fats and oils, forestry residues and wood processing residues, are specified on the country level [6].

At the model conversion nodes, the raw biomass is converted into intermediate products, pre-treated biomass or vegetable oil, or biofuels. The specific conversion costs take the prices of auxiliary input products or by-products (e.g. electricity surplus) into account at fixed prices. Full details on conversion costs build-up can be found in Wit et al. [7] and Deurwaarder et al. [6]. In Table 1, these are summarised.

The transport costs associated with the biomass flows take fixed transport distances into account for local and regional transport and assume truck transport. International transport costs are the least-cost choice out of the modalities of road transport, rail transport and short sea shipping, see Table 2. International transport costs use the border-to-border distances between countries. Raw biomass, intermediate products and biofuels can be imported from and exported to another country, see Fig. 1. Export outside the EU is not possible, and only two import flows from outside the EU are optionally allowed in BioTrans: unrefined palm oil from Asia, and bioethanol from South America. Both import flows have a time-independent import capacity at a fixed price.

The costs of distributing biofuels from the production facilities to the fuelling stations are included in the cost assessment. Up to and including the latter distribution costs, BioTrans gives a cost estimate for the biofuels. This cost estimate reflects the cost of delivering the biofuels to the consumers at the fuelling stations, albeit without profit margins and ignoring all the price dynamics. The final cost factor is the end use costs, the costs of using a biofuel in a vehicle. It is fairly arbitrary which costs should be included, only the engine costs, or the costs of the entire vehicle or perhaps even the infrastructure. As BioTrans considers only competition between biofuels, and does not look at the competition of biofuels against fossil fuels, the latter choice can be avoided by considering only the additional end use costs vis-à-vis those of fossil fuels. The changes to vehicles to use biofuels are limited and therefore easier to quantify. For cleaner-burning fuels, e.g. DME in trucks, these costs are negative as some exhaust cleaning components are not necessary, which outbalances additional costs for, e.g. the fuel

Table 3 – Distribution and additional end use costs assumptions [6].

Biofuel	Type	Distribution	End use pass. cars	End use buses	End use trucks
		Costs (€ GJ^{-1})	Costs (€ GJ^{-1})	Costs (€ GJ^{-1})	Costs (€ GJ^{-1})
Biodiesel	5% Blend	3.44	0	0	0
Biodiesel	100%	3.44	0.91	0.17	0.17
Bio-SNG	Compressed SNG	6.28	3.42	3.32	n/a
Bio-DME	Bio-DME	7.09	4	0.9	−0.43
Bioethanol (E5)	5% Blend	4.32	0	n/a	n/a
Bioethanol (E85)	85% Blend	4.32	0.85	2.49	n/a
Bio-FT-diesel	Fischer–Tropsch diesel	3.44	0	0	0

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Fig. 2 – Flow diagram of the BioTrans model.

tank. The end use costs are not modelled to be dependent on penetration level, as the end use costs for most for most biofuels are small compared to the full chain costs, see Table 3.

Fig. 2 shows the flow diagram of the BioTrans model, going from feedstock to intermediate product and biofuels via conversion processes taking the auxiliary input products and output products into account.

2.2. *Time dependencies in BioTrans*

BioTrans optimizes the total costs from base year 2005 to the time horizon of 2030 for each year consecutively, and the model has no foresight knowledge. The biofuel use must meet the predefined targets, defined either on a country basis, or as a single EU wide target. Biofuel production and use is computed by meeting the targets at the least-costs. Price dynamics are not considered in the model, nor the competition with fossil fuels. BioTrans results are quite independent of assumptions on fossil fuel prices. Only very indirectly, fossil fuel prices are present in parameter assumptions, e.g. in the costs of fertilizer that is used for the energy crop cultivation [4].

Most cost factors decline as a function of time, most notably the feedstock costs. The conversion costs decline as function of its use, where a distinction is made between 1st and 2nd generation biofuels. 1st Generation biofuels learn through cumulative production output ($GJ_{biofuel}$). For the 2nd

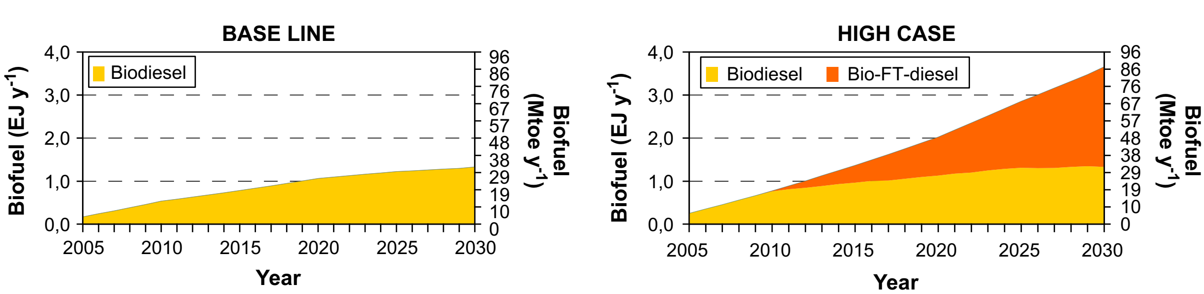

Fig. 3 – Biofuel mix in the base line run (10% share by 2030, left hand side) and in the high case run (25% by 2030, right hand side).

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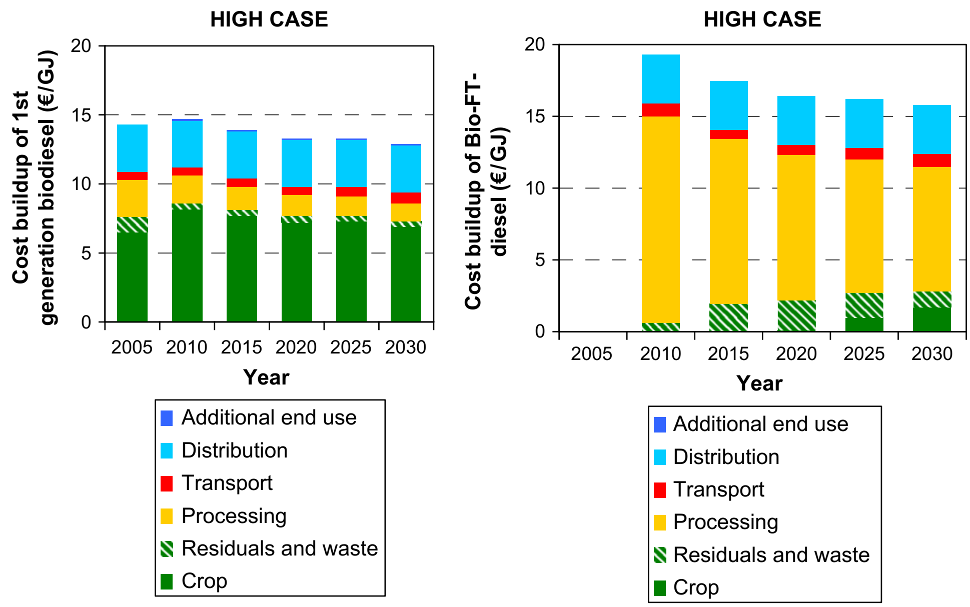

Fig. 4 – Biofuel cost build-ups for 1st generation biofuels (left hand side) and 2nd generation biofuels (right hand side). The former have high feedstock costs and low conversion costs, for the latter this is the opposite.

generation biofuels, it is considered that upscaling is the most important driver in cost reductions of emerging technologies. The upscaling is constrained by the size of the relevant biofuel market, by the rate of doubling of individual factory capacity and by the maximum scale. Only a small part of the costs can be reduced by scale-independent learning through cumulative production output. See [7] for an elaborate discussion. In the context of this paper, it is worth noticing that 2nd generation biofuels only learn if they are produced and used. More information on the input data used can be found in Fischer et al. [5,8] on crop potentials, in Wit et al. [4] on crop costs, in Deurwaarder et al. [6] on non-crops potentials and costs and in Wit et al. [7] on initial conversion costs.

3. Model validation

Various parts of the REFUEL project use the output of the BioTrans model. It gives information on the biofuel production and consumption mix, the costs (and cost build-up) of meeting a biofuel target and the associated greenhouse gas emissions. The model runs use an externally defined biofuels consumption target, and can incorporate various policy measures.

Model validation in this paper means determining whether the BioTrans model behaves as intended. The validation of using the BioTrans model for assessing the impact of policies on 1st and 2nd generation biofuels requires that the model can produce at least one policy variant in which only 1st generation biofuels are produced and at least one policy variant in which both 1st and 2nd generation biofuels are produced.

Using the base line run, with a 10% biofuels share in 2030, the target is met with biodiesel from oil crops (see Fig. 3 left hand side). The high case run, with a 14% target in 2020 and a 25% target in 2030, shows lignocellulosics-based bio-FT-diesel entering the market (see Fig. 3 right hand side).

To understand the driving factor behind the possible introduction of 2nd generation biofuels, one looks at the cost build-up, which is typically distinct between 1st and 2nd generation biofuels. 1st Generation biofuels have high crop costs but low conversion costs, while 2nd generation biofuels have low crop costs and high conversion costs, see Fig. 4.

Fig. 4 shows the average costs of the biofuels. However, at the introduction point of 2nd generation biofuels, the marginal costs of 1st generation biofuels equal the marginal costs of their 2nd generation competitors biofuels. In the high case, the marginal costs for additional oil crop production rise sharply, see also Fig. 5. The sharp cost increase is caused by necessity to bring marginal, low productive and expensive

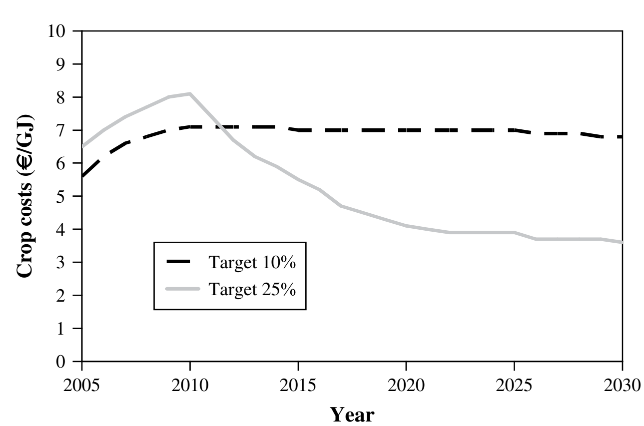

Fig. 5 – Rising oil crop costs facilitate emerging technologies (shown are the average crop costs, not the marginal ones).

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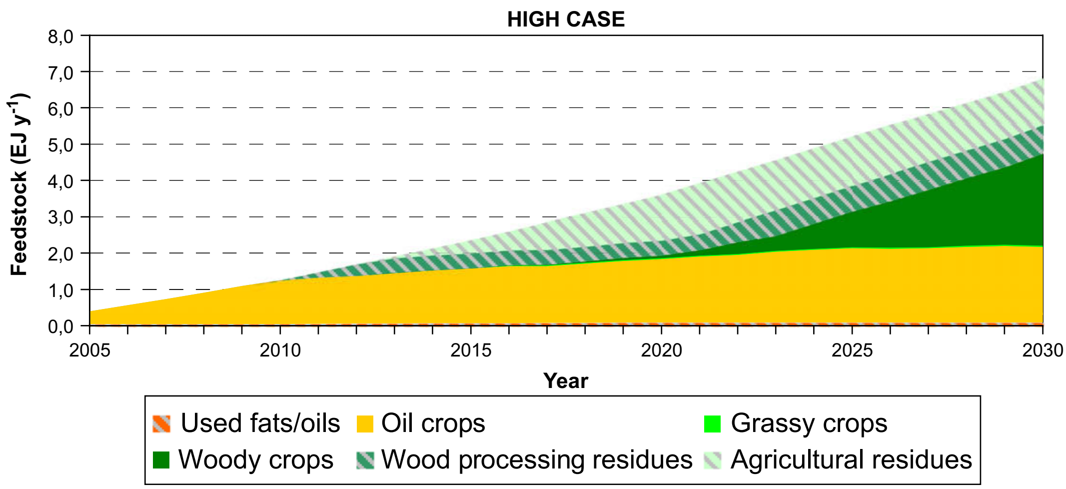

Fig. 6 – 2nd Generation biofuels first use residues as their feedstock.

land into crop cultivation. At this margin, a niche is created at which 2nd generation FT-diesel can be produced at lower costs than traditional biodiesel. The niche is sufficient for the 2nd generation biofuel to learn and reduce its costs.

Due to the stochastic approach of the crop costs, with a detailed cost-supply curve, the effects of niche markets for 2nd generation biofuels are well captured. The niche is created due to high costs for conventional energy crops, whereas the lignocellulosic biofuels can use relatively inexpensive residues. Only after some time, energy crops for lignocellulosic biofuels will be applied, see Fig. 6.

The ability of BioTrans to produce variants in which only 1st generation biofuels are produced and in which both 1st and 2nd generation biofuels are produced, is demonstrated. The dynamics behind its ability are connected to the stochastic approach for the feedstock costs for 1st generation biofuels. As such, niche markets are simulated that are often essential for emerging technologies. These are considered necessary preconditions for using the BioTrans in the assessment of biofuels promoting policies.

4. Main results and implications for policy

Key results discussed here refer to cost structures, lock-in risks, bifurcations and other path dependencies, and the effect of setting high targets.

4.1. *Biofuels cost structures*

BioTrans clearly shows that 1st generation biofuels have high feedstock costs that are correlated with food and feed production rather than the volume of biofuel. Conversely 2nd generation biofuels have feedstock costs that decline with increasing biofuel production. The dynamics of competition between existing and emerging technologies are discernable in the model outcome; it seems that the competition is captured well by the model. Therefore, the model is suitable to evaluate the effects of policy options on this competition.

4.2. *Lock-in of existing technologies – getting over the initial investment hurdle*

The presence of sufficiently low cost crop potential, combined with the initial high conversion costs of 2nd generation biofuels, creates a lock-in effect favouring traditional biofuels. In theory, this lock-in effect is removed by imposing a sufficiently high biofuels target. The adverse effects such a high target might have, such as risking detrimental environmental effects, high margins on the prices due to shortages, etc, does not make it a very appealing measure in itself. But other supporting policy measures are conceivable, aiming at reducing the conversion costs for the producer, e.g. by granting investment subsidies. Note however, that also adverse policy is possible: Increasing land premiums for farmer can

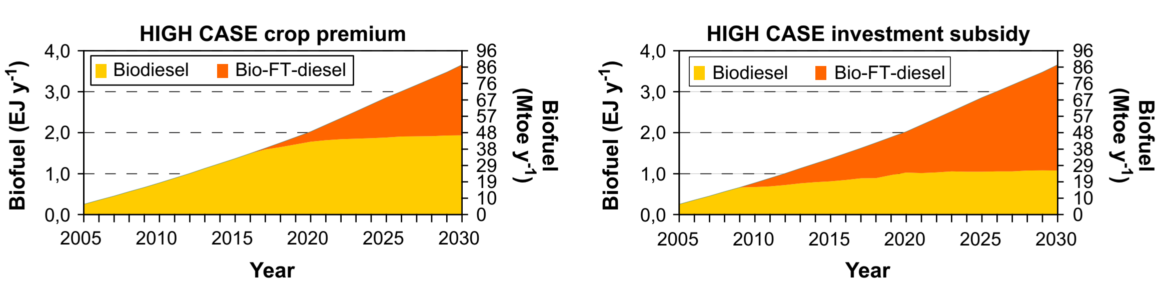

Fig. 7 – Impacts of an energy crop premium per ha (left hand side) and of an investment subsidy (right hand side) on the penetration of 1st and 2nd generation.

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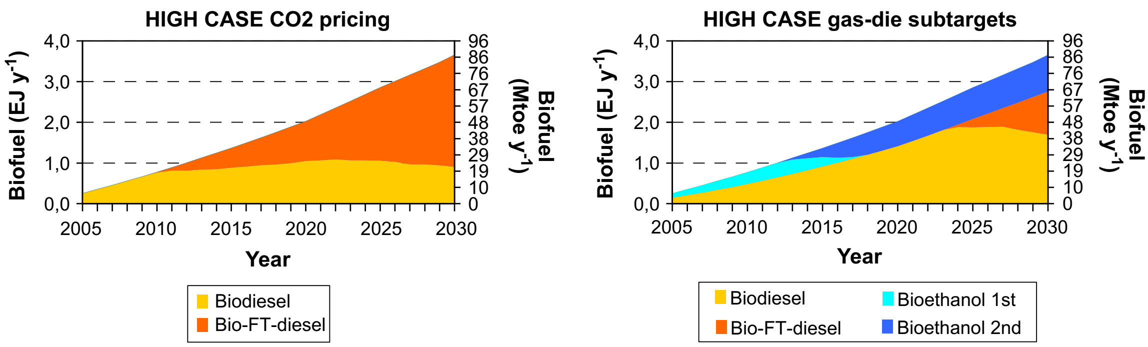

Fig. 8 – Biofuel mix if CO_2 pricing is included (left hand side, and if gasoline and diesel markets must comply with the target separately).

actually favour traditional biofuels, if the premium is paid per hectare. After all, traditional energy crops have lower yields per hectare, thus a higher benefit of the premium in euro per energy content. In BioTrans, a premium of 40 euro per hectare leads to a delay in introduction time of 2nd generation biofuels of about 5 years, see Fig. 7.

The time of 2nd generation biofuels entering the market depends on the opportunity that is created by high conventional feedstock costs. Lower biofuel targets hamper the creation of these opportunities. In the moderate case (15% biofuel target in 2030), the introduction is delayed by several years to around 2017. Setting a high target seems to be an effective way of promoting the market introduction of 2nd generation biofuels. However, the side effects in terms of the impact on nature, the impact on food prices and the resulting instability of public opinion and policy, need to be addressed. Setting a high biofuels target alone, might not be sufficient for successful market introduction of 2nd generation biofuels. Crop premiums are a further hindrance for 2nd generation biofuels, thereby possibly aggravating the side effects. On the other hand, investment subsidies soften the side effects and lead to greater investor confidence in the 2nd generation biofuels market.

4.3. *Bifurcations – aiming for portfolio approach*

The myopic character of the BioTrans optimization facilitates the inclusion of endogenous learning. However, it cannot compute the optimal path to a least-cost biofuel production solution. It is known [9] that several solutions may be near optimal, with quite different transition paths and end solutions. Results of BioTrans show that different policies may lead to different biofuel mixes in 2030 (see Fig. 8), but against roughly the same costs (Fig. 9).

Compare two cases, both against a target of 25% in 2030. In the left hand side of Fig. 8, a CO_2 price of up to 70 € t^{-1} is included in the costs. In the right hand side of Fig. 8, no CO_2 price is added, but the biofuel target is specific into separate targets of 25% gasoline replacing biofuels and 25% diesel replacing biofuels. In the latter case, cellulosics-based ethanol develops rather soon, while the introduction of lignocellulosics-based biodiesel is postponed for more than a decade.

After a transitional period between 2005 and 2015, the average costs of both cases converge at 16 € GJ^{-1}, although the biofuel mix is different, see Fig. 9. In the example mentioned, the starting conditions in 2005 are different since policy measures in place are different. However, it is likely that almost identical starting conditions can lead to very dissimilar end conditions.

4.4. *Path dependency – creating niche markets*

To show the robustness of the model outcome with respect to the specific biofuels, Monte Carlo analyses were performed. Only a limited number of countries were included, of which the combined cost-supply curve of bioenergy crops, relative to the biofuel demand, resemble the full cost-supply curve of Europe. In Fig. 10, the probabilities of specific biofuels being produced in 2030 are shown (market share more than 1%). Clearly shown is the lock-in effect of 1st generation biodiesel. If the target is too low, the chances of 2nd generation biofuels remain very small. If the target is sufficiently high, the probability of 2nd generation biofuels to enter the mix is significant, but the type of biofuel remains uncertain. In the high case Monte Carlo analysis, bio-FT-diesel enters in 65% of the runs, bio-DME in 15% of the runs, and lignocellulosic ethanol in 25% of the runs.

Due to the nature of optimization and the uniformly modelled cost structure of 2nd generation biofuels, the results are generally radical in choosing a biofuel to be produced. For

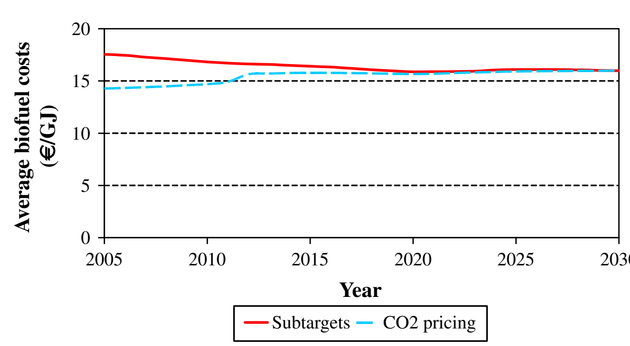

Fig. 9 – Average biofuels costs converge at 16 € GJ^{-1}, for both runs in Fig. 8.

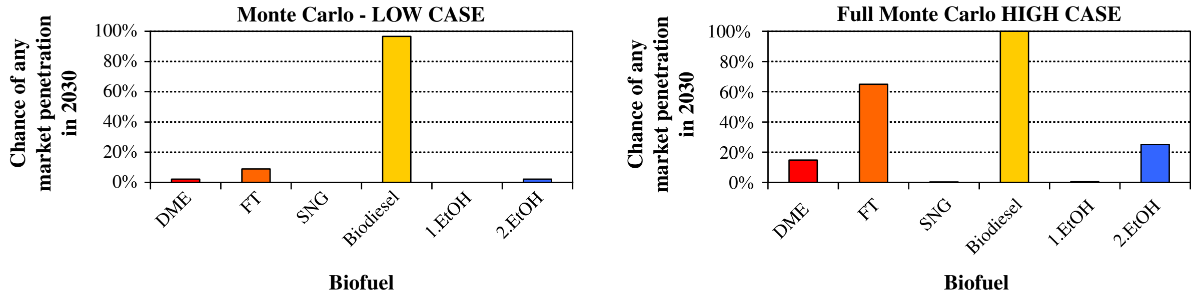

Fig. 10 – Probabilities of market penetration for biofuels given a target of 10% (left hand side) and 25% (right hand side) in 2030.

example, if DME compared to Fischer–Tropsch-biodiesel can be produced at lower costs in country x, it will probably have the same profit edge in country y. Thus, the entire model shifts in its mix to bio-DME, even though the cost differences between DME and FT-diesel might not be significant. However, due to this shift, DME is produced in the model, learns in the model, and achieves cost reductions, while FT-diesel remains expensive - thereby locking-in the favourable position of DME among the 2nd generation biofuels. Given these, and the often not significant differences in parameter assumptions for the various second generation technologies, it is better to interpret the BioTrans results while speaking in general terms of introduction of 2nd generation biofuels rather than of introduction of specific second generation biofuels.

The optimization behaviour dictates that the winner takes it all. Risk spread suggests that it is better to aim for the introduction of more than one new technology. Although niche markets might exist in real-life, even in the case of undiscriminating support policies, favouring the introduction of more than one new technology in the market, policies should also try to promote the existence of niche markets in the deployment phase of the emerging technologies. The cost reductions in BioTrans suggest that several 2nd generation biofuels might develop simultaneously without compromising the speed of the future cost reductions, see, e.g. Fig. 9.

4.5. *Setting a high target for fast development*

Generally speaking, one of the motives of promoting 2nd generation biofuels is the expected cost reduction of these

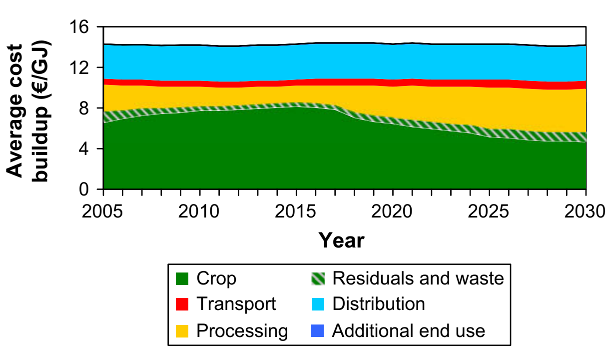

Fig. 11 – Biofuel costs (€ GJ^{-1}) in moderate case.

biofuels on the long run. However, the biofuel targets are also set to rise steadily. The increase in crop costs is about compensated by the decline in conversion costs. As a consequence, the average biofuel cost in euro per GJ remains fairly constant. A successful introduction of 2nd generation biofuels into the market creates an opportunity in which biofuel targets can increase steadily, without a significant price increase per liter of fuel, see Fig. 11.

2nd Generation biofuels are supposed to have several advantages over 1st generation biofuels, of which the expected cost decrease is one. Steadily rising and firm biofuel targets can help reaching these cost decreases. However, the firm biofuel targets also lay a significant claim on available biomass, causing the production costs of biomass to rise. The cost decrease in the conversion processes might just be cancelled out by the increase in biomass costs.

5. Conclusions and discussion

The computations with the BioTrans model show the dominance of oil crops based biodiesel even with high biofuel targets. Conventional biodiesel occupies the most inexpensive part of the cost-supply curve throughout the considered period of 2005–2030. In the expensive part of the cost-supply curve, a transition towards 2nd generation biofuels might occur, if the demand for biofuels is sufficiently large. This transition might cause a period of resource scarcity, stress on nature and high price volatility. To combat these adverse indirect effects, it is recommended to formulate additional policy to soften these transition effects. In the interest of harvesting public support for biofuels policies, it should be noticed that cost decreases in conversion processes might not be reflected in lower prices for consumers. It seems safer, if one aims at stable biofuels policies, to advocate the stimulation for 2nd generation biofuels on other grounds than cost developments.

As the 2nd generation biofuel production is still in its demonstration phase, a portfolio approach on the different 2nd generation biofuels significantly mitigates the risk of technology setbacks. Given the relation between gasoline and diesel markets, 2nd generation biofuels might develop in both the gasoline and diesel markets. The market in itself might not produce a portfolio of 2nd generation biofuels for both submarkets. Thus policy aiming at developing a portfolio of

2nd generation biofuels warrants additional measures, e.g. to create niche markets.

Endogenous learning for emerging technologies gives better insight in cost structure and cost reduction in the future. Specific attention for robustness of results is necessary (specifically with regard to the level of detail). Endogenous learning has not been difficult to implement in BioTrans, as it is a myopic optimization model. The model remains a single-year lp optimization model. However, the model behaviour over the years is more difficult to interpret. Some distinctions that the model makes, e.g. the specific 2nd generation biofuels, do not lead to robust differences. Endogenous learning in cost models can take more parameters into account for cost reduction prognoses than traditional learning curves present. Learning in emerging conversion technology does not only depend on the traditional learning effect of cumulative production, but also on the rate at which the technology is up-scaled to achieve significant cost reduction per unit throughput. How fast new installations can increase the size is important for cost reductions for emerging technologies. At the same time, this size increase depends heavily on investor confidence, which is not explicit part of the model. The time of emergence of new technologies is a divergence point in the model. Minor, insignificant variations can cause major changes in the 2030 biofuel mix.

BioTrans can exhibit complex behaviour, among which lock-in effects, path dependencies and bifurcations. Lock-in effects and bifurcations do have their real-life counterparts. Bifurcations can be illustrated using computational models. Bifurcations seem to imply that one cannot always identify the best biofuel mix to strive for. And as long as the support for technological innovation for one technology does not seriously hamper the technological innovation for another technology, it is better to adopt a portfolio approach and support both technologies.

The dynamics between existing and emerging technologies are captured well in BioTrans, among which the lock-in effects of existing technologies. It is a necessary prerequisite if one wants to use the model for designing policies to overcome these effects. The competition between specific emerging technologies is captured poorly. The chances for the different 2nd generation biofuels result mainly from cost assumptions in 2010, and not on other important differences, such as compatibility or developments in the vehicle fleet. However, BioTrans can show how different policy measures impact the chances in a comparative analysis. Macro-economic dynamics, such as rising food prices and decreasing prices of by-products, are not considered in the analyses shown in this paper. BioTrans will be committed in the ELOBIO research project to examine the dynamics of the latter kind.

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