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The REFUEL EU road map for biofuels in transport: Application of the project's tools to some short-term policy issues

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ABSTRACT

The current hot debate on biofuels calls for a balanced and realistic long-term strategy for biofuels. The REFUEL project provides several ingredients for such a strategy. Analyses in this project indicate that domestically produced biofuels can cover a significant share of EU fuel demand in the coming decades, with the EU-12 new member states and Ukraine as most promising regions. This potential can be realised with residual streams and on existing agricultural land, without conversion of e.g. nature reserves. Second generation biofuels are essential for the long-term success of biofuels due to their superior performance in many ways. But generally, the key challenge for the near future would be how to enhance the development of biofuels in a responsible way, i.e. stimulating the production chains with the best performance, and preventing negative impacts e.g., by paying careful attention to possible system impacts of biofuel production such as indirect land use changes and rising food prices. Finally, 2nd generation biofuels require specific policy: the precursor role of 1st generation is overrated, both in technical terms as well as in their role as market precursors. When it comes to synergies, 2nd generation biofuels might benefit more from other developments in the energy sector, such as initiatives in co-firing of biomass for (heat and) power, than from 1st generation biofuels, also because of the public resistance that the latter induce.

1. Introduction

Biofuels production and consumption in the European Union are growing rapidly at the moment. With this tempestuous short-term development comes the need for an integrated long-term vision for biofuels. The REFUEL project contributes to this vision formation. In this project, funded by the Intelligent Energy Europe programme, seven EU institutes of

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different backgrounds have analysed the prospects for biofuels in terms of resource potential, costs and impacts of different biofuels, effects of different policy strategies, and broader system impacts of biofuels [1–8]. For this paper, we applied the key REFUEL tools and findings to the policy challenges of today. We focus on three important elements in biofuels development:

- Potential availability of land and feedstock for biofuels; indicating that there is a vast potential in Europe, even sufficient to meet a 10% biofuels target by conventional 1st generation biofuels;
- The drawbacks of such a future, and the importance of 2nd generation biofuels in the light of the underlying drivers for biofuels;
- Policy strategies for the enhancement of 2nd generation biofuels.

2. The EU 2020 objective and biofuels potentials

2.1. EU ambitions

In its proposal for the new renewable energy directive, the European Commission set out a number of frame conditions for the future development of biofuels. Key ingredients are:

- A binding minimum target of 10% by 2020. In contrast to the renewable target of 20%, which is differentiated among the member states, this target applies to every country.
- A minimum greenhouse gas emission reduction of 35% compared to fossil fuels. On the basis of current knowledge on greenhouse gas balances for biofuels, this minimum level is attainable for all common biofuels of today and for the longer-term options.
- Possible competition for resources between biofuels and biomass use for renewable heat and power is not explicitly mentioned in the directive.

The proposal also contains a specific incentive for 2nd generation biofuels: any biofuels produced from lignocellulosic materials should count double towards a national biofuels target. However, as it is unclear how such a policy would affect the opportunities for 2nd generation biofuels (as further specified in Section 5) our first analysis focuses on biofuels potentials regardless of this double-counting option.

2.2. Meeting the 10% target

On the basis of the REFUEL assessment of feedstock potentials and full-chain biofuels costs, we analysed the least-cost biofuels mix that would meet the proposed 10% biofuels target by 2020. For this exercise, we used the Biotrans model [5], with the feedstock settings as specified in Wit et al. [4]. Additional assumptions were that imports from outside Europe would account for 30% of the target and that other bioenergy sectors would put no claim on agricultural land. When the Biotrans model [5] is run under these conditions, the fuel mix meeting the demand for biofuels solely consists of 1st generation biofuels (mostly biodiesel). This appears to be the most cost-effective model solution to meet the target. Particularly the Eastern European countries and Ukraine have the resource potential to produce the required amounts of feedstock at low costs: of total European feedstock production in such a future, more than half would be produced in the EU-12 new member states, more than one-third would come from Ukraine, and less than ten percent would be produced in the EU-15.

In such a future, the introduction of 2nd generation biofuels is hampered by the high initial investment costs and corresponding biofuel production costs of the first installations. As feedstock for 1st generation biofuels is available against relatively low costs, these fuels prevent the introduction of 2nd generation biofuels. In our analysis, it appears even possible to meet a 15% target cost-effectively by 2030 using conventional fuels, mainly produced from European feedstock.

3. Objections to a development pathway with mainly 1st generation biofuels

A 10% biofuels share in 2020 with conventional biofuels may be achievable and cost-effective, but does such a future align with the reasons why biofuels have been proposed? There are grounds for considerable doubt. Key reasons are:

3.1. Conventional biofuels only have modest greenhouse gas emission savings

One of the key motivations behind biofuels is the reduction of greenhouse gas emissions from transport. Most conventional biofuels have greenhouse emission reductions between 40% and 60% compared to fossil fuels, while advanced biofuels such as lignocellulosic ethanol and FT-diesel are assumed to achieve emission reductions above 80%. This is mainly due to higher land use efficiency and lower agro-chemicals' requirements. Therefore, it is questionable whether a biofuels mix dominated by conventional biofuels is a sufficient way of responding to the climate challenge. This is illustrated by several REFUEL chain analyses: if, for example, a CO_2 emission pricing mechanism is introduced in transport, the competitiveness of 2nd generation biofuels improves significantly.

Growth of conventional biofuels may cause negative effects on the environment. For reaching higher land use efficiencies (energy output per hectare) conventional biofuels grown in temperate Europe usually require high input agricultural management systems. Unless managed cautiously, there is concern that increased fertilizer and pesticide use may cause water and soil pollution, as with food crops. In contrast, production of lignocellulosic feedstocks allows less input-intensive cultivation practices. Therefore, the production of lignocellulosic feedstocks tends to be environmentally less harmful than production of 1st generation conventional crops.

3.2. Conventional biofuels require significant amounts of agricultural land and directly compete with food production

Reducing fossil oil dependency is the other key motivation for biofuels. As such, any biofuel will basically do. However, as

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cultivation of feedstock requires land, there is a risk that improved energy security would come at the expense of deteriorated food security. Therefore, land-efficient biofuels, with high biofuel yields per hectare, would be advantageous. In this respect, 2nd generation biofuels have several benefits. Firstly, these biofuels can use a range of agricultural and wood-related residues as their feedstock without any direct claims on land. Secondly, the land use efficiency of 2nd generation biofuels is a factor two to four higher than that of 1st generation biofuels (see Fig. 1), leading to less land required per unit of energy produced. Thirdly, a wider spectrum of land could be available for these feedstocks. Notably grasslands not viable for 1st generation biofuels due to environmental and greenhouse gas implications, could become an additional resource for high-yielding lignocellulosic feedstocks under zero tillage practices. In addition, marginal areas could be considered for feedstock production under low input agricultural management systems. In short, meeting a specified biofuels target by 2nd generation biofuels entails less direct competition for land with food and feed production, and reduces the risk of price hikes.

Land efficiency may become even more critical if ambitious targets for renewables also induce demand for dedicated energy crops for power, heat and biomaterials. As an illustration: a REFUEL analysis in which we reduced feedstock potential due to demand for other applications directly leads to an increase in the share of 2nd generation biofuels. In such cases, the relatively limited availability of land directly pushes the higher yielding crops into cultivation.

3.3. *If 10% is not the end term for biofuels, 2nd generation biofuels will become more competitive*

Finally, it would be a bit too simplified only to look at 10% biofuels by 2020. First, a sustainable long-term development will most probably call for further growth of the share of renewable fuels after 2020. Second, it remains to be seen whether the EU will meet its overall 20% renewable target with a 10% share of biofuels in transport. For example, the German sub targets for meeting the 20% renewable target include a 17% target for biofuels. However, with increasing ambitions, the urge for biofuels to be land-efficient will only be stronger. Illustrative in this context is a REFUEL analysis with targets up to 14% by 2020 and 25% by 2030 (see Fig. 2): in these analyses, the most cost-effective biofuels mix contains a significant share of 2nd generation biofuels.

3.4. *The development of 2nd generation biofuels would require innovation, improving the EU's position in an emerging market*

A future more sustainable energy economy will strongly depend on technologies allowing low-grade feedstock to be converted into high-value energy carriers. By taking early steps in the domain of these types of technologies, the EU could reach a strongly competitive position on an emerging international market with substantial export opportunities. Furthermore, once the initial cost barrier for 2nd generation biofuels is overcome, technological learning leads to substantial cost reductions improving the competitiveness of these fuels compared to 1st generation biofuels.

3.5. *Second generation biofuels create less (low-educated) employment in agriculture, but more (high-educated) employment in an innovative industry*

A final argument on biofuels and renewable energy in general is that they enhance the development of a sustainable and competitive new industry, including new employment. However, analyses in REFUEL clearly indicate that 1st generation biofuels use relatively conventional conversion technology. The major part of the employment creation takes place in rural areas – mainly in the agricultural sector – involving relatively low-qualified employment. On the other hand, 2nd generation biofuels create more highly qualified employment in the industrial sector. From a neoclassical economy perspective however, the use of employment creation in nations as a rationale for energy policies for bioenergy can be questioned.

4. Perspectives on biofuel policy

Working only with a biofuels target of 10% by 2020 may lead us to a biofuels mix that is cost-effective in strict terms, but less

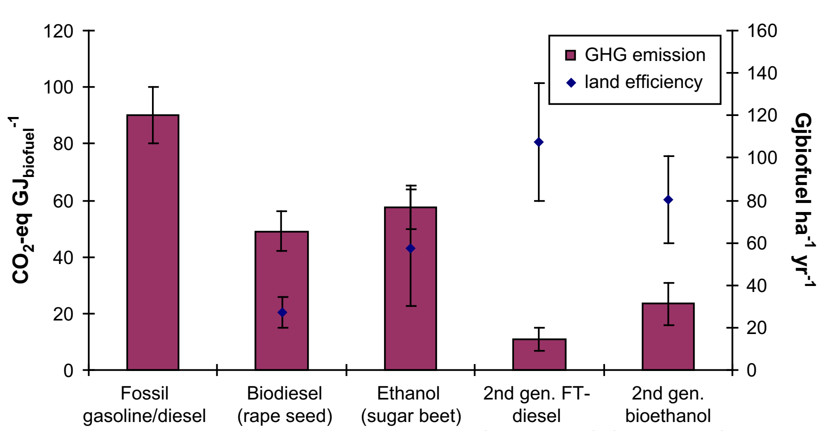

Fig. 1 – Greenhouse gas emissions and gross annual biofuel yields per hectare for the most common biofuels, on a well-to-tank basis. GHG data source: JRC/CONCAWE/EUCAR [9], land efficiency based on REFUEL calculations [3,4].

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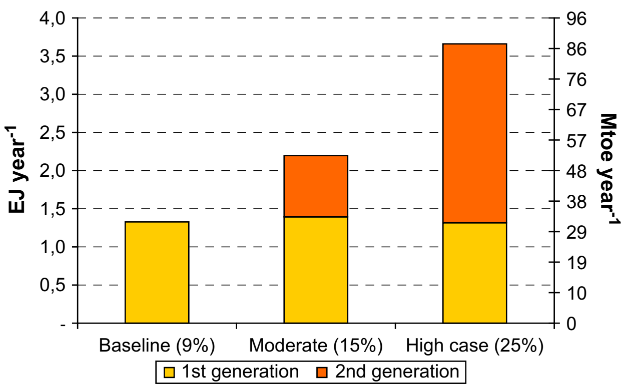

Fig. 2 – Split between 1st and 2nd generation biofuels by 2030 at different levels of total production if the target is met by European biofuels only.

attractive when we take the underlying interests in biofuels into account. Next question would be how to translate these interests into additional policies. A first-order option would be to include a specific subtarget for 2nd generation biofuels. But in order to broaden the minds, we conducted some supportive analysis on biofuels development if we start our reasoning by the key underlying motivations for biofuels, and define (sets of) policy measures consistent with these motivations.

4.1. *Policy perspectives for biofuels*

Therefore, we defined three *policy perspectives* for biofuels related to their key drivers, as a basis for discussion.

- A *climate protection perspective*. In this perspective, biofuels are chiefly introduced as a measure to reduce greenhouse gas emissions. They are part of several measures to reduce these emissions: increasing energy efficiency, renewable power and heat, etc. As biofuels are generally considered a relatively expensive option in terms of costs per tonne of avoided CO_2, priority is set to the use of biomass in the stationary sector and biofuels have a moderate target.
- An *energy security perspective*. In this perspective, security of energy supply is considered the dominant issue to be addressed. As the transportation is the sector with the highest (forecast) fuel import dependency, and oil is the fossil fuel with the lowest reserve-to-use ratio, there is a high ambition level for biofuels, with a more moderate attention for biomass in other sectors.
- A *competitiveness and innovation perspective*. In this perspective, enhancement of an innovative and competitive EU industrial sector is the key driver for biofuels. As biofuels, and specifically the 2nd generation, are generally products with relatively advanced and innovative production processes to substitute are relatively expensive fossil fuel (compared to e.g. co-firing of biomass in coal-fed power plants), the ambition level for biofuels is high, specifically for 2nd generation biofuels.

Furthermore, we defined a couple of perspectives that address other arguments in the biofuels debate. These are:

- A *biodiversity perspective*. Possible detrimental effects of biofuels on (EU and global) biodiversity are often used as an argument against biofuels. This perspective is a combination of measures aiming at the prevention of such effects.
- An *agricultural support perspective*. Support of agriculture in the EU has always been one of the motives for biofuels. This perspective is based on a preference for this argument

As a final contribution, we defined a 'REFUEL' perspective; a set of measures that we as a team of experts consider an ambitious but balanced approach to biofuels given their underlying drivers and the possible critical factors.

These perspectives were translated into policy packages as given in Table 1. Such a translation is by nature subjective, but it provides a fair range of possible policy mixes to show the impacts.

4.2. *Analysis of the perspectives in REFUEL*

An evaluation of biofuels development subject to these policy packages shows substantially different results compared to the developments when only the 10% target is applied.

- First, there is an earlier introduction of 2nd generation biofuels in all perspectives. The introduction year varies between 2010 and 2015, which is ambitious but possible given the developments in the related technologies.
- By 2030, 2nd generation biofuels dominate in all perspectives (see Fig. 3). The dominance is clearest in perspectives with high ambitions for biofuels, but also packages based on a strong environmental perspective (such as the Kyoto and biodiversity perspectives) induce a major development of 2nd generation biofuels. Even in the agricultural perspective, the high ambition level finally necessitates the introduction of these biofuels.
- In terms of feedstock use, 2nd generation biofuels first start consuming agricultural and wood processing residues, and only after this low-cost feedstock has run out of potential, dedicated crops are being introduced. By 2030, roughly one-third of 2nd generation biofuels is still based on residues (see Fig. 4)
- Obviously, these perspectives show substantially better greenhouse gas emission reductions than the 'base' policy with a 10% target alone. For example, while a biofuels mix dominated by 1st generation biofuels reduces greenhouse gas emissions by roughly 40% compared to fossils, the innovation perspective increases this reduction to more than 90%.
- In terms of land efficiency, the strong role of 2nd generation biofuels leads to significantly higher average biofuel yields per hectare than in the 'base' policy.
- In terms of costs, policy packages inducing higher shares of 2nd generation biofuels also lead to higher average costs per GJ biofuel. However, this cost increase lies in the order of 1 € GJ^{-1} (or several cents per litre), given the approach and limitations of this study.
- An early start with advanced biofuels leads to biofuels that better meet the drivers behind biofuels promotion than the conventional mix, and an early start also leads to an earlier cost reduction.

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Table 1 – Translation of different perspectives on biofuels into policy packages.

Policy measures	Policy making priority			Critical issue		Team
	GHG	SES	Innovation	Biodiversity	Agriculture	'REFUEL'
Biofuels target pathway[a]	Moderate	High	High	Moderate	High	High
Ambition levels RES-E, H[b]	High	Moderate	Moderate	Moderate	Low	High
Ex-EU import levels[c]	High	None	None	Limited	None	High
GHG pricing[d]	Yes	No	Yes	Yes	No	Yes
Energy cropping premium[e]	No	Yes	No	No	Yes	No
Investment subsidies[f]	Diff	Yes	Yes	No	No	No
Specific targets 2nd gen.[g]	No	No	Yes	Yes	No	Yes

a High pathway: 5.75% (2010), 14% (2020), 25% (2030). Moderate pathway: 5% (2010), 10% (2020), 15% (2030).
b Low ambition level for RES-E/H: 80% of feedstock potential for biofuels. Moderate: 60% of feedstock potential is for biofuels. High: 40% of feedstock potential is for biofuels.
c High: imports' potential is 13 Million tonnes of bioethanol against € 280 m^{-3}, and 10 Million tonnes of palm oil against € 220 t^{-1}. Maximum import share is 30% ('high'). 'Limited' excludes palm oil, none excludes all imports.
d Yes: CO_2-eq pricing starts with € 20 t CO_2^{-1} in 2012 and increases linearly to € 70 t CO_2^{-1} in 2030.
e Yes: subsidies calculated as the number of eligible farm hectares [ha] × regional reference yield [t ha^{-1} yr^{-1}] × direct payment [€ t^{-1}] × rate of aid [%] (current method for cereals and oil crops). For an average regional yield of 5 t ha^{-1} of cereals this results in: 1 [ha] × 5 [t ha^{-1}] × 63 [€ t^{-1}] × 80 [%] = 252 € ha^{-1} yr^{-1}.
f Yes: investment subsidy for conversion technology of 50% for all technologies.
g Yes: subtarget of 2.5% of all biofuels for 2nd generation in 2011, increasing linearly with 2.5% a year to a 50% share in 2030.

- In terms of employment effects, there is a clear difference between the 'base' policy and the perspectives discussed here. The high share of 2nd generation biofuels leads to less (lowly educated) employment being created in agriculture, but there is more (highly educated) employment created in industry. Especially in agriculture, these impacts are relatively minor compared to total employment in the sector, and in both sectors the impacts will (partly) be counterbalanced by indirect effects.
- There are several ways to increase the share of advanced biofuels, given these perspectives. Specific policy for 2nd generation may be the easiest, but other options are also possible.

5. Strategies for 2nd generation biofuels: how to pave the way?

As shown, 2nd generation biofuels can be considered crucial for a responsible development of biofuels that significantly contribute to climate change mitigation and energy security. Their development however, requires actions from different stakeholders, varying over time and a manifold of measures can be conceived to support this process. Key REFUEL findings provide several contributions to this process, as summarised in this section.

5.1. *Current policies hardly pave the way for 2nd generation biofuels*

In defense of current biofuel policies, it is often argued that 1st generation biofuels are essential for the development of their 2nd generation successors. We feel that this role is often overrated. In technical terms, the argument does apply to a certain extent to ethanol production, as a 2nd generation ethanol plant partly uses the same process steps (fermentation, distillation, etc.). Biodiesel production technology, however, is in no way relevant for the 2nd generation diesel substitutes such as FT-diesel.

Furthermore, the cost build-ups and related risk profiles of 1st and 2nd generation biofuels differ greatly (see Fig. 5): due to their high investment costs, 2nd generation biofuels require a more stable investment climate and related biofuel prices. As a consequence, current biofuel policy mechanisms that are effective in creating a market for 1st generation biofuels may not create a sufficiently stable environment for investments in 2nd generation options.

Current biofuel policies may not be a pathway to a long-term perspective for biofuels as there are also other issues that are affecting their evolution: (1) the required shift towards higher blends; (2) farmer inertia to a switch to perennial crops from annual row crops, and (3) public

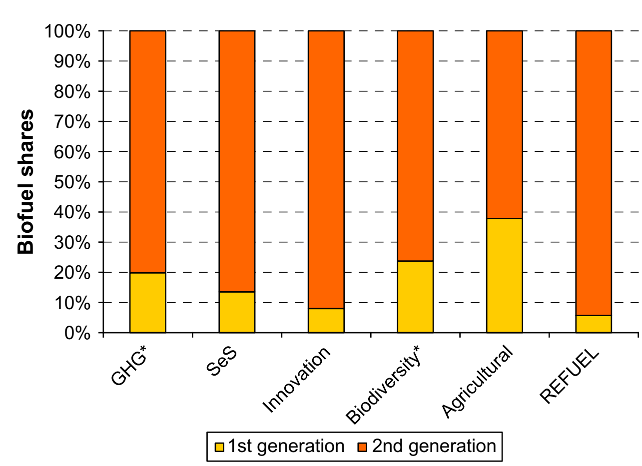

Fig. 3 – The 2030 balance between 1st and 2nd generation biofuels in the different perspectives, indicating the effect of the different policy packages.

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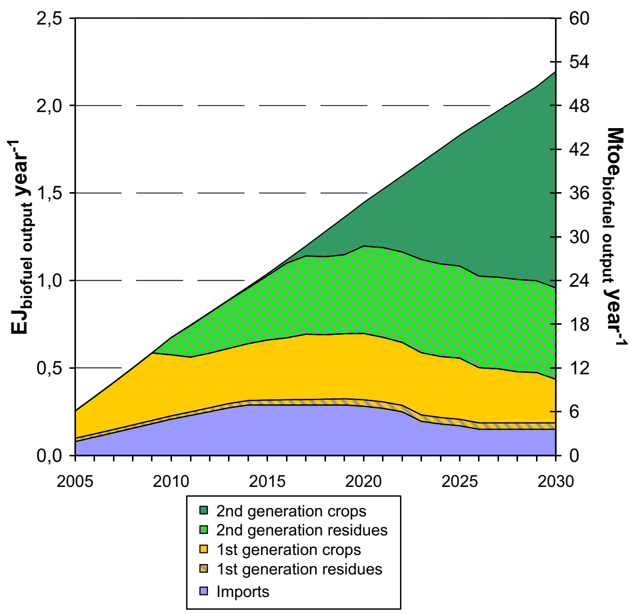

Fig. 4 – Biofuels development and their feedstock base in the policy package based on the Kyoto perspective.

resistance generated by 1st generation biofuels that may affect the adoption of the 2nd generation.

5.2. *Development of lignocellulosic feedstock supply*

The introduction of 2nd generation biofuels will require the establishment of new feedstock supply chains of lignocellulosic materials. This will require technical, institutional and even legal changes, which probably require supportive policy to be established in a consistent way. Key points of attention are:

- The support for research on cultivation practices of perennial crops. As European experience with the production of lignocellulosic feedstocks is limited, additional research is required for optimizing management of lignocellulosic energy crops for the across Europe.
- Large-scale production of lignocellulosic feedstocks implies a major land use conversion to crops with plantation cycles of 10–20 years. Such a development needs careful considerations beyond agronomic and economic factors. In particular, potential uses of some arable land for perennial energy crops would have to be reflected in regulations and spatial policies both at the national level and in the Common Agricultural Policy (CAP).
- Furthermore, cross-sector policy harmonisation would be required to enhance these new supply chains, as well as the development of lignocellulosic markets able to absorb large-scale supply chains.

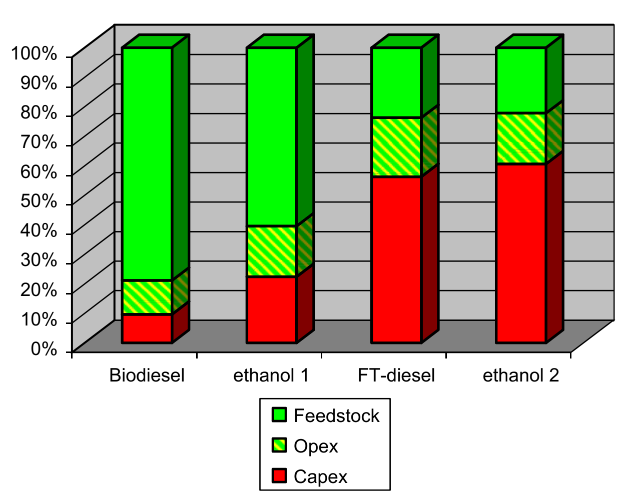

Fig. 5 – Shares of feedstock costs, OPEX and CAPEX in cost build-up of key biofuel chains. Representative Biotrans case.

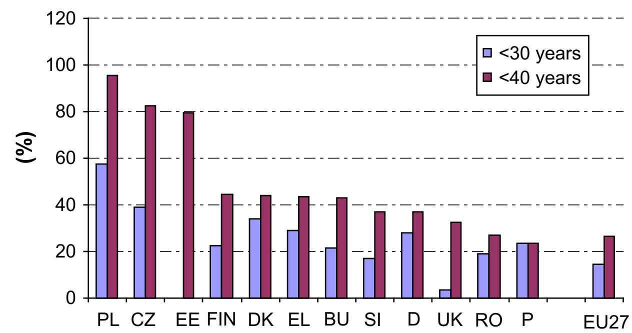

Fig. 6 – Current biomass co-firing potential in coal-fired power plants as a share of the amount of biomass needed to meet the 10% biofuels target in 2020. Top-12 EU member states and EU27 average, power plants < 30 and < 40 years old are assumed to be used for co-firing.

5.3. *Stepping stones for the introduction of 2nd generation technologies*

In order to reduce the initial risks for 2nd generation production installations, stepping stones may be created by finding synergies with other parts of the energy sector. For example, initial establishment of biomass co-firing in existing coal-fired power plants would prepare stable feedstock supply that can later be used for 2nd generation biofuel production. The potential for biomass co-firing in existing power plants is sufficient to provide a significant start-up for these supplies (Fig. 6). Also integration of gasification-based biofuels plants in district heating systems may lead to benefits (output diversification).

6. Conclusions

6.1. *Domestically produced biofuels can cover a significant share of EU fuel demand*

Given the extensive resource potentials that gradually open up in the coming decades, particularly in the EU-12 new member states and Ukraine, Europe will be able to produce biofuels sufficient than 10% of EU gasoline and diesel demand by 2020 and beyond. This potential can be realised on existing agricultural land, without conversion of e.g. nature reserves.

6.2. *Second generation biofuels are essential, and biofuels development requires careful policy making*

In terms of biofuel chains, the development of 2nd generation biofuels seems to be essential for a long-term future of biofuels. Their environmental performance is superior to that of 1st generation biofuels, in terms of greenhouse gas emissions of the production chain, broadness of the feedstock base and biofuel yields per hectare. But generally, the key challenge for the near future would be how to enhance the development of biofuels in a responsible way, i.e. stimulating the production chains with the best performance, and preventing negative impacts e.g., by paying careful attention to possible system impacts of biofuel production such as indirect land use changes and rising food prices.

6.3. *Second generation biofuels require specific policy; the precursor role of 1st generation is overestimated*

In defense of current biofuel policies, it is often argued that 1st generation biofuels are essential for the development of their 2nd generation successors. We feel that this role is often overrated. In technical terms, the argument does apply to a certain extent to ethanol production, but biodiesel is in no way relevant for the 2nd generation diesel substitutes such as FT-diesel. Especially the risk profiles of 1st and 2nd generation biofuels differ greatly: due to their high investment costs, 2nd generation biofuels require a more stable investment climate and related biofuel prices. Furthermore, current focus on low biofuel blends does not spur the introduction of higher blends needed in the long term, and the conventional feedstock may even create vested interests that may act as barriers to the required introduction of new cultivation of perennial crops. When it comes to synergies, 2nd generation biofuels might benefit more from current initiatives in co-firing of biomass for (heat and) power than from 1st generation biofuels, also because the public resistance that the latter induce may also spill over to 2nd generation options.

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