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Commission Energy 2030
Renewable energies

Contents :

1. Introduction

The main objective of the present section is to provide the data needed to estimate the achievable contributions from renewable energy resources in Belgium till 2030. Most of the renewable energy technology description can be found in the Ampere report and will not be repeated here. Only new elements and adjustments in the potential achievements will be emphasized, in particular off-shore wind energy on the one hand, and liquid biomass fuels on the other hand. In contrast to the Ampere report, biomass in now considered for heat, power and transport applications, which will be discussed more in the details in section 6. Photovoltaic solar energy is considered but its contribution by 2030 is still expected to be limited. Thermal solar energy has been included. Although this may be a significant contribution on the micro-scale, its impact on the global energy picture is pretty limited. Other increase in renewable energy resources such as hydro, waves, tides and geothermal are considered as marginal on the global scale.

2. Definition of potentials

The present potentials represent reasonable maximum achievable 'technical' potentials. The technical potential has the same definition as in the Ampere report : it is the result from a 'global primary energy potential', reduced to a 'theoretical potential' after conversion to either heat, power or liquid fuel, and to a 'technical potential' after taking all kinds of boundary conditions into account. The potentials are used for both PRIMES and MARKAL simulations although it is not always clear how the given numbers fit into the PRIMES data.

The major boundary conditions limiting the technical potential are limited surface allocation, limited available waste streams and achievable import. There is no technical electric grid penetration limit for the non-dispatchable wind and solar PV. These values are to be used as upper boundaries, regardless of the cost and other market mechanisms. An indication is however given of reasonable market penetration rates which in practice represent an extra limiting factor.

Potentials for electric power may exceed the final figures from the Ampere Report because in Ampere only a part of these maxima was considered as realistic within the time horizon considered at that time.

3. On-shore wind energy

Based on detailed studies made in the past, a total of about 1600 MWe capacity can be installed, leading to about 3 TWhe or 11 PJe. On the average, this means 1850 FLE hours per year.

This can eventually be split into wind quality zones. Limiting this to two zones (which should be sufficient for CE2030), the following can be used :

- 500 MW with 2400 FLE hours per year
- 1100 MW with 1600 FLE hours per year

These figures lead to a total production of about 3 TWhe. These results can partly be deduced from the Ampere report, and have been cross-checked with the most recent studies in Flanders (where most of the capacity is found). In theory these figures are expandable by further softening the considered boundary conditions. According to 'Renewable Energy evolution in Belgium 1974 - 2025' (www.belspo.be CP/23), this can lead to 3.8 TWhe. If this is distributed equally over the wind zones, we can add the following 'extra measures' :

- 133 MW extra with 2400 FLE hours per year
- 293 MW extra with 1600 FLE hours per year

4. Offshore wind energy

The present section and data are mostly based on the report 'Optimal offshore wind energy developments in Belgium' (www.belspo.be CP/21). Offshore wind energy is achievable by large wind farms, where the installed capacity can range between 10 (present) to 14 MWe (Ampere) per km^2. The higher installed capacities are technically possible but should not lead to substantial increase in produced electric power. A second limiting level is the capacity of the present grid to absorb the power, which according to ELIA amounts to some 600 MWe installed capacity. Assuming 10 MWe per km^2 this requires 60 km^2 which is far below the theoretical available sea surface. Adaptation on the 150 kV grid increases this limit to 900 MWe with a still quite acceptable 90 km^2 surface. Further increase needs adaptation on the 400 kV grid.

If grid extensions are accepted, the next limit is set by the availability of good quality sites. A limit can be set to 270 km^2 which is the concession area presently considered by the government. Assuming 10 MWe per km^2 this would lead to 2700 MWe installed capacity. Taking all kind of improvements into account the maximum capacity of 14 MWe considered by the Ampere report can be assumed as upper limit, leading to some 3800 MWe.

These 270 km^2 are however expandable depending on the destinations given to the sea surface (1300 km^2 are in theory available with less than 20 m depth and less than 40 km distance). This can in theory lead to an installed capacity of more than 13000 MWe, which is almost the total installed capacity in Belgium. When compared to the installed capacity in Germany this is not technically impossible provided the required connections are built. It is clear however that the grid surrounding this area will experience extreme unbalances from both technical and financial viewpoints. It is also to be observed that this capacity is anyway not reachable by 2030 due to growth limitation.

In terms of power produced, an average of 3400 FLE hours can be assumed, leading to the following potentials :

Limiting factor	capacity MWe	power TWhe/y	power PJe/y
Present grid connection :	600	2.0	7.3
150 kV grid connection :	900	3.0	11
Max. concessions :	3800	12.8	46
Max. suited sea areas :	13000	44	159

Table 1 : offshore wind limits

5. Solar energy

Several possible limits can again be considered. The yearly solar irradiation amounts to about 1 TWh per km^2. Although extendable, a maximum of 5% of overall surface allocation sounds as realistic when taking into account surface from roofs, highways a.o. suited areas. This leads to 1500 km^2 or 1500 TWh solar irradiation per year..

The equivalent full load time is as low as 1000 EFL hours, which means that installed capacities are enormous. Spending 100 km2 is considered as very feasible on roofs, highways a.o. This would lead to some 10000 MWe installed. Assuming 10% PV efficiency this would lead to 10 TWhe or 36 PJe per year. As is for off-shore wind this would lead to major impact on the grid. Extreme high costs and growth limitations till 2030 however strongly limit this scenario.

Solar boilers mainly provide sanitary water and water for swimming pools which needs an installed capacity of some 3000 MWth, delivering 3 TWhth or 11 PJth per year (deduced from www.belspo.be CP/23). The efficiency is in the range of 30%, leading to a surface requirement of 10 km^2 of boiler surface. This corresponds to less than 10 m^2 per roof.

In conclusion much surface remains available for use of mainly PV cells, provided the energy can be stored or further dispatched. At this point it is proposed to include the possibility of hydrogen storage through electrolysis, at least within reasonable penetration within 2030. The overall efficiency from sun to hydrogen through electrolysis is in the range of 5%. Allocating 1500 km^2 leads to 75 TWhth or 270 PJth energy contained in the produced (and extremely expensive) hydrogen. This is less than 15% of our total primary energy consumption but more than half of the energy used for transportation.

In conclusion the following table can be given :

Limiting factor	capacity MW	power TWh/y	power PJ/y	
100 km2 surface :	10000	10	36	electric
Boiler capacity :	3000	3	11	thermal/low grade heat
Surface :	75000	75	270	thermal/hydrogen

Table 2 : solar energy limits

6. Energy from biomass

6.1 Selected routes to produce energy from biomass :

In the Ampere report biomass was mainly (if not solely) considered for electric power production. The major feedstocks considered were woody fuels and waste streams. The last years have seen a huge change in the approach of biomass use, which is mainly due to

- the European directive 2003/30/EC pushing the application of biomass for transport
- the increased oil prices
- new markets for agriculture

The possible resources and usages of biomass became more diverse than it already was, with now inclusion of cereals, oily crops and sugar rich crops for energy applications, and ethanol and biodiesel production as new outcome even for woody biomass fuels. Since this was not discussed in the Ampere report, some more technical details are given below.

Figure 1 summarizes most of the possible routes to replace fossil fuels by biofuels in both automotive and heat & power applications, with the exclusion of hydrogen production for fuel cells and some other more exotic potential applications. The routes which are considered as relevant on the short to medium term are indicated in fat lines and have been studied within the project 'Liquid Fuels in Belgium in a global bio-energy context'

(Libiofuels, www.belspo.be CP/54). Within the considered routes, some are still in the demonstration phase but are considered to be of importance in the medium term, namely biodiesel from wood through Fisher-Tropsch synthesis and ethanol from wood through hydrolysis. In the framework of the Libiofuels project, it was decided not to further study biogas, hydrogen and dimethylester (DME). Both hydrogen and DME will most likely not be available before 2040. Biogas is suspected to be of little importance for automotive applications in Belgium, but it seems to be an interesting option for treatment of by-products from the other routes. It is finally to be observed that liquid fuels obtained from biomass can be (and effectively are) used in heat and power applications.

Bioethanol is a fermentation ethyl alcohol which can be further transformed into ETBE (Ethyl-Tri-Butyl Ether) by adding fossil isobutylene. Ethanol can replace a limited amount of gasoline whereas ETBE can fully replace the fossil methanol based MTBE which is used as an octane enhancer. If ethanol is used pure or in high concentrations it may damage engine parts made of certain plastics, elastomers and metals like steel, aluminum and magnesium. Fermentation, distillation and drying processes for ethanol production are energy intensive and reduce the efficiency of the conversion process, unless e.g. straw from the wheat can be used for heat supply. Production of ethanol from wheat and sugar beet produce considerable amounts of protein rich residues for use as animal feed. About half of the energy leaving the process in contained in this animal feed which must be taken into account in any energy balance exercise.

Pure plant oil or PPO is easy to produce but some engine modifications are needed when blending diesel with more than 50% PPO. Biodiesel has properties much closer to the conventional diesel, although it is still advised to blend no more than 30% biodiesel into diesel because of its corrosiveness. The process of making biodiesel from vegetable oils is called trans-esterification, which is a well-known process and largely applied. If produced from rapeseed, the biodiesel is called RME (Rapeseed Methyl Ester), if produced from used vegetable oil it is called FAME (Fatty Acid Methyl Ester). The process consumes methanol and produces glycerin as a residue, which finds its way in the market as a high value product (cosmetics, paints, food industry, pharmaceuticals, etc..).

Biodiesel can also be produced from wood through prior gasification, gas cleaning and Fischer-Tropsch synthesis. This process is still to be demonstrated for biomass application, where the most critical and uncertain steps are the integration of biomass gasification and the cleaning of the synthetic gas. The resulting biodiesel can easily be mixed with fossil diesel, applied in current diesel engines and in the existing diesel distribution network without any specific adaptations. However, additives may be necessary to meet all the diesel standards.

Wood can finally be used for heat and/or power production through direct combustion in selected cases which are co-combustion in steam plants (e.g. Ruien Electrabel plant), full combustion in steam plants (e.g. Les Awires), pure heat production in small to medium size boilers (e.g. Vyncke boilers) and finally small scale combined heat and power through Organic Rankine Cycle (ORC) which is the sole commercially available and viable alternative for external combustion in the small scale (e.g. Turboden, Italy). Gasification in a fixed bed gasifier combined with internal combustion engines is considered as the sole available and viable alternative for internal combustion of biomass (e.g. Xylowatt, Belgium).

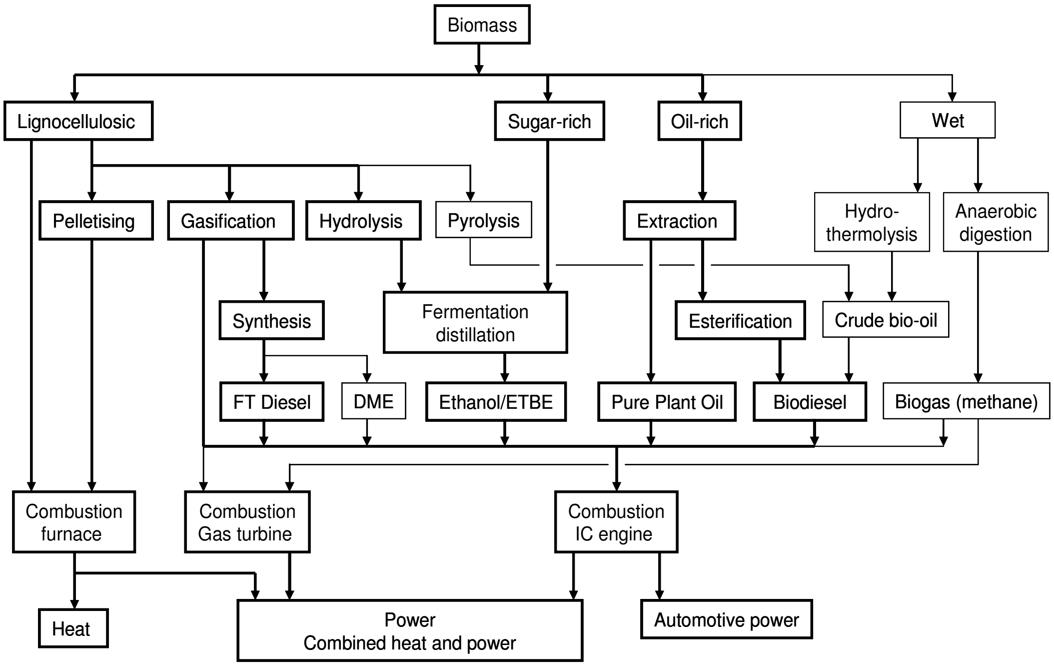

Fig 1 : Main routes for use of biomass for transport, heat and/or power production. Fat lines are considered in the Libiofuels project

6.2 Achievable potentials

To fit into the data of MARKAL, the potentials for biomass are grouped into three types : fresh biomass from arable and forest land, imported biomass and biomass residues.

The biomass from arable and forest lands is limited by the available surface areas in Belgium, which amount to 14000 and 7000 km^2 respectively. The amount of biomass energy which can be produced in both cases varies between 1 and 5 GWhth per km^2, which sets an average limit of 60 TWhth if the entire available surface is used for energy purposes. According to the project Libiofuels up to 10% of the arable land is acceptable for energy production, leading to 1400 km^2 and some 4.2 TWhth. The availability of forest residues should be higher and is assumed here to be 30% of the total forest area, leading to 2100 km^2 and 6.3 TWhth. The availability of the domestic biomass cultivation is therefore estimated at some 10.5 TWhth, eventually extendable by higher acceptable surface shares and increasing yields (beyond 2030).

Import is virtually unlimited because of the small size of our country. The reality of a high biomass demanding Europe or even World however leads to increase of the cost. In practice it is therefore proposed to limit the imports to three times 60 TWhth of three times 10% of our primary energy consumption for the three following feeds : imported wood, imported ethanol and imported rapeseed.

According to the Ampere report, biomass energy from dry biomass residues (other than forest) is in the range of 9 TWth/y, being to a large extent energy from municipal waste. Energy from wet biomass residues leading to biogas can be estimated at 3 TWth/y, coming mainly from sludges and manure.

In summary, 22.5 TWth or 80 PJth energy should be obtainable from domestic sources, to be converted into either heat, power or biofuel suitable for transport. It is proposed either to limit the energy from import to a total of 180 TWhth equally spread over wood, ethanol and rapeseed, either to include a growing cost function in Markal. Annexes A and C further detail the considered potentials.

6.3 Energy and CO2 balances

The present section discusses the indirect effects to be taken into consideration when using biomass for energy purposes. This includes the full chain from growing the biomass in the field, harvesting and transporting it, and converting to a suited energy carrier. Valorization of secondary products (rapemael, glycerine, DDGS, a.o.) is taken into account.

The Figures 2 to 5 below summarize results obtained by the Libiofuels project. They show the global energy and CO2-eq balances obtained in a selection of scenario's as described below :

Sugar rich biomass cases :

- Wheat for ethanol, straw for bedding : wheat is produced in Belgium on set aside land, the straw is used for bedding and reduces straw inport, the wheat is converted to ethanol for replacement of gasoline in cars, the residues are used as animal feed reducing its import.
- Wheat for ethanol, straw is burned : same as previous but the straw is collected and burnt for heat production (distillation) replacing natural gas
- Wheat for ethanol - imported : same as previous but the wheat is imported from neighbouring countries (allocation required)
- Sugar beat for ethanol : sugar beat is produced in Belgium on set aside land and converted to ethanol for replacement of gasoline in cars.
- Ethanol for gasoline - imported : ethanol is imported from Brazil for replacement of gasoline in cars (allocation required).

Oil-rich cases :

- Rapeseed for PPO - local : rapeseed is produced in Belgium on set aside land and pressed to PPO for replacement of diesel in cars, the residues are used for animal feed reducing its import.
- Rapeseed for RME - local : rapeseed is produced in Belgium on set aside land and converted to biodiesel (RME) for replacement of diesel in cars, the rapemeal is used for animal feed reducing its import, the glycerine is sold on the market reducing its import.
- Rapeseed for RME - imported : same as previous but the rapeseed is imported from France
- Used vegetable oil for FAME : used vegetable oil converted to biodiesel (FAME) for replacement of diesel in cars, the glycerine is sold on the market reducing its import.

Lignocellulosic cases :

- Wood for co-combustion - SRF : short rotation wood (SRF) is produced in Belgium on set aside land and used for co-combustion in a coal steam plant for replacement of coal

- Wood for CHP (FBG with PE) - SRF : same resource but the wood is used for combined heat and power production through fixed bed gasification (FBG) and piston engine (PE) for replacement of natural gas and electricity imports.
- Wood for heat - SRF : same resource but the wood is simply burned for heating purposes in an advanced wood combustion heater for replacement of fueloil.
- Wood for FT biodiesel - SRF : same resource but the wood is used in a Fisher-Tropsch biodiesel production plant for replacement of diesel in cars
- Wood for ethanol - SRF : same resource but the wood is used in a hydrolysis plant to produce ethanol for replacement of gasoline in cars.

Figures 2 and 3 first show results where a ’worldwide’ impact is computed. Figures 4 to 5 next show the same scenario’s but making the balance over the Belgian system.

Figure 2 shows the global energetic efficiency of the selected cases. This efficiency is defined as the ratio of the saved fossil energy worldwide to the produced renewable energy on the field, when taking all side effects into account (including the energy in the by-products). The figure tells us to what extent fossil energy is really replaced by renewable energy : this efficiency should at least be positive and preferably close to 100% or even beyond. According to the analysis all these efficiencies are quite positive and range from 45 up to 120%. Efficiency higher than 100% is possible in the wood CHP case because SRF consumes only little amounts of energy in combination with the positive effect of CHP versus separate production in the reference case. Rapeseed, wheat and sugar beat need more energy in the production processes, and conversion consume energy, particularly in the ethanol distillation process, leading to lower overall efficiencies which are in the range of 40 to 60%. In case residues are used as fuel for energy production these efficiencies improve significantly.

Figure 3 shows the corresponding global CO2 savings, expressed in kg CO2 saved per saved GJp of primary fossil energy. For reference : direct fossil fuel emissions range between 56 kg/GJ for natural gas to 96 for coal, whereas the selected cases show savings from 42 kg/GJ to 102 kg/CO2. The CO2 balances therefore appear to be quite positive in all selected cases. Wood for co-combustion shows the highest score because the wood replaces coal which is a high CO2 emitter, in combination with a high efficiency.

Figures 4 and 5 show the same type of results but taking Belgium as system border. Figure 4 now compares the net fossil energy savings crossing the Belgian border against the gross biomass energy produced and/or imported. Efficiencies are almost all reduced when compared with the global results in Figure 2 : they now range from a poor 10% to attractive values exceeding 90%. This high disparity and rather strong reduction are due to the fact that Belgium is a net importer of electricity, wheat, rapeseed and animal feed : much of the corresponding utility energy is spent outside of the system and the efficiencies are therefore lower when compared to LCA or global SPA analysis. Similar conclusions are drawn for CO2 in Figure 5, where all scenarios yield CO2 savings ranging from very poor to high. The import scenarios show high CO2 savings because the CO2 cost is outside whilst the benefit is inside! This is a perverse effect which should be compensated by the CO2 emission trading costs. The CO2 savings show on the contrary pretty low values for rapeseed and wheat due to a combined effect of high N2O emissions from the land and net import of animal feed in Belgium.

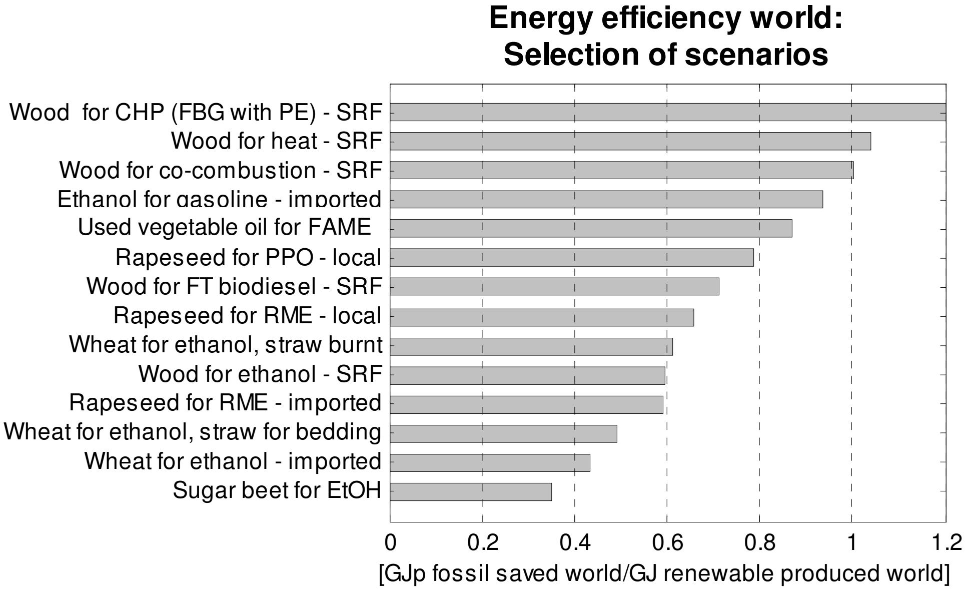

Fig 2 : Libiofuels results for global energy efficiency

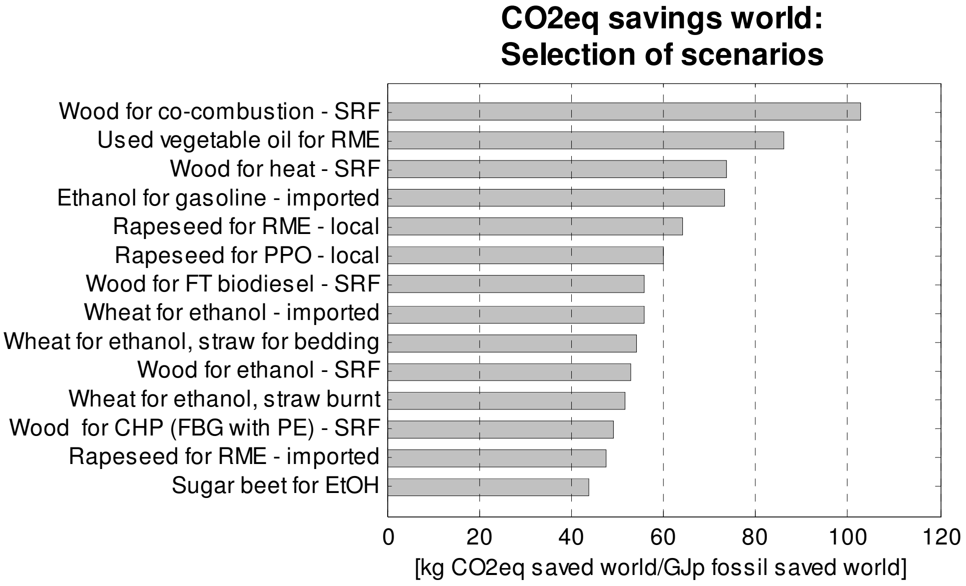

Fig 3 : Global CO2 savings per GJ saved fossil energy, according to Libiofuels

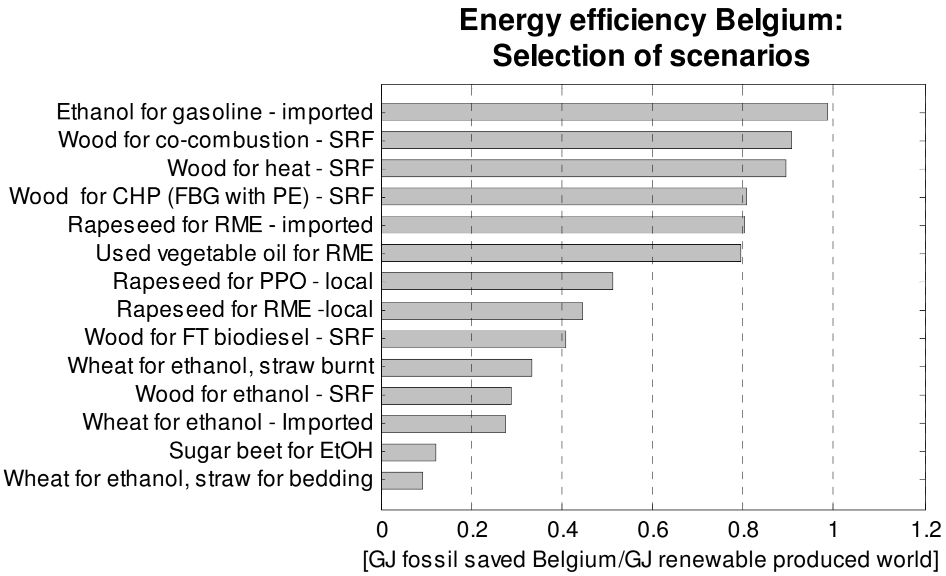

Fig 4 : Libiofuels results for energy efficiency inside Belgium

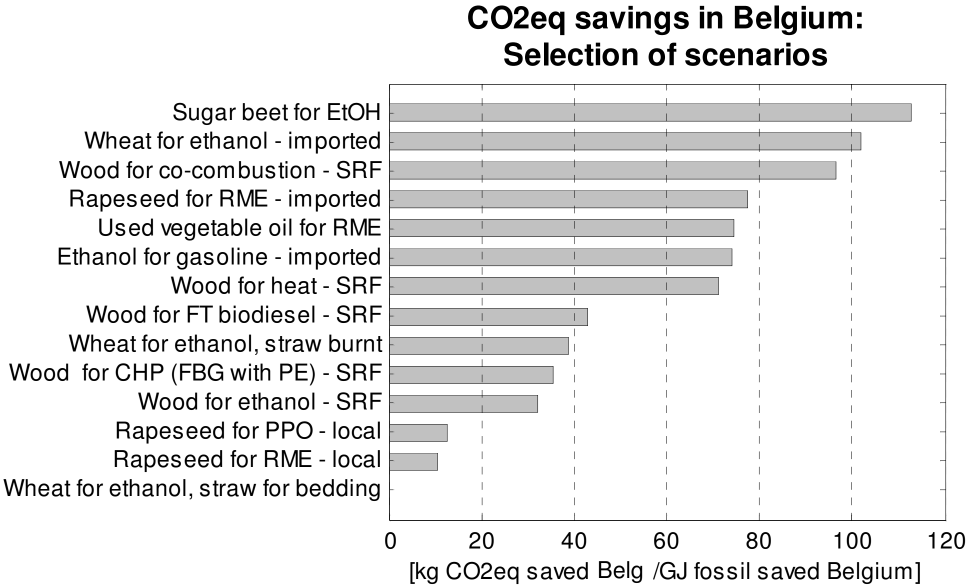

Fig 5 : CO2 savings in Belgium per saved fossil energy, according to Libiofuels

It is to observed that the indirect effects discussed here are to a large extent covered by MARKAL. MARKAL therefore uses only the basis data taken mainly from the Libiofuels project detailed in Annex C. I

7. Growth limitations

The above limits do not take into account the time required to achieve them. Looking into literature no clear methodology was found (at least not by me) to find out what the potential growth rates are or should be. Current growth rates from literature cannot be used : they are rather results from scenarios than inputs to them. The maximum allowable growth rates in a MARKAL type study should be pure technical upper limits: suppliers must be able to follow and the market needs time to penetrate. Looking into overall market penetration of energy vectors a figure of 6% share in- or decrease per year is mentioned in the literature. Faster grow rates are however technically possible (e.g. growth of nuclear in the sixties-seventies). The maximum technical growth rate of wind is tentatively assumed as 11% in the following table for wind, biomass and hydrogen. Growth for solar is assumed to be possible at 20% per year because solar equipment is small in size and readily available (Tables 3 and 4). In the scenario ’extra measures’, it is conceivable to force upon the technical growth rates on offshore wind and solar energy as proposed in Tables 5 and 6. *These are technical limits, no forecasts nor engagements ! The growth limits have not been considered in the MARKAL simulations.*

	growth	(2005)	2010	2020	2030	
onshore	11 %	150	253	718	1600	MWe
offshore 600	11 %	(200)	337	600	600	MWe
offshore 900		0	0	300	300	MWe
offshore 3800		0	0	57	1817	MWe
solar PV	20 %	2	5	31	191	MWe
solar thermal	20 %	2	5	31	191	MWth
solar hydrogen	11 %	(0.5)	1	2	7	PJth
biomass domestic	11 %	(10)	17	48	80	PJth
biomass import	11 %	(10)	17	48	136	PJth

Table 3 : capacity limits, scenarios other than ’extra measures’

	growth	(2005)	2010	2020	2030	
onshore	11 %	281	474	1346	3000	GWhe
offshore 600	11 %	(680)	1146	2040	2040	GWhe
offshore 900		0	0	1020	1020	GWhe
offshore 3800		0	0	194	6180	GWhe
solar PV	20 %	2	5	31	191	GWhe
solar thermal	20 %	2	5	31	191	GWhth
solar hydrogen	11 %	(0.5)	1	2	7	PJth
biomass domestic	11 %	(10)	17	48	80	PJth
biomass import	11 %	(10)	17	48	136	PJth

Table 4 : produced energy limits, scenarios other than ’extra measures’

	growth		(2005)	2010	2020	2030	
onshore extra			0	0	0	426	MWe
offshore 3800	13	%	0	0	351	2900	MWe
solar PV	25	%	2	6	57	530	MWe
solar thermal	25	%	2	6	57	530	MWth

Table 5 : capacity limits, ’extra measures’

	growth	(2005)	2010	2020	2030	
onshore extra		0	0	0	799	GWhe
offshore 3800	13 %	0	0	1193	9800	GWhe
solar PV	25 %	2	6	57	530	GWhe
solar thermal	25 %	2	6	57	530	GWhth

Table 6 : produced energy limits, ’extra measures’

Annex A : Data for renewables energy resources

Feed ID	Feed description	Maximum	Feed Unit	Cost Low	Cost High	Upstream CO2	Upstream CO2		comments
		yearly supply	UnFd	Meuro/UnFd	Meuro/UnFd	kton CO2/UnFdBelg	kton CO2/UnFd outside		
WIINDON	Energy from onshore wind	13.68	PJe	0.00	0.00	0.00	0.00		
WINDOF	Sea surface for offshore wind, concessions	46.30	PJe	0.00	0.00	0.00	0.00		max concessions
SOLAR	Surface for solar energy	1.91	PJe	0.00	0.00	0.00	0.00		limited by growth
ARABLE	Arable land surface	1400	km2	0.00	0.00	0.00	0.00		10% of total arable land in Belgium
FOREST	Forest land surface	38	PJth	1.33	6.67	3.56	0.00		30% forest area in Belgium
WOODIN	Energy from imported wood	216	PJth	6.67	10.00	0.20	8.00		virtually unlimited, max 10% primary cons.
ETHIN	Energy from imported ethanol	216	PJth	20.52	20.52	0.00	16.37		virtually unlimited, max 10% primary cons.
RAPEIN	Energy from imported rapeseed	216	PJth	8.82	8.82	0.00	48.32		virtually unlimited, max 10% primary cons.
WOODRES	Energy from dry wood residues	11	PJth	0.00	1.33	0.00	0.00		from Ampere
BIORESDRY	Energy from other dry biomass residues	29	PJth	0.00	1.33	0.00	0.00		from Ampere (attn : mainly MSW)
BIORESWET	Energy from wet biomass residues	11	PJth	0.00	0.00	0.00	0.00		from Ampere (attn : mainly sludges and manure)

Annex B : Data for products from biomass

Product ID	Product description	Product Unit
		UnProd
EL	Electric energy	PJe
HEAT	Heat	PJth
RME	Biodiesel from rapeseed	PJth
ETH	Ethanol	PJth
BIOG	Biogas from residues	PJth
HYDR	Hydrogen	PJth
DIESEL	Diesel from FT	PJth
ANF	Animal feed (average)	PJth

Annex C : Data about technologies

						Yield 1	Yield 2	max 2010	max 2020	max 2030	equiv. full load	out- ages	commodities land % product 1 energy					CO2 kton/ PJ	up- stream cost	comm. conv. & transp. % product 1 energy					CO2 kton/ PJ	investment	O&M	Life time
comment	**Techn. ID**	**Techn. Description**	**Feed ID**	**Product ID 1**	**Product ID 2**	**UnProd/ UnFd**	**UnProd/ UnFd**	**capac. in MW**	**capac. in MW**	**capac. in MW**	**running hours**	**frac.**	**elec**	**nat gas**	**gas oil**	**coal**	**other**	**other**	**euro/ GJfeed**	**elec**	**natg as**	**gas oil**	**coal**	**othe r**	**other**	**euro/kW 1**	**% inv**	**years**
Biogas from wet biomass residues	BIOGAS	Digestion	BIORESWET	BIOG		0.6	0	unl	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	1200	4	20
Ethanol from wood	ETHWD	Wood, fermentation	WOODIN,WOODRES	ETH	EL	0.417	0.150	0	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	4.4	0.0	15.8	9.9	2152	4	20
Ethanol from wood, forest	ETHWDFOR	Wood, fermentation	FOREST	ETH	EL	0.417	0.150	0	unl	unl	8500	0.90	0.5	0.0	0.0	0.0	6.6	0.3	feeds	0.0	0.0	4.4	0.0	15.8	9.9	2152	4	20
Ethanol from wood, arable land	ETHWDAR	Wood, fermentation	ARABLE	ETH	EL	0.00750	0.0027	0	unl	unl	8500	0.90	0.2	4.7	4.6	0.4	0.7	14.2	10.0	0.0	0.0	4.4	0.0	15.8	9.9	2152	4	20
Ethanol from wheat, import	ETHWHIMP	Wheat, fermentation	ETHIN	ETH	ANF	0.465	0.397	unl	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.7	32.7	5.2	0.0	0.0	0.0	537	4	20
Ethanol from wheat, import	ETHWHIMP	Wheat, fermentation	ETHIN	ETH	BIORESWET	0.465	0.397	unl	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.7	18.0	5.2	0.0	0.0	0.0	387	4	20
Ethanol from wheat, arable land	ETHWHAR	Wheat, fermentation	ARABLE	ETH	ANF	0.00696	0.00594	unl	unl	unl	8500	0.90	0.5	10.0	8.0	1.1	3.6	36.8	5.2	0.7	32.7	6.9	0.0	0.0	0.0	537	4	20
Ethanol from wheat, arable land	ETHWHAR	Wheat, fermentation	ARABLE	ETH	BIORESWET	0.00696	0.00594	unl	unl	unl	8500	0.90	0.5	10.0	8.0	1.1	3.6	36.8	5.2	0.7	18.0	6.9	0.0	0.0	0.0	387	4	20
FT diesel	FTD	Wood, Fisher Tropsch	WOODIN,WOODRES	DIESEL	EL	0.287	0.141	0	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.8	0.0	3.4	1.2	2713	4	20
FT diesel, forest	FTDFOR	Wood, Fisher Tropsch	FOREST	DIESEL	EL	0.287	0.141	0	unl	unl	8500	0.90	0.8	0.0	0.0	0.0	9.6	0.4	feeds	0.0	0.0	0.8	0.0	3.4	1.2	2713	4	20
FT diesel, arable land	FTDAR	Wood, Fisher Tropsch	ARABLE	DIESEL	EL	0.00517	0.00255	0	unl	unl	8500	0.90	0.4	6.8	6.7	0.6	1.0	20.6	10.0	0.0	0.0	0.8	0.0	3.4	1.2	2713	4	20
Electricity from PV	PV	Photovoltaic	SOLAR	EL		1	0	5	31	191	1000	0.99	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	4000-7000	1	25
RME from import	RMEIMP	Rapeseed, esterification	RAPEIN	RME	ANF	0.543	0.438	unl	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	1.5	9.5	3.3	0.0	7.0	4.5	400	4	25
RME from import	RMEIMP	Rapeseed, esterification	RAPEIN	RME	BIORESWET	0.543	0.438	unl	unl	unl	8500	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	1.5	9.5	3.3	0.0	7.0	4.5	400	4	25
RME from arable land	RMEAR	Rapeseed, esterification	ARABLE	RME	ANF	0.00464	0.00376	unl	unl	unl	8500	0.90	0.7	14.8	14.8	1.7	0.1	31.8	10.1	1.5	9.5	3.3	0.0	7.0	4.5	400	4	25
RME from arable land	RMEAR	Rapeseed, esterification	ARABLE	RME	BIORESWET	0.00464	0.00376	unl	unl	unl	8500	0.90	0.7	14.8	14.8	1.7	0.1	31.8	10.1	1.5	9.5	3.3	0.0	7.0	4.5	400	4	25
Heat from solar boiler	SOLBOIL	Boiler	SOLAR	HEAT		1	0	5	31	191	1000	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	3000	2	15
Hydrogen from PV	*SOLHYDR*	*Photovoltaic*	*SOLAR*	*HYDR*		0.5	0	1	2	7	1000	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	8000-14000	2	25
CHP from wood	WDCHP	Wood, Gasification/pist. eng.	WOODIN,WOODRES	EL	HEAT	0.25	0.55	unl	unl	unl	6000	0.80	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	1.0	0.0	0.0	0.0	2800	4	20
CHP from wood, forest	WDCHPFOR	Wood, Gasification/pist. eng.	FOREST	EL	HEAT	0.25	0.55	unl	unl	unl	6000	0.80	0.9	0.0	0.0	0.0	11.1	0.4	feeds	0.0	0.0	1.0	0.0	0.0	0.0	2800	4	20
CHP from wood, arable land	WDCHPAR	Wood, Gasification/pist. eng.	ARABLE	EL	HEAT	0.00450	0.00990	unl	unl	unl	6000	0.80	0.8	15.3	15.3	1.7	0.1	32.8	10.0	0.0	0.0	1.0	0.0	0.0	0.0	2800	4	20
Co combustion	WDCOCOM	Wood, Co-combustion	WOODIN,WOODRES	EL		0.35	0	100	200	300	8500	0.80	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.7	0.0	0.0	0.0	1429	4	20
Co combustion, forest	WDCOCOM	Wood, Co-combustion	FOREST	EL		0.35	0	100	200	300	8500	0.80	0.6	0.0	0.0	0.0	7.9	0.3	feeds	0.0	0.0	0.7	0.0	0.0	0.0	1429	4	20
Co combustion, arable land	R	Wood, Co-combustion	ARABLE	EL		0.00630	0	100	200	300	8500	0.80	0.5	10.9	10.9	1.2	0.0	23.4	10.0	0.0	0.0	0.7	0.0	0.0	0.0	1429	4	20
Heat from wood	WDCOMFOR	Wood, Combustion	WOODIN,BIORESDRY	HEAT		0.8	0	unl	unl	unl	4000	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.3	0.0	0.0	0.0	250	2	20
Heat from wood, forest	WDCOMFOR	Wood, Combustion	FOREST	HEAT		0.8	0	unl	unl	unl	4000	0.90	0.3	0.0	0.0	0.0	3.5	0.1	feeds	0.0	0.0	0.3	0.0	0.0	0.0	250	2	20
Heat from wood, arable land	WDCOMLOC	Wood, Combustion	ARABLE	HEAT		0.01440	0	unl	unl	unl	4000	0.90	0.2	4.8	4.8	0.5	0.0	10.2	10.0	0.0	0.0	0.3	0.0	0.0	0.0	250	2	20
IGCC wood	WDIGCFOR	Wood, gasification/IGCC	WOODIN,BIORESDRY	EL		0.45	0	0	100	200	8500	0.80	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.5	0.0	0.0	0.0	2667	4	20
IGCC wood, forest	WDIGCFOR	Wood, gasification/IGCC	FOREST	EL		0.45	0	0	100	200	8500	0.80	0.5	0.0	0.0	0.0	6.1	0.2	feeds	0.0	0.0	0.5	0.0	0.0	0.0	2667	4	20
IGCC wood, arable land	WDIGCLOC	Wood, gasification/IGCC	ARABLE	EL		0.00810	0	0	100	200	8500	0.80	0.4	8.5	8.5	1.0	0.0	18.2	10.0	0.0	0.0	0.5	0.0	0.0	0.0	2667	4	20
Energy from wind	0	Offshore turbine, high cost	WINDOF	EL		1	0	0	100	1800	3400	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	?	4	20
Energy from wind	WINDOF600	Offshore turbine, low cost	WINDOF	EL		1	0	337	600	600	3400	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	1600-2000	4	20
Energy from wind	WINDOF900	Offshore turbine,medium cost	WINDOF	EL		1	0	0	300	300	3400	0.90	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	1600-2000	4	20
Energy from wind	WINDONH	Onshore turbine, high wind	WINDON	EL		1	0	79	224	500	2400	0.95	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	1000	3	20
Energy from wind	WINDONL	Onshore turbine, low wind	WINDON	EL		1	0	174	494	1100	1600	0.95	0.0	0.0	0.0	0.0	0.0	0.0	feeds	0.0	0.0	0.0	0.0	0.0	0.0	1000	3	20
Used vegetable oil		Esterification		RME				unl	unl	unl	8500																	

Rem. : Balancing costs are not included in the above table. These costs are to a large extent considered through the MARKAL simulation