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Role of Biomass in the Energy Market of Western Balkans, Moldova and Ukraine.

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Abstract

The main purpose of this work is to estimate supply from agriculture and forest based biomass in Western Balkan countries as well as in Moldova and Ukraine. A bottom up approach was employed in order to estimate the technical potential per feedstock type in each country. Forest based biomass is dominant in Montenegro, Bosnia and Herzegovina, Albania and FYROM. On the other hand, agriculture is the main source of biomass in Moldova, Ukraine, Serbia and Croatia. Currently, these countries depend heavily on fossil fuels and imports to cover their energy requirements. However, the results of this work indicate that biomass could supply 10 to 15% of the energy needs in each country, with the exception of Moldova, where biomass contribution could be as high as 42%. Electricity generation via either co-firing in existing power plants or new CHP plants is a realistic option for future investment in these countries. Estimated potential capacities range from 5MW_e in Montenegro to 1.500MW_e in Ukraine. As far as heat generation is concerned, local, domestic use of wood for space heating is an important sector in all studied counties and high efficiency- low emissions modern boilers could be used to heat domestic and other public buildings. The results of this study could be used for future assessments of the economic biomass potentials and the investment opportunities for biomass exploitation in each of the under study countries, since identification, understanding and implementation of bankable bioenergy project options in the region should be included in the regional energy portfolio for the short to medium term future.

Keywords: biomass supply; energy market; Energy Community

Introduction

Western Balkan countries depend heavily on fossil fuels, mainly coal and oil, to cover their energy needs. The situation is similar in Moldova and Ukraine, where natural gas is the dominant energy carrier. Furthermore, a common feature of these countries is strong dependence on energy imports. In 2008, Western Balkan countries produced on average approximately half their primary energy consumption, with energy independence ranging from 44% in Croatia to 74% in BiH. In Ukraine, energy production amounts to 60% of the primary energy consumption, while Moldova is reliant on imports for 95% of its needs [Energy Institute Hrvoje Pozar 2010; IEA 2010; Ministry of Economic Development of Montenegro 2007; National Bureau of Statistics of the Republic of Moldova 2009; NANR 2010; Statistical Office of the Republic of Serbia 2009].

With the situation described above, there is clear opportunity to reduce energy import dependency of these countries by improving energy efficiency in the production, transmission, distribution and utilization of energy and by higher energy production from renewable energy sources and other domestic resources.

Renewable energy sources are mostly undeveloped with the exception of solid biomass fuels (mostly fuelwood). According to national statistical energy data, solid biomass accounts for 10% of the domestic energy production in Western Balkans with the exception of Albania, where this number climbs to 20%. In Ukraine, solid biomass share in domestic energy production is just 0,5%. Moldova is on the opposite side, where half of the population is rural and the high prices of conventional fuels have led to a significant level of exploitation of field crop residues and prunings from orchards and vineyards. Solid biomass is the most significant domestic energy source in Moldova accounting for 70% of domestic energy production according to the national bureau of statistics.

At this point, it should be mentioned that there are significant unregistered-informal quantities of solid biomass consumed in the countries studied. These quantities are currently used mainly by the rural population for household heating, cooking and hot water preparation [FAO 2010; Savcor 2005].

The aim of this study was to estimate supply from agriculture and forest based biomass in the Western Balkan countries, namely Albania, FYROM, Montenegro, Croatia, Serbia and Bosnia and Herzegovina, as well as in Moldova and Ukraine.

Approach

The study employed a bottom-up approach to estimate the biomass potentials (Figure 1) per feedstock type in each country. Two types of biomass potentials were considered:

Theoretical Potential: The total quantity of biomass that can be produced annually from a specific crop or waste / residue / by-product. Theoretical Potential is the quantity grown or disposed, constrained only by macro-factors such as land availability and growth yield.

Technical Potential: This considers the key issues around “practical availability” and is invariably a proportion of Theoretical Potential. Thus, calculation of Technical Potential considers factors such as other competing demands, the need for residues to stay on the land to replenish soil nutrients, etc.

Theoretical Potential can be considered a step on the way to calculating the Technical Potential. The Technical Potential provides, in a sense, the useful data, because this shows how much resource could actually be exploited. Therefore, only the technical potential is presented in this paper.

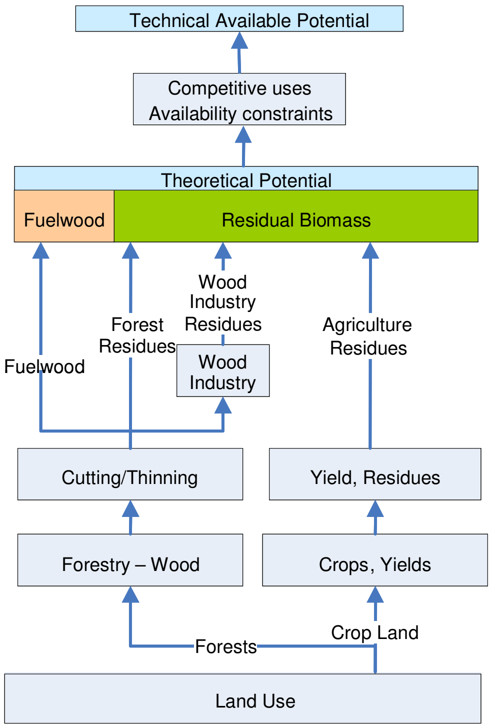

Figure 4. Bottom up approach to estimate biomass potential.

Data sources included: official statistics from national and international governmental organisations; published and unpublished surveys and studies as well as direct communication with local experts. The reference year for all calculations was 2008.

Biomass Feedstocks

Agricultural based biomass

Agricultural biomass examined in this study includes field crop, arboricultural and livestock residues.

- ✓ *Field* crops are producing two types of field residues, i.e dry and fresh or green residues. Green field crop residues, such as sugarbeets, potatoes, etc., are left in the field in fresh, succulent condition. These residues are usually rotting in the field and in some occasions they are used for animal feeding. That type of residues because of high moisture content, usually more than 70%, can be considered as potential feedstock for biogas applications. Dry field crop residues are derived from field crops, such as small grain cereals (wheat, barley, oat, rye, and rice), maize, oil crops (sunflower, rapeseed, etc.), etc. These residues are incorporated into the soil, burned in the field or collected and used for various purposes (animal feed, bedding, mushroom cultivation, etc.).
- ✓ *Arboricultural residues* are the prunings of grapes and trees such as apple trees, olive trees, pear trees, etc.
- ✓ Two main sources of *livestock residues* are manures and slaughter residues – the latter is not included in this study. Energy can be derived from animal manure as long as it is collected in lagoons or large tanks and can be considered feasible only in in-stall livestock systems. This precludes sheep and goats since their husbandry is extensive making collection of manure impossible. Intensive livestock in the studied countries consists of cattle, pigs and poultry farming. Since animal manure is of a high water content, it can be digested anaerobically for the production of biogas, which can be burnt for heat or/and electricity production (AD units).

Forest based biomass

Forest based biomass includes fuelwood, forest residues and wood industry residues.

- ✓ *Fuelwood* is the form of wood used primarily for heat or for conversion to a form of energy.
- ✓ *Forest (or logging) residues* are woody biomass by-products which are created during harvest of merchantable timber. They are usually left at the logging site due to the high cost of collection and the maintenance of soil condition. Forest residues that can be used either for industrial heat or densified wood fuels (pellets and briquettes) production include tops, branches, stumps and bark.
- ✓ *Wood industry residues* are woody biomass by-products originating from the wood processing as well as the paper and pulp industry. In each phase of wood processing several by-products are

produced such as chips and particles, sawdust, slabs, edgings and shavings. These residues can be either used in particleboards or pulp production or used for energy purposes in industrial boilers and for densified wood fuels production (pellets and briquettes). Bark is also included in industrial residues, if industrial wood is debarked at the sawmills. Black liquor, which is a by-product of the pulp industry, can also be used for energy production.

Biomass supply potentials

The estimated total biomass potentials in each country are presented graphically in Figure 2.

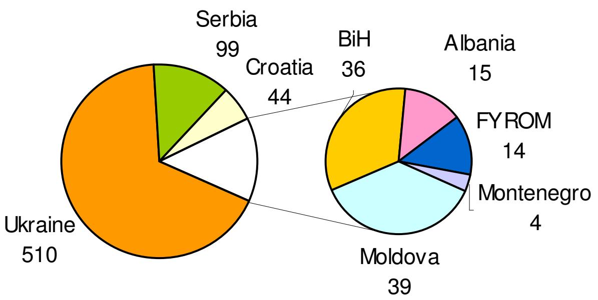

Figure 5. Estimated biomass potentials (PJ).

Results are related with land area and land use in the under study countries. As expected Ukraine exhibits the highest potential (510PJ) and Serbia follows with 99PJ. Croatia, Moldova and BiH have similar biomass potentials of around 40PJ, while the same is true for Albania and FYROM whose potential is estimated at around 15PJ. The lowest value is found in Montenegro.

The respective contribution of each feedstock type to the total biomass potential is presented in Figure 4. Agricultural biomass is dominant in Ukraine and Moldova as well as in Serbia and Croatia. On the other hand, forest based biomass represents the highest share in Bosnia and Herzegovina, Montenegro, Albania and FYROM.

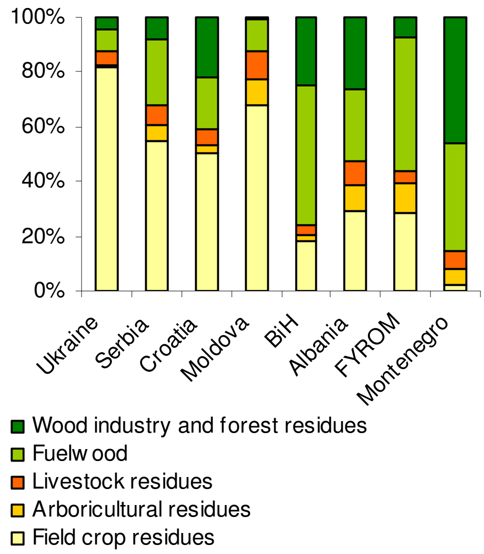

Figure 6. Biomass contribution (per feedstock type) to the total potential in each country.

Field crop residues in Western Balkan countries derive mainly from the cultivation of maize and wheat. Oilseeds as well as sugar beet are significant biomass sources only in Serbia and Croatia, with the first category having a significant contribution to the total crop residues potential also in Moldova and Ukraine. The latter was the world's second largest sunflower seed producer in 2008. Furthermore, maize, small grain cereals and sugar beet residues have also a high share in the crop residues potential of these countries.

In the arboricultural residues category, apples and plums are the most significant sources of tree prunings, while vineyards also have significant potential in most of the countries. Olive prunings exist only in Albania, Croatia and Montenegro.

Significant quantities relative to the total potential of livestock residues are found in Moldova, Albania and Serbia. In Albania, FYROM and Montenegro livestock residues come mostly from cattle farming, while in BiH, Moldova and Ukraine cattle and poultry are dominant. Lastly, in Serbia and Croatia cattle and pig manure have the highest share.

Finally, forest based biomass comes mainly from fuelwood. However, residual biomass coming from logging activities and wood processing has a high share, which is as high as 54% of the total forest based biomass potential in Montenegro and Croatia.

Biomass role in the energy system

In order to appreciate the share biomass can have in the energy system within the countries under study the estimated potentials in relation to the total primary energy supply (TPES) are presented in Figure 4. Biomass could supply 10 to 15% of the energy needs in each country. Moldova is an exception, as biomass could contribute up to 42% to the country's primary energy consumption.

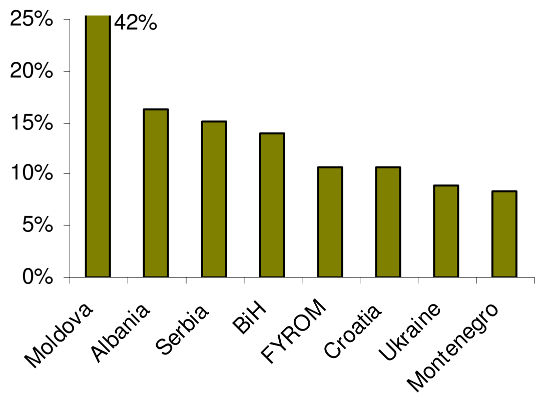

Figure 7. Estimated biomass potentials as a percentage of each country's TPES.

During the study, a list of potential biomass applications in the heat & electricity markets has been identified.

Electricity generation

Most of the under study countries have the opportunity to co-fire indigenous biomass resources (typically wood but also straw) with fossil fuels via either large power plant or in smaller district heating units. A further possibility is to build new combined heat and power (CHP) units dedicated to use of biomass feedstocks. Most of the study countries have sufficient wood resources to fuel new build plants with installed capacity 5MWe plus per plant. Straw-fired CHP plants are economic at larger scale, say 30MWe plus per plant, so given the disparity of the source this opportunity seems, from a high level analysis, more attractive for larger countries like Ukraine & Serbia. Finally, most countries have the opportunity to install AD units, with installed capacity in the range 1-3MWe.

Considering the above approaches to power generation, the study reviewed a selective number of promising 'biomasss-to-electricity' projects in the countries. The opportunities for exploiting biomass energy for electricity production are quite low in Albania, FYROM and Montenegro, with potential capacities ranging from 5 to 30MWe. In Croatia and Serbia it is estimated that the indigenous biomass can supply respectively more than 90MWe and 176MWe.

As expected, the potential for biomass electricity in Ukraine is an order of magnitude greater, based on the country's geographical size and abundant resources. The opportunities for exploiting biomass energy for electricity production exceed 1.500MWe.

Heat generation

An important sector for biomass use in all countries is the local, domestic use of wood for space heating. This is an important sector because it offers large parts of the population – typically relatively poor, rural people – access to affordable energy. Nowdays, in EU27, there are growing examples of more modern boilers - with high efficiency and improved environmental performance – being used to heat domestic and other buildings such as schools, hospitals and municipal offices. These technologies certainly have great potential in the future for the under study countries too. As data is scarce and non-uniform it was not possible to disaggregate the stoves/ovens component of the bioheat sector with the modern boilers component. Thus, sector potential was assessed in terms of energy (GWh / PJ) generated but it was not considered meaningful to provide installed capacity (MWth) figures for this sector.

The sector that was analysed for heat installed capacity was the share of heat from CHP units (as described above under electricity).

Based on the results of the study, the opportunities for exploiting biomass energy for heat production are quite low in Albania and FYROM, with capacities ranging from

40-60MWth. The respective capacity for BiH is higher, with around 100MWth, while Croatia and Moldova were considered to have potential in the range 190-240MWth. The potential in Serbia was estimated in the study to be 750MWth.

Finally, the opportunities of exploiting biomass for heat purposes in Ukraine exceeds 3.500MWth.

Conclusions & Recommendations

The results of this study illustrate that countries have the opportunity to use indigenous biomass resources to displace significant amounts of imported fossil fuels, with all the various economic and environmental benefits that would result. Indeed, it may be added that, if these countries do not exploit these resources, then it is possible or indeed likely that portions of these resources will be exported and form part of the growing international trade in biomass fuels..

There are two areas of analysis which could readily follow from this study. Firstly, the data that has been collated would enable analyses of the greenhouse gas emission benefits that would result from exploitation of biomass resources. Secondly, there is clear need to take forward the results of this study as an important contribution to an assessment of the economic biomass potentials and the investment opportunities for biomass exploitation in each of the study countries. Identification, understanding and dissemination of bankable project options in the region should be a priority.

Acknowledgements

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Improving green-house gas balances of organic farms by the use of vegetable oil from mixed cropping as farm own fuel and its competition to food production

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Abstract: Mixed cropping is frequently used in organic farming and recommended worldwide in low external input areas to increase productivity, yield security and product diversity. In trials with different oil crops (*Camelina sativa L., Linum ustitatissivum L., Brassica napus L., Carthamus tinctorius L., Sinapis alba L)* grown together with legumes or cereals on German sites the potential of renewable fuel production parallel to food production was evaluated in organic farming. Depending on the crop-combination between 10 - 900 kg/ha vegetable oil could be produced. This could cover the fuel demand of agricultural machinery for 0.1 to 9 ha farmland. Most food crops combined with oil plants in mixed cropping had relative yields higher as 0.5, showing that also yield increases in food production are possible parallel to the production of renewable fuel. As example for a successful introduction of a non-common oil crop in farm cycles, results on the use of crude vegetable oil as fuel and of oil-cake as feedstuff for livestock from *Camelina sativa* are described. Improvements in GHG-emissions of organic farms can be expected by savings in production and yield stabilisation in mixed cropping as well as by direct substitution of diesel and imported feed components for livestock.

Keywords*: organic farming, renewable fuel, feed components*

1. Introduction

Mixed cropping is a management tool that is used in organic farming in terms of efficient resource use and risk minimization (Jensen 2006, Hof and Rauber 2003). A very special production line is mixed cropping with oil crops (Paulsen 2007a and 2008a, Carr et al. 2003, Szumigalski and van Acker 2005 and 2006). Due to very insecure yields of oil crops in organic farms mixed cropping could be used to secure oilseed production at all if suitable companion crops are found. Special yield goals of this cropping type could be defined for co-production of food and renewable energy.

As vegetable oil can be directly used as fuel for farm machinery (Ramadhas 2004, Hassel and Wichmann 2005) oil crop yield from mixed cropping must be adapted to the fuel demand of the farm and feed crops could be produced parallel (Paulsen 2008b, Paulsen and Rahmann 2004).

Green house gas-loads of organically produced vegetable oil can be very low due to the low external energy input in organic production (ADAS 2000). Oil crops cultivated in mixed cropping systems have additional energy demands for technical equipment for seeding and sieving, for seed production. Even probable yield reduction of the main crop would cause loads for the oil crop e.g. in green house gas-balances. But also positive yield effects of companion oil crops are reported and would have reducing effects on the green house gas emission of whole production as well as the use of renewable energy. Additionally oil cake from oil production can replace other imported feed components with indifferent climate loads (Steinfeld 2006).

Mixed cropping for energy production would probably be needed over the whole crop

rotation to supply sufficient fuel in organic farming. This implies a need for the use of vegetable oil from different oil crops in the machines and for the use of different oil-cakes in animal feeding.
In the following, yield results of field trials from different mixed cropping systems with different oil crops in organic production are given. Results of the use of *Camelina sativa* oil in machinery and oil cake in chicken feeding are summarized. Additionally the effects of the introduction of these measures on the green house gas load of production are described.

2. Materials and Methods

Field trials
Field trials of mixed cropping with oil crops were undertaken at four sites in Germany with the oil crops *Camelina sativa L., Linum ustitatissivum L., Brassica napus L., Carthamus tinctorius L.* and *Sinapis alba L.* The oil crops were sown in completely randomized block designs with four repetitions together with different legumes or cereals. Also the mixed cropping of two oil crops - *L. ustitatissivum* together with *C. sativa* - was tested. In the following text the introduced oil crops are further called 'oil crops'. The other crops in the mixture are called 'main crops'. Both crops were sown in separate rows and optimal depths each. The seed row distances were kept constant in sole and mixed cropping (12-12.5 cm). Consequently most seed numbers per area of oil crops and main crops were reduced to 75% or 50% compared to the sole cropping, according to existing field experiences. The trial design is given in Paulsen (2007b). Yield effects compared to sole cropping therefore could be expected by plant reduction per area, by different intrarow plant distances as well as by interrow plant competition of different varieties. After harvest the seeds were divided and weighed separately. Additionally all crops were grown in pure stand to calculate the Land Equivalent Ratio (LER) (Mead and Willey 1980).

Feeding trials with oil cakes
C. sativa oil cake was taken as example for a novel crop with special fatty acid composition and its usability in diets for broiler fattening. *C. sativa* oil cake as ingredient was critically discussed in terms of negative influences on fat odour and taste when used in pig or broiler nutrition (Böhme and Flachowsky 2005). Since 2008 it is accepted in the EU feed law (Commission directive 2008/76/EC). In a feeding trial on chicken fattening energy equal feed rations with 0, 2.5 or 5% *C. sativa* oil cake were used. Chicken were slaughtered, parameters of fattening performance, carcass quality, organ weights and sensoric meat quality were determined (Weissmann et al. 2007).

Tests in plant oil driven tractors
Usability of mixed vegetable oils was exemplarily examined in agricultural tractors with engines adapted to the use of pure *Brassica napus* oil. Two modern common rail tractors with 150 kW were compared over 1000 h in one year in a field test. One tractor was driven with cold pressed *B. napus* oil and one with a mixture of 30 % *C. sativa* oil and 70 % *B. napus* oil. Fuel qualities were examined according to DIN V 51605 (2006). Motor oil samples were controlled on vegetable oil content, viscosity and carbon residues.

Estimation of green house gas loads
The potential of green house gas reduction on farms by the substitution of diesel fuel by vegetable oil was calculated with an emission factor of 83.3 g CO_2eq/MJ diesel and an energy content of diesel of 43 MJ/kg or 36 MJ/l (EU 2009).

3. Results and Conclusions

Yield potential of mixed cropping with oil crops
Mixed cropping is seen as measure to ease overall yields, due to different growing habits and resource demand of the different plants (Trentbarth 1986). Due to this and to special site conditions also in the reported trials a very large bandwidth of yield combinations was obtained. Reasons for the yield variation were low field establishment of spring seeds due to spring drought periods (obvious in low yield levels of the main crop in sole cropping), problems with seeding technology of fine seeds and insect pests (*Melingetes anuus*) on nearly all sites and years in all cruciferous plants which is typical for organic farming conditions (Petterson et al. 2002, Valantin-Morison and Meynard 2007 and 2008). In table 1 the average values over all sites and years are given.

Table 1: Average grain yields of mixed and sole cropping systems of various main crops and oil crops in organic farms [kg/ha dry matter] and land equivalent ratio of mixed cropping (LER) (4 German sites in 2004 and 2005)

crop combination*	oil crops		main crops		mixed cropping	LER
	sole	mixed	sole	mixed	total	
H.v./B.n.	720	250	3580^a	1910	2160^b	0.88
S.c./B.n.	610	230	4490^a	2630	2750^b	0.96
P.s.^{wi}/B.n.	720	490	320^b	370	870^a	1.84
P.s./C.s.	1100	750	1470^b	1120	1870^a	1.44
P.s./C.s.^{II}	1260	470	2480^b	2350	2830^a	1.32
P.s./B.n.^{sp}	40	40	1470^b	1760	1800^a	2.20
P.s./S.a.	630	450	1470^a	700	1150^b	1.19
L.a./C.s.	1100	750	1410^b	910	1660^a	1.33
L.a./C.t.	1080	800	1410^a	470	1270^a	1.07
T.a.^{sp}/C.s.	1100	370	3660^a	2660	3030^b	1.06
T.a./L.u.	740	140	3660^a	2990	3140^b	1.01
C.s.^{m}/L.u.	740	240	1100^a	890	1140^a	1.13

B.n.: Brassica napus   *L.u.: Linum ustitatissivum*
C.s.: Camelina sativa   *P.s.: Pisum sativum*
C.t.: Carthamus tinctorius   *S.a.: Sinapis alba*
H.v.: Hordeum vulgare   *S.c.: Secale cereale*
L.a. Lupinus angustifolius   *T.a.: Triticum aestivum*
wi winter variety, sp spring variety, II *C. sativa* in broadcast seeding, m main crop *C. sativa*
a,b significant differences between yields of main crops are indicated by different letters (p<0.05)

Mixed cropping of legumes with *B. napus* or *C. sativa* on average lead to a remarkable total yield increase compared to the sole cropped main crop. High LER values between 1.32 and 2.20 indicate the high area efficiency of production of those mixtures (table 1).
C. sativa delivered on average between 370 and 750 kg/ha seeds with a moderate yield reduction of the main crops *P. sativum* or *L. angustifolius*. LER values between 1.32 and 1.44 were reached. Maximum yields of 1.75 t and 2.36 t ha *C. sativa* occurred in *P. sativum* or *L. angustifolius*, respectively. At this yield level the yields of the main crops were strictly reduced (Paulsen 2007a). *P. sativum* (winter variety) was kept upright by the *B. napus* (winter variety) and reached higher yield in mixed cropping. But both cultures were at an unsatisfactory low yield level. Flowers and seeds of *B. napus* (spring variety) were almost destroyed completely by insects in mixed and sole cropping. This and an average yield increase of *P. sativum* in mixed cropping with *B. napus* (spring variety) lead to the high LER value of 2.2. Due to their described extreme yield risk mixtures with *B. napus* need further evaluation.
C. tinctorius proofed to be very competitive in mixture with *L. angustifiolius*. At an LER of 1.07 of mixed cropping the yield was dominated by *C. tinctorius* (table 1). This tendency was additionally increased by the differing ripening times of both cultures which lead to pre-harvest yield losses in *L. angustifolius*. Further *C. sativa* or *L. ustitatissivum* were dominated by *T. aestivum* in mixed cropping. *T. aestivum* realized dis-proportionately high yields in mixed cropping if plant number reduction and extension in row distances in relation to sole cropping which were given by the trial design are considered. In those systems the oil crops *C. sativa* or *L. ustitatissivum* showed seed yields of 3.7 t/ha and 1.4 t/ha (dry matter), respectively. Maximum yields of *C. sativa* of 9.6 t ha dry matter only occurred together with at low yield levels of the main crop *T. aestivum* (Paulsen 2007a). In mixed cropping with *L. ustitatissivum, C. sativa* dominated the yield. But also in the four latter mixed cropping systems LER values larger than one could be reached (table 1).

Mean absolute yield gains and losses of mixed cropping with oil crops in organic farms at same area use are tabulated in table 2. This scenario can be helpful, when oilseeds shall be produced in the farm and mixed cropping shall help to overcome cropping difficulties e.g. in weed or pest management (Saucke and Acker-mann 2006, Paulsen et al. 2006). In table 2 the introduction of 2 ha mixed cropping is compared with the production of 1 ha of each culture in sole cropping.
Except for combinations of *P. sativum* with *S. alba* and of *L. angustifolius* with *C. tinctorius* all combinations lead to an improvement of the absolute seed production of the main crop on farm level. Oil crops were produced in all systems. A decrease in oil crop production on farm level compared to sole cropping systems was obvious in combinations of oil crops with *T. aestivum,* when *C. sativa* was grown in broadcast seeding together with peas, in most combinations with *B. napus* and finally in *L. ustitatissivum* if combined with *C. sativa* (table 2).

Table 2: Yields and yield gains or losses by mixed cropping compared to sole cropping at equal land use [kg/ha dry matter]

crop combination*	farm yield 2 ha mixed cropping / 2 ha oil crop	main crop	sole cropping 1 ha/1 ha oil crop	main crop	Additional farm yield by mixed cropping /1 ha oil crop	main crop
B.n./H.v.	500	3820	720	3580	-110	+120
B.n./S.c.	460	5260	610	4490	-75	+385
B.n./P.s.^{wi}	980	740	720	320	+130	+210
P.s./C.s.	1500	2240	1100	1470	+200	+385
P.s./C.s.^{II}	940	4700	1260	2480	-160	+1110
P.s./B.n.^{sp}	80	3520	40	1470	+20	+1025
P.s./S.a.	900	1400	630	1470	+135	-35
L.a./C.s.	1500	1820	1100	1410	+200	+205
L.a./C.t.	1600	940	1080	1410	+260	-235
T.a.^{sp}*/C.s.*	740	5320	1100	3660	-180	+830
T.a./L.u.	280	5980	740	3660	-230	+1160
C.s.^{m}*/L.u.*	480	1780	740	1100	-130	+340

*abbreviations: see table 1

But an overall yield gain (oil crops + main crops) in all mixed cropping systems is obvious. The decision which cropping system is preferred therefore is dependant of yield risk assessments of sole cropping and of positive aspects mixed cropping may deliver (stabilisation aspects, weed suppression, yield buffering aspects). Also goals for seed yields will influence the choice of the cropping system.

Organic mixed cropping systems with *C. sativa* proofed to be relatively robust in yields and ripening times over the years and showed yield buffering capacities (Paulsen 2007a). Therefore further studies on the use of its oil and oil cake were undertaken. These experiences are described in the following. The possible effects on changes of green house gas balances on farm level after introduction of the system are described.

Use of oil cakes in livestock feeding and alternative usages

In organic livestock nutrition the use and production of a sufficient amount of high-quality feed components containing protein and amino acids is essential for the creation of pure on farm diets (Zollitsch et al. 2004). The use of locally produced oil cakes would help to avoid external environmental effects and green house gas loads by import of feed components (Steinfeld et al. 2006). Replacement of oilcake from *Glycine max* which might be polluted with GMO from conventional production (Partridge and Murphy 2004) would be another important aspect to guarantee food security in organic farms.

In terms of its gucosinolate contents and its content of linolen- and linolenic acid the use of *C. sativa* oil cake in animal nutrition was critically discussed (Böhme H and Flachowsky 2005). But considerations and trials on an adequate dosage (Jaskiewicz and Matyka 2003, Weissmann et al. 2007) lead to a general allowance of the ingredient in livestock feeding (Commission directive 2008/76/EC).

Results on the successful complete replacement of *G. max* oil cake by *C. sativa* oil cake in organic chicken feed ratios are presented in table 3, exemplarily. Animal performance and meat quality in the chicken fattening were not influenced (Weissmann et al. 2007).

Table 3: Effects of the complete replacement of oil cake of *G. max* (5 %-content) by oilcake of *C. sativa* in feeding ratios for chickens on performance and meat quality (Weissmann et al. 2007)

	***G. max* oil cake**	***C. sativa* oil cake**
Fattening performance, n=	44	48
Slaughtering weight, g	3741 ^{b}	3883 ^{ab}
Daily weight gain, g	44.0 ^{a}	45.8 ^{a}
Feed intake, g/d	100.7 ^{bc}	107.6 ^{ab}
Feed conversion, g/g	2.38	2.35
Organ weights, n=12		
Thyroid, g	0.341 ^{b}	0.351 ^{b}
Liver, g	70.8 ^{ab}	74.3 ^{ab}
Carcass yield, %	69.4 ^{ab}	69.5 ^{ab}
Sensoric meat quality (leg) (1= bad, 6=very good)		
Tenderness	4.3	4.2
Juiciness	4.3	4.5
Aroma	4.1	3.9
Fatty acid composition of intramuscular fat		
SFA[1], %	28.2 ^{a}	28.0 ^{a}
MUFA[2], %	38.5	40.5
PUFA[3], %	33.1	31.3
Rest, %	0.2	0.2

a, b, c different letters indicate significant differences ($p \leq 0{,}05$), [1] Saturated Fatty Acids: C14:0 , C16:0, C18:0; [2] Mono Unsaturated Fatty Acids: C16:1, C18:1, C20:1, C22:1; [3] Poly Unsaturated Fatty Acids: C18:2, C18:3, C20:4

The consequences for the reduction of green house gas emission of organic production which might be caused by this replacement is unclear but would surely be high if land use changes for e. g. organic production of *G. max* can be avoided (Weightman et al. 2010).

Alternative usages of the oil cakes are seen in organic fertilization (Laber 2003) and in the use as additional substrate in biogas plants (Paulsen et al. 2009). In general usages like this might cause additional mitigation effects on green house gas emissions of farms by substitution of other fertilizers, by a yield increase through fertilization or by the substitution of other biogas co-substrates and the increase of the amount of renewable energy that is produced.

Tests in plant oil driven tractors

Tractors which were technically adapted to the use of vegetable oil as pure fuel are on the market or can be constructed by special suppliers. Several studies on the use of vegetable oil in diesel engines are available (Ramadhas 2004, Knothe et al. 1991) and were updated in practical field studies with modern agricultural machinery that was adapted to the use of *Brassica napus* oil according to the DIN V 51605 in Germany (Hassel and Wichmann 2005) and Austria. Research on possibilities to fulfill the coming exhaust regulations and on the newest technical development is running in an EU-wide demonstration project (http://www.2n vegoil.eu/default.asp?Menue=93). Further technical development concentrates on the purification of cold pressed and refined vegetable oils to exclude unwanted P, Ca, Mg contents (Remmele 2002, http://www.faqs. org/patents /app/20100024284).

For the demands of organic farming and of the mixed cropping approach a variety of oil crops is needed to be used in engines. The results of the exemplary field tests on the replacement of 30 % *B. napus* oil by *C. sativa* oil and the use as mixed fuel can be summarized as follows:

The tractor was driven without complications over 1000 h under different loads. The motor oil quality was always suitable and wide below critical thresholds (vegetable oil content, carbon particles, viscosity) also after the maximum period between the oil change of 350 h that was used.

Oxidation resistance of the vegetable fuel mixture was always under the DIN norm for given for *B. napus* oil when used as fuel (table 4).

Table 4: Parameters of fuel characteristics of a 70%/30% mixture of *B. napus* oil and *C. sativa* oil

Paramter	Unit	Threshold DIN V 51605	Oil mixture
CCR*	%(*m*/*m*)	≤ 0.40	0.46
Iodine number	g $100g^{-1}$	95 - 125	125
Acid value	mg KOH g^{-1}	≤ 2.0	1.59
Oxidation stability	h	≥ 6.0	4.0
P-content	mg kg^{-1}	≤ 12	11
S-content	mg kg^{-1}	≤10	3
Σ Ca + Mg	mg kg^{-1}	≤ 20	20.9

* Conradson Carbon Residue

After 1000 h carbonaceous deposits at the fuel injectors were detected. But it remained unclear if they were caused by the use of cold pressed oils which in general are of lower pureness than raffinates or by the use of the oil mixture itself because Ca and Mg contents of pure *C. sativa* oil was nearly in range with that of the used *B. napus* oil. Anyway the CCR values of the oil-mixture exceeded the DIN threshold (Table 4). The tractor had the same power and showed no difference in emission of NOx, CO, HC and particles compared to the use of pure *B. napus* oil. Principally the use of 30%/70% *C. sativa/B. napus* oil as fuel in diesel engines that are adapted to the use of vegetable oil is possible. In general increased attention on motor control (injectors, motor oil quality) must be taken when cold pressed and unrefined vegetable oil is used. But the use of vegetable oil beyond the DIN norm cannot be recommended if warranty aspects of the engines are considered.

But market studies on the practical trading of vegetable oils showed that different vegetable oils are mixed as fuel and are sold as vegetable oil according to DIN V 51605 (Paulsen et al. 2007). Vegetable oil mixtures for the use as fuel are obviously market conform and can therefore be part of considerations on the replacement of fossil fuels.

Estimation of green house gas loads

The additive potential of the mixed cropping system, the use of the vegetable oils as fuels in agricultural machinery and the use of oil cake as feed component to reduce the emission of CO_2-equivalents per hectare must be calculated based on the allocation of emission factors for the substituted materials (fossil fuel and other feed components) and by the hectare wise yield effects of the mixed cropping systems. Values on these overall effects of mixed cropping for the described mean yield levels (table 1) are given in table 5.

Table 5: Gains (+) and losses (-) in grain yields (dry matter) of various main crops in organic farms when mixed cropping with oil crops is introduced (a), additional oil (b) and oil cake yields (c) and change in produced raw protein (XP) (d) and energy production (e) by the introduction of mixed cropping, (yields: see table 1 and 2) and the reduction of green house gas emissions by the substitution of diesel fuel by vegetable oil (f)

	(a)	(b)	(c)	(d)	(e)	(f)
crop combination*	+/- main crops	+ veg. oil	+ oil-cake	+/- XP[b]	+/- heating value	- CO_{2eq}
	kg/ha				[c]MWh/ha	[d]kg/ha
B.n./H.v.	-1670	100	150	-105	-6.3	-313
B.n./S.c.	-1860	92	138	-95	-7.3	-288
B.n./P.s.[wi]	+50	196	294	+126	+3.7	-614
P.s./C.s.	-350	285	465	+116	+3.6	-893
P.s./C.s.[II]	-130	179	291	+118	+2.7	-561
P.s./B.n.[sp]	+290	16	24	+6	+1.7	-50
P.s./S.a.	-770	113	338	-26	-0.5	-354
L.a./C.s.	-500	285	465	+11	+2.9	-893
L.a./C.t.	-940	160	640	-229	+1.1	-502
T.a.[sp]*/C.s.*	-1000	141	229	-16	-2.2	-442
T.a./L.u.	-670	53	87	-55	-2.2	-166
C.s.[m]*/L.u.*	-210	91	149	+17	+0.7	-285

*abbreviations: see table 1 , [b]effects of mixed cropping on grain N contents (Paulsen and Schochow 2007) are considered, XP=N*6.25, [c]oil crops 7 kWh/kg dry matter, cereals/legumes 4.8 kWh/kg dry matter, [d]3603.4 gCO_{2eq}/kg diesel = 83.3 gCO_2eq/MJ (EU 2009)

On the contrary to the interpretation given in connection with table 2 the values in table 5 have to be interpreted with the background that mixed cropping is introduced in a farm to combine feed and fuel production in one field. So the pure yield effect per hectare is given here and not the effect on farm level.

Under this assumptions in the most cropping systems the yield of the main crop per hectare is reduced, exceptional are *P. sativum* (winter variety) yields in combination with *B. napus* (winter variety) and *P. sativum* in combination *B. napus* (spring variety) (table 5, column a). But inherent to the system all mixed cropping systems delivered additional vegetable oil and oil cake per hectare (Table 5, columns b and c). Considering the total produced raw protein content of the different crop combinations (table 5, column d) it is obvious that if the yield reductions are moderate and the oil yields are relatively high additional protein can be produced. This protein can replace necessary feed protein imports and replace their green house gas loads directly or can increase the yield of animal production by better feed quality. This can decrease the product related green house gas emissions.

The heating value of the whole seed production of mixed cropping compared to the sole cropped main crops in given as integrating value for overall energy production of the systems (table 5, column e). The combinations delivering higher protein yields and also the combination of *L. angustifolius* with *C. tinctorius* show an energy win per hectare compared to the sole cropping of main crops. In the latter combination high yield losses in *L. angustifolius* occurred and the raw protein losses on this side couldn't be compensated by the lower protein content of *C. tinctorius,* whereas the energetic approach delivered an increase in energy per hectare due to the assumed heating value of the oil crop.

By the direct replacement of fossil fuel with vegetable oil from mixed cropping between 50 and 893 kg/ha CO_2-equivalents could be replaced. Assuming a fuel demand for agricultural machinery of 100 kg/ha farmland vegetable oil from average mixed cropping oil yields could make 0.1 to 3 ha self reliant in fuel. With the reported maximum values of oil production in mixed cropping with *C. sativa* reported before fuel self-reliance for up to nine hectare could be reached.

Further considerations of the effects of mixed cropping systems with oil crops have to consider the possible additional energy demand for their introduction. It can be minimized e. g. by the combination of seeding technology (Paulsen und Pscheidl 2007). Additional factor demands of mixed cropping arise in the seed production and in the seed separation after harvest. But these points are seen to be of minor importance in life cycle balances (Sergis-Christian und Browers 2005) and must be compensated by the advantages of the cropping systems described before. In general mixed cropping with oil crops in organic farming is seen as highly specialised opportunity to produce oil crops (Gruber and Vogt-Kaute 2007) which has clearly to be adapted to site conditions.

Conclusions

Mixed cropping with oil crops can enable organic farmers to introduce oil crops in their crop rotation. Looking from this direction sole cropping of main and oil crops on different fields compared to mixed cropping on one field lead to increased farm production of both products. This alone can mean clear reducing effects on the product related green house gas emission of organic agricultural production.

Mixed cropping with oil crops can also be introduced as cropping concept to produce vegetable oil as fuel for agricultural machinery. Yields of the main crops will be reduced in that case but are replaced by products with other quantities and qualities. This has to be considered in farm balances and in their scenario descriptions.

Mixed cropping with oil crops allows a replacement of fossil fuel. The co-product oil cake and an increased protein production per hectare mean an added value for livestock productivity and a reduction of imported feed components can be expected. These aspects offer clear potential of the described system to reduce green house gas emissions of organic farms.

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Building sustainable biomass-to-biofuel systems: Prospects for biohydrogen generation in two EU regions

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Abstract: In this paper possibilities and roadmaps are explored, for the establishment of a technico-economically feasible, environment-friendly and sustainable, biomass-to-biohydrogen economy in Europe. Focus is put on the long range (2010-2030) potential of 2-step fermentative hydrogen generation. Current and future biomass feedstocks are assessed at EU, and regional level, taking into consideration their technical suitability, cost and sustainability. The regional differences affecting policy priorities are examined by a comparative study of two EU regions, Rotterdam (NL) and Thessaly (GR). These case studies have resulted in an inventory of potential stakeholders, and the foresight of their role in 5-year segment of the considered period. The establishment of a sustainable bio-based energy system can be made possible by the appropriate synergies between such stakeholders with usually diverging interests, within the frame of a common "biohydrogen culture". Some other findings follow:

- Incentives should be provided to local agro-industries and current biofuel producers for the transition from 1st generation biofuels to 2nd generation ones, including biohydrogen, with emphasis on sustainability.
- The biomass/biohydrogen potentials in the 2 regions are quantitatively similar, but qualitatively different: in Mt/a (dry biomass), 1.5 for Thessaly (energy crops, farm residues), 1.8 for Rotterdam (agro-industrial residues, imported feedstocks), or 80 and 83 kt/a of biohydrogen, respectively. In both cases, the estimated potential can cover the expected regional H_2 demand in the next 20 years.
- The economic feasibility of such plants will require significant yield improvements, both in carbohydrate recovery and hydrogen generation rates, and high value-added co-product applications.

Keywords: biomass, sustainable biofuels, biohydrogen, Europe, Rotterdam, Thessaly

7.1.4

11. Introduction

7.1.5

Mapping the biological resources within specific geographical boundaries, qualitatively and quantitatively, and assessing the conditions under which they will be available, constitutes the basis for the design and sustainable operation of any biomass-to-biofuel system. Given that the role of biomass in the future energy landscape will be increasingly important (Van Dam et al, 2005), a more accurate and "conversion technology oriented" assessment of its potential availability becomes necessary for policy making, long term planning and overall biomass-to-biofuel system design and optimization.

The research presented in this paper was carried out within the framework of EU funded Integrated Project, Hyvolution (2006-2010). The main objective of Hyvolution project is:

- the development and optimization of a 2-stage bioprocess for the generation of pure hydrogen from biomass (from this point forward to be mentioned as "Hyvolution technology"),
- the simultaneous optimization of technical, economic, environmental and social parameters of the whole biomasss-to-biohydrogen chain, and
- the exploration of the sustainable operation of the specific technology under various regional conditions within EU. (Hyvolution, 2010).

It should be noted that one of the major benefits of the examined technology is its applicability at a relatively small scale (2 MW Hydrogen generation unit), which provides the flexibility and option of decentralized resource exploitation.

The carbohydrate resources from agricultural and agro-industrial sector are considered as potential feedstocks for the examined technology. (Claassen et al, 1999) The overall annual hydrogen generation potential, based on the major, non forest originated, EU biomass resources, has been assessed as about 30 Mt (Karaoglanoglou et al, 2008).

The accurate estimation of the actual resource availability can take place only if the geographical boundaries of the system are kept quite limited, e.g. at regional level. Data collection at this level would provide the necessary basis for such estimation. The competition and synergies, which will be created during the implementation of the Hyvolution technology, not only with food sector but also with other biofuel/bioenergy generation options will be crucial for the feasibility and sustainability of the potential biomass-to-biohydrogen generation chains. The impact of the future plants on the natural resources, their social acceptance, which is highly dependent on their relevant effect on the local employment and economy, have to be examined regionally, as potential further incentives or constraints.

Within this framework, the present paper will provide an overview of the activities which took place, for the assessment of the prospects of the Hyvolution Technology integration, into the energy system of two EU regions, in a 20 year (2010-2030) perspective. The ultimate purpose of the whole process was to derive strategy, investment and policy hints for the development of Hyvolution technology applications in EU regions with different characteristics.

12. Methodology

Two European regions were selected in order to explore the potential logistic chains which can be built for the supply of feedstocks to biohydrogen facilities and their dependence on the regional factors.

The region selection took place, according to the criteria of Rural vs. Urban, Low vs. High income, Low vs. High innovativeness and South vs. North, and targeting at the maximum possible diversification of the two selected regions (Eurostat 2010; Pro Inno Europe, 2010):

(A) The Region of Thessaly, Greece: As a typical low income and innovation, primary sector based region of South Europe

(B) The Region of Rotterdam, The Netherlands: As a typical high income, highly industrialised and innovative region of North Europe

The methodological approach which was followed, in order to collect and process data for these two regions can be summarised into three major activities:

- Desktop research, where crucial regional characteristics were identified (Figure 1), and statistical and other data were collected in a systematic way in order to have the profile of each region,
- Workshops and on-site visits to the key players in both regions,
- Scenario-based potential assessments and socio-economic analysis through the projection of the current situation into the future.

13. Results and Discussion

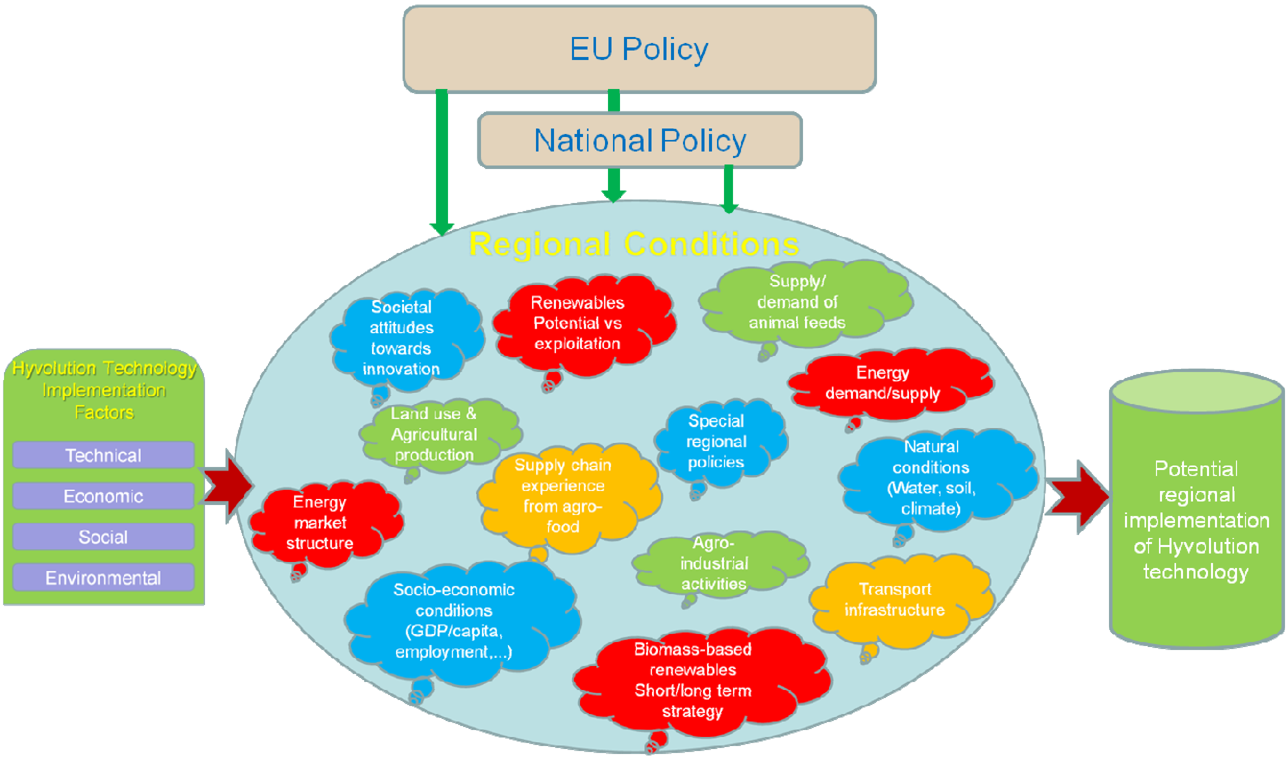
- *Desktop research - Data Collection*

The regional profile of each studied region was outlined, according to the key regional factors identified in the methodology. The results of this process are presented in Table 1.

This data along with the insight already acquired, throughout the Hyvolution project, are used, first in the immediate and future potential estimation and then in the scenario development.

The application of technical, economic, social and environmental criteria lead in the identification of sugar beet juice, potato peels, barley straw and wheat bran as the most promising feedstocks for the examined technology in EU. (Diamantopoulou et al, 2007; Diamantopoulou et al, 2008; Diamantopoulou, Koukios, 2010)

The biomass/biohydrogen potentials in the 2 regions are assessed to be quantitatively similar, but qualitatively different: in Mt/a (dry biomass), 1.5 for Thessaly energy crops, farm residues), 1.8 for Rotterdam (agro-industrial residues, imported feedstocks), or 80 and 83 kt/a of biohydrogen, respectively.



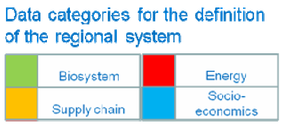


Figure 1: Regional dimension of the implementation of Hyvolution technology

Table 1: Profile of two case study regions

	"Rural South": THESSALY	"Industrial North": ROTTERDAM
Land use / Main Agricultural Products	- Total Agricultural Land: 490000 ha - Cotton: 150000 ha - Wheat: 110000 ha - Barley: 14000 ha - Sugar beet: 7000 ha - Fallow/pasture land/other not utilised agricultural land: 38000 ha	- Total Agricultural Land: 150000 ha - Cereals: 12500 - Potatoes: 9000 ha - Sugar beet: 4000 ha
Estimated Agricultural Income	850-2500 €/ha (40-50% coming from national or EU subsidies)	900-2500 €//ha (much higher for greenhouse agriculture)
Agro-industrial Units	2 large wheat mill units 1 large juice production unit Several small canned product units Several oil production/processing units	- oilseed crushing - grain processing - large beer breweries - potato processing facilities
Spatial Distribution of Agro-industrial Units	- 2 wheat mills are placed in Larissa and Magnesia prefectures - The juice production unit is placed in Magnesia prefecture - The rest units are distributed throughout the 4 prefectures	Main agro-industrial units are placed around the port of Rotterdam, within a 30 km radius
Potentially Available Agricultural and Agro-industrial By-products	- wheat bran - wheat and barley straw - pulp from juice industry - cake from oil industry	- wheat bran - potato steam peels - cake from oil industry
Transport Infrastructure	- a major port in Magnesia prefecture - good road network	- Rotterdam port (Europe's cheapest bunker port): the third largest port in the world - railway and road network supplying the port
Available Supply Chain Infrastructures	Already existing import (oil/oil seeds, cereals) and export (flour and other processed cereal and juice products) activities in the region	The agro-industrial units of the region are largely based on imported feedstock. The Agri-bulk handled in Rotterdam is about 9.5 million tones
Renewable Energy in the Region	135 MW power produced in H/E plants, and 2 biodiesel production units	- electricity production using imported wood residues(1 Mton dry wood residues) - wind energy
Biomass-based Energy Production	- 2 biodiesel production units (using imported feedstock) of 55000 tonnes total capacity - 1 bioethanol unit (from sugar beet and cereals) to be operational within 2010 *	- co-firing of wood for electricity - surplus of heat from oil refinery - farm scale biogas digesters - several bioethanol facilities around the port area
Population	About 750000 persons	About 1600000 persons
GDP/Capita - Employment	73.2 (considering 100 the GDP of EU25) 13% employed in primary sector	- 204 billion Euro regional product - 21% of the total employment of NL, 1.5% in primary
Special Regional Conditions - Policies	Governmental initiatives encouraging the land use change (especially from cotton to alternative crops)	Sustainable production program for all the economic sectors
Social Acceptance of Bioenergy Projects	"Thessaly Biofuel Technology Platform" along with the Thessaly University play a positive role in the social acceptance of biofuels	- Positive public response to "green electricity" - Negative public response to large biofuel plant projects

* Hellenic Sugar Industry announced in March 2010 that the specific project was cancelled, since they assessed that such a large plant will not be feasible and sustainable in long term.

Only a small part, (5 to 10%), of this potential originates from the 4 most promising feedstocks (Karaoglanoglou, Koukios, 2010)

The potential plants, in the two regions, which can be based on the 4 most promising feedstocks are presented in Table 2 and 3.

Table 2: Mapping the landscape of potential biohydrogen units in Thessaly

Potential Feedstock	Location	Co-operation with existing or potential industrial units	Hydrogen Unit Type	Potential Capacity
Sugar beet	Larissa	Bio-ethanol Production Unit (under construction)	Add-on	>> 8000 dry t/year
Wheat Bran	Volos	Wheat Mill (locally produced and imported wheat)	Add-on	> 8000 dry t /year
Potato Steam Peels	Lamia (city close to Thessaly region)	Potato Chips Production Plant	Add-on	~ 8000 dry t/year
Barley Straw	Karditsa-Trikala	Regionally produced straw	Local stand alone	~ 8000 dry t/year

Table 3: Mapping the landscape of potential biohydrogen units in Rotterdam

Potential Feedstock	Location	Co-operation with existing or potential industrial units	Hydrogen Unit Type	Potential Capacity
Sugar beet	Rotterdam port area	Sugar Production Unit	Add-on	>> 8000 dry t/year
Potato Steam Peels	Rotterdam port area	Potato Chips Production Plant	Add-on	>> 8000 dry t/year
Wheat Bran	Moerdijk industrial area	Wheat Mill (mainly imported wheat)	Add-on	>> 8000 dry t /year
Barley Straw	Rotterdam agricultural land area	Regionally produced straw	Local stand alone	~ 8000 dry t/year

- *Workshops and on-site visits*

Two major on-site visits and workshops, in Thessaly (Sugar beet factory, October 2007) and in Rotterdam (Port area, May 2009) were carried out.

Furthermore, numerous communications and on-site visits took place, to:

- academics, farmers and biofuel (biodiesel) production companies in Thessaly
- potential feedstock providers (Meneba mills, Farm Frites, etc.), already existing or under construction biofuel plants and the port authority in Rotterdam

Some crucial feasibility and sustainability issues, and key stakeholders were identified throughout this process. The degree of involvement of these stakeholders on the implementation of Hyvolution technology differs, for each region and 5 year sub-period in a 20 year perspective. An assessment of this involvement can be seen in Table 4.

- *Scenario-based analysis*

An attempt for the identification of the main priorities, bottlenecks and driving forces in each of the 5 year sub-periods, also took place. The positive or negative developments in these issues will lead in the "Best case" or "Worst case" scenarios for Hyvolution technology, respectively.

The outline of such a roadmap to the future application of Hyvolution Technology in both regions is presented in Figure 2a, b.

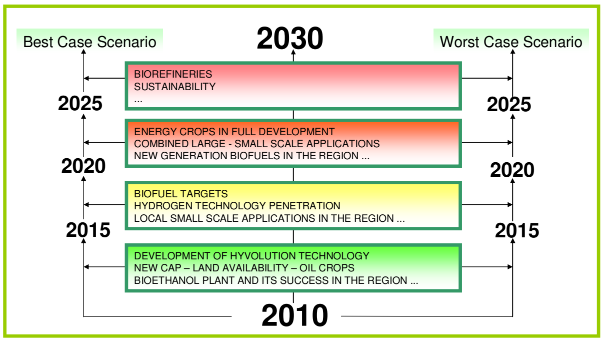


Figure 2a: Roadmap to Hydrogen through Hyvolution technology in Thessaly

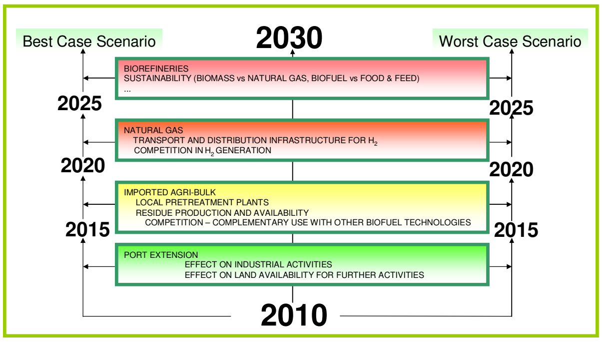


Figure 2b: Roadmap to Hydrogen through Hyvolution technology in Rotterdam

i. *Future Hydrogen generation potential in Thessaly*

The prospects of the future hydrogen generation potential of the region will highly depend on the land use change which is expected to take place due to the new Common Agricultural Policy (CAP) of EU. Under this perspective, 3 scenarios for the future land use, for the period 2010-2020, were considered assuming, in the meantime, that the agricultural yield will have an improvement for all the crops, equal to 1%/year [EEA, 2006]:

- Minimum energy crops scenario: 1/3 of current set aside land used for sugar crop cultivation
- Medium energy crops: Starting from 1/3 of current set aside land in 2010, and ending to 2/3 in 2020, to be used for sugar crop cultivation
- Maximum energy crops: Starting from 1/3 of current set aside land in 2010 and 0% of current cotton land, and ending to 2/3 of set aside land and 70% of cotton land in 2020, to be used for sugar crop cultivation.

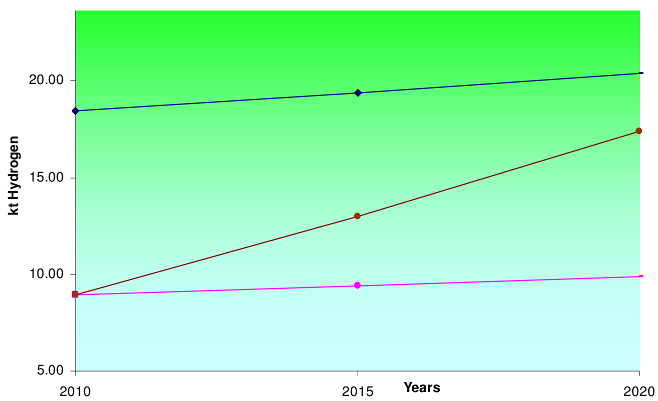
Table 4: Key Socio-economic actors and their involvement 2010-2030

	THESSALY				ROTTERDAM			
Key actors	2010-2015	2015-2020	2020-2025	2025-2030	2010-2015	2015-2020	2020-2025	2025-2030
Farmers	*	***	**	**	*	*	*	*
Local society	*	**	***	**	**	**	**	**
Existing biofuel industry	**	**	**	*	**	***	**	*
Existing food industry	*	***	**	*	**	***	**	**
Feed and fodder sector	*	**	**	**	*	**	***	**
Transport	*	*	**	**	*	**	***	***
Distribution	*	*	***	***	*	**	**	**
End-use	*	*	**	***	*	**	**	***
Technology research and development	***	**	*	*	***	**	*	*
EU policy	***	**	**	**	**	**	**	**
National policy	*	**	***	**	***	**	**	**
Hyvolution by-product market	*	*	**	***	*	*	**	**

Stakeholders' involvement	
*	simple involvement
**	significant role
***	key (dominant) actor

It should be also noted that the transition from the current agricultural land use to the future energy crop agriculture can take place only under certain conditions. The farmers' income expectations will play a major role in this process. Under the current conditions the land use change, for the replacement of cotton cultures, should lead in a gross margin generation about 400 Euro/ha in order to provide the necessary incentives to the farmers (LMC, 2007).
Moreover, the effect of the improvements in the refining and conversion technologies (especially for starch and lignocellulosics) was examined in a multiple scenario basis, starting from the currently obtained efficiencies and assuming future technology improvements, in order to assess the hydrogen generation potential from selected feedstocks in the region. (Figure 3a, b)

Figure 3a. Effect of technology efficiency on minimum energy crops scenario



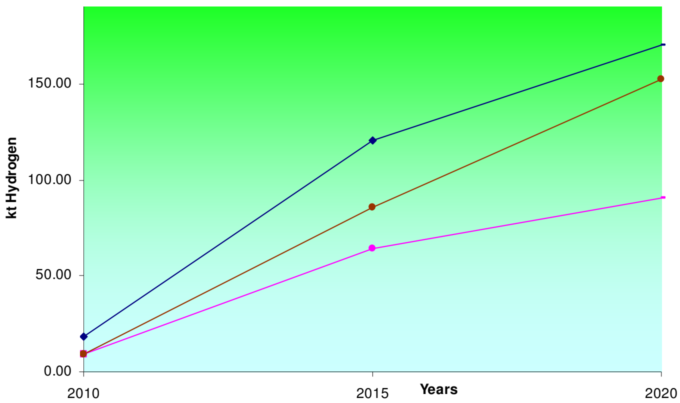


Figure 3b. Effect of technology efficiency on maximum energy crops scenario

ii. Future Hydrogen generation potential in Rotterdam

The region attracts a lot of industrial activities and it will do it even more in the short/medium term future, due to the expansion of the port area. However, the main limiting factor for the region will be the land availability for new industrial units and any other activity (e.g. agriculture).
The price of agricultural land is particularly high for growing energy crops in the region (29-68 kEuro/ha depending on the type of land). Consequently, the main feedstock for short-medium term future will be by-products from agro-processing industry, especially wet products, which are less useful for other purposes:

- Wheat processing: wheat bran (Meneba)

- Potato processing: potato steam peelings (Cosun/Aviko, Mccain)
- Beer breweries: spent brewery grains (Heineken, others)

The future “supply side” Hydrogen generation potential, through Hyvolution technology, for the region, was based on the total agribulk handled by the regional industrial units, and the future prospects of its development.
Several scenarios, considering the agro-industrial development and Hyvolution technology efficiency, were developed in order to map this potential. The parameters considered for each scenario are presented in Table 5.

Table 5: Supply-side scenarios

Scenarios	Annual increase in agribulk handled in industries of port area	Available by-products/residues for hyvolution	Carbohydrate recovery	Hydrogen conversion *
1	3%	10%	30%	100%
2	3%	10%	70%	100%
3	3%	10%	30%	50%
4	3%	10%	70%	50%
5	6%	10%	30%	100%
6	6%	10%	70%	100%
7	6%	10%	30%	50%
8	6%	10%	70%	50%
9	3%	15%	30%	100%
10	3%	15%	70%	100%
11	3%	15%	30%	50%
12	3%	15%	70%	50%
13	6%	15%	30%	100%
14	6%	15%	70%	100%
15	6%	15%	30%	50%
16	6%	15%	70%	50%

* 100% conversion = 0.1 t hydrogen from 1 t carbohydrates

The outcome of these scenarios along with the respective demand-side scenarios are presented in Figure 4.

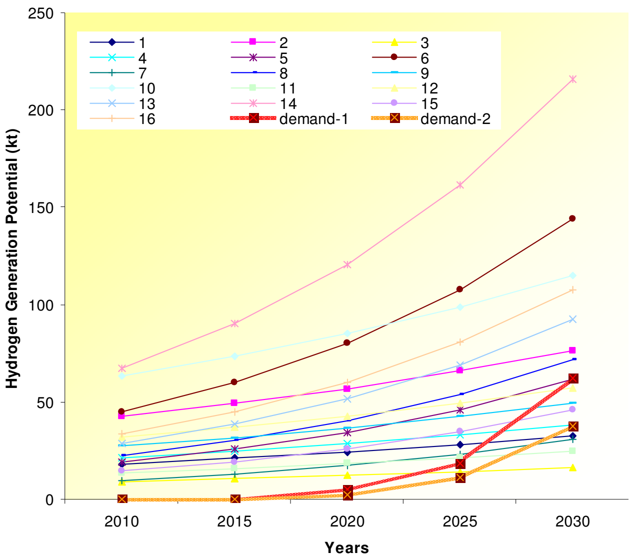


Figure 4: Supply and demand of Hydrogen in Rotterdam

The direct connection of the feedstock availability with the development of the food sector (agribulk handled and residues produced due to the pretreatment practices) in the region should be underlined.
Although, the Hydrogen generation potential through the Hyvolution technology from the feedstock supply side can be within a wide range (10-65 kt/year in 2010 and 15 to 220 kt/year in 2030), due to the high degree of uncertainties, it can be observed that most of the supply side scenarios provide the necessary potential to fulfil the respective demand assessment.

14. Conclusions

4.1 General remarks for both regions

- The future success and sustainable application of the examined technology is a function of the positive or negative progress of the issues identified and analysed in this paper. The respective priorities of each 5 year period should be monitored and the targets should be re-assessed in order to succeed in an optimised integration of the hyvolution technology in the EU’s future energy map.

- It is assessed that the transition from first generation to second generation biofuels and biohydrogen will play a crucial role for the land and infrastructure availability in both examined regions. Motives should be provided, especially to the local agro-industries and current biodiesel producers of the regions for this transition, as long as simultaneous improvement of the overall biofuel sustainability indices is achieved.

- Although the current refining and conversion technology can provide the necessary hydrogen potential, the economic feasibility of such plants will require the yield improvement and value added co-product applications.

- In a fully bioenergy integrated energy future, the competitive biofuel applications will further decrease the availability of the feedstocks. As a consequence, simultaneous research on the improvement of the hydrogen production efficiency and on the enrichment of the techno-economically suitable feedstock portfolio should be carried out.

- There will be diverse effects of existing biofuel production plants on the development and domination of Hyvolution technology:
  - Positive, in the "start-up" phase, providing the necessary infrastructure for pilot or small scale production
  - Possible negative effect in further development phase due to land use competition
  - "Success stories" of first generation biofuels will improve the social acceptance of biofuels and will create a "bio-society" culture which will facilitate the integration of Biohydrogen generation into the existing energy system

- The land need for the reactor of the photochemical fermentation (currently 60ha for an 8000 dry tonne/year biomass plant capacity, estimation for 10 ha after process optimisation) is a further concern especially for Rotterdam case where the land availability is already limited. This obstacle probably could be by-passed using otherwise unused areas (which primarily was water). In the case of Thessaly the availability of lower quality and non utilised agricultural land is estimated to provide the necessary land source in the start-up phase.

- The prospects of imported feedstock utilisation in biohydrogen generation plants is expected to play a crucial role in the future hydrogen economy especially in the case of Rotterdam, where the agricultural land availability for dedicated energy crop production is also extremely limited. Furthermore, this option would exploit the major strategic advantage of the region, the port infrastructure, which already supports import activities for large amounts of agri-bulk products, in the framework of the current industrial activities. As far as Thessaly region is concerned, the imported feedstocks will not be the key player for the full scale implementation of Hyvolution applications, given the current and estimated future land availability. However, they are expected to have an indirect effect, especially in the case of wheat milling residues, since the operation of already existing wheat milling plants is highly dependent on the imported (either from other Greek regions or from other countries) feedstocks. The future of this sector will affect the relevant by-product generation (wheat bran) in the region and its consequent availability for energy applications.

- Despite the potential feedstock availability for Biohydrogen generation:
  - 70% of biofuels is expected to be firt generation biofuels in 2020. This situation will limit significantly the actual feedstock availability (especially in the energy crop category) for Hyvolution Technology at this time period
  - The Hydrogen distribution and end use technology will still be capable to support a small contribution of Hydrogen in regional and national energy balance

4.2 "Thessaly" Case

- The current hydrogen generation potential from the 4 selected feedstocks in Thessaly region can cover the expected from the literature annual Hydrogen-from biomass demands of the region for the period 2010-2020 (even without any energy crop use and assuming that all the biomass-hydrogen will come from Hyvolution technology).

- The energy crop cultivation scenarios, even the most conservative ones, increase the potential significantly, increasing the importance of Thessaly in the future hydrogen economy, as well. According to the assumed "maximum energy crops" scenario in the region, **2.5 to 4.7%** of the expected transport sector energy needs [EC - DG for Energy and Transport, 2007] (or **1.0 to 1.9%** of the expected overall energy needs) of Greece in 2020 can be covered by the "Hyvolution" Hydrogen which will be produced in the region.

- The social impact assessment of cotton culture replacement, in Thessaly, by energy crops should also consider the impact of this situation on the secondary sector, the cotton gin plants of the region, which employ a large number of labourers (about 200 permanent and 600 seasonal)

4.3 "Rotterdam" Case

- The supply and demand site scenarios showed that the hydrogen demand of the region can be easily covered by the feedstock availability from the regional agro-industrial units, under the conditions that the continuous future development of these units is secured and that the techno-economic feedstock suitability issues for a larger number of potential Hyvolution feedstocks are solved.

- The feasibility and sustainability of the add-on to potato unit hydrogen plants will depend on:
  - The competitiveness of bio-hydrogen against natural gas
  - The reduction of CO_2 emission due to less transport movements
  - The potential to sell the CO_2 credits earned
  - The reliability of the biohydrogen plant (no malfunctions) since long-term storage of the by-product is not desired/possible
  - The exploitation of the co-products and effluents of the $BioH_2$ facility
  - The assessment of other impacts of the bio-hydrogen plant, such a nuisance and safety regulations, and the local environment/habitat

- Given that one add-on hydrogen conversion plant may not be able to be fully supplied with potato steam peelings as feedstocks, the feasibility of using other industrial by-products in a multi-feedstock hydrogen plant should be assessed.

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Biogas-conversion renewable process for enhanced hydrogen assisted combustion

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Abstract: A new biogas based conversion process via catalytic reforming for the conversion of gaseous, methane–rich biogas feedstocks into hydrogen and carbon oxide mixtures is described and analyzed. The exit hydrogen rich gas is used for enhanced hydrogen assisted combustion, for final cleaner electricity generation .
This work also researches the design parameters of catalytic reformers carrying the conversion process of biogases into hydrogen rich combustion gas.
A developed model is applied to the reformer to describe its function with a number of parameters. Extension of the model can predict reformer operation at regimes which are not applied experimentally.
Furthermore, targets of this research include turnkey system and process development for the power generation and cleaner-electricity generation industries. Moreover, the efficient utilization of bio- and waste type resources used in the generation of biogas feedstocks with an increased processing capacity and efficiency.
It is also important to take into account the pollution reduction aspect with additional design consideration in the described catalytic reformer-hydrogen assisted combustion operation.

Keywords: biogas utilization, biogas fed systems, catalytic reformers, hydrogen assisted combustion, renewable fuels.

I. INTRODUCTION

In our earlier papers published by IASTED (PGRES ’02, Marina Del Ray, CA; Modeling and Simulation, ‘03, Palm Springs, CA) we described and analyzed new findings and results on catalytic reactors/heterogeneous processors for the steam reforming of methane, natural gas and biogas for use in power generation systems and fuel cells [12].

The current communication, continues this research by giving emphasis in the so-called “Green Power” and “Biogas Energy” systems. We analyze the use of biomass gases (biogas generating feedstocks) as sources for power/electricity generation via hydrogen assisted enhanced combustion.

Use of biomass derived gases rich in methane for synthesis gas production is an attractive route in “biogas-bioenergy” based systems [3,4,5,8].
There is a recent emphasis on the development and commercialization of such systems for energy and heat/cooling generation applications. Such installations exist currently mainly in USA, Europe, Japan, China and other countries. Fig.1 below, shows the itemized distribution and usages of biogas energy-applications which is coming from various renewable sources [2]. Emphasis is given in current installations.

Such power systems require the development, use and commercialization of an effective catalytic reformer utilizing active metals such as Ni, Rh, Ru, Cr, or bimetallic combinations of those. Enrichment of the catalyst with earth metals, such as Ca, Mg, La and K promotes the catalyst stability on stream and minimizes the deactivation from carbon deposition, especially at the reactor inlet (deactivation propensity is especially high at the inlet of the reactor due to the lack of hydrogen which is generated during the course of the reaction) [6-12].

The reformer under consideration can be a fixed bed catalysis-reactor operating under plug flow conditions. Its outlet gas stream can be used directly as feed in the accompanied combustor-turbine system for direct electricity generation. The outlet stream is rich in hydrogen, carbon monoxide, and methane and consists the proper mixture for enhanced hydrogen assisted combustion. It is moreover beneficial, to operate the reactor at a lower temperature range for increasing the reactor and catalyst life times and for reducing the endothermic heating load (Btu/hr) of the endothermic reformer [8].

Below, we give design emphasis in the specific reformer configuration for the generation and delivery of hydrogen rich synthesis gas into the adjacent power system.

II. PROCESS AND OPERATIONS DESCRIPTION

The proposed process of reforming biogas rich in methane and possibly in higher hydrocarbons, with steam is a key catalysis route for producing quality hydrogen or synthesis gas in an economical way [6-12]. Synthesis gas contains mainly hydrogen mixed with carbon monoxide. Blended with the unreacted methane, the final outlet mixture from the reformer constitutes a valuable additive for enhanced hydrogen assisted combustion. The reforming processes are endothermic and use similar catalysis metals as described above.

The following reactions take place in the reformer by adding steam as the oxidant in the biogas-feedstock, as shown below:

$CH_4 + H_2O = CO + 3H_2$
(ΔH^o_{298}=+206.1 kJ/mol)
(1)
(biogas - steam reforming reaction)

$CO + H_2O = CO_2 + H_2$ (ΔH^o_{298}= -41.15 kJ/mol)
(2)
(parallel water gas shift reaction)

A part of the tail gas exiting from the turbine can be diverted in the shellside of the specific reactor to provide the endothermic heat for running the reformer.

Mathematical modeling of the biogas-steam reformer for a steady state catalytic reactor under plug-flow conditions includes the species reaction terms in the mass balance equations and is as follows:

$$dX^A/dz = (\pi\, d_T^2 / 4n_{Ao})\, \rho_B\, R_A \qquad (3)$$

Species A can be any of the reactants and products of the reactions (1) and (2) above.
With: $R_{CH4} = - R_1$
$R_{CO2} = R_2$, $R_{CO} = R_1 - R_2$,
$R_{H2} = 3R_1 + R_2$, $R_{H2O} = - R_1 - R_2$,
Where R_1 and R_2 are the descriptive heterogeneous reaction rates of the reactions (1) and (2) given above. R_1 and R_2 can be written according to a number of heterogeneous kinetic expressions [9,10].

The thermal balance in a non-isothermal reformer is given as follows:

$$dT_T/dz = (\pi\, d_T^2 /4)\, (1/m'c_p)\, \{ \rho_B\, [(-\Delta H_r^1)\, R_1 + (-\Delta H_r^2)\, R_2] - 4(U/d_T)(T_T - T_S) \} \qquad (4)$$

The reformer pressure balance which describes the pressure variation along the fixed bed of catalyst particles is given as follows:

$$- dP_T/dz = 2\, f\, \rho_g\, u_s^2 / g_c\, d_p \qquad (5)$$

The above equations are complemented by the initial conditions as shown below:

at z=0 (reactor inlet) , $X^A = 0$, $T_T = To$, $P_T = P_{To}$

A detailed analysis of the model, its parameters and their range of variation is given in earlier communications [8,11].
The system of equations (3), (4) and (5) is integrated numerically as an initial value problem to provide the reactant conversions, product yields, reactor temperature and pressure along the axial length and to obtain the axial profiles of these variables and their values at the reactor exit.

By using the above equations (3),(4), and (5), within the modeling procedure a detailed reactor analysis is obtained for the described reformer configuration. Solution of the equations is obtained numerically by using an initial value integration technique for ordinary differential equations with variable stepsize to ensure higher accuracy (implicit Adams-Moulton method). The solution provides the final exit conversions and product yields of the reformer, together with its exit temperature and pressure. The integration technique can be coupled with a non-linear least squares optimization technique where it is necessary to calculate the reaction constants, the preexponential factors, and the activation energies of the heterogeneous reactions (1) and (2) given above [8].

In our previous research communications we have as well described and analyzed the reaction, separation (i.e., permeation), and process (conversion, yield) characteristics of permreactors (membrane based catalytic reactors) and related processes for methane- steam reforming, water gas shift, and methane-carbon dioxide reforming reactions including catalysis and membrane materials characteristics. The main types of reactors described were membrane reformers which were utilized as single permreactor, permreactor-separator or reactor-separator sequence and permreactor-permreactor sequence [6-8,11,12]. These effective and versatile catalytic reaction systems were applied for pure hydrogen, H_2 and CO_2, or H_2 and CO (syn-gas) generation to be used as fuel gas for power generation or as synthesis gas for production of specialty chemicals (such as methanol and higher hydrocarbons). More than one type of membrane reformers were examined in previous work based on the location of the fixed catalytic bed and the inert or catalytic nature of the inorganic (alumina based) membrane tube [8].

Computational modeling of the described reformers in this paper was also performed which shows performance measures (biogas-reactant conversion, product yield, H_2 rich gas composition) versus the variation of intrinsic model parameters (reactor space time, reaction temperature and pressure, feed composition, space velocity). The models also analyze and show performance measures under new operating conditions which are of interest to new biogas-energy process and project applications [4,8,11].

The interconnected or integrated combustion system is fed directly by the fuel-gas generated by the described reformers. The focus of our studies includes solutions in a number of problems associated with the installation, operation, and mass, energy conservation of the entire reformer-combustion unit.

The solutions focus into the operative improvement of the combined reactor-combustion unit and include catalysts and reformer internal and wall materials optimization, and feedstock specifications. Catalysis studies focus to install improved catalysts with minimal deactivation on stream for continuous reliable reactor and turbine operation on a long term basis. Materials studies focus to improve on the life and constant activity of materials including catalysts and internal components of the reformer and turbine systems. Design and process studies focus on system integration, efficient operation, increased power output (kW/m^3), and adaptability to different biogas-based feedstocks.

The economic feasibility of the overall installation is correlated to high efficiency (e.g., 55%-80% for advanced units) and high current density output (A/cm^2), increased system reliability for continuous electricity generation, and reduced plant installation, operation and maintenance cost. These targets combined with the systematic elimination of pollution by use of the combined biogas system make this technology highly applicable and attractive. Clean biogas electricity generation minimizes NOx, and hydrocarbon species in the emissions. This is achieved via the hydrogen assisted enhanced combustion process which is especially useful in lowering the NOx concentration in the tail gases.

III. RESULTS AND DISCUSSION

Use of biogas in the reformer coming from biomass and landfill feedstocks, constitute an alternative innovative approach for direct usage of those feedstocks for power generation. There are significant resources of these feedstocks and their accumulation in land is growing. Gas coming out of landfill dumpsites (landfill gas) and from the treatment of biomass and municipal sewage and sludge (biogas) is rich in methane and constitutes the proper renewable mixture for direct conversion into the described reformer/turbine system. Catalytic conversion of these biogases in the reformer yields a hydrogen rich mixture for powering the interconnected turbine system. As the flowrates of the biogas increase in the feed (for larger sites and treatment systems) a larger capacity reformer and turbine may be required to handle the conversion; consecutively, the final turbine electricity and heat output (kW) increases as well.

Fig.1 shows the percentage of income from the direct utilization of biogases coming from agricultural and farm-animal waste sources. The figure shows the different energy utilization of biogas in terms of percentage [2].

We are also presenting below two figures relating with the experiments, modeling, and simulation of the biogas-steam reforming reactor. We have used the model of the equations (3),(4),(5) to simulate the catalytic reformer.

Fig.2 shows the effect of the space time of the reactor to the conversion of biogas or methane feedstock, as also shows the effect of the reaction temperature to the same conversion. This is related with the conversion of reaction (1).

The ratio of the biogas feedstock in the reactor inlet is set at $CH_4:H_2O:H_2=1:4:0.2$. The temperature range examined was set from 450◦C to 550◦C. Fig.2 shows that the biogas/methane conversion at the reformer exit increases as the space time of the reformer is tripled. This is true for all reaction temperatures examined. The experimental data obtained was simulated by the computational model shown in equations (3), (4), and (5). The model results are shown as dotted lines in Fig.2, and they simulate well the experimental points. The heterogeneous kinetic rate expression used in the equations and in the modeling was obtained using reference [9].

Fig.3 moreover, shows experimentally the effect of the space time of the reactor and reaction temperature to the conversion of reaction (2). This is the water-gas shift reaction and what is plotted is the so called experimental yield to carbon dioxide which is a product of reaction (2).

Fig.3 shows that the yield to carbon dioxide at the reformer exit increases as the space time of the reformer is tripled. This is true for all four reaction temperatures examined. The experimental data obtained was also simulated by the computational model of equations (3), (4), and (5). The model results are shown as dotted lines in Fig.3, and they also simulate well the experimental points.

These two plots define the level of conversions obtained experimentally in the reformer for the above two reactions. Thus, they define the composition of the exit hydrogen rich gas used directly for hydrogen assisted enhanced combustion. They are also shown the type of syngas (in terms of composition) which is entering into the combustion system for electricity and heat generation.

Moreover, Table 1 below shows a summary of specifications and details from a biogas processing plant, for energy cogeneration from farm-animal wastes. It provides details on the energetic distribution outcome and the various useful quantities of the entire plant. This table is given for comparison purposes, in order to be evaluated the potential of the newly described biogas to hydrogen rich gas combustion unit.

IV. CONCLUSIONS

Hydrogen assisted combustion process can be coupled with reforming operations of biomass and landfill gases. The specific electricity and heat generation system can operate in series or integrated with a catalytic reformer which converts biogas feedstocks at various operating conditions. These biogases are rich in CH_4 and are converted into a H_2 and CO rich mixture suitable for the continuous operation of the turbine-combustion unit. Our reformers have been also simulated by computational models which account for the reactions taking place within the reformers. Several flexible operating conditions in the reformers have been tested via these models and results have been derived.

Useful distributed power generation within a wider power grid can be accomplished with this operation, which can cover the local needs of municipal and remote areas rich in biogas sources. Final power output relates to the reformer conversion and the efficient utilization of the syngas by the turbine system. The waste heat from the conversion of syngas to electricity can be reduced through the hydrogen assisted enhanced operation and higher overall efficiencies can be achieved. Hydrogen enhanced combustion from biogas, in a continuous operation mode offer as well pollution minimization (specifically NOx reduction), higher power density and increased efficiency (reduced waste heat) in comparison with conventional power systems.

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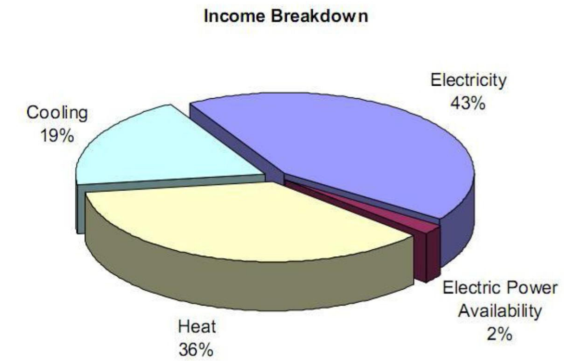

Fig.1. Percentage of income from the direct utilization of biogas coming from agricultural and farm-animal wastes [2].

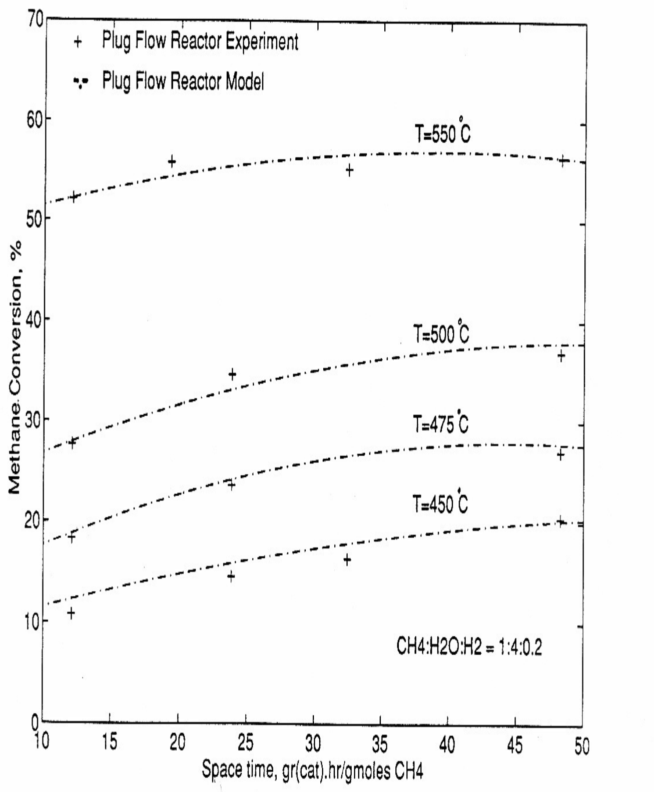

Fig.2. Experimental and modeling data/results of a biogas-steam reformer in a plug flow mode of operation. Methane conversion data at various space times and operation temperatures.

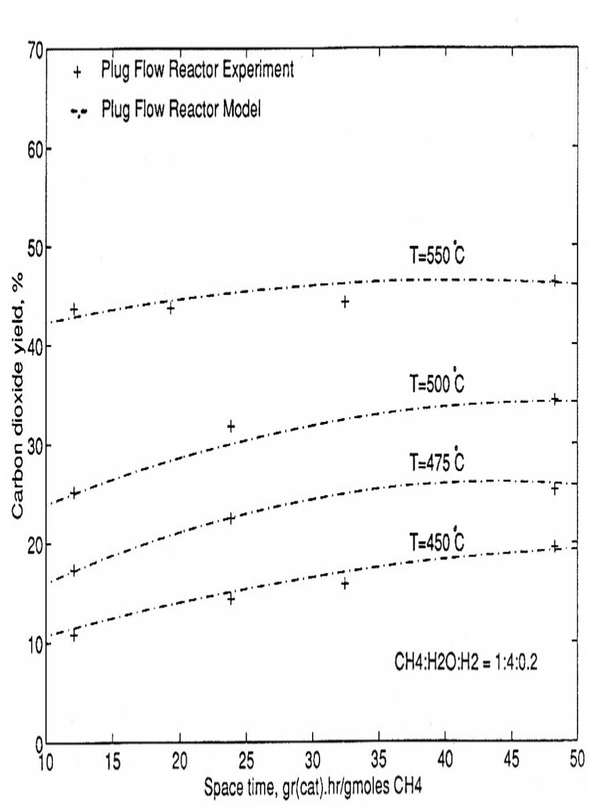

Fig.3. Experimental and modeling data/results of a biogas-steam reformer in a plug flow mode of operation. Carbon dioxide yield data at various space times and operation temperatures.

Table 1. Specifications and details of a biogas processing plant, for electricity and heat cogeneration from farm-animal wastes, (Northern Greece area), [3]

Biogas production volume:	3600 m^3/day (70% methane in biogas)
Total number of farm animals : (swines)	2210
Methane production volume:	2520 m^3 CH_4/day
Total energy generation:	26100 kWh/day
Electricity generation (35% min):	9100 kWh/day
Heat generation (45% min):	11745 kWh/day
Waste heat (about 20%):	5255 kWh/day
Annual Electricity Generation:	3000-3300 MWh/year
Sale price per MWh (to DEH, Greek Electricity Authority),	73 Euro/MWh about 241000Euro/year
Annual Heat generation:	4200-4300 MWh/year
Equivalent Oil capacity (Annual)	363 m^3/year
Oil sale price: about	1100 Euro/m^3

Contribution of biomass to decentralised energy supply with the objective of public services and supply security for peripheral regions in Germany

a project financed by the German Federal Government, 2009

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Abstract: The aim of the present project is to assess the spatial relevance and the technical requirements for an intensified use of biomass for energy purposes in rural regions, either exclusively or in combination with other renewable energy sources. The analysis is based on the characterisation of relevant technologies for the provision of bioenergy and other renewable energy sources as well. Three typical rural regions in Germany were selected for the case study. To determine the coverage of energy supply by local bioenergy and other renewable energies, a Status Quo (2007) and two scenarios (2020) are illustrated. While the reference-scenario assumes a moderate expansion of renewable energies, the objective scenario presumes an ambitious use of renewable energies for the reference regions. It will be discussed under which conditions the three investigated regions are able to cover their energy demand by regional bioenergy or by a combination with other renewable energies. In this context, influence parameters were ascertained and discussed, for example land allocation (cultivated crops), per-hectare yields, adequacy for other renewable energies (wind appearance, solar radiation) as well as demographic development and the prevailing business situation (e.g. located industry). Additionally, the regional characteristics of rural areas influence the technology mix for the provision of renewable energy considerably.

Keywords: bioenergy, decentralised, energy supply

7.1.6

15. Introduction

7.1.7

The utilisation of renewable energies has increased considerably within the last few years, especially due to political incentive systems. Reasons for the expansion are the savings in fossil CO_2-emissions to meet climate protection aims on the one hand and the enhanced security of supply because energy and raw material imports are substituted on the other hand.

Within the political debate, mainly the security of supply on the EU or national level is being discussed. However, renewable energies can contribute to a regional security of supply, too. This is especially true for rural areas in a large distance to conurbations or cities.

Besides renewable energy from wind, water and the sun, the production of biomass is of great importance. First, bioenergy can be generated regardless of weather conditions and is available in different capacity ranges, from a few kilowatt up to several megawatt. Second, it can serve as base-load energy as well as control energy. Furthermore, raw materials can be gained directly in the respective region, which strengthens rather weak local economies and leads to additional value added.

Against this background, the question is being discussed regarding the extent to which a typical peripheral region in Germany could cover its energy demand through regional bioenergy either exclusively or combined with other renewable energies.

Therefore, three regions were chosen as reference regions and classified by different characteristics. These characteristics allow to calculate the specific regional energy demand and to determine the extent of a possible self-supply in the status quo (2007) and in two development scenarios for the year 2020. Although the study is focused on the utilisation of bioenergy, the remaining renewable energies from wind, solar and water power as well as near-surface geothermics are also taken into account.

16. Characterisation of the three reference regions

The three chosen reference regions are so-called „peripheral regions“ with a population density of < 100 inhabitants/km², characterised by a lack of technical and social infrastructural facilities, an above-average decrease in population caused by migration and a problematic economic situation. By means of these characteristics, the county of Cham (Bavaria), the county of Kyffhäuser (Thuringia) and the county of Uecker-Randow (Mecklenburg-Western Pomerania) were chosen. The geographical location in Germany is shown in fig. 1.

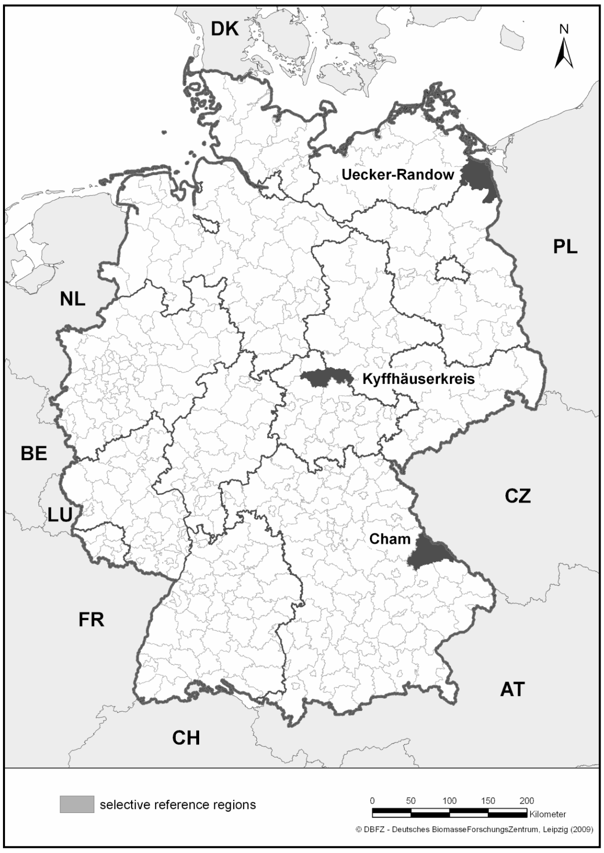

Fig. 1: Geographical location of the 3 reference regions in Germany

To calculate the energy demand and its coverage by regional renewable energy, the regions are inter alia characterised by the specific values shown in table 1.

Tab. 1: Data for the characterization of the 3 reference regions

parameter	Cham	Kyffhäuser	Uecker-Randow
Spatial aspects			
- Area	151,187 ha	103,514 ha	162,428 ha
- Population density	0.86 inh./km²	0.83 inh./km²	0.47 inh./km²
Bioenergy aspects			
- Share of arable land	21%	59%	35%
- Share of forest area	43%	23%	32%
- livestock	0.6 LUs/ha	0.8 LUs/ha	0.3 LUs/ha
Socio-economic aspects			
- Population 2007	129.817	85.882	75.842
- Population 2020	128.537	72.486	68.379
- Gross value added	23,092 €/inh.	13,886 €/inh.	13,468 €/inh.
- Energy demand 2007	17.4 PJ	7.4 PJ	5.6PJ
- Energy demand 2020	18.5 PJ	6.7 PJ	5.2 PJ
- Energy demand per capita 2007	134 GJ/inh.	86 GJ/inh.	73 GJ/inh.
- Energy demand per capita 2020	144 GJ/inh.	79 GJ/inh.	77 GJ/inh.

17. Selection of energy technologies

Numerous renewable energy technologies in different capacity ranges are available for various energy sources. As to the selection of the technologies that could be utilised in the three regions, the following aspects are regarded: with view to a regional self-supply, technologies for the production of heat, electricity and liquid biofuels are considered that are able to cover a broad range of regional raw materials such as wood, energy crops and liquid manure and that are available in different capacity ranges. Furthermore, regarding a self-sufficient energy supply, the chosen technology mixture needs to cover both the base load and the peak load.

Table 2 (below) shows the technologies that are factored in the calculation of the scenarios.

18. Scenarios

The study determines the status quo for the year 2007 and develops two scenarios with reference to the year 2020 that picture the supply with bioenergy only as well as the supply with bioenergy combined with other renewable energies.

Status Quo

To illustrate the actual state within the regions, they are at first characterised with reference to the year 2007. With the help of statistical data regarding population size, livestock and the use of arable land, the technical biomass potential is determined. In this respect, the (theoretical) assumption is made that there is a self-supply with food for each county. Assuming so, competitive uses are excluded since arable land is only regarded when not used for food production. In the next step, the calculated technical biomass potential is assigned to the biotechnologies „small scale heating with local heating grid“, „agricultural biogas plant“, „biomass heating and power station“ and „liquid biofuel“. As regards the remaining renewable energy sources, heat and electricity generated by existing facilities is taken as a basis for the status quo.

Reference and objective scenario

To illustrate possible future developments, two scenarios with reference to the year 2020 are regarded that differ in the extent to which renewable energies are used. The "reference-scenario" assumes a moderate increase of renewable energies. In addition to the technologies established in the „status quo", this scenario comprises the technologies „biomass gasification and CHP", „biogas plant with upgrading for fuel cell", „bioethanol facility and biogas plant" and „biomethane (as transport fuel) from thermo-chemical and bio-chemical route". In the "objective-scenario", on the contrary, an increase of regional renewable energies with the aim of a total self-supply is assumed. However, the regarded technologies remain the same. In both scenarios, priority is put on the more efficient stationary facilities. A list of these assumptions regarding to which the different energy technologies are extended can be found in table 3. The assumptions – apart from those relating to bioenergy – are based on trend projections and data from a pilot study of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Besides the utilised energy technologies, regional technical raw material potentials play a crucial role regarding the amount of generated bioenergy. Table 4 shows the assumptions that were made as to land use and the development of crop yields compared to the year 2007. The frame conditions determined in table 4 entail a fundamental increase of arable land for the cultivation of energy crops. This is due to recultivation of fallow land and increasing yields per hectare so that less land is needed for the cultivation of food crops. This is reinforced by a decrease of population and the resulting decreased demand of food. In addition, increasing yields per hectare lead to an increased technical fuel potential in the reference regions.

Tab. 2: Technologies of renewable energies which are used in the scenario approach

Technology chains	Electricity		Heat		Liquid biofuels	
	Installed capacity [kW_{el}]	Final energy [MWh_{el}/a]	Installed capacity [kW_{th}]	Final energy [MWh_{th}/a]	Installed capacity [kW_{th}]	Final energy [MWh_{th}/a]
Small scale heating + local heating grid	-	-	100	430	-	-
Agricultural biogas plant	500	3,900	448	3,494	-	-
Biomass CHP + OCR	1,000	7,800	7,500	33,000	-	-
Biomass gasification + CHP	500	3,750	1,020	4,080	-	-
Biogas plant (treatment) + fuel cell	1,300	10,000	-		-	-
Biodiesel	-	-	-	-	3,750	34,280
Bioethanol facility + biogas plant	2,700	22,880			5,850	57,600
Biomethane (from the bio-chemical route)	-	-	-	-	11,530	83,000
Biomethane (from the thermo-chemical route)	-	-	1,900	15,600	83,300	600,000
Heat pump	-	-	15	14	-	-
Solar collector (6 m²)	-	-	1.4	2	-	-
Photovoltaic module (20 m²)	2	2	-	-	-	-
Onshore wind energy plant	2,000	4,200	-	-	-	-
Hydroelectric power plant	500	3,250	-	-	-	-

Tab. 3: Assumptions of the renewable technology chains in the scenarios

Technology chains	Reference scenario	Objective scenario
Bioenergy	Consideration of all listed technologies for the generation of heat, electricity and liquid biofuels	Generation of electricity and heat is priority. In case of a 100 % coverage, technologies for mobile use are considered as well
Wind energy	Expansion of the status quo by 30 %	Total expansion on sites designated for wind energy use in the spatial development plan
Solar energy	Solarthermics: trend projection	Solarthermics: expansion of the status quo by 460 %
	Photovoltaics: expansion of the status quo by 250 %	Photovoltaics: expansion of the status quo by 500 %
Geothermal energy	Trend projection	Expansion of the status quo by 550 %
Water power	Increase of the installed capacity by 5 % compared to the status quo due to modernisation measures	Increase of the installed capacity by 10 % compared to the status quo due to modernisation measures; reactivation of closed facilities and construction of planned facilities

Tab. 4: Assumptions of land use in the scenarios

Land use	Reference scenario	Objective scenario
Settlement area/traffic	Increase by 30 ha/d nationwide, conversion to the respective reference region	Increase by 10 ha/d nationwide, conversion to the respective reference region
Fallow land	Recultivation of 50 % for cultivating energy crops	Recultivation of 100 % for cultivating energy crops
Forest	Increase by 0.07 %/a	Increase by 0.14 %/a
Arable land		
- for food production	Decrease as a result of declining population figures and increasing yields.	
- for energy crops	Increase of areas Distribution of crops: • 10 % of land for SRC • 20 % less land for rapeseed • remaining land: corn, grain	Increase of areas Distribution of crops: • 40 % of land for SRC • 40 % of land for corn • 20 % of land for grain
Yields per hectare		
Grain	0.5 %/a	1.0 %/a
Corn	1.0 %/a	1.5 %/a
Rapeseed	0.8 %/a	No energetic use because of little output
SCR	1.0 %/a	1.0 %/a
Forestry biomass	0.5 %/a	0.5 %/a

Energy-Scenarios

Based on the described frame conditions, the scenarios were developed as „bioenergy scenarios", assuming the use of bioenergy only, and as „renewable energy scenarios", assuming the use of all available forms of renewable energy. The scheme in fig. 2 illustrates how the scenarios were calculated.

Results of the scenarios

The regional biomass potentials in the bioenergy-scenarios are determined with the help of population figures as well as basic data about land use, hectare yields and livestock.

As a first step, the biomass potentials are calculated considering the basic data (for example size of the

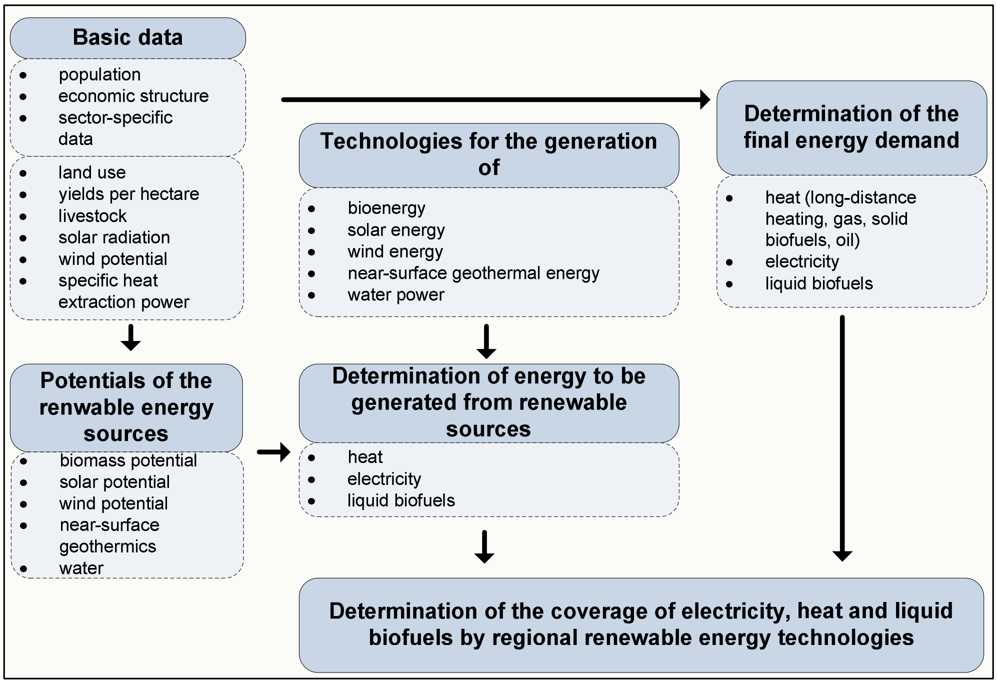

Fig. 2: Scheme of the scenario calculations

region, allocation of land use, development of yields), the frame conditions for the scenarios and the population development until the year 2020. In the next step, the technical biomass potentials are assigned to the respective bioenergy technologies and the amount of electricity, heat and biofuels that can be generated therefrom is determined. Its contribution to the final energy coverage is calculated by comparing the energy demand and the available biomass potentials. The essential influencing factors in this respect are the population development, the crop-specific yields and the final energy demand.

The renewable energy scenarios consider not only bioenergy but also renewable energy from wind, water, sun and earth. In order to do so, values for solar radiation, wind potential and the specific heat extraction power for near-surface geothermal energy are determined for each region and then allocated to the different technologies, taking into consideration the assumptions from table 4. Thus, the extent to which the heat and electricity demand can be covered by the remaining renewable energies is identified.

Fig. 3 shows the coverage of renewable energies for the regions in the different scenarios. There are considerable differences both between the regions and between the scenarios. However, none of the regions can provide for a 100 % self-supply. This is due to the fact that none or only very little liquid biofuel is provided because stationary, more efficient facilities are preferred.

Regarding the specific coverage of heat, electricity and fuel, fig. 4 illustrates that a surplus of energy can be generated, especially a surplus of electricity. This results from a large amount of windpower especially in Uecker-Randow and Kyffhäuser on the one hand and from the little demand of electricity opposed to the demand of heat on the other hand. The total heat demand, on the contrary, can only be met in Uecker-Randow in the objective scenario. The demand of liquid biofuels, however, can hardly be covered by regional bioenergy. At the same time, a surplus of heat and electricity can be reached. This offers a possibility for energy exports.

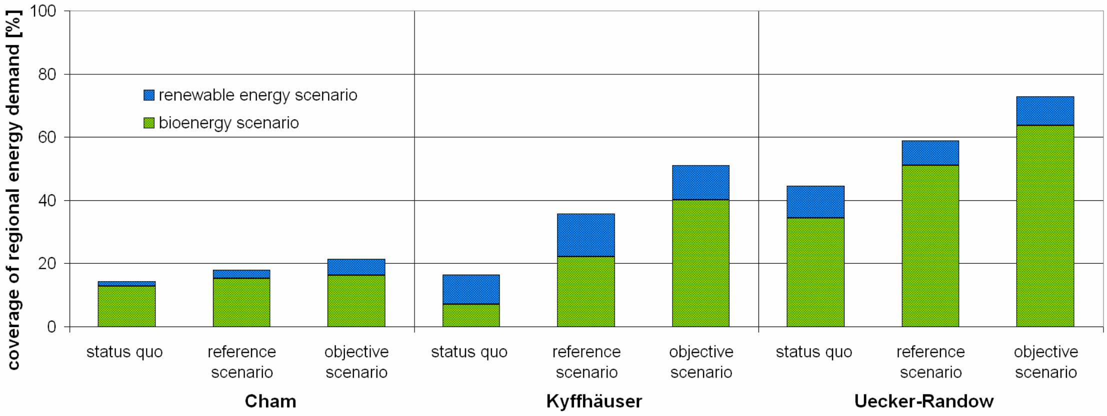

Fig. 3: Coverage of renewable energy for the regions in different scenarios

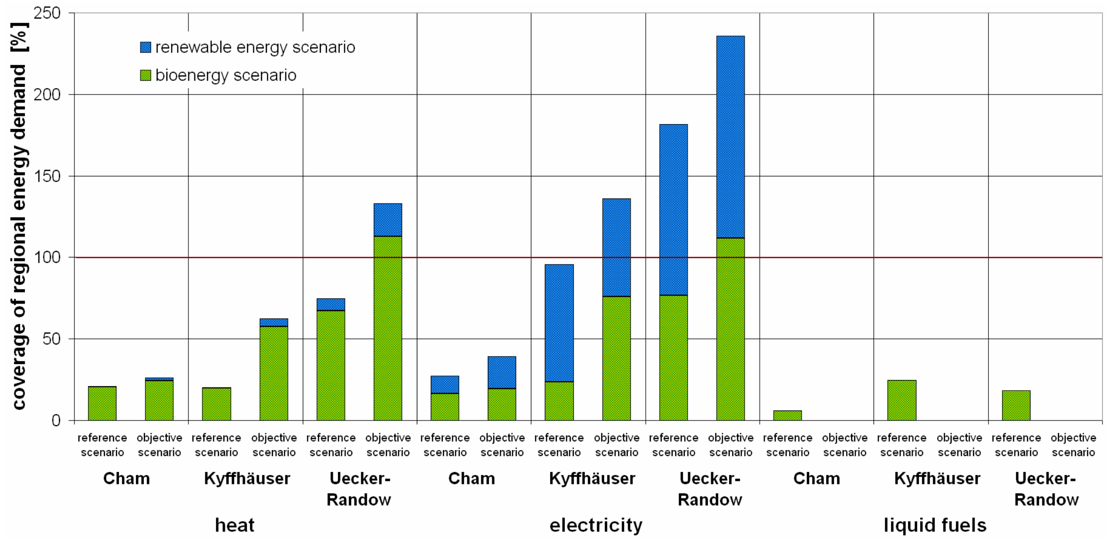

Fig. 4: Coverage of heat, electricity and liquid fuels for the regions in different scenarios

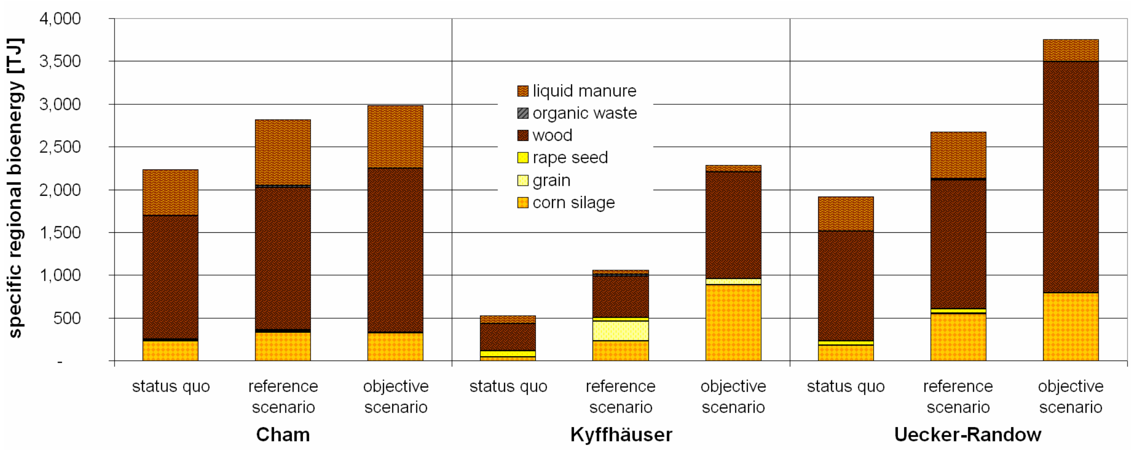

Fig. 5: Bioenergy for each region, separated to the raw material fractions

Discussion of the scenario results

There are significant differences between the regions as to the possibility of a 100 % self-supply with regional biomasses. This is caused by different preconditions regarding supply and demand. Looking at the composition of the bioenergy raw materials in fig. 5, it becomes apparent that the regions differ not only in their potentials as a whole, but also in the substrate-specific composition. Reasons are the differences in land (use), the combination of crops, hectare yields and livestock.

The most significant increase of regional bioenergy can be observed in the county of Kyffhäuser. However, it does not reach the potentials of Cham or Uecker-Randow, especially due to differing area sizes. Compared to Uecker-Randow and especially Kyffhäuser, there is only little potential for development in Cham. Besides the total size of the county, land use (i.e. the allocation of forest areas, permanent grass land and arable land) plays an essential role for the amount and the composition of raw materials. Because of the recultivation of fallow land, increasing yields and a declining population, more arable land can be used for energy crops. Regarding forest areas, the results show that there is only little potential to enhance the regional wood production in the examined period.

Wind energy is influenced by the geographical position of a region. A rather northern location entails a higher potential and an enhanced use of wind power. Another influencing factor is the extent to which the use of wind power is considered in the regional development plan. Thus, the use of wind power is dependent on the guidelines of regional planning and influenced respectively. Water power depends essentially on the regional relief since a certain gradient is needed for the utilisation of hydroelectric plants. Consequently, Cham has the best water power potential among the three regions whereas Uecker-Randow, on the contrary, has hardly any. For the examined regions, as for Germany in general, it can be said that the water power potential is already exhausted as far as possible. Merely modernisation measures or the reactivation of closed facilities could imply a small development potential. As to solar power, all of the reference regions still have a substantial potential for solar thermal energy. This also applies to photovoltaics, regarding Uecker-Randow and Kyffhäuser. Only in the southern part of Cham, there is a comprehensive use in the status quo already. Compared to solar power, the potential of near-surface geothermal energy is used to a much lesser extent. This is mainly due to the fact that despite a comparably high technical potential, there are quite a few practical difficulties, for example the fact that heat pumps can only reach temperature levels of about 60°C. Therefore, it can only be utilised in well-insulated houses with an adapted heating system.

Summarising, it can be said that wind power provides the best potential for the implementation of renewable energies that are not based on biomass. Geothermal and solar energy do have big technical potentials, too, but are not yet realisable in economic and technical terms.

Considering the energy demand, table 1 shows a significant difference between the regions. The energy demand in the county of Cham is three times higher than in the other two regions. This shows that the final energy demand and the economic situation of a region are connected. Cham has a gross value added that is two times higher which indicates a significantly better economic situation and thus a lot of trade and industry. Cham also shows the highest specific energy consumption, compared to Uecker-Randow and Kyffhäuser. Regarding the demand for heating, two reasons could be determined for this: firstly, Cham has longer and colder winters and secondly, there are more single-family homes and thus a higher demand than in the other regions.

It shows that Cham also has a higher final energy demand in the traffic sector, compared to the other two reference regions. This is due to the high population in Cham and the improved economic situation which leads to an increased logistical effort and more traffic. Concluding, the population, the economic and the climatic situation as well as the allocation of the different building types and their state of redevelopment can be named as the significant influencing factors on the demand side.

5. Conclusions and Outlook

As a result of the scenarios, it has to be emphasised that none of the reference regions would be able to cover their total energy demand with local bioenergy or bioenergy combined with other renewable energies. Merely Uecker-Randow could meet 100 % of its demand of heating using regional bioenergy under the assumptions of the objective scenario. Taking into account the other renewable energy sources, the county of Kyffhäuser could provide for its electricity demand in the objective scenario, too. The demand of liquid biofuels, however, cannot be covered in either of the three reference regions.

A comparison of the three regions shows that the energy coverage is not only affected by the demand, but also significantly influenced by the supply. The possible share of bioenergy is directly dependent on the biomass in the respective region. Besides increasing yields per hectare, the kind of land use has a significant influence on the available amount. The scenarios of the examined regions make clear that a large share of forest areas entails a relatively high biomass potential in the status quo already. However, forest areas have only very little development potential regarding the bioenergy production, compared to arable land which offers an enhanced biomass potential. This arises from increasing per-hectare yields of the individual crops, the choice of different crops, for example with focus on high-yielding and high-energy crops like SRC (short rotation coppice) and corn, and the available efficient conversion technologies. Furthermore, arable land for food production could be used for energy crops in the future, due to increasing per-hectare yields. With an expected decrease of population, this development will reinforce.

With view to the type and the scope of a possible scenario implementation regarding the enhanced biomass utilisation in peripheral regions, the mere examination of biomass potentials is not sufficient. Environmental and spatial aspects have to be considered, too. Furthermore, all renewable energy technologies have to be classified and integrated systematically in superordinated regional development strategies. These could for example be included in regional plans or guiding principles in regional energy concepts. With a specific regional focus e.g. on tourism, regional value added or employment, the different bioenergy technologies and the remaining renewable energies are rated in different ways. Therefore, taking into account the perception and acceptance of the various interest groups, the utilisation of the different renewable energy technologies has to be scrutinised carefully to enable a sustainable supply concept for renewable energies that considers the regional specifics, too.

Further examination within the presented work has shown that a 100 % self-supply with regional bioenergy would only be – if at all – possible when taking drastic measures, for example abandoning the regional supply with food. However, this approach would have to be examined critically because of the expected loss of biodiversity and a fundamental change of the landscape since only a few dominating crops would remain. Also, from a regional point of view, being independent from fossil energies would mean being dependent on food. Even though this is a theoretical consideration, it distinctly points out the danger of competing land uses in the sense of "food versus fuel". Hence, on behalf of the region, a strategic decision-making as regards its objectives and the corresponding orientation is necessary.

Summarising, the studies have clearly demonstrated that a detailed analysis of the region in question has to be incorporated into the considerations. With view to a possible realisation of such scenarios, it is essential to include the different regional stakeholders. It has to be emphasised that rural areas can have a supply function for conurbations. Therefore, renewable energy should be generated beyond the actual regional demand. To reach this aim, it is absolutely necessary to include the regional stakeholders and stakeholder networks comprehensively from the very beginning.

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