Accelerating Renewable Energies through

Valorisation of Biogenic Organic Raw Material

Development of regional strategies for the acceleration of bioenergy in North-West Europe

with focus on secondary raw materials and the considerate use of agricultural resources

– 2015 –

Colophon

This report was compiled in the framework of action 14 of the ARBOR project. ARBOR is an INTERREG IVB NWE project with 13 partners from 6 European regions dealing with the development of technological solutions and regional strategy development for improved sustainable biomass utilisation. ARBOR is co-funded by local authorities from the United Kingdom, Flanders, Saarland, Luxemburg, the Netherlands and Ireland.

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Publication Date: September 2015

Please check www.arbornwe.eu for the other reports that have been compiled within ARBOR:

- Benchmark report 2015 on biomass for energy use in NWE
- Five case study reports dedicated to specific ARBOR subjects i.e. nutrient recovery, low impact energy crops, agro-side streams, synergy parks and biomass closed-loop systems.
- Inventory: Techniques for nutrient recovery from digestate
- Small-scale anaerobic digestion - case studies in Western Europe
- Green heat with small-scale wood combustion for agriculture, SME and industrial plants
- An overview of pilots and investments
- Four fact sheets: Buffer strips for biomass sourcing, Cover crops for energy production, Digestate treatment systems for nutrient recovery, Energy from Short Rotation Coppice

Statements by Governments from Northwest Europe ARBOR target countries as Germany, Luxemburg, Netherland, Belgium, United Kingdom, Ireland

“Energy from biomass will continue to become more significant within the overall energy mix. Extensive research into technological and sustainability aspects, as well as scientific monitoring of demonstration projects and market introductions, will be essential if bioenergy is to become internationally competitive, and if it is to be produced and utilised in a manner that is both climate- and environment-friendly”. ***National Research Strategy BioEconomy 2030 Germany***

„The Netherlands will implement the EU Directive by gradually increasing the proportion of energy from renewable sources such as biofuels, biogas and electricity for road transport. The aim is to build confidence that biofuels are a viable energy source and to move gradually towards the EU target of 10 % share of biofuels by 2020 in the transport sector. For electricity, the target is 14% by 2020.” ***Energieakkoord 2013, Government of the Netherlands***

„Meeting our 2020 renewable energy targets is not without its challenges particularly in the areas of heat and transport. The potential of the bioenergy sector to make a significant contribution in this regard is well recognised, both here in Ireland and by the EU. However, realisation of this potential requires coordinated cross Government support, in particular in relation to agriculture, forestry, waste recovery, job creation, and innovation policies“ Alex White T.D., ***The Irish Minister for Communications, Energy and Natural Resources***

„ Bioenergy, or biomass as it is most commonly referred, is one of the most versatile forms of low carbon and renewable generation. It can be used to produce heat, electricity or transport fuel. It can provide a continuous and constant flow of energy. It can create opportunities for growth along the supply chain both in the UK and abroad (…) Bioenergy can also help us make use of wastes that are currently being sent to landfill. (…).We recognise that bioenergy is not automatically low carbon, renewable or sustainable. So that’s where our role as Government is important as this sector develops “

Charles Hendry, The UK’s Minister of State for Energy 2010-2012

„The challenge for Luxembourg is to meet the increasing demand for renewables by considerate exploitation of land available in agriculture and forestry sector. (...) The material use and subsequent energetic valorisation of biomass should (...), where possible, have a priority to direct energetic use. (...) The material cycles should be closed on regional level to increase self-sufficiency of the regions. The production and the use of materials recycled from waste streams (e.g. liquid and solid manure, sewage sludge, compost, greenery cuttings, smallwood, ...) should, if feasible, take place within a region. Only then the scarce resource biomass will have a significant contribution to more efficient resources use.” ***Conseil Supérieur pour un Development Durable, Grand Duchy of Luxembourg***

„Within the energy budget, the means for green heat will be fortified. Biomass will preferably be used for the production of green heat. The production of green electricity should be combined with heat production, whenever possible“ ***Flemish Government Agreement, 2014***

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1 ARBOR project – Supporting biomass strategy development

1.1 Aim and structure of the project

The ARBOR project (Interreg IVB NWE) was launched by 13 partners from 6 European regions dealing with the development of technological solutions and regional strategies for improved sustainable biomass utilisation. ARBOR stands for “Accelerating Renewable Energies through Valorisation of Biogenic Organic Raw Material”. ARBOR was unique in the way it analysed the whole biomass energy supply chain. The project dealt with concepts and implementations of biomass sourcing (WP 1) and efficient conversion systems (WP2). These were complemented with policy, economic and environmental assessment and summarized in the created strategy guideline (WP3).

ARBOR activities included:

- A state of the art analysis of biomass for bioenergy initiatives and projects in NWE
- Pilot and demonstration actions on the use of agricultural residues for bioenergy, closed loop organic residue valorisation systems managed by local authorities, industrial biomass based synergy parks, sourcing and energetic conversion of low-impact energy crops such as biomass from buffer strips, cover crops or contaminated soils
- A market analysis of biomass equipment providers, manufacturers and investors in NWE
- An up-to-date inventory and technology watch on biomass conversion technologies and side stream valorisation options
- An analysis of the political and legal framework conditions on bioenergy utilisation in NWE
- An environmental and economic assessment of the developed ARBOR bioenergy implementation schemes
- A strategy development for the ARBOR pilot regions and the examined value chains

The project was co-funded by local authorities from the United Kingdom, Flanders, Saarland, Luxemburg, the Netherlands, and Ireland.

Source: ARBOR Consortium, Final Conference Brussels, 2015

1.2 Trans-sectorial and interregional cooperation

The core project activities were closely related to the knowhow transfer between the NWE regions. Several dissemination and exchange bodies have been created to boost the trans-sectorial and interregional cooperation (see Figure 1).

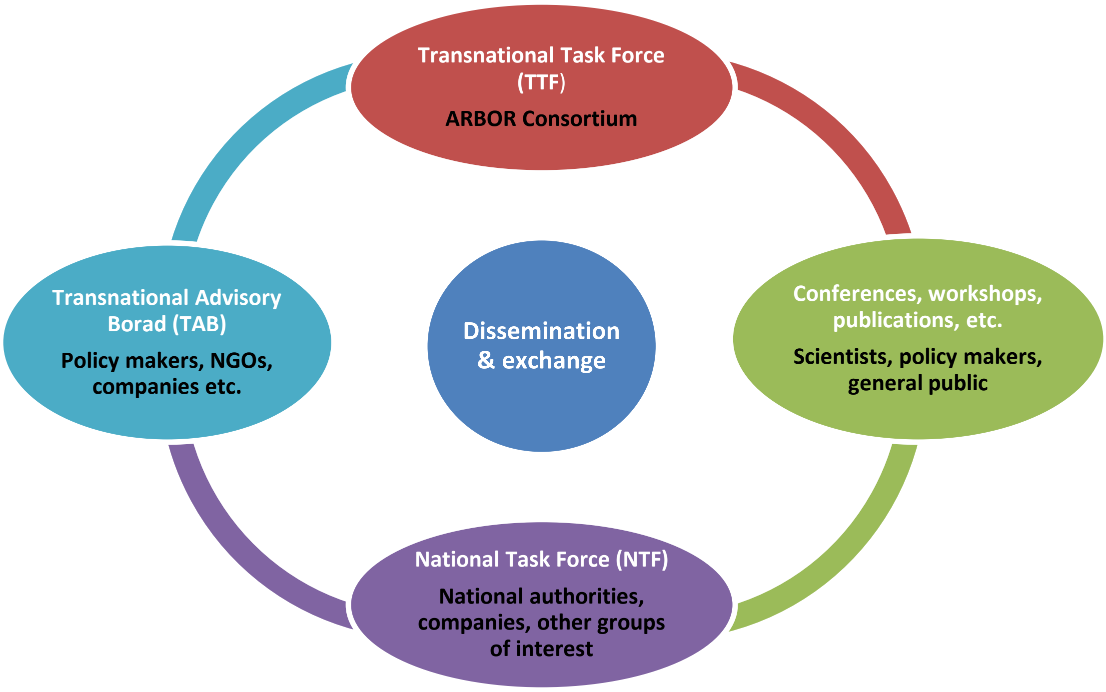


Figure 1 The Dissemination and know-how exchange channels within the ARBOR projects

The ARBOR partners with their expertise, experience and knowhow build a Transnational Task Force (TTF), which guided the execution of all actions in the project. Depending on the specific actions, external experts and stakeholders were invited to participate in the TTF. This was in particular important for the realisation of the pilots (including the investments). Each pilot was realized through a process of design, implementation, execution and evaluation. These development stages have been discussed in TTF in order to obtain maximal input of knowledge during this process. It resulted also in a very efficient transfer of knowledge and experience from one region to another and was reflected in the organised regional meetings and study visits.

In order to support and profit from the TTF, each region has created its own National Task Force (NTF), set up to guarantee transfer of the project related knowledge to regional stakeholders, which can benefit through enhancing their biomass production, collection and conversion into energy. The NTFs comprised the regional project partners, selected national observers, subcontractors, local industrial or agricultural platforms, agencies, governments, policy makers, etc. The NTFs relayed on the transnational discussions had also the function to provide regional feedback on the discussed topics to the project team (TTF). Furthermore, they acted as local steering groups of partners within their regions. The NTFs were also responsible for dissemination to various regional stakeholder groups and maximizing the response of local actions and to support the TTF.

A third contact platform, the Transnational Advisory Board (TAB), has been set up on NWE level and consisted of national and regional experts representing the European, governmental, regional and local administrations, sector companies, universities, research institutes and consulting companies. The TAB members have actively supported the TTF consortium in the development of concepts and addressing the transferability related challenges. Four TAB meetings have been organised (see Figure 2) within the life time of the project to identify and discuss the barriers and drivers for regional implementation of bioenergy concepts from the perspective of country-specific political, economic and administrative framework conditions. The TAB- and NTF-based feedback was essential to evaluate the regional bioenergy concepts developed within ARBOR and to facilitate their transfer to other European regions.

Figure 2 Focus of the Transnational Advisory Board Meetings and Final Conference

2 Introduction into strategy development

Within the last decade biomass energy has become a consistent source of renewable power in North-West Europe (NWE). Biomass currently accounts for around 44-65% of all renewable energy used in the EU and 4% of the EU energy needs (69 million tonnes of oil equivalent (toe)) (European Commission, 2005). At the beginning of the 2000s thanks to the availability of potential biomass resources, the construction of bio-energy plants encountered only minor problems and succeeded in yielding primarily positive results (e.g. an increase in land value, improved income stability for farmers, etc.); However, as biomass use expanded, potential resource-related limitations began to hamper further development. The problems occurred in particular on the intersection with the emerging agricultural and forestry sectors (food production, animal feed production, as well as primary, raw, biogenic materials for material use), national nature conservation requirements (biodiversity-related), and in the context of overall land-use impacts (landscape appearance, water preservation, erosion, nutrient management, etc.) These potential resource related issues widely discussed in public, have contributed to raise public awareness in relation to biomass linked subjects, and resulted in acceptance problems for biomass used as energy source in some regions of NWE.

At the same time, biomass still has an important role to play over the next decade in supporting the transformation of the existing energy system. In particular, biomass conversion to biogas, through substrate and product storage possibilities, offers a practical option to balance the variability of other fluctuating alternative energies such as wind and solar. With regard to building heating, biomass could to a limited extent help to cover the existing and future heating demand. This, however, should be considered as a temporary solution only until a European-wide architectural change, allows for the installation of heat supply systems such as heat pumps and geothermal heating, will take place. In order to support this sustainable development, a consistent, coherent strategy is urgently required. This should establish the necessary guidelines to moderate the interests of individual stakeholders and set up a comprehensive plan to improve public acceptance of biomass.

2.1 Policies and Programs for bioenergy acceleration

The European Union has set overall policies and binding targets for the acceleration of Renewable Energies. Until the year 2020 the share of renewable energies has to reach 20% by the total energy needs, defined by the EU Ministerial Council in March 2007. This objective is uptaken by the *European Renewable Energy Directive (2009/28/EC)*, which allocates quantitative targets for the renewable energy development for all Member States. Within the *National Renewable Energy Action Plans*, the Member States have published their country specific targets and general policy directions how to achieve their commitments in the year 2020.[1] In order to report the interim results, the Member States have to submit official Progress Reports all two years to the European Commission.

One important driver within the renewable energy sources is the biomass to bioenergy conversion, which covers currently 2/3 of the total renewable energies in the EU (10%)[2]. Within the Communication from the Commission of 7 December 2005, the *European Biomass Action Plan* [COM(2005) 628 final – Official Journal C 49 of 28.02.2005] was presented with the target to increase the biomass to energy use up to 150 million toe by 2010. This increase refers to the heat, electricity and transport fuel sectors. In comparison to the obligatory NREAPS the earlier call for National Biomass Action Plans (BAPs) was optional[3].

Biomass is defined as a key objective within the EU structural and cohesion programs as well as in the EU research funding programs. Cross cutting sectors are addressed for bioenergy creation, as the agricultural, forest, waste and animal by-products sectors. The EU and the Member States have already adopted a holistic framework for bioenergy production, e.g. tackled in the *Common Agricultural Policy (CAP)*, stressing the supply of bioenergy from agriculture and forestry and the use of bioenergy on farms and in rural areas. Bioenergy recovery from organic waste is encouraged within the *Circular Economy Strategy* under the *Waste Framework Directive (2008/98/EC)* and the *Landfill Directive (99/31/EC)*, the *Europe 2020 Strategy for Smart, Sustainable and Inclusive Growth* as well as the *Bioeconomy Strategy*. Also the

[1] RE targets ARBOR Member States NREAP 2020: Belgium 13%; Germany 18%;Ireland 16%; Luxembourg 11%; The Netherland 14%; United Kingdom 15%: Bioenergy targets ARBOR Member States NREAP 2020: Belgium 8,9%; Germany (9,9%); Ireland 6,9%; Luxemburg 6,7%, The Netherland 7,5%, United Kingdom 7,3%.
[2] Within the United Nations Framework Convention of Climate Change (UNFCCC) biomass is declared as emission neutral source, reflected again in the Europeans Emission Trading System (EST).
[3] The implementation in national policies must comply with Community state aid policy.

Cascading Use of Biomass is attributed more attraction on political agendas in Brussels but currently not a binding policy in Europe.[4] Considering the intensive livestock production and the limited amount of arable land for manure disposal the *European Nitrate Directive (91/676/EEC)* and the *Water Framework Directive (2000/60/EC)* do encouraging bioenergy treatment options in order to reduce nitrate accumulations. The European "Consultative Communication on the sustainable use of phosphorus" validates the scarcity of phosphorus and accelerates P-recovery processes from multiple residue origins (e.g. sewage sludge), so introducing new management and technology activities

The EU *Renewable Energy Directive* provides sustainability criteria for biofuels for transport and bioliquids, which are not addressing solid and gaseous biomass used for electricity, heating and cooling. For general biomass production sustainability criteria in terms of sustainability assessment have been communicated in terms of the LULUCF accounting (Land Use, Land Use Change and Forestry) in 2011. These LULUCF are valid for energy, food, feed or fibre but are not mandatory but broadcast the way towards giving sustainability criteria for solid and gaseous biomass. The Commission has stated in the context of the 2030 climate and energy framework, a tool which accounts lifecycle greenhouse gas emissions and submitted the Staff Working Document to review the state of play of the sustainability of solid and gaseous biomass for electricity, heating and cooling production in the EU in 2014.

These European policies have fostered the national legal binding and incentive instrument development for an increased bioenergy sector. The European policies on bioenergy are not designed to create generally European harmonized RE support instruments. According to member states baseline situation and potentials, the national governments have to develop policies, programs and legislations.

3 Strategic recommendations for the acceleration of a sustainable bioenergy growth in NWE

The Europe-wide transition of the energy sector aims at creating different energy supply models which enable integration of renewable energy sources. Taking into account the possible potential and resources dependant limitations, the future energy production will be based on fluctuating energy sources such as wind and solar. These sources will become the main pillars of the future energy system when combined with a variety of flexible solutions to bridge the potential supply gaps. In this context, bioenergy, which already now has a significant contribution to the energy market, has an important role to play. Through its storability, biomass, but also its gaseous conversion products biogas, bio-methane and pyrolysis/syngas, can be applied as flexible energy solutions stabilizing supply and markets.

According to current trends and forecasts, the heat market will further interlinked with the electricity production sector. This will happen through development of combined heat and power systems, a more widespread use of electric heat pumps, and the joint optimization of electricity, gas, and heat networks. Providing its growing energy efficiency, the heat market, at least in the building sector, will shrink over the time in the middle to long term perspective. In addition,

[4] EC A blueprint for the EU forest-based industries, Brussels 2013

the very different structural requirements, e.g. in high density urban areas or sparsely populated rural areas, in which bio-energy can be immediately used should be considered. Furthermore, the biomass currently used for heating buildings could in the long term future be considered to be applied in industrial energy production processes.

Taking into account the above summarized aspects as well as the variety of possible biomass applications in dedicated energy production sectors, the question about the role of bioenergy in future long-term energy and heating supply needs to be raised. For the moment no straightforward answer to this question can be given, considering the “unfavourable” position in which the biomass has been placed both in the public perception as well as political discourse. The problems, which can be derived for a range of dedicated topics, are discussed below with reference to the current frameworks and programs in NWE.

3.1 Bioenergy and balancing conflicts of interests

From the frameworks described above a biomass-use-hierarchy can be derived. In this scheme, the supply of variety of safe and healthy food products is given the highest priority. After securing this basic need the raw biomaterials can be used for generating high quality industrial products and only in the third step biomass can serve as a source of sustainable energy.

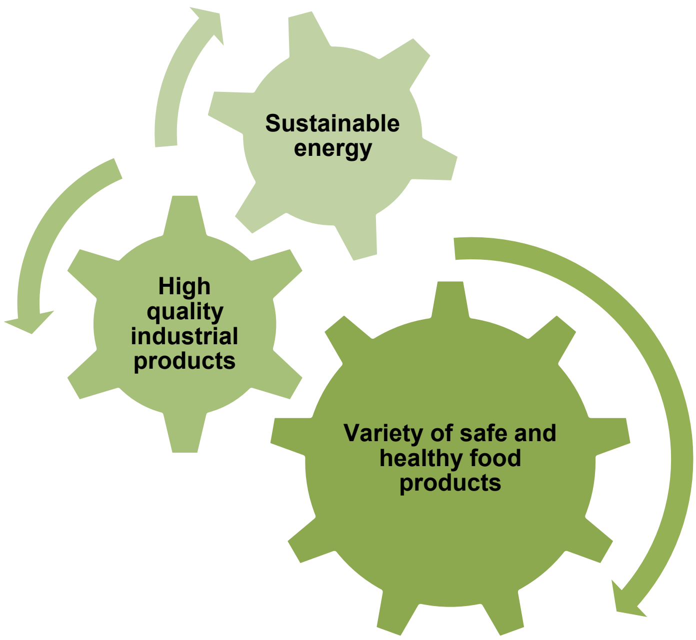


Figure 3 Hierarchy use concept for biomass

The biomass position considered through the hierarchical use concept is summarized in Figure 3. The potential production of energy undergoes additional analysis not only with regard to the raw material and technical availability but also has to be seen from the perspective of the socio-economic and energy market framework as well as the public acceptance perspective. These aspects are discussed more in depth in the subsequent subchapters.

3.1.1 Material aspect

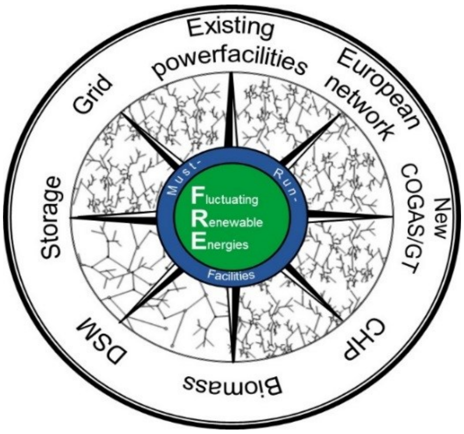
The material dimension refers to raw material availability, which is mainly related to access to agricultural land or sourcing from forests. This is the aspect addressed by the latest critical positioning and assessments against the expansion of bioenergy (particularly those related to cultivation of biomass but also to harvesting forests). These lines of argument are largely based on the importance of (global) food security as well as biodiversity goals and its subsequent restrictions. Given the current domestically sourced supplies in the EU, which for the relevant sectors of cereals, potatoes, meat, and milk do only slightly exceed 100% necessary to cover the EU demands, as well as the scientific and sectorial publications, presenting a large data scattering with regard to the estimations of agricultural land availability for additional crops cultivation, the final uncertainty in the assessment of the potential for bioenergy applications remains immense. A further uncertainty source with regard to the assessment of the available potentials is created through the new market developments in the bio-economy sector, in particular with respect to the currently unpredictable emerging biomaterial supply chains. This aspect is in particular highlighted by the timber industry lobbyists warning of a possible wood shortage in a biomass based energy system. The use of biogenic residues for energy production is not as controversial as for the primary biomass. However, also here a question needs to be raised regarding the possible contribution of the organic waste sector to the future energy systems transformation. While municipally managed wastes (e.g. organic wastes, sewage, etc.) do not in total represent sufficient potential to play an important role in the transformation, the residues from the agricultural sector (manure, straw, etc.) can only be used to limited extent and do face mobilization problems due to scale and distribution.

A partial relief to the biomass availability issue could be expected from the cascading use systems. However until now only a few cascade processes have been established (e.g. in wood industry the chipboard and paper recycling). Since the bio-based plastics market is still in the early development stage, the establishment of separate supply and conversion chains for cascading use of the materials is still necessary. Without this development step, fossil fuel and bio-based plastic materials could be mixed in the valorisation chains, which could hamper products recycling and redirect them straight towards thermal and energetic valorisation.

3.1.2 Technical aspect

The technical dimension refers in particular to technical optimization and efficiency increase potential as well as the technical requirements in order to successfully provide the solutions necessary for reaching the energy transformation goals. In addition to the market related improvements of technical systems (e.g. for nearly market-ready emerging technologies like pyrolysis and gasification), it has to be in particular assessed whether on medium to long-term perspective the biomass could be assigned to dedicated use paths. To this end, the potential (market-driven) influence of the fuel sector as well as the strengthening of the link between electricity and heat supply via cogeneration applications in combination with heat networks will be in the focus of the developments. The demand driven bio-based electricity generation will require both seasonal (dynamic process management) and short term (gas/heat storage) management flexibility, which according to the current technology advancement should not create any technical difficulties. The discussions that arise here focus rather on economic as well as administrative and organizational questions e.g. for biogas, what conditions need to be fulfilled to generate of biogas in quantities which would make it economically feasible for injection into the natural gas grid (biogas hub).

3.1.3 Energy market aspect



Source: IZES, 2014

The intended transition of the European energy supply, especially in the case of the electricity supply system, represents a paradigm shift as it will change its basic concept with its foreseeable focus on the regenerative energy source wind and solar. The role of bioenergy in the future system has therefore to be revised and if necessary re-defined. Unfortunately, the current evaluation of this role focuses rather on one-dimensional cost-related aspects instead of taking a more holistic perspective. The current costs of bio-based electricity generation compared to the on-shore wind and solar electricity production are, specifically considering most recent developments, relatively high. This, in the context of the current electricity price debate e.g. in Germany, leads to very restrictive requirement being claimed by the involved policy makers with respect to the future financial support schemes for bioenergy. The current discussion does not yet include the value added (and corresponding costs) of an on-demand electricity injection. Moreover, it neither reflects nor monetary estimates the additionally induced optimizing effects e.g. for climate protection, waste management, water protection, rural development etc. In this context, considering solely bioenergy's influence on electricity price development is a short coming evaluation which overlooks a wide range of its true economic impacts. In fact, the current support schemes in NWE have directly or indirectly contributed to relevant economic impacts in form of cost reductions in the other economic sectors, such as the agricultural, waste management and forestry sector. The financial contributions through energy related incomes within these sectors have partially co-financed these activities, which, from the economic perspective, in many cases enabled setting higher quality standards with regard to sustainability (e.g. for climate protection through manure digestion in agriculture, establishing pre-treatment by anaerobic digestion in organic waste treatment plants, etc.).

Additionally, through the strong electricity price focus of the debate, not much attention is paid to the optimizing bioenergy use in the heating sector, which should result from the stronger coupling of heat and electricity supply required to obtain a high efficiency standard. In this regard, evaluation of the role of bioenergy requires a systematic approach to a far greater extent than for the other renewables. It should consider the full range of potentials and impacts linked to biomass use for energy production, which would illustrate additional effects beyond the electricity sector from a comprehensive socio-economic perspective (and might identify potential alternative financing measures).

3.1.4 Socio-political aspect

Recent developments in the implementation of the bioenergy projects have shown, in particular concerning biomass cultivated for energy production, that projects are confronted with enormous acceptance problems. These constrains must be taken seriously and need to be addressed through participatory project planning approaches in the early development stage as well as should involve versatile stakeholders groups. It could therefore be reasonable to establish an additional communal/regional planning authority which would interact with all the possible types of stakeholders (incl. the general public) to develop land use concepts, which would assure generating the highest regional added value.

The possible acceptance problems can thus be very complex and, depending on the region, may include a wide variety of aspects such as food supply vs. other biomass use competition, biodiversity, landscape changes (e.g. monocultures), emissions (e.g. GHGs and odours), increased traffic as well as the soil nutrient balance in the context of water protection.

Through the involvement of all the necessary stakeholders, the potential problems have to be identified to clarify the project-related effects. One of the main aspects addressed in such participatory processes should be the regional added value pursuit by the project. It should be demonstrated that bioenergy projects can generate local added value, for example by creating and securing jobs or that the economic value of land can be upgraded. Furthermore, the use of regional biogenic resources will, in the long-term, allow for stabilizing or even reducing the energy supply costs as well as help to develop network infrastructures (e.g. communal district heating networks) which increase the identification with the communes in the region.

3.1.5 Central principles determining the role of biomass in the future renewable energy systems

The following principles are particularly important to support the further development in the biomass for energy sector:

- **The supply of biomass from the agricultural and forestry sectors must be sustainable**, with regard to farming practices, biodiversity/species conservation, water preservation, etc. Necessary frameworks regarding these topics must be defined (e.g. the implementation of a general certification).
- ***The expansion of biomass use must be in line with market demands on food production***. For this purpose, a discussion regarding current and future land use, targeting self-sufficient supply chains as well as our contributions to a global food security is needed.
- ***Biomass use must become more efficient.*** This principle has two implications: Firstly, material use concepts should be re-designed for cascading use. Such new concepts should foresee the multiple use of biomass through material re-cycling prior to the final energetic valorisation step through e.g. combustion. Secondly, all biomass conversion and use technologies need to be at the highest possible efficiency level (e.g. strengthening of cogeneration applications in combination with heat networks).
- **Biomass must provide the services required for the energy transformation goals with a systematic view** to provide flexibility and multifunctional usage in the renewable energy systems (e.g. storing capacity to be flexible regarding energy supply as gas/heat storage to react on-demand in the electricity market)
- ***The use of organic waste and biomass that does not contribute to land competition is preferred***. In particular the organic waste sector must undergo a structural shift by changing its current disposal approach to a more holistic concept including the integration of organic biomass in the supply contracts (energy, nutrients, etc…). This requires a cross-sectorial planning amongst actors and at the administrative level.
- ***The use of biomass must address the cost discussion towards transsectoral and external effects and regional added values*** (climate protection, agrosystems, circular economy, development of rural areas)

The INTERREG IV B-Project ARBOR case studies covers subjects related to all of the above mentioned principles, in particular those related to land competition. The guiding principles and strategic approach are applied in the case studies within the subsequent chapters. This report, following the scope of the ARBOR project, mainly focuses on biomass mobilizing for electricity and heat production.

Biomass for Energy
Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

4 Strategic recommendations for the acceleration of a sustainable bioenergy growth – a thematic & case-study oriented approach

The above derivated central guidelines determining the role of biomass in the future renewable energy systems have been applied to the thematic fields of the ARBOR project.

Based on the current state of biomass utilization, ARBOR strategy recommendations propose measures to foster and optimize biomass use - in particular focusing on biogenic residues[5]. The organic residue sector is not the central driver for the bioenergy transformation because of its limited potential in comparison to other biomass sources as by cultivated biomass and agricultural residues as well as from forest.[6] The transformation of the waste and residue disposal into a resource management sector provides the following values:

- ***Transition to a circular economy and contribution to sustainable growth***
- ***No land use competition for food, fodder and other biomass products***
- ***Contribution to climate change mitigation and low carbon society***
- ***Provision of high resource-efficiency, as energy production and material products***

The strategic recommendations are clustered in four thematic biomass to bioenergy topics, analyzed by the corresponding legal, environmental, economic and technical assessment for all ARBOR case studies. The thematic sessions are:

- ***Closed loop systems of biomass valorization by local authorities (organic waste and greenery cuttings, sewage sludge)***
- ***Biomass from agricultural activities (agricultural residues, considerate exploitation of arable land)***
- ***Biomass from nature and biodiversity conservation systems (landscaping materials from nature conservation land, short rotation coppice for biodiversity)***
- ***Mass streams in the "circular economy" (circular nutrient management, synergy parks based on biogenic secondary raw materials)***

[5]This strategy does not consider changing the structure of existing land use patterns or economic branches, e.g. relocation of agricultural or other commercial activities with the objective to improve the regional situations or to facilitate the use of certain biomass streams. Furthermore, the recommendations do not include forestry linked activities, since these were not considered in the scope of the ARBOR project.

[6]Biodegradable waste from municipalities is expected to achieve a moderate growth with 10.8 Mtoe (2012) up to 16.7 Mtoe (2020) in Europe. Agricultural biomass significant growth: 13.2 Mtoe (2012) → 41.7 Mtoe (2020), mainly residues & by-products, Source: European Commission (SWD(2014) 259 final)

4.1 Closed loop systems of biomass valorization by local authorities

ARBOR aims in particular at the development of sustainable closed loop strategies for the valorization of energy and material recovery from organic wastes by local authorities. The research focus is addressing the organic waste management by local authorities, as they are officially responsible for the management and recycling of these waste streams. As public entities they can integrate organic waste recycling principles in their internal policies and reflect their experiences in higher-level policy development processes (federal/ provincial and state level) as well as public tender systems for implementation by third parties.

The current state of the art of public waste management in Northwest Europe reflects rather a disposal character instead of a full activation for inherent potentials for material recycling and energy production. The case study oriented research analyses drivers and barriers and has accompaigned and consulted the regional transformation processes to shift the general public disposal order into resource efficient supply services by local authorities and private sector (summarized in green boxes below).

ARBOR responds to the heterogeneous situation of municipal organic waste valorization in United Kingdom, Ireland, Belgium, the Netherland, Luxembourg and Germany, addressing the following public owned and steered organic waste streams:

- ***Separate collected bio waste from households***
- ***Collected greenery cuttings***
- ***Collected sewage sludge***
- ***Landscaping material from nature conservation areas***

Three regional ARBOR strategies have been developed for the German Federal State of Saarland and one EFRE cofounded investment was realized for the City on Stoke-on-Trent in the United Kingdom. These case studies for regional strategy development have been supported and implemented by the corresponding public authorities, as the Saarland Ministry for Economy, Employment, Energy and Traffic, the Saarland Ministry for Environment and Consumer Protection, The Disposal Association Saar and the City Council of Stole-on-Trent:

- ***Saarland strategy development for a sustainable organic waste and greenery cuttings valorisation***
- ***Saarland strategy development for a sustainable sewage sludge valorisation***
- ***Saarland strategy development for a sustainable landscape material valorisation in the UNESCO Biosphere Reserve Bliesgau***
- ***Investment: Implementation of a closed loop woody biomass supply chain in Stoke-on-Trent, United Kingdom***

The analyzing and comparison of the situation in Northwest Europe on organic waste stream valorization by local authorities and its transfer of the findings has been conducted through:

- ***Mutual development of findings and review by Transnational Advisory Board Meetings***
- ***Comparative study on main findings by questionnaires***
- ***Mutual on-site visits to best-practice technology and management sites in Northwest Europe***

4.1.1 Closed loop systems of biomass valorization by local authorities- Organic household waste and greeneries - Case Study Germany, Federal State of Saarland

The full study can be downloaded as "Case Study Report: Closed Loop Systems of Biomass Valorization by Local Authorities, link www.arbornwe.eu.

- **Available potential:** The German Federal State of Saarland provides sound conditions to promote a regional transition towards a Circular Economy Society. Separately collected organic household waste volume of 60.000 tons per year and 85,000 tons per year of municipal collected greenery cuttings (wooden part by 30-35%) in 2011 pose potential to contribute to regional climate protection targets and sustainable growth.
- **Legal drivers and barriers:** The German Federal Circular Economy Act postulates the highest possible recycling standard for organic waste under the barriers of economical and technical reasonability. As an incentive, the German Renewable Energy Act emphasizes anaerobic digestion of organic waste with one of the highest biomass feed-in tariff for electricity production. The German Federal State Saarland had introduced the separate collection of organic household waste already in 2001. In Saarland the collection of organic waste is divided into municipal and state-level responsibilities. Organic household waste is collected and treated by the Disposal Association (EVS) Saar for the Federal State Saarland. The collection and composting/treatment of municipal greeneries was at ARBOR project start in the responsibility of each municipality, where the greeneries are mowed. Based on ARBOR policy recommendation, an amendment in 2014 of the Saarland waste legislation was published, to treat all organic wastes (households and greeneries) by the EVS in order to realize a sound closed loop system by Saarland waste authorities. The collection duty of the greeneries remain by the municipalities. In Germany the state of technology for organic waste (household) recycling prohibits landfilling since 2004 but leaves diverse options for treatment processes. Anaerobic digestion and thermophile composting are valid treatment options. Until the year 2015 a treatment of greeneries was not obligatory in Germany, providing the baseline for high quality recycled fertilizer.The new treatment order for greeneries (hygienization and stabilization) needs to be applied in Saarland. To commission third parties for treatment activities, European public tender law warrants the option to include regional and environmental criteria (e.g. GHG reduction).
- **Technical challenge**: Dry fermentation plant with post-rotting process was selected for organic household waste with greenery fermentation. Thermophile composting process as mandatory and minimum standard treatment process for greeneries. Decentralized woodship-combustion installations with 500 kW_{th} represent the best technology to convert lower quality greenery wood. Organic Rancing Cycling (ORC) was selected as one alternative technology to treat full wooden greenery potential in one plant with 1,5 MW_e. All technologies are state of the art and market ready technologies.
- **Saarland on-site scenarios:** All scenarios have been compared with the status quo reference scenarios.
    - To implement best fitting ***organic household recycling*** in Saarland; Central biogas plant in Saarland (60,000 Mg / a); Central recycling plant in Saarland

(40,000 Mg / a) + additional smaller scale plant (20,000 Mg / a); Decentralized biogas plants in Saarland (3 x 20,000 Mg / a).

- To implement best fitting ***grass-like greenery cutting recycling*** in Saarland: Status Quo with maintaining the current waste management with a heterogene composting situation (quality and amounts); Co-digestion with biowaste (40,000 Mg /a organic waste and 20,000 Mg /a green waste; 20,000 Mg / organic waste and 40,000 Mg /a green waste); Co-digestion with biowaste + decentralized monofermentation (40,000 Mg /a organic waste and 20,000 Mg /a and 20,000 Mg /a organic waste and 10,000 Mg /a green waste), two pure green waste fermentation plants (15,000 Mg /a; co input energy crops);decentralized Monofermentation plants (4 x 15,000 Mg / a), each with 15,000 tons of annual throughput; Decentralized composting thermophile plants (4 x 15,000 Mg / a).
- To implement best fitting ***wooden greenery cutting recycling*** in Saarland: Status Quo approach of the current recovery situation (13% in energy recovery, 30 small-scale decentralized woodship-combustion installations); Decentralized 60 woodchip-combustion installations with 500 kW_{th} (e.g. recycling in municipal properties or heat networks); Decentralized CHP + central 30 decentralized woodchip-combustion installations with 500 kW_{th} and a central heating plant (Organic Rancing Cycle ORC) technology with 750 kW_e; Central heating plant (ORC) technology with 1.5 MW_e.

- **Environmental impact**: The conducted Life Cycle Assessment (LCA) is assessing the Global Warming Potential (GWP) and no other environmental impacts. In total about 26,000 Mg / a GHG emissions could be reduced by technology optimization. The central concept causes additional emissions in the area of transportation within Saarland, nevertheless this surplus is compensated by the higher efficiency of the larger systems (e.g. CHP efficiencies, waste-air management, water supply systems, etc.).
- **Economic assessment:** The economic analysis provides reasonable argumentation for the strategic outline for organic waste and greenery cuttings recycling scenarios:
  - **Organic wastes form households:** central biogas plant of 60,000 tons per year recommendable (118-52 € / Mg) with respect to the currently market prices for the recycling of organic waste from households (62 € / Mg). Prices for cross-border organic waste exchange (20.000 Mg /a) to French biogas plant (Sydeme, Forbach) integrated.
  - **Grass-like greeneries:** a) mono fermentation of greenery cutting, according to specific treatment, costs almost 70 € / Mg in comparison to the current cost for greenery cutting treatment in Saarland between 50 and 60 € / Mg as currently economically unreasonable. b) Resource efficient and central composting plants (15.000-20.000 Mg / a), specific treatment price of under 33 € / Mg (net) as recommendable. Prices for cross-border greenery exchange to French mono fermentation plant (Sydeme, Sarguemines) integrated.
  - **Co-digestion of greenery cuttings with organic waste from household:** results (amount of 40,000 Mg / a organic waste and 20,000 Mg / a greenery cuttings) to specific treatment costs of almost 35 € / Mg greenery cuttings by organic waste reference price of 40,000 Mg (70.55 €/ Mg). The cost of treating organic waste is reduced to almost 67 € / Mg.

- **Wooden greeneries:** For wooden greenery cuttings, burned in thermal 500 kW_{th} boilers, market competitive heat production costs in a range from 8.7 to 10.6 cents / kWhth can be derived.
- **Strategy development**: Regular meetings of the ARBOR Saarland Task Forces "Organic Waste" [2011-2015], environmental and socio-economic assessments for all ARBOR scenarios as well as scientific review at the ARBOR Transnational Advisory Board Meeting [11/2014] guarantee the strategic fit of the outcomes:

STRATEGY RECOMMENDATION

Closed loop systems of biomass valorization by local authorities- Organic household waste and greeneries - Case Study Germany, Federal State of Saarland

VISION: To increase the material and energy efficiency for municipal organic waste recycling; To shift the general public disposal order into regional resource efficient supply services by local authorities; To strengthen cross-border synergies in the waste sector with the French region of Lorraine and the German Federal State Saarland

SCOPE OF ACTION: Adjustments in administrative structures and policy framework for collection and treatment; Redesign of greenery collection and recycling hubs; Regional product chains and marketing (high quality fertilizer, wooden fuels, biogas to power and heat) for energetic by products; Planned increase of organic waste flows from households (Saarland) to already running anaerobic digestion plant Methavalor (Forbach, F); Scientific support on building and operation of mono-fermentation plant for French-Saarland municipal greenery cuttings (Saargemünd, F).

MEASURES: On-going political patronage to drive regional organic waste recycling; Legal amendment in Saarland waste legislation to simplify organic waste collection and treatment responsibilities; execution by public tender of EVS (2014-2015) to further elaborate a greenery recycling concept for Saarland as a follow up step; Need for technology change & implementation towards recommended anaerobic dry digestion plant with post rotting of combined bio-waste and greenery cuttings; thermophile composting plants for herbal greenery cuttings; wooden greeneries for near district heating systems (min. 500 kW_{th} or ORC); Optional Innovation Center for Integrated pyrolysis / hydrothermal carbonization at anaerobic digestion for biochar production.

Figure 4 Closed Loop Systems on organic waste from household and greeneries

4.1.2 Closed loop systems of biomass valorization by local authorities- wood from municipal parks and land -- Case Study United Kingdom, Stoke-on Trent

The full study can be downloaded as "Case Study Report: Closed Loop Systems of Biomass Valorization by Local Authorities: www.arbornwe.eu. The main conclusions and strategic recommendations arising from the studies are the following:

- **Available potential:** In Stoke-on-Trent 1,380 hectares of park and open space have to be managed. Wood waste from those parks are circa 40,000 tonnes within the city from public and private sector (civic amenity sites, tree maintenance, local tree surgeons, local wood processing business, forestry holdings, waste wood recyclers). The city has currently no biomass boilers, opportunity to start from scratch. The City has a compact urban area (minimum transport distances). Previously the wood have been chipped at roadside or left at site with a small quantity sold as logs to public
- **Legal drivers and barriers:** Financial support for renewables: The UK is establishing a financial framework that provides in the long term to bring forward and support the take up of renewable energy. This includes maintenance of the banded Renewables Obligation, Feed in Tariffs (FiTs) for small scale electricity (under 5MW), the Renewable Transport Fuel Obligation, the Renewable Heat Incentive tariff (for industry, commercial premises and public sector), and the Renewable Heat Premium Payment Scheme (for household). Unblocking barriers to delivery: DECC are intent on overcoming supply chain blockages and promoting business opportunities in the renewables sector in the UK. Investigation is being carried out to identify and address those issues that affect the timely deployment of established renewable technologies and thus remove the non-financial barrier to renewables deployment, including measures to improve existing grid connection arrangements.
- **Technical challenge:** Different technical options for heating system at St James House have been assessed. That building had previously an electric heating system: Created demand for 75 tonnes of wood fuel. gasification/pyrolysis versus direct combustion, but pyrolysis combustion technology not proven at the scale required. Chip versus pellet, key decisions: wood waste sourced from tree maintenance arisings & wood chip preferred medium. Decision to install a biomass boiler at St James House in October 2013, allowed for increased savings and maximum carbon impact.
- **Stoke-on- Trent on-site scenarios:** As the project changed direction during implementation, the assessment of the pilot was undertaken using the three different processing scenarios:
    - Supply Chain (Sourcing): Tree maintenance currently carried out by third party, Alteration of tree works contract to require contractor to deliver waste to location of our choice, Actually solved a waste problem for contractor, Long term economics still to be proven
    - **Supply Chain (Processing):**
        - Purpose Built Wood Fuel Hub processing 1,000 tonnes wood waste per year: no suitable site found –200 investigated, 2 thought suitable;
        - Utilise existing location to process 100 tonnes wood waste per year: one site possible –later ruled out;

    - Let the processing capacity to third party –Implemented solution: allows us to be flexible with quantities, directly replicable with little upfront expenditure, allows us to get assurances on quality, does require a higher quality of wood waste
  - **Supply Chain (Delivery):** Wood chip purchased as heat to incentivise quality, Year 1 (2013-14) the boiler consumed 65 tonnes or 190MWh.
- **Environmental impact:** The conducted Life Cycle Assessment (LCA) is assessing the Global Warming Potential (GWP) and no other environmental impacts. The GHG assessment through UK Solid and Gaseous Biomass Carbon Calculator (B2C2) take into account emissions resulting from harvesting, transport, drying, conversion storage etc. but not embodied carbon –i.e. equipment, construction, Implemented supply chain results in 1.71 kgCO2e/GJ -12% less CO2e emissions against standard wood chip values. The wood fuel hub solution would have resulted in 0.87kgCO2e/GJ–demonstrates the transport burden. The Overall –Supply chain solution has delivered 97% reduction in CO2e at St James House
- **Economic assessment:** All three scenarios modelled over minimum 5 years, Third party most economical as no start-up costs, Wood fuel hub becomes far more competitive in year 7+ : Economic viability as: commercial price (69,47 €/ MWh) in comparison to Wood fuel hub (1,000 + tonnes, 69.45 €/ MWh) to Pilot Hub (100 tonnes, 282.54 €/ MWh) to Third Party Processing (100 tonnes, 48,35 €/ MWh)
- **Strategy development:** Regular meetings of the ARBOR Stoke-on-Trent Task Force, environmental and socio-economic assessments for all ARBOR scenarios as well as scientific review at the ARBOR Transnational Advisory Board Meeting [11/2014] guarantee the strategic fit of the outcomes.

STRATEGY RECOMMENDATION

Establishing a cradle to grave supply chain within Stoke-on-Trent using clean waste wood from municipal parks and land - Case Study Stoke on Trent, United Kingdom

VISION: To increase the biomass demand in the UK 10 fold between 2010 and 2020; To increase the material and energy efficiency for municipal organic waste recycling; To shift the general public disposal order into regional resource efficient supply services by local authorities.

SCOPE OF ACTION: Strengthening collaborators of closed loop supply chains to bodies with large demand and also requirements to maintain significant areas of green space (local Authorities but other public institutions such as Local Health Trusts, and Local Housing Authorities); Overcome largest barrier to implementing closed loop supply chains in the UK is from the distance between the source of the waste wood and the end user; Regional product chains and marketing (regional wooden fuel).

MEASURES: Undertake a mapping exercise to understand the areas of demand around which clusters of waste wood can be drawn from; Different processing delivery methods offer advantages that should be considered by any organisation wishing to implement such a supply chain. To understand the impact that recovering waste wood from arboreal arising can have on associated biomass streams.

Figure 5 Closed Loops organic clean waste wood from municipal parks and land, Stoke-on-Trent

4.1.3 Closed loop systems of biomass valorization by local authorities- sewage sludge-- Case Study Federal State Saarland

The full study can be downloaded as “Case Study Report: Closed Loop Systems of Biomass Valorization by Local Authorities : www.arbornwe.eu. The main conclusions and strategic recommendations arising from the studies are the following:

- **Available potential**: The German Federal State of Saarland provides sound conditions to promote a regional transition towards a Circular Economy Society. 19,000 tons dry matter of sewage sludge (2011) pose potential to contribute to regional climate protection targets and sustainable growth. ARBOR demonstrates sustainable closed loop strategies, shifting the general public disposal order into resource efficient supply services.
- **Legal drivers and barriers:** The German sewage sludge and fertilizer legislation will postulate stricter regulation on the application of sewage sludge on agricultural soils within the next years, referring mainly to heavy metals (e.g. Cadmium and mercury) as well as synthetic polymers. The current composition of sewage sludge in Saarland cannot meet these legal thresholds, so that the agricultural appliance will be banned in future. Parallel the recovery of phosphorus and other scare resources (as magnesium) as well as the demand for energy production are general German quadrilles, where sewage sludge can provide the necessary qualities for resource recovery.
- **Technical challenge**: Mono-incineration plants for sewage sludge are state of technology and already operated in Germany, recommendable with centralized fluidized bed combustion. The recovery of phosphorus from mono-incineration ashes or from wet sewage sludge are not state of the technology, only few pilot plants are currently running. The thermo-chemical processes as hydrothermal carbonization (HTC) and pyrolysis technologies are state of the technology, but the HTC process causes a higher technical complexity in comparison to pyrolysis with a bigger insecurities.
- **Saarland on-site scenarios:** All scenarios have been compared with the status quo reference scenarios.
    - Status Quo with 8,633 t dm in incineration (Germany), 2.100 t dm in re-cultivation and composting (France), 8,500 t in agricultural appliances (Germany: Rhineland-Palatinate, Saarland)
    - Scenario 1: Central mono incineration with phosphorus recovery from ashes in Saarland
    - Scenario 2: Central mono incineration with phosphorus recovery from ashes outside Saarland
    - Scenario 3: Decentral thermo-chemical treatment process with pyrolysis and phosphorus recovery from ashes in Saarland
    - Scenario 4: Decentral thermo-chemical treatment process with hydrothermal carbonisation processes and phosphorus recovery from ashes in Saarland

- **Environmental impact**: The conducted Life Cycle Assessment (LCA) is assessing the Global Warming Potential (GWP) and no other environmental impacts. In general incineration processes do delete resources if not recovery processes are integrated. This LCA study only address GWP in regard to phosphorus recovery. In general the thermo

-chemical conversion processes provide the highest emission reduction potential, on top with the pyrolysis technology, with an emission reduction of 8 million kg CO_2eq / a. The thermo-chemical processes (pyrolyses and HTC) provide the lowest GWP, only if biochar will be calculated as a substitute for conventional soil fertilizer. The substitution of conventional fertilizer causes vast GWP offsets. The HTC implicates a higher technical complexity in comparison to pyrolysis, with increased insecurities, also in regard to other environmental impacts (waste water, heat use for biochar drying). Mono incineration is only recommendable if phosphorus recovery is integrated (resource aspect). The phosphorus recovery on the other hand entails a very high energy consumption.

- **Economic assessment:** In the status quo scenario, the cost of the disposal of sewage sludge are approximately € 8.7 million. In case of a disposal of the entire sewage sludge in mono-incineration, the annual disposal costs are around € 12 million; a mono-incineration outside Saarland implies costs even around € 13.5 million. In scenarios 3 and 4, the disposal costs are around € 4 million. In Scenario 3 ,the costs due to the technical uncertainties in a range between € 2.4 million and € 5.8 million. In general revenues from bio char have not been included.
- **Strategy development:** Regular meetings of the ARBOR Saarland Task Forces “Sewage Sludge” [2011-2015], environmental and socio-economic assessments for all ARBOR scenarios as well as scientific review at the ARBOR Transnational Advisory Board Meeting [11/2014] guarantee the strategic fit of the outcomes.

STRATEGY RECOMMENDATION

Closed loop systems of biomass valorization by local authorities- Sewage Sludge - Case Study Germany, Federal State of Saarland

VISION: To increase the material and energy efficiency for municipal organic sewage sludge recycling; To shift the general public disposal order into regional resource efficient supply services by local authorities; To strengthen cross-border synergies with the French region of Lorraine and Luxembourg

SCOPE OF ACTION: To react on future legal ban for agricultural appliances; To review options for material recycling & energy recovery; To build up cross-border cooperation and exchange with public entities and authorities.

MEASURES: Start-up for cross-border political patronage to drive sewage sludge recycling; Conference (04/2015) " Future Technologies - Using secondary biogenic raw material, Case Study Sewage Sludge in the EU Grand Region" in order to conceptualize their potential range of services and to discuss possible applications in the Greater Region SaarLorLux; Sewage Sludge technology review on pyrolysis, hydrothermal conversion, co-incineration and mono-incineration. Recommendation for a pyrolysis plant for sewage sludge recycling in Saarland (energy and material recovery), which resulted into the construction and operation of the Pyrolysis plant in Homburg.

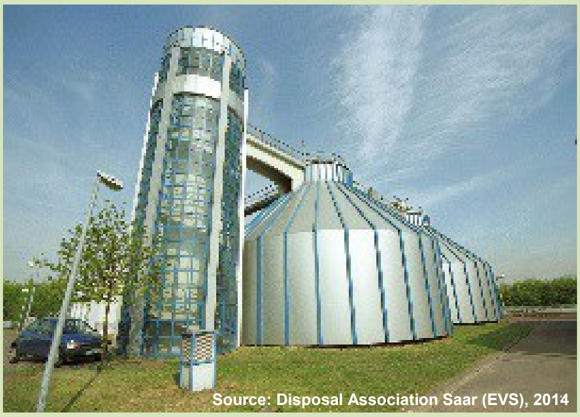


Figure 6 Closed Loops Sewage Sludge, Saarland

4.2 Biomass from agricultural activities

Within the ARBOR project, the consortium focused on residues from agricultural activities. The analysis did not include the activation of additional biomass streams for energetic use through the classic cultivation of energy crops on agricultural soils, in competition to agricultural food production. However, different concepts supporting the activation of biomass from currently unused agricultural soils e.g. the extensive utilization of buffer strips along water bodies or unused industrial land, have been developed and investigated. Further, more considerate use of agricultural land i.e. multi-purpose land use has been analysed. The full study can be downloaded as “Case Study Report: Biomass from agricultural activities, link www.arbornwe.eu.

sed through the concept of cover crops as well as multifunctional short rotation coppice.

4.2.1 Agricultural residues

Agricultural residues represent large biomass streams which are nowadays already partially valorised either in material or energetic value chains. *As* for the largest residue streams, well-established valorisation pathways have developed over years, e.g. use of straw as litter or manure as organic fertilizer or substrate for anaerobic digestion. However, numerous smaller but highly specific biomass streams often remain unused and are either disposed of or left on the fields, sometimes even generating additional environmental impacts.

Due to their low dry matter content, many types of agro-residues are seen as potentially interesting for valorisation through anaerobic digestion. In most agricultural installations organic residues are co-digested with manure. According to the local interpretations of the Nitrate Directive in several countries in the NWE region, even if manure is co-digested with other residues, all the nutrients captured in the digestate are considered as animal based. Consequently, the fertilizing limits foreseen for ‘animal based’ fertilizers applied on the field, in particular in the regions with a nutrient excess problem, contribute to increased co-digestion costs. Therefore, when using agro residues in AD, technologies of nutrient recovery certainly offer perspectives for local closing the nutrient cycle instead of importing mineral fertilizer and exporting ‘animal based’ nutrients.

Each particular residue stream is exposed to different technical and legal hurdles, which strongly reflect the very specific character of the related support strategies. In the framework of the ARBOR project partners focused on vegetable residues of particular importance in the Flemish region (leek leaves, chicory, Brussel sprouts, corn stover, cabbage, cauliflower).

The main conclusions and strategic recommendations arising from these studies are the following:

- **Environmental impact**: Environmentally seen, the valorisation of vegetable residues is an interesting solution in the context of efficient resource use and avoiding odour emissions that may occur if the residues remain on the field, e.g. as observed for cauliflower or cabbage. The energetic valorisation via anaerobic digestion (AD) or other valorisation paths can contribute to avoiding such environmental impacts. For selected crops valorisation of agro-residues is expected to help avoiding nitrate leaching.[7] However, further studies are necessary to validate this assumption.

- **Economic and energetic potential for anaerobic digestion:** Conversion through anaerobic digestion can represent an interesting value chain for vegetable residues, enabling their activation, but the economic and energetic potential need to be evaluated on a case by case basis. Nevertheless, experiences show that currently, based on the low energetic potential and high collecting costs but also still undeveloped industrial valorisation chains, economic support is often necessary to mobilize these biomass streams and in parallel contribute to reductions in environmental emissions.
- **Potential for bio-based industry**: Agricultural residues could potentially be used in the bio-based industry and replace fossil fuel based products. In this context one of the main hurdles is the large scale of industrial applications. For the example of corn stover (a residue from maize grain production) a profitable plant requires at least 250.000 tons of dry matter input per year, which constitutes more than the half of the amount yearly produced in Flanders. Additionally, even if several supply chains might seem interesting for the industry, it is a new market, in which technical developments are still necessary. The equipment producers are not willing to invest in the design of new machines without having the exact specifications given for the harvested agro-residues, while the biomass valorising companies can only work on industrial applications when the supplies are secured. In this context the further research would be needed to analyse economical, ecological and social aspects for different valorisation chains.
- **On-site valorisation**: Some vegetable residues are characterized by the low dry matter content which is not only the reason for their low biogas potential but is also disadvantageous for the transportation. For such residue streams the on-site valorisation, e.g. in pocket digesters (or as an animal fodder could be an interesting opportunity.
- **Material use:** Not always the energetic valorisation constitutes the best solution: For Brussel sprouts the scoping study conducted within the ARBOR project indicated that the use as fodder for cows might turn out to be a more interesting option which would still enable the subsequent energetic valorisation of this biomass stream through manure digestion. A more extensive economic study for this valorisation chains is planned for the future.
- **Technical challenge**: Current harvesting techniques for vegetables do often either not allow for subsequent or simultaneous collection of residues or, e.g. as found in the ARBOR study for leek leaves, the collection is technically possible but too much soil or sand is incorporated in the biomass, which creates difficulties for the subsequent conversion process.
- **Legal hurdles:** If the residues can't be utilized on site, administrative hurdles might arise from the European Waste Framework Directive and its national transpositions. In many EU countries, once a residue leaves the farm, it is being considered a waste and specific regulations account for their transporting and subsequent use. Specific permits might become necessary for waste transport and "disposal", even if this step would

[7] Studies on N emissions from dedicated crop residues have been assessed in the framework of project initiated by the Flemish authorities. The results (in Flemish) can be found under the following link: http://www.vlm.be/landtuinbouwers/mestbank/studies/Onderzoek_oogstresten_groenten/Pages/default.aspx

constitute the energetic or material valorisation. To improve this situation, which creates legal constrains for use of agricultural residues, local authorities, national governments and EU decision makers should strengthen their efforts towards harmonization and simplification of the rules to be followed in this field.

- **Pocket digestion potential**: Pocket digestion is a potential technology to mobilize currently unused residues from small- and medium-scale farms (see box below). However, in order to stimulate its market implementation, a clear supporting policy is necessary. Financial support has shown good effects in Flanders and is, in most cases, necessary (e.g. if fresh manure with low energetic potential should be used as input to reduce GHG emissions). Solutions reducing bureaucratic hurdles, e.g. facilitated permit procedures and compensating counters allowing for both electricity feed-in but also for electricity obtaining through counting back principle, are of particular importance for small scale applications.

Pocket digesters in Flanders (BE)

an opportunity for energetic valorization of agro-residues at small scale

Energetic valorisation of agricultural residues at small scale can be difficult in implementation due to economic and technical constrains and the development in this sector rather stagnates. A current development in Flanders, supported by the information campaigns and technical advice of *Inagro* in the framework of the ARBOR project, still remains an exception: Within the last 4 years 86 pocket digesters (mostly below 10 kW nominal power and using only cattle slurry as an input) were put into operation. Main driver of this development for the farmers was the possibility of a partially self-supply with electricity and heat. Additionally, the digestion of manure or other residues on site means less administrative burden than transporting to a third party and the permit procedure for pocket digesters is less complicated than for larger systems.

Source: Bioelectric, 2015

This development is additionally accelerated by 30% investment support given by the Flemish government (Climate Fund) for site equipment installed to make small scale AD possible (e.g. external manure storage, separate piping for rinse water of the milk installation, etc.). This support is granted due to the potential which AD shows in reducing greenhouse gas emissions in particular through shortening manure storage time (e.g. about 10% of GHG emissions for cattle husbandry and up to 62% for pigs breeding are generated during manure storage). Electricity production from the pocket digester (and all other renewable sources < 10W) is accounted for by compensating counters – a non-bureaucratic solution.

See market study under: www.*arbornwe.eu*

Figure 7 Pocket digesters in Flanders

4.2.2 Considerate exploitation of arable land

Regarding the total area and the volumes of biomass which can be activated, the temporary **unused industrial land** is estimated to represent a rather low potential as compared to the other land types and biomass streams. On the other hand, in the times of extremely limited resources effective use of all available land types gains on importance.

Some examples, also within the ARBOR project, have demonstrated the successful cultivation of short rotation coppice (SRC) on industrial land, which due to different reasons, is currently not in use by its industrial owner (e.g. potential extension areas). If the wood chips produced from the SRC can be used for heat production on site by the company, the company gains on independence from the unstable developments of the fossil fuels market and increases fuel supply security for several years. However, the biomass available on the market can often be purchased at lower prices, so that the economic aspect might not be the main driver for such investments. Further important drivers might be: (i) the company's need to fulfil greening obligations, often defined by the municipalities, (ii) the willingness to demonstrate company's environmental engagement or (iii) a demand to reduce emissions from the industrial site (odour, particulate matter, etc.). Cities and communes can play an important role in encouraging companies to use their free land resources by the concepts similar to the one investigated in the ARBOR project (biomass from multifunctional SRC plantations used for energy purposes).

Multifunctional Short Rotation Coppice on industrial land
Productivity and economic performance

MIROM is an intercommunal association which distributes waste bags, collects garden waste, processes household waste and coordinates sensitizing projects related to waste recycling. Green waste heat of the incinerator located in Roeselare (mid-West-Flanders) feeds one of the biggest district heating systems in Belgium.


Source: West-Flanders Development Agency (POM), 2015

In 2012 the West-Flanders Development Agency (POM) planted 1,6 ha of willow (Swedish clones and experimental INBO clones) on an unused parcel owned by MIROM, next to its waste incinerator. The investment cost for the cuttings summed up to 1985 €/ha and the cost for the field preparation and the subsequent weed control measures reached 1850 €/ha.

In March 2015, 1,2 ha of the parcel was harvested for the first time with an adapted maize chopper. 33 tons of wood chips (fresh matter) per ha were collected, while dry matter yields per clone varied from 4 to 7 tons per ha and year. The total cost of the harvest amounted to 1133 €/ha, including transport to a sheltered storage place next to the field. The dried wood chips (70% DM) will be sold to a local farmer for heating its greenhouses and/or stables. Taking into account the considered price of 80 €/ton of dry wood chips, the return can reach 1667 euro/ha. Since the parcel will be harvested 7 times (3-year rotation cycle, life span of 21 years) and yields of the next harvests are expected to be higher, the net profit after 21 years is expected to be positive. In cases were landowners can use their own short rotation coppice in a wood boiler to produce the green heat on site, financial forecasts can be even more optimistic.

Figure 8 Multifunctional Short Rotation Coppice on Industrial Lands

Combining poultry breeding and short rotation coppice (SRC) cultivation on one parcel represents a perfect pioneering concept implementing the idea of multiple land use. More details of this concept are explained in info box. Based on the study's findings it can be concluded that SRC in combination with poultry could have a great value for satisfying the energy and heat demand of the farm and could contribute to the farm's independency from the energy/biomass market developments (e.g. costs of pellets or natural gas). However, the benefits may differ and depend on particular farm conditions. Moreover the concept of heat self-supply could be applied to the free range meat production farms rather than the laying hens, since the heat demand of such farms is much higher. Finally, also the farmers' reluctance and the lack of knowhow in SRC cultivation may be a barrier for such concepts which could be removed through the consulting support of the local agricultural administration and associations.

SRC on chicken farm

Combination of SRC with poultry in the free range

The ARBOR case study was meant to promote the innovative and sustainable way of energy production, without land competition effects. Within the project 2 plantations of in total 1.5 ha has been established.

In such combined plantation poultry can enjoy the shelter of the trees and shrubs, while at the same time the trees benefit from the nutrients provided through the poultry manure. Additionally, animals with access to a free range with willows or poplar tend to spend more time outside (come out more often and move further away from the stable) than those having the classic grassy free range. This helps to better distribute the chickens on the parcel. The wood from the SRC plantation can additionally be valorised for heat production purposes.

Despite the clear benefits for animal welfare, wood sourcing, creating odour buffer, etc. it turned out to be a very challenging task to convince the poultry farmers to the concept. The main reasons for their reluctance were the fear of undesired predators attraction as well as disease spreading by wild birds. Additionally the poultry farmers indicated their lack of experience and knowledge in SRC cultivation.

See more information under: www.arbornwe.eu

Figure 9 Short Rotation Coppices on Chicken farms

Buffer strips along water bodies are proven and well established measures to protect water resources and biodiversity. Situated between a water body and agricultural areas, the buffer strip reduces leaching of nutrients or chemicals (pesticides, herbicides, fungicides) into the surface water. The support mechanisms (if any) for buffer strips differ from country to country. Several country wide, regional or local authorities subsidize farmers in order to establish or maintain buffer strips on their plots. Additionally the new CAP, in force since 2014, recognizes and financially supports buffer strips as eligible greening measures within so called ecological focus areas. However, if those incentives will be sufficient to maintain the buffer strips and prevent the farmers from re-starting regular cultivation on these surfaces, will also depend on the market developments. Harvest and use of the material from the buffer strips is currently prohibited, often by national regulations but also on the EU level by the CAP. A demonstration site established by DLV plant (NL) within the ARBOR project aimed at investigation of the possibilities to mobilize additional biomass streams for energy production from buffer strips. Such biomass valorisation concept should include extensive cultivation of the buffer strip in line with nature- and bird protection and should ideally generate additional income for the farmer and thus additional motivation to maintain buffer strips. In order to develop the concept which could fulfil these criteria (if possible) and which would be potentially transferable to other regions, practical demonstrations incl. harvesting step (for which exceptional permissions are necessary) would be necessary as well as the improvement of economic framework conditions. According to the findings of the economic and environmental assessment, more focus in the future investigations should be put on perennial crops, since these seem to be the only ones which could lower the total ha based costs. Furthermore different crops should be investigated to find those delivering, under the given conditions, the products with the highest market value.

Cover crops are a proven measure to maintain soil fertility. They cover the plot during winter time and thereby reduce erosion, weed development and nutrient leaching though nutrient fixing in the plant tissues. Cover crops sown just for this protection purpose are not harvested but ploughed under before the main crop is being sown. However, harvesting and energetic valorisation can be an effective measure to activate additional biomass from the same ha of agricultural surface. This measure, already popular in many regions of NWE and even more widespread in the past for the soil fertility purposes, found now also its way into the common agricultural policy (CAP) and is considered as ecological focus area (with different equivalence factors depending on the country). The ARBOR pilot has shown that cover crops for energy production through anaerobic digestion are an economically interesting and environmentally sound solution and should be not only legally supported but even promoted by the local authorities - independent of the energetic use of the crops, but also as an interesting option for a resource efficient bioenergy solution.

4.3 Biomass from nature and biodiversity conservation systems

4.3.1 Landscaping materials from nature conservation land

The full study can be downloaded as "Case Study Report: Biomass from Closed Loop systems by local authorities, link www.arbornwe.eu.The main conclusions and strategic recommendations arising from the studies are the following:

- **Available potential**: In the Biosphere Reserve Bliesgau only 7700 ha or 78 % of the grasslands are managed. The grass yield in the region is consistently weak. Only 4 t grass (dry matter) per ha can be harvested. The grasslands of the biosphere reserve have a total potential of 32,200 t grass per year. A part of this is a currently used as cattle feed. The region hold approximately 10.000 livestock units. They have a fodder use of grass and silage of 28,200 t per year. According to these findings the grass yield and use left a gap of 4,000 t per year.

- **Legal drivers and barriers:** While the normal grasslands were cut twice (or even three times) a year, the grassland in the buffer zone is mown only once. Especially in nature conservation areas the harvest time is limited by nature conservation legislation. In accordance with the regional lease agreements, the meadows may only be cut once or twice per year. Moreover the earliest date for cutting is the 24th June (concerning two cuts it is 24th June and 15th August). Additionally to receive the feed in tariff for energy production from landscaping material from nature conservation areas, there is a legal limitation for mowing the areas maximum twice a year (Renewable Energy Act (EEG) 2012, plants in first operation from 2012-2014). This higher fee was provided because of the lack of activating these materials. In general landscaping material is under the waste legislation. The latest EEG 2014 pays this material off with the organic waste fee for anaerobic digestion and stopped the extra category for landscaping materials from nature conservation areas. Requirements on mowing are not described but at least 90 % of organic waste have to be proceeded with an additional post rotting process. The caloric minimum value (11 MJ/kg, ca. 3 kWh/kg) for energetic recycling instead of material use is not any longer applicable.
- **Technical challenge**: Combustion and anaerobic digestion have been chosen for scenario design as they are fully established in the market. Dry fermentation as small scale system are quite rare at the market. Because of the lignocellulose content these materials have a low digestibility and should be co digested with higher methane input biomasses. The combustion of the material needs to be burned in bigger scale plants, recommended from 500 kW_{th} as the small-scale plants face difficulties by proceeding impurities (e.g. mineral compounds cause emissions, corrosion, fouling and slagging). The tested and analysed material show a moisture content about 10 %, only the coarse fraction of the greenery cutting lie near 18 %. The ash content is also below 10 %, only the fine fraction shows values over 25 %. The heating value ranges between 15 and 19 MJ/kg. Novel techniques (such as Integrated generation of solid fuel and biogas from biomass - IFBB) show promising results for an energetic use of species-rich semi-natural grasslands but are currently in pilot plant phase (no ARBOR scenario but presented at 1st TAB Meeting).

➢ **Saarland on-site scenarios:** Biosphere_0: Status Quo Material use as fodder or as litter in livestock farming; Biosphere_1: Dry Fermentation: Dry fermentation process with input mix of landscaping material, municipal green and garden waste and horse straw; Biosphere_2: Dry Fermentation small scale Dry fermentation process with input mix of landscaping material and greenery cutting; Biosphere_3: Combustion Burning of biomass of landscaping materials and greenery cuttings 3a) wooden biomass 3b) Hay and straw burner. Biosphere_4: Pocket digester.

➢ Pocket Digester based on exclusively manure input

- **Environmental impact**: no life Cycle Assessment has been conducted for this case study with regard to proposal.
- **Economic assessment:** In general the material is used as fodder or litter for animal husbandries. It is handled at the market. The market price for hay is between 85.00 and 150.00 €. The costs of the fine fraction of municipal greenery cuttings for collecting, shredding and sieving are between 16 and 20 € per ton. Landscape material can be acquired for 20 € per ton, material from greenery cutting is sold for 45 – 84 € per ton (dry). The fertilizer value from manure- concerning the nutrient content - is about 7.93 € pro ton fresh matter. The dry fermentation costs are between 60 – 65 €/t. Therefore, the fermentation of municipal green waste with landscape material from economic point

of view appears - at least in terms of a comprehensive approach - currently as unreasonable. A cost analysis of 100 kW small-scale plants is, because of the rare numbers of installations and the so far specific cost constellations, not possible. An economic assessment has been carried out for a 500 kW wood combustion plant based on greenery cutting materials. The heat price is between 8.7 and 10.6 ct/kWh. As comparison the price for gas is around 6.5 ct/kWh and for oil 8 ct /kWh

- **Strategy development:** Regular meetings of the ARBOR Saarland Task Forces "Organic Waste" [2011-2015], socio-economic assessments for all ARBOR scenarios as well as scientific review at the ARBOR Transnational Advisory Board Meeting [04/2013] guarantee the strategic fit of the outcomes.

STRATEGY RECOMMENDATION

Closed loop systems of biomass valorization by local authorities- Landscaping materials from nature protection areas in the UNESCO Biosphere Reserve Bliesgau

VISION: To valorise the material and energy efficiency for landscaping material from nature conservation areas; To shift the landscaping order into a regional resource supply service

SCOPE OF ACTION: Landscape cultivation management plan; Technology change towards challenging biofuels; Regional product chains and marketing (high quality fertilizer, wooden fuels, biogas to power and heat)

MEASURES: Need for on-going political patronage to combine climate change and nature conservation; Need for exchange with other nature conservation reserves; Examination of the potential of extensive landscaping (as a nature conservation measure) to serve as a source for bioenergy supply; Need for landscaping collection and recycling hubs; Need for market demand on material use as e.g. fodder or litter in livestock farming; Need for testing of different qualities of landscape materials for combustion purposes; Introduction of innovative bioenergy concepts for the nature conservation area: dry fermentation process (input mix of landscaping material, municipal greenery cuttings and horse straw; manure pocket digesters)

Figure 10 Closed Loop Systems Nature Conservation Landscaping Material, Saarland

4.3.2 Short rotation coppice for biodiversity

If planting SRC on agricultural soils, an increase in biodiversity as compared to the classic agricultural cultivation (e.g. maize monocultures) could be achieved through the introduction of a group of measures at the stage of SRC plantation design and management. Based on the analysis of 3 plots (4.7 ha in total) the following measures are recommended to successfully combine planting SRC for energy production purposes with biodiversity improvement of the agricultural landscapes:

Figure 11 short rotation coppice for biodiversity

- Introducing indigenous species (other than the classic monocultures of Swedish willow clones and Italian poplar clones used in majority of the classic plantations);
- Ecological management of headlands: flowering margins sown for pollinators;
- Increasing nest places through installing insect hotels and nest boxes;
- Phased harvesting (the site divided in several spots and harvested in subsequent years);
- Sowing white clover and rye grass between poplar rows, to host natural predators of occurring pests and to reduce pesticide and herbicide use;
- Conservation of nearby small landscape elements

4.4 Biomass streams in the “circular economy”

The European Commission currently works on the development of the circular economy strategy for the Europe[8]. The new approach will help to transform Europe into a more competitive resource-efficient economy, addressing a range of economic sectors, including waste. In the new economic model biomass streams, be it residues or biogenic raw materials for material use or energy purposes, will be redirected in value chains that enable or facilitate the resources reuse and, thus, prevent leaking of valuable materials from our economies. In the ARBOR project, and also in this strategy paper, this approach is particularly addressed in the case studies related to the nutrient flow management in residual biomass streams such as sewage sludge, digestate or compost as well as in the concept of synergy parks.

4.4.1 Circular nutrient management

The world’s growing population and changing nutritional habits increase the need for mineral fertilizers in agriculture, such as nitrogen (N), phosphorous (P) and potassium (K), necessary in highly productive, industrialized agriculture to reach the optimal yields per hectare. Nevertheless, phosphorous and potassium (respectively phosphate rock and potash as their main sources) are finite resources and their exploitation is often accompanied by strong environmental damages at the exploitation sites. In case of phosphate rock, since 2014 considered

[8] European Commission communication (COM(2014) 398 final

by the EU as one of the 20 most critical raw materials, the existing resources may contain contaminants such as uranium, cadmium, radium, thorium, caesium and other heavy metals which are consequentially partially brought to the fields together with the fertilizers. Furthermore, the reserves of P and K are situated in a limited number of countries (China, USA, Morocco), predominantly outside Europe (in the case of P) or in the hands of few companies, which make Europe highly dependent and may threaten the security of supply [2012 JRC].

Unlike for P and K the context of nitrogen is completely different, especially as nitrogen represents the major element of our atmosphere (78%) and is available worldwide in “endless” quantities. However, its transformation into ammonia (usually by the Haber-Bosch process) requires large amounts of energy and especially natural gas. At a global scale, mineral nitrogen extraction from the atmosphere using Haber-Bosch requires approximately 3,3% of the global natural gas consumption (representing 0,75% of world energy consumption). Considering today’s volatile energy market, the energy dependency of N fertilizers represents a major factor for price instability of the agricultural sector.

On the other hand, animal manure, digestate, compost and sewage sludge not only contain considerable amounts of all those nutrients (N, P, K) but are in several EU regions considered as a surplus/excess material to be disposed of.

While the shortage in nutrient supply remains a future challenge, the nutrient surplus on agricultural soils in regions with dense livestock breeding is a currently pushing problem (as for example in Flanders (Belgium), large parts of the Netherlands and Ireland, Brittany (France) or Münsterland (Germany). Increased concentrations of nutrients in the soils result in contaminations of surface waters and ground water resources and cause additional GHG emissions. As a result, farmers in some of those regions are forced to put much effort and financial means in treatment of manure and digestate and export of the products including vast streams of nutrients.

Digestate

Improved transportability: In view of the above mentioned problematic, the recovery of nutrients from digestate and its processing to more convenient, easier transportable, stable and marketable products creates an important step towards the circular nutrient use.

Technical feasibility: Nutrient recovery from digestate is technically feasible and is being carried out at several sites. There is a range of technologies which can be applied. For more info please consult the Inventory report on www.arbornwe.eu. Nevertheless, the choice of technology should be based on the preferred type of end-product. An overview of technologies and deriving end-products can be found on www.arbornwe.eu.

Economic feasibility: Treating digestate seems at the moment to be only economically feasible in the regions which suffer from high manure surpluses, since in these regions the raw digestate spreading is either too expensive or sometimes legally restricted. Producing dry, stable products or liquid, nearly mineral products is in general much more expensive and energy consuming than robust separation techniques, which generate a broader range of different streams with different nutrient distribution and environmental performance.

New products: The more specific and constant in their composition the new fertilizing products could be, the higher potential market prices they could reach. The main potential end users of digestate derivatives (the farmers) are not willing to use products with high heterogeneity. Therefore, quality controls, standardization and certification could help to increase farmers trust into those products.

Industrial applications: Industrial end users, such as the mineral fertilizer industry or other chemical bulk subsectors, are interested in derivatives without organic carbon and a constant quality and composition of the product over time. For the moment only ashes of combustion processes can meet these criteria. If this issue could be solved, the new products could enter the fertilizer industry which would allow following the real circular economy approach.

Fertilizing potential & legal constrains: Large-scale field trials within the ARBOR project demonstrated that untreated digestate is at least as good as raw manure in promoting optimal crop yields enjoying moreover higher nutrient use efficiency. In addition it can provide improved soil organic matter content, resulting in improved soil fertility. Liquid fraction of digestate, scrubber water from acid air washers, struvite and concentrates from membrane filtration can be used to partially replace fossil-based mineral fertilizers, without reductions in crop yields. However, except for scrubber water, these products are all considered as ‘animal manure’ under the Nitrates Directive for some regions (e.g. Flanders and the Netherlands), which impedes their use as a mineral fertilizer substitute. Other countries (e.g. Germany and France) have implemented the Nitrate Directive differently and do not suffer this constraint. This in itself illustrates how different legislative implementation of European regulations can result in a ‘non-level playing field’ as far as regional competitiveness is concerned. Introduction of a generalized intermediate category in the fertilizer classification for digestate products (currently only organic and inorganic fertilizer are recognized), would facilitate their marketing and would reflect much better their character and behaviour as a fertilizer[9]. The European Commission may strive towards a revision of the Fertilizer Regulation (2003/2003) which may be helpful if properly implemented. *Environmental conclusions:* Life Cycle Assessment analysis has shown, that treating digestate locally with use of the electricity and heat generated on the biogas plant, has a lower environmental impact than spreading it on the fields untreated, or even transporting it over long distances to arable land, as common practice in regions with limited nutrients uptake capacities.

4.4.2 Synergy parks based on biogenic secondary raw materials

A founding principle of the circular economy concept is the, so called, “waste is a resource” principle, which, translated to the idea of synergy parks, means that a residue stream of one company becomes the raw material for another. Biogenic materials seem to be predestined for such concepts, as they can in many cases be used for material purposes, for energetic valorisation and as nutrients in the subsequent value chains. Consequently they can often create a resource for development of synergy parks linking industry and agriculture.

[9] Additional recommendations regarding the improvement of the legal situation can be found in the conclusion paper of the ManuResource conference 2013 organized in the framework of the ARBOR project (http://vcm-mestverwerking.be/publicationfiles/2014.01.03ConclusionsoftheManuresourceconference2013BrugesES.pdf)

Experiences with synergy parks over the past years show, that such successful movements towards a circular economy are often grassroots movements, mainly driven by the involved players themselves, and realised through a long-term development process (> 10 years). Moreover, through the study of such initiatives in the ARBOR project, several recommendations could be derived with regard to how public stakeholders can support and stimulate the implementation of synergy parks.

Role of trust: Cooperation and synergies between companies can hardly be planned by city planner or local authorities, but they can identify opportunities and organize matchmaking of suitable enterprises. By stimulation of exchange between potential partners and sensitization for successful synergy concepts, agencies or authorities can try to increase the trust in such concepts and, in particular, try to raise the trust between companies, which is key to succeed with such an endeavour. Good inventories for material and energy flows are necessary, which require effort, trust and openness which companies are only willing to invest if each of them separately can clearly see the added value for the own business model.

Long term contracts: A major hurdle can be the reluctance of companies to accept long-term contractual obligations, either concerning investments or supply and demand of exchanged streams. Intercommunal companies can be a facilitator and interface between the companies and authorities, as they have often a higher social responsibility and are locally bonded. Public stakeholders could, e.g. in cooperation with intercommunal companies, share risks of investments in exchange infrastructure (such as district heating systems) or back up facilities, which are often necessary to compensate seasonal / weekly variations of exchanged streams or to assure the security of supply. Even if exchanged goods or energy streams represent a waste stream for a delivering company, it would be advantageous if the streams could be expressed in a monetary value or would be contractually bonded, as the withdrawal of a single company always generates higher efforts and risks for the remaining partners.

Management: Another important factor is the “park manager”, coordinating and organizing the synergy park. This key person should be an insider in the companies, with entrepreneurial thinking and paid collectively. A good starting point is the organization of shared services such as security service or the common buying of energy.

Legal hurdles: Legally, the “waste vs. product” issue as well as the “end of waste criteria” can complicate the exchange of material flows between companies, but experience also shows that in many cases the stakeholders are discouraged already before they seriously tried to tackle these legal aspects while the solutions could be discovered during an open exchange with local authorities.

5 Future challenges

In the past decade bioenergy has become an important source of renewable energy in Northwest Europe. Meanwhile, following this development, as well as changes in other industrial sectors the resource-related constraints have emerged, such as scarcity of primary resources or conflicts of interests in the biomass valorisation sector. Although the use of organic residues for energy production purposes does not generate the negative impacts associated with energy crops based energy production (land use competition, effects on nature conservation), there is still a tremendous improvement potential in terms of efficiency of the solutions. Energy production systems based on organic wastes and side streams are often designed from a disposal perspective which contributes to considerable potentials for material recycling and energy production being wasted. Relatively large streams of residues and side streams from agriculture are considered as difficult in sourcing, and handling. Moreover the industry is often not interested to search for such substrates due to their lower and heterogeneous quality. Additionally the available biomass conversion technologies could be improved regarding resource- and energy-efficiency. Beside those technical improvement measures to be implemented, there is also a lack of strategy and policy schemes to manage the particular material flows in a resource efficient way and in accordance with the circular economy approach.

Based on the benchmark studies and analysis conducted in the framework of the ARBOR project the following general challenges are to be addressed in the future:

- Integration of resource-efficient, multi-stage valorisation (biocascading, multi uses) in the current valorisation concepts and strategies (Improving the efficiency from a resource point of view)
- Alternative services in the energy and nutrient market
- Identifying necessary management, policy and strategy frameworks to stimulate the transformation
- Implementation oriented focus with commercial target group addressing
- Continuous inter- and transregional cooperation for overcoming knowledge disparities within Northwest Europe

Base on the benchmark studies and analysis conducted in the framework of the ARBOR project the following aspects grouped in the thematic domains have been identified as needing further research and development focus:

<u>Organic waste from municipalities (organic wastes, greeneries, sewage sludge)</u>

- Case studies on flexible supply services in the renewable energy market as a storable electricity & heat or fuel provider
- Case studies on improving the energy efficiency from a resource point of view
- Integration material and energy conversation technologies in closed loop systems (e.g. of thermo-chemical processes with anaerobic digestion for alternative nutrient and soil improver production)
- Investigation on resource-efficient, multi-stage valorisation chains (biocascading, multi uses, carbon based materials, phosphorus recovery) for organic wastes

- Investigation on supply chains and logistic framework for multi-stage valorisation
- Identifying necessary management, policy and strategy frameworks to stimulate adapted governance and transformation processes
- Addressing the cost discussion towards transsectoral and external effects and regional added values
- Bundling of organic waste streams on inter-municipal/ -regional level
- Labelling of (inter-)regional bio-based products from organic waste streams
- Impact assessment for closed loop transformation processes

Vegetable residues and pocket digesters:

- Investigating the reduction potential of the emissions linked to implementing of particular measures in small scale AD
- Research on the technical developments for small scale AD oriented towards other agricultural sectors (e.g. vegetable residues or mono-digestion of pig slurry)
- Further development of specific harvesting machines allowing for the collection of the residues
- Investigation of the influence of the removal of particular vegetable residues on the nitrate emissions
- Economic and environmental assessment for different agro-residues valorisation chains (e.g. use as fodder vs. energetic conversion)

Buffer strips:

- Environmental and economic study of different types of perennial crops cultivated on a buffer strip. Based on the ARBOR findings these cultures seem to be the only economically feasible cultivations to mobilize biomass from these extensively cultivated areas.
- Search for different value chains not only limiting to the energetic valorisation
- Promoting legal change on the country or European level towards including harvesting of biomass from extensively cultivated buffer strips as approved activity within the financial support schemes

Nutrient recovery from digestate/manure:

- a Determining of the nutrient uptake coefficients for digestate derived products
- Standardization of the European definition of the nutrient uptake coefficents
- Development of the European legal framework for use of bio-based fertilisers
- Development of homogenous labelling system for bio-based fertilizing products
- Market demands in certain areas with nutrient and organic carbon scarcity – which products from digestate could be interesting in these regions, and can transport costs be compensated through price
- Promoting safe use of digestate through creating standardized European quality control system
- Conducting consequential LCA for implementing different nutrient recovery technologies from digestate to analyse the environmental consequences of the influence of the substitution of mineral fertilizer with the new digestate-derived products for particular regions

Some of these challenges are planned to be targeted within the ARBOR follow-up project. Currently the ARBOR consortium is regrouping and working on a future initiative, which would focus on valorisation of organic residues in different valorisation chains including material and energetic use.

Source: ARBOR Consortium, Kick-Off Meeting, Bruges, 2010