Urban waste for biomethane grid injection and transport in urban areas

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UrbanBiogas website: www.urbanbiogas.eu

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1 Introduction

The UrbanBiogas project (Urban waste for biomethane grid injection and transport in urban areas) was supported by the Intelligent Energy for Europe Programme of the European Union from May 2011 to April 2014. The objective was to prepare selected European target cities for the production of biomethane from urban bio-waste which will be fed into the natural gas grids or optionally used for transport: City of Zagreb (Croatia), Municipality of Abrantes (Portugal), City of Graz (Austria), City of Gdynia/Rzeszów (Poland), and North Vidzeme Region including the City of Valmiera (Latvia). Core of the project was the implementation of more than 130 events, including workshops, working group meetings, study tours and city exchange visits in order to elaborate five WtB concepts for the target cities. These concepts describe measures how to implement WtB projects in the target cities.

UrbanBiogas was coordinated by WIP Renewable Energies (Germany) and involves ten partners: Fraunhofer Institute for Wind Energy and Energy System Technology (Germany), Hrvoje Pozar Energy Institute (Croatia), Polish Biogas Association (Poland), IrRADIARE (Portugal), Câmara Municipal de Abrantes (Portugal), Ekodoma (Latvia), Zagreb Holding - subsidiary Čistoća (Croatia), North Vidzeme Waste Management Organisation (Latvia), Graz Energy Agency (Austria), and Podkarpacka Energy Management Agency (Poland).

This publishable summary report presents the main discussions, results and achievement of the UrbanBiogas project that are described in various publications (e.g. Rutz et al. 2013, 2012, 2011). This report is mainly based on the publication of Rutz et al. (2013) and includes updated information from the partners of the target cities.

2 Background Information

2.1 Overview on Bio-Waste in Europe

About 14% of all generated waste is Municipal Solid Waste (MSW) Eionet (2009). The collection of MSW is usually in the responsibility of local public bodies such as municipalities and cities. It consists of waste generated by households as well as by smaller businesses and public institutions whose waste is similar to that of households. The characteristics of MSW highly depends on the local situation, season, waste management system and waste producers. It consists of residual waste, bulky waste, secondary materials from separate collection (e.g., paper and glass), household hazardous waste, street sweepings and litter collections. It includes paper, cardboard, metals, textiles, bio-waste, glass, plastic and other materials. According to Figure 1, the largest fraction of MSW is paper and cardboard with about 35%, followed by bio-waste with about 25% of the waste stream Eionet (2009).

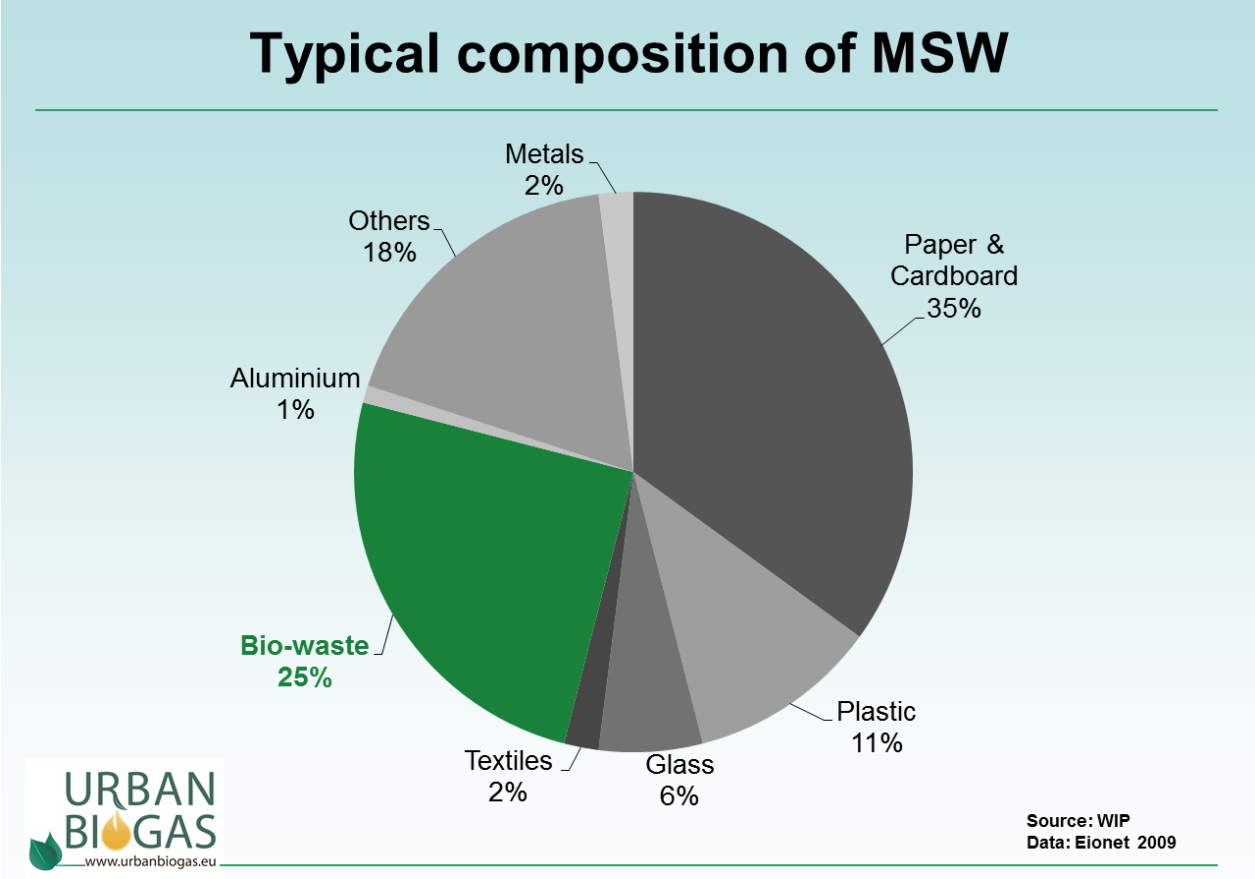

Figure 1: Typical composition of MSW (Data: Eionet European Topic Centre on Sustainable Consumption and Production, 2009)

As Figure 2 shows, many countries have still dumped large portions of MSW on landfills in 2010. The European policy asks Member States to ban landfilling of MSW within the next years. Besides other environmental problems associated with landfilling such as land use conflicts, water pollution and odours, a major environmental impact of landfilling is the production of methane mainly from bio-waste, which accounted for some 3% of total greenhouse gas emissions in the EU-15 in 1995 EC (2012).

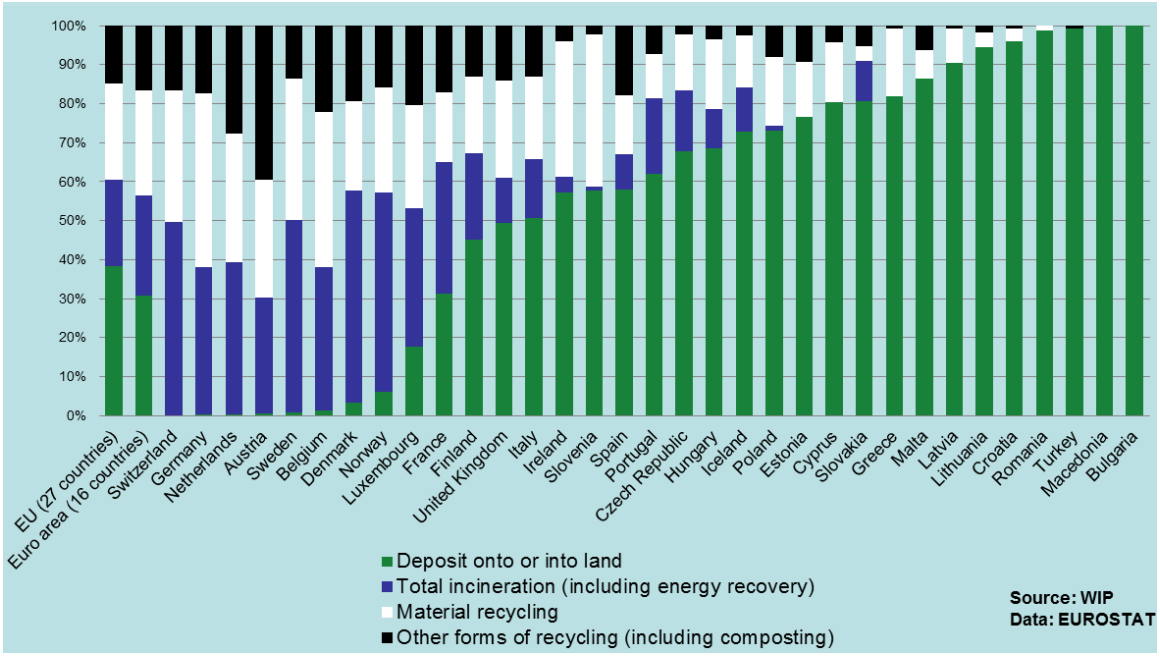

Figure 2 The share of different treatment options for municipal waste in Europe in 2010 (Data: EUROSTAT)

2.2 European Legislation on Bio-Waste

This chapter summarises briefly the current legislation and debate on waste management aspects in the European Union. This provides the backbone and arguments for the promotion of the WtB concepts of the UrbanBiogas project, as it will be described in the following chapters.

The two most important directives in the field of MSW and bio-waste treatment are the Landfill Directive 1999/31/EC EC (1999) and the Waste Framework Directive 2008/98/EC EC (2008).

The objective of the Landfill Directive is to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills. The Directive is intended to prevent or reduce the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health.

It defines "biodegradable waste" as “any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard”. It obliges Member States to reduce the amount of biodegradable waste that they landfill to 35% of 1995 levels by 2016. The Member States have a number of choices that they can take in terms of alternative treatment for this biodegradable waste, taking into account local conditions such as climatic conditions to the composition of the collected biodegradable waste.

The WFD lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use. A core content of the directive is the application of the waste hierarchy shown in Figure 3 as a priority order in waste prevention and management legislation and policy:

Figure 3: Waste hierarchy defined in the WFD (EC, 2014)

The directive defines “bio-waste” as “biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants”. Article 22 on bio-waste of the directive asks Member States to take measures to encourage:

(a) the separate collection of bio-waste with a view to the composting and digestion of bio-waste;

(b) the treatment of bio-waste in a way that fulfils a high level of environmental protection;

(c) the use of environmentally safe materials produced from bio-waste.

The directive highlights the importance in accordance with the waste hierarchy, and for the purpose of reduction of greenhouse gas emissions originating from waste disposal on landfills, to facilitate the separate collection and proper treatment of bio-waste in order to produce environmentally safe compost and other bio-waste based materials.

Furthermore, the European Commission has released a Green Paper EC (2008) on the management of bio-waste in the European Union proposing measures on how to consider bio-waste in European legislation.

In 2010, the European Parliament called in a non-legally binding resolution for a Bio-waste Directive, with mandatory separate collection, since this could generate major economic and environmental benefits European Parliament (2010). According to the European Parliament proposal, compulsory separate collection and recycling of bio-waste should be core of the legislation, as every year, between 118 and 138 million tons of bio-waste is produced in the EU. Full implementation of existing bio-waste legislation could result in environmental and financial benefits of €1.5 billion to €7 billion. A specific directive for bio-waste would offer greater clarity, better monitoring and enforcement of implementation and legal certainty in this area. A bio-waste directive should include:

(a) the establishment of a mandatory separate collection system for the Member States, except where this is not the appropriate option from the environmental and economic point of view;

(b) the recycling of bio-waste;

(c) a quality-based classification of the different types of compost from bio-waste.

The resolution emphasizes that the separate collection of bio-waste needs to be increased to reach the targets for recycling and renewable energies and to help achieve the goals of the EU 2020 strategy, in particular resource efficiency.

Despite this initiative of the European Parliament, it seems that the European Commission sees bio-waste aspects already fully covered by the WFD, and thus does not promote the idea of a Bio-waste Directive. Thus, the set-up of such a directive remains uncertain.

2.3 European Legislation on Renewable Energies

Besides the European legislation on waste and landfilling, another important Directive which supports the WtB concept is the Renewable Energy Directive 2009/28/EC.

The directive establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. It lays down rules relating to statistical transfers between Member States, joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from renewable sources. It establishes sustainability criteria for biofuels (for transport) and bioliquids (for stationary use in CHP plants).

The production of biogas or biomethane from bio-waste could contribute to achieve the targets of the RED, independently if the biogas is used for electricity and heat production in a CHP plant, or for upgrading to biomethane and grid injection or use in transport.

Biomethane as transport fuel is defined by the RED as “biogas from municipal organic waste as compressed natural gas”. Its potential to mitigate greenhouse gases is considered as very high, as the typical and default numbers for greenhouse gas emission savings of the RED are very high:

(a) Typical greenhouse gas emission saving: 80%

(b) Default greenhouse gas emission saving: 73%

This is an important aspect, since the GHG emission savings from the use of biofuels for transport (including biomethane) need to be above certain thresholds in order to comply with the sustainability criteria set in the RED. They need to be for all installations at least 35 % and at least 50 % from 1 January 2017. In installations in which production started on or after 1 January 2017, GHG emission savings shall be at least 60 %. According to the typical and default values for GHG emission savings, biomethane from bio-waste is far above these thresholds and would be therefore very suitable for use in transport.

2.4 Treatment Options of Bio-waste

As it was mentioned already, general options for the collection and treatment of bio-waste include separate collection, segregation of bio-waste from mixed waste, incineration, composting, and anaerobic digestion (Figure 4). Although still on-going practice in several European countries, landfilling of bio-waste is no future option due to EU legislation.

From the environmental viewpoint, clear prioritisation is given to the anaerobic digestion pathway of separate collected bio-waste. The following advantages of this pathway are highlighted and further described below:

- Production of high-quality fertilizer
- Substitution of fossil fertilizer
- Closure of nutrient cycles
- Renewable energy production
- Technology with high GHG emission savings in comparison to other bio-waste treatment technologies

- Production of transport fuel (biomethane) with high energy content
- Biomethane from bio-waste as transport fuel fulfils the GHG reduction mandates of the RED
- Smaller decentralizes treatment plants allow short transport distances of the bio-waste

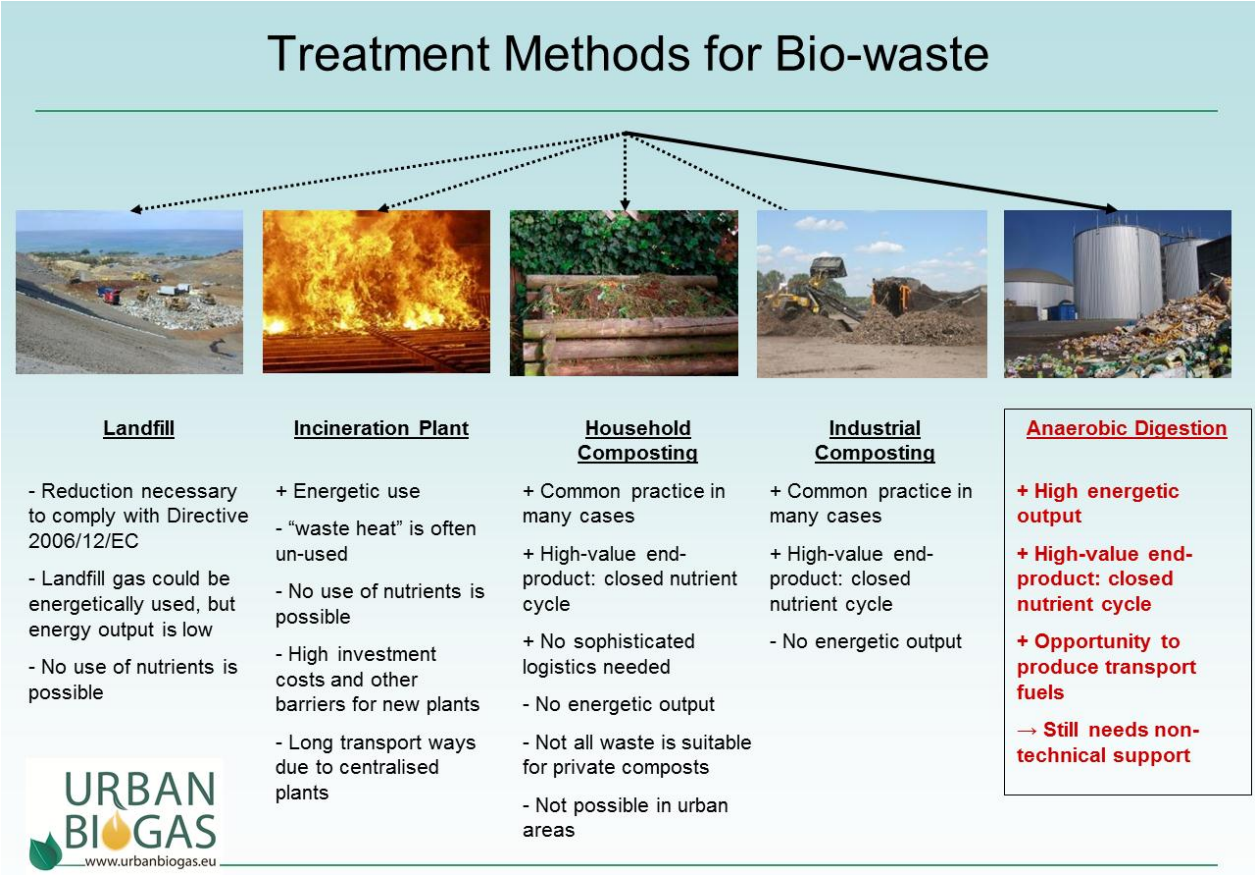

Figure 4: Treatment Methods for Bio-waste

Anaerobic digestion (AD) of separate collected bio-waste produces a high-quality product: digestate can be used as fertilizer, planting substrate and soil improver. It contributes to increase the carbon content of the soil and substitutes artificial fertilizer produced from fossil resources.

Digestate can be also produced from the organic fraction of MSW that is not collected separately, but sorted only at the waste treatment facility into organic and non-organic fractions. This can be done by different methods. One approach that is done in several biogas plants in Sweden is the use of differently coloured plastic bags for bio-waste and for the remaining MSW. Both bags are collected in joint bins. At the treatment facility these bags are sorted by colour sensors. Several problems are associated with this method, such as lower quality of the digestate, higher plastic consumption, high amount of impurities, and need of further treatment for impurities. Thus, the separate collection of bio-waste at the place of origin (household) is strongly recommended.

In comparison to composting of bio-waste, AD also valorises the energy content of the bio-waste and thus contributes to increase renewable energy production. This contributes to the achievement of the renewable energy targets of the RED and all other benefits associated

with renewable energy production. Furthermore, in biogas facilities nearly all methane is captured and used, whereas in composting facilities considerable amounts of methane emissions occur.

In waste incineration plants, no recycling takes place leading to a loss in nutrients and carbon stock for soils. Furthermore, incineration plants are usually large facilities requiring high amounts of investment. Bio-waste is generally transported for centralized incineration plants at longer distances creating several disadvantages. Finally, it is not possible to produce biofuels with high energy density like biomethane in incineration plants.

Although there exist many advantages for the AD treatment of bio-waste, it is also associated with several challenges, among the most important ones are:

- Introduction of a separate collection system or waste selector facilities
- Raising public awareness about the need of separate collection and getting public acceptance
- Education of households in waste separation
- Reduce investment and operational costs for AD facilities
- Introducing policies which allow the introduction of a profitable separate waste collection system with adjacent AD process
- Creating a suitable market for the sale of digestate as fertilizer, substrate, or soil improver

Several of the UrbanBiogas target cities are in the phase of introducing new waste management and treatment systems. Although the above described European policies clearly support the introduction of separate bio-waste collection systems with subsequent AD or at least composting, the current debate in some UrbanBiogas target cities is targeting towards other routes such as e.g. incineration or segregation of bio-waste from mixed MSW with subsequent composting or AD.

The objective of the UrbanBiogas project is to convince the local stakeholders of the UrbanBiogas target cities that the separate bio-waste collection with AD treatment is usually the most sustainable solution. The following chapter describes how this can be achieved.

3 The WtB Concept in Europe

The simultaneous energetic use of bio-waste and the creation of a closed nutrient cycle is one of the main advantages of anaerobic digestion with biogas plants as they turn waste materials into “desirable” feedstock. In addition, the conversion of bio-waste in biogas plants has several other advantages in comparison to other bio-waste treatment options (landfill, incineration, composting).

Biogas production from bio-waste has the potential to contribute to the European waste and renewable energy targets. Adjacent upgrading to natural gas quality and use for transport (Figure 5) or for grid injection into the natural gas distribution network is an opportunity to efficiently use renewable energy in urban areas too. This approach, Waste-to-Biomethane (WtB), is promoted by the UrbanBiogas project. Figure 5 shows the Waste-to-Biomethane value chain promoted in the UrbanBiogas project.

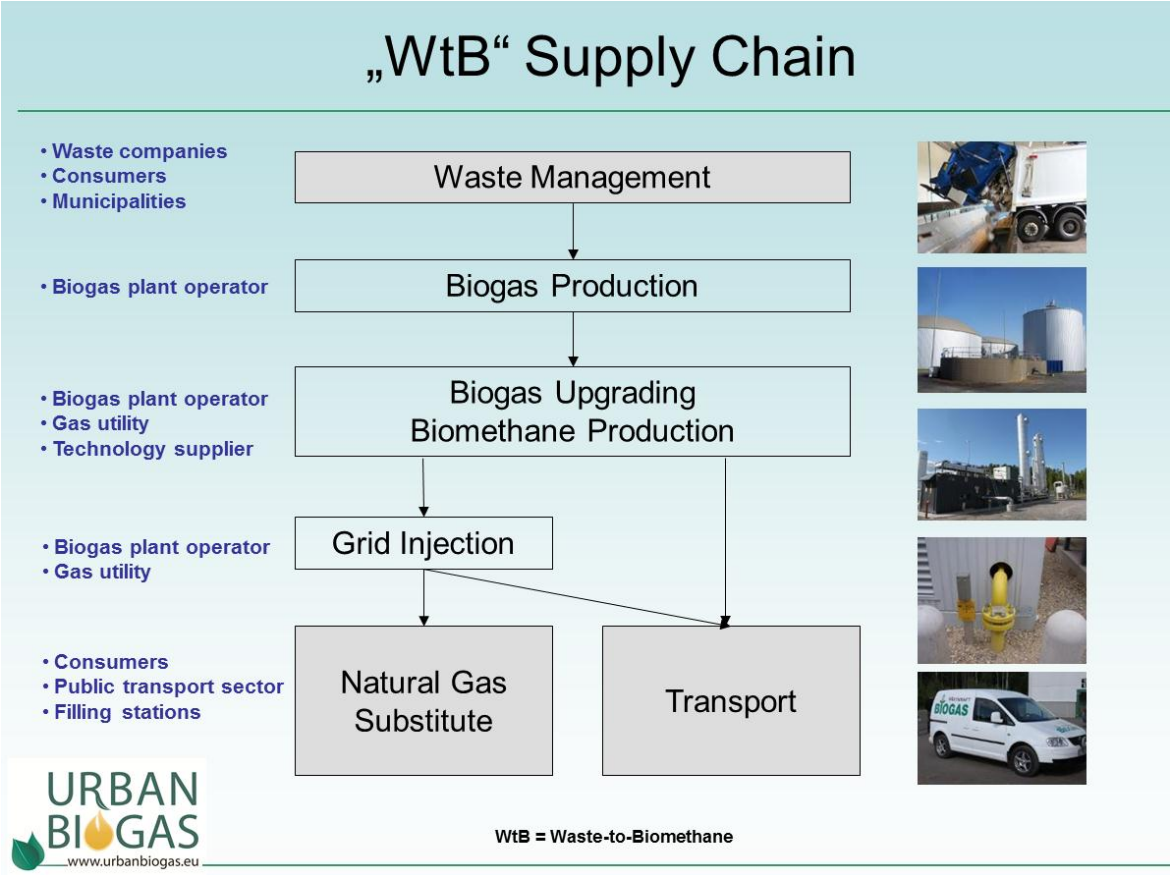

Figure 5: Waste-to-Biomethane value chain of the UrbanBiogas Project

4 The UrbanBiogas Project

The objective of the UrbanBiogas project (Urban waste for biomethane grid injection and transport in urban areas) is to prepare 6 European target cities for the production of biomethane from urban bio-waste which will be fed into the natural gas grids or optionally used for transport: City of Zagreb (Croatia), Municipality of Abrantes (Portugal), City of Graz (Austria), Cities of Gdynia and Rzeszów (Poland) (Rzeszów was the initial target city and replaced during the project by the city of Gdynia), and North Vidzeme Region including the City of Valmiera (Latvia). Core of the project is the implementation of more than 130 events, including workshops, working group meetings, study tours and city exchange visits in order to elaborate five WtB concepts for the target cities. These concepts consist of detailed descriptions on measures how to implement WtB projects in the target cities.

4.1 Main activities and results

Core of the project was the implementation of more than 130 events, including workshops, working group meetings, study tours and city exchange visits in order to elaborate five WtB concepts for the target cities. Most activities were organised in the UrbanBiogas target cities, whereby also additional cities were addressed. The following results were achieved:

- **1 tender** (Valmiera) for a biogas plant was **published**
- **1 tender** (Graz) is **close to publication**, the land for the installation is currently being purchased
- **3 WtB plants are considered** in the near future (Zagreb, Abrantes, Gdynia)

- More than **770** participants attended the **Task Force Meetings**
- **354** participants attended **13 training courses**
- **143** participants attended **4 promotional events** for biogas companies to stimulate interest in the target cities
- More than **170 people attended public events** about waste collection
- **21 signed partnership certificates** were signed with other cities
- **316 group members** at Facebook are discussing about WtB issues

Some impressions of the project are presented in Figure 6.

Figure 6: Impressions of selected activities the UrbanBiogas project

4.2 Lessons learned

There are many lessons learned, either referring to the individual situation of the target cities or, more general. The consortium would like to highlight the following lessons:

- UrbanBiogas gave some organisations that participated for the first time in an Intelligent Energy for Europe project, the opportunity to participate and learn about the IEE programme.
- Without supporting policies on National level it is economically challenging to implement a new WtB plant in a city. The evaluation of the economic feasibility of WtB plants indicated that support should be provided in means of good framework conditions for biomethane use in transport or for grid injection. Increasing waste

management tariffs (or tipping fees) would be another option (e.g. in Latvia), however, this option often lacks political support.

- Often, the common way of treating biodegradable waste in municipal organizations is composting. AD is more complicated and requires deeper understanding of the technology. For that reason replacing composting with biogas production is often met with reluctance.
- Citizens of Zagreb (Croatia) in general support separate bio-waste collection. However, lack of information on the biogas production processes fed the present NIMBY syndrome (not in my backyard syndrome). The biggest obstacle to biogas production in the City of Zagreb is the lack of interest in the City Council to decide on the waste management strategies for the City. Therefore in the future solutions need to be found to affect the decision makers in that field.
- In Croatia, a clear picture on the framework conditions for a biomethane market development is needed. In Croatia, neither technical specification standards for biomethane and priority grid access nor support mechanisms for biomethane production exist. Because of that, potential biomethane plant developers will currently decide to invest in biogas plants for electricity and heat generation, instead of biomethane production. It will guarantee low risk investment and attractive returns, because of the feed-in tariffs for electricity production.
- The lack of knowledge has been identified as potential barriers in implementation of a WtB project in the City of Zagreb. The public sector including the local and national decision makers need to learn more about the production and use of biogas or biomethane. In addition, engineers, architects, as well as energy and bank sector representatives need additional education to be able to integrate sustainability in their respective fields of work. The results of UrbanBiogas project was a good starting point for public awareness raising and educational campaigns.
- During the project implementation Valmiera city (Latvia) and ZAAO accumulated experience about different approaches in bio-waste management biogas production and upgrading technologies from the partner cities. ZAAO came to conclusion that the implementation of the WtB chain is a very long term process which demands involvement of all relevant stakeholders. Also, it is necessary to have favourable legal and economic framework conditions.
- Existing framework conditions in Valmiera (Latvia) and current development plans did not allow immediate implementation of WtB chains in the most efficient way. If investments in waste management infrastructure has been made and they first need to pay-off before a new technology can be applied.
- It was very challenging to find appropriate technical solutions for a small scale biogas plant, as it is foreseen in Valmiera (Latvia), with limited amounts of waste collected and at reasonable cost. The density of the population and scale factors has significant impacts on the economy of plant.
- The example of Rzeszow (Poland) showed that political support and lobbing is more important than any substantive arguments. Unsuccessful stories about biogas plants in Poland are famous and taken as the only truth, and successful news as propaganda of companies. The absence of supportive legislation for biomethane grid injection is blocking the set-up of upgrading units in existing biogas plants.
- The “waste market” got more and more important in the last years in Austria. This has important effects to the tipping fees for handling the substrates and on the availability of organic (urban) waste in general. It is very difficult to agree on long term contracts (above 3-5 years) with fixed prices for substrates.
- Neighbourhoods often show problems with accepting biogas/biomethane plants near cities. So finding a plant location which is accepted by the neighbourhood and policy and which has short transport distances and connection to natural gas grid is essential. This was an issue for Zagreb (Croatia) and Graz (Austria).

- In Abrantes (Portugal), the Local Support Group (Task Force Group) facilitated stronger commitment by the region. The commitment expressed by a large number of partner municipalities and cities was a significant basis for the implementation of sustainable processes. The development of an integrated concept of waste, biogas and biomethane allowed a better understanding of the necessary process from the "raw material" to the final result.

4.3 Success stories

The following success stories of the UrbanBiogas project can be reported:

- Visiting municipal waste organizations, explaining the benefits of biogas as a renewable fuel and getting them to sign partnership certificates, even seriously considering biogas production in their future, are success stories.
- UrbanBiogas has undoubtedly contributed to the fact that biogas production is included in the official waste planning documents of the City of Zagreb.
- By giving numerous presentations about the WtB concept and talking to many people and stakeholders the view of many concerning biodegradable/bio-waste processing and directing it toward biogas production was certainly changed in Zagreb.
- Until recently all MSW in Zagreb was landfilled. A pilot project on separate waste collection in a large residential building complex in Zagreb was introduced during 2012. The building complex (so called Mamutica) includes 13 buildings and is home of 4,000 inhabitants. During that period, Zagreb CH implemented a system for separate collection of bio-waste, plastics, paper and glass and did educational workshops among citizens. As a result almost 7.000 kg/month of various waste fractions were collected. The main portion was bio-waste which was treated at the composting site of the city. All compost produced in the City of Zagreb is used for local parks in the City area. Throughout the pilot project lifetime, Zagreb CH actively promoted the WtB idea of UrbanBiogas.
- UrbanBiogas contributed to dialog formation between waste management process stakeholders and raised the importance on bio-waste waste management issues in Valmiera city and in the region. As a main result of UrbanBiogas, a public tender of procurement for a dry fermentation plant was published.
- The question about the optimal location for a potential biogas/biomethane plant in Graz was one of the most critical ones in the last 2 years. Right before the end of the UrbanBiogas project a municipality in the vicinity of Graz was identified that has interest in such a WtB-plant. As a result of UrbanBiogas, the purchasing process of the land for the WtB plant has started.
- Although the preparation-process for the plant in Graz took much longer than estimated at the beginning of the UrbanBiogas project it is very positive to see that the consortium (city of Graz, local energy supplier, waste management company) is still the same and all of them highly support the implementation of the project.
- The continuous discussions in the task force meetings and also of the other meetings and events of the UrbanBiogas project contributed to the modification of the regulations for feeding-in green electricity, a better and clearer understanding of the biomethane trading in Austria and a high interest of investors and plant suppliers in such WtB-plants.
- Particularly after the final project conference in Brussels, March 2014, and respective press releases FRAUNHOFER gained a fair number of promising contacts with R&D partners und industrial clients. The preparation of future projects and drawing up quotations for studies and consulting services are successful outcomes.
- Detailed investment implementation plans where prepared for each municipality in Portugal that shares the same waste management system as Abrantes. Those plans successfully integrate the waste-to-biogas option and are complying with the

Covenant of the Mayors procedures. The local support group in Abrantes was used as dialog platform to achieve the relevant commitments respecting to waste-to-biogas investments and the summer school as a capacity building action to prepare the region to absorb new waste-to-biogas investments.

- The UrbanBiogas project and the activities implemented in Valmiera has raised attention not only on city level, but also on national level. Biomethane training, training on business agreements and presentations of technology providers at the competition stimulation event, which were all organised in Riga, were well attended and positively evaluated by participants. These events started discussions about the role of biomethane in the future renewable energy policy in Latvia and about anaerobic digestion as good technology for organic municipal solid waste management. National dissemination events were attended by stakeholders working in the waste management sector in Latvia, in ministries, the biogas sector of Latvia, environmental protection organisations and other market actors. All together 90 national level stakeholders were directly informed about benefits of the waste-to-biomethane concept and challenges associated with its implementation.
- Ekodoma was invited to present the experience of Valmiera concepts at the energy forum on Liepāja city (located on a Western part of Latvia and comparable to the size of Valmiera). During this forum the use of waste for biomethane production in Liepāja was discussed. The outcome of the discussions was a list of measures that were included in the sustainable energy action plan for Liepāja city prepared in the Covenant of Mayors initiative.

5 Summary of the results in the UrbanBiogas Target Cities

The following chapters present the target cities in the UrbanBiogas project: City of Zagreb (Croatia), Municipality of Abrantes (Portugal), City of Graz (Austria), City of Gdynia/Rzeszów (Poland), and North Vidzeme Region including the City of Valmiera (Latvia). A map of the target cities is shown in Figure 7.

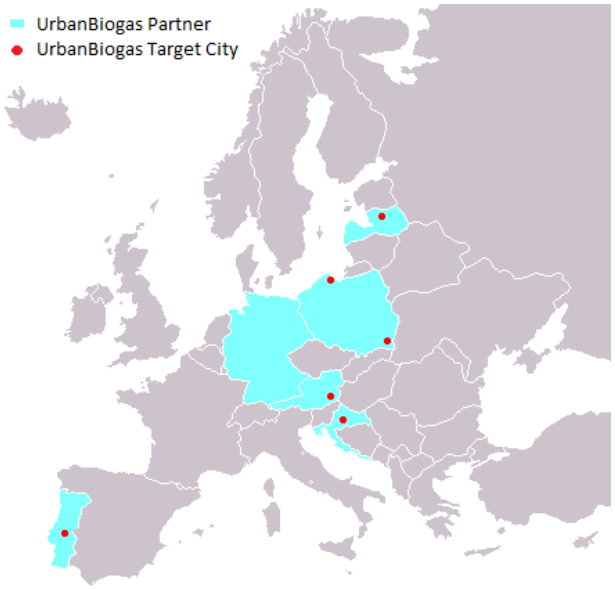

Figure 7: Involved countries in UrbanBiogas (blue) and target cities (red points)

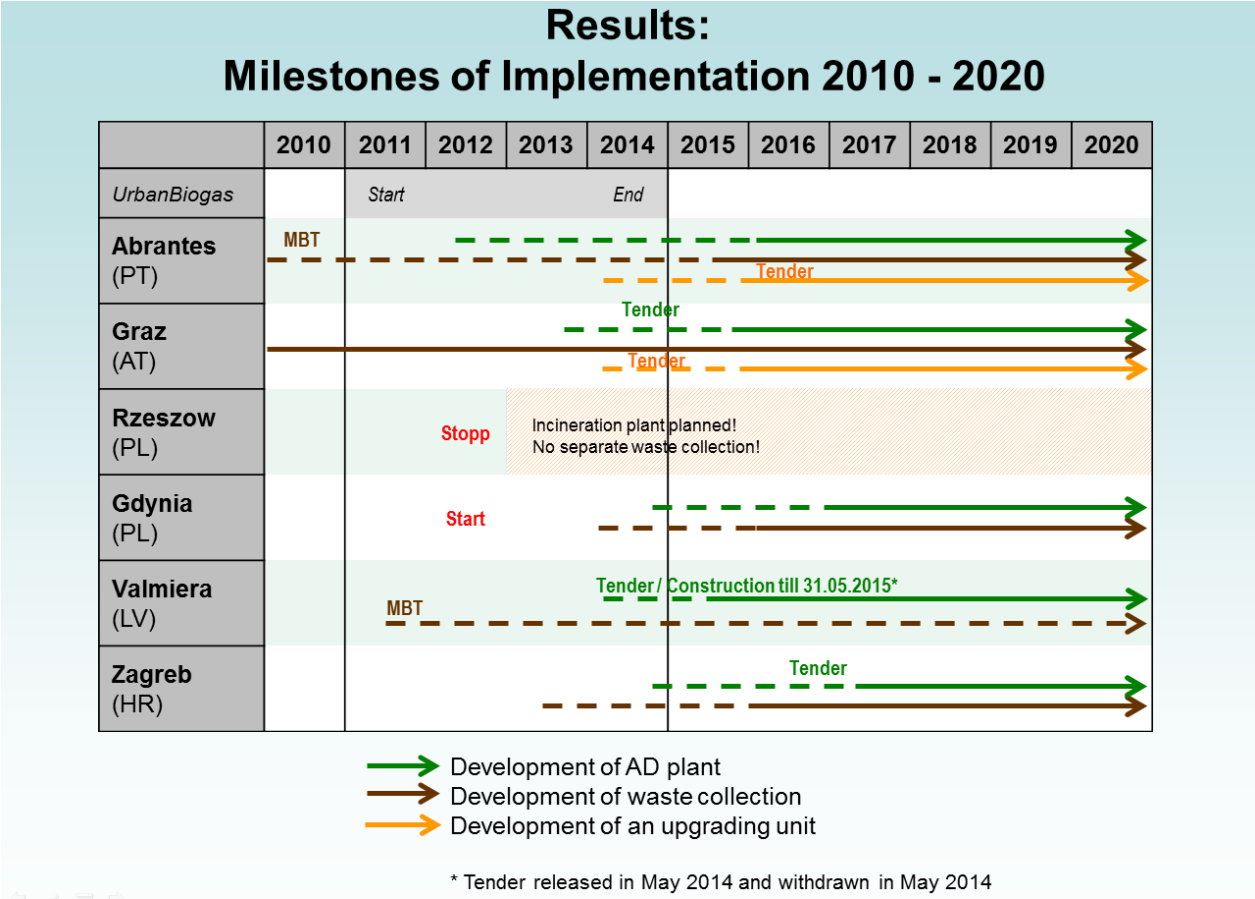

Figure 8: Status and milestones of the implementation of WtB projects in the UrbanBiogas target countries

5.1 Abrantes, Portugal

Abrantes is a Portuguese city in the District of Santarém, in the sub-region of Médio Tejo. The area of Abrantes is 714 km^2 and includes 39,325 inhabitants (2011), subdivided into 19 parishes. The population density is 56 inhabitants per km². In its regional context, Abrantes is one of the largest cities in the region, and thus a strategic position regarding the waste management including its treatment.

Under UrbanBiogas, Abrantes represents a region with 15 municipalities. The waste management responsibility relies on each municipality being each one included in an integrated management system. In the region represented by Abrantes there are three waste management companies that cover different municipalities of the region:

- **Resitejo**: Tomar, Ferreira do Zêzere, Constância, Vila Nova da Barquinha, Torres Novas, Alcanena e Entroncamento;
- **Valnor**: Abrantes, Mação, Oleiros, Proença-a-Nova, Sardoal, Sertã e Vila de Rei
- **Valorlis**: Ourém

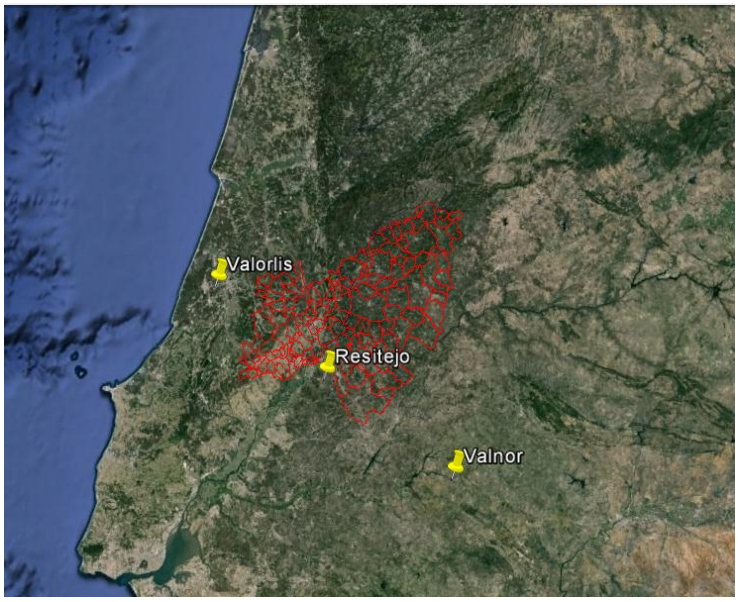

Figure 9: Location of the waste management companies Resitejo, Valnor and Valoris, and their regional coverage

Resitejo is responsible for the treatment of 93,354 t of urban solid waste per year and serves a population of 209,587 inhabitants. Resitejo has the following infrastructures: landfill site, sorting centre, three transfer units, four transfer centres, eight eco-centres, 1,272 eco-points, 298 glass containers, and 49 used cooking oil containers. Resitejo also collects source separated cardboard, plastic, metal and used batteries.

Valnor has an integrated system of waste treatment in the region being currently responsible for sorting, valuing and treating solid waste. Valnor serves 25 municipalities and covers the following responsibilities:

- Energetic enhancement of the obtained biogas that makes possible the energy production with a power connection of 1075 kVA;
- Fuel derived from waste, used as substitute of fossil fuels;
- Used cooking oil gathering and biodiesel transformation for fleet use;
- Gathering of used tires and its valorisation;
- Selective gathering, trough eco-points and eco-centres or door-to-door methods;
- Composting, through the organic valorisation plant that uses a mechanic and biological treatment of the urban solid waste resulting in compound for use in agriculture and forestry;
- Gathering and treatment of waste from construction and demolition;
- Gathering and treatment of waste from electric and electric equipment;
- Gathering and treatment of urban solid waste;
- Gathering and treatment of biodegradable urban waste;
- Gathering and treatment of different sorts of waste such as furniture, sofas and others.

The unit of anaerobic digestion in Valnor produces around 2,750 GWh/year. This installation allows the treatment of 25,000 t/year of organic matter.

Valorlis is responsible for the selective gathering, sorting, and waste valorisation of solid urban waste in municipalities with in total 317 thousand inhabitants. Valorlis manages the following systems:

- Sorting station;
- Landfill;
- Transfer stations;
- Eco-centres;
- Organic valorisation plant.

In the Waste-to-Biomethane (WtB) concept developed in the UrbanBiogas project for the region of Abrantes, three scenarios were analysed:

Scenario 1 "User-Pays" principle: Among the basic principles of environmental policy, it includes the "principle of responsibility". Thus, the consumer (polluter) is forbidden to pollute. The consumer should pay the costs of waste disposal and if he does not, he has the responsibility of paying the "social" cost of a pollutant action (through fines, damages, etc.).

Scenario 2 "Waste separation incentives": In order to prevent waste production, it is important to raise awareness and involvement of all stakeholders by promotional activities that contribute to waste production prevention. Monetary incentives can be considered to support promotional actions for source-separation of waste.

Scenario 3 "Technical development of transfer stations": Waste recovery is currently a popular subject. Most companies that are dealing with waste management do their best to develop their business according to the state of the art technologies. In this scenario it is important that companies invest in best technologies in order to maximize the efficiency of the process.

After careful analysis of the three presented scenarios, the third scenario was considered the most feasible scenario. Therefore, it is proposed that until 2020, a promotion is made on the development of the transfer units, according to Figure 10.

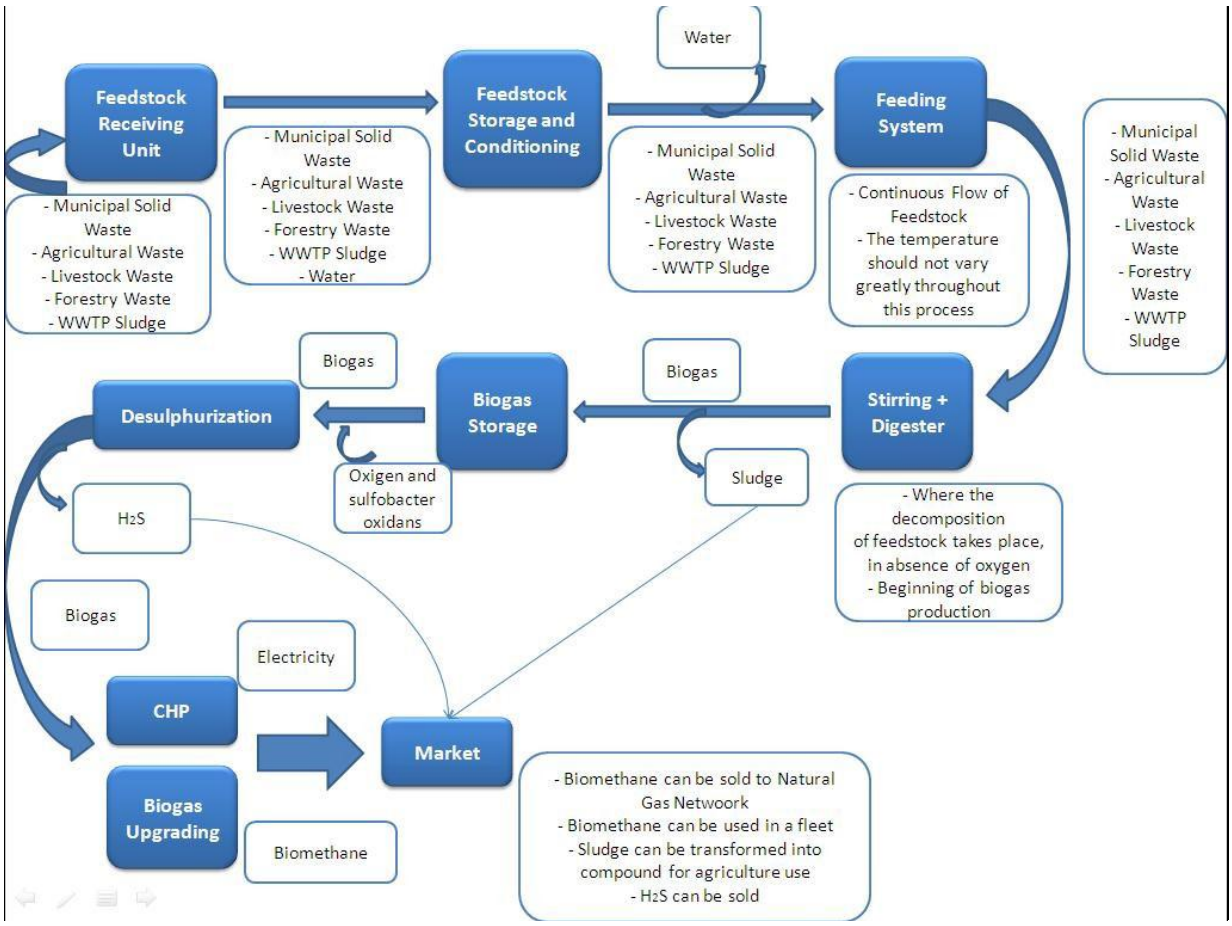

Figure 10: Biomethane production chain – Materials flow

Parts of this model was already implemented by the three waste management companies in the region that have accomplished the following activities during the UrbanBiogas project timeframe:

- Resitejo inaugurated a biogas production unit in 2013;
- Valorlis has enlarged its collection of landfill gas in 2014;
- Valnor started to operate a biogas production unit in 2011. Furthermore, a biogas plant in Concavada (Abrantes) started operation in 2013, including the mechanical-biological treatment and anaerobic digestion facilities. The produced electrical energy is 2,750 GWh/year.

Currently, the biogas produced from the anaerobic digestion units of Resitejo and Valnor is used for the production of electric energy, only.

Valnor predicts for 2016 an increase of the biogas production capacity which will result in 80% more capacity than the currently installed capacity and therefore alternatives for the use of biogas are being analysed. One option that was proposed in the UrbanBiogas project is to upgrade biogas to biomethane and to use it transport.

UrbanBiogas brought the needed investments for the biomethane upgrading facility into the long term financial planning of the region, namely under the Covenant of Mayors and the 2014-2020 framework of programme funds. The regional sustainable energy action plan of Médio Tejo now includes a budget of 29,162,720 € for biomethane.

This investment option in Médio Tejo was, resulting from UrbanBiogas activities, included in the Sustainable Energy Action Plans (SEAP) of the Covenant of Mayors under the scope of the 2014-2020 measures. This plan foresees several investments in the field of sustainable energy provision, as shown in Table 1. The plan is executed together with the next structural funding programme, specifically the European Regional Development Fund (ERDF) application to the NUTIII Médio Tejo region. The region's municipal community is the relevant managing authority.

As part of the regional SEAP, waste-to-biomethane measures resulting from the UrbanBiogas action, cover around 10% of the planned investment and 7.28% of the CO_2 target.

Table 1: Sustainable energy measures in the Sustainable Energy Action Plans (SEAP) of the Covenant of Mayors for Medio Tejo

SUSTAINABLE ENERGY MEASURES	NET INVESTMENT [€]
Efficient lighting in buildings	950.308 €
Public lighting improved management	3.953.623 €
Energy audits, efficient construction and building certification	18.824.438 €
Vehicles and efficient fleets	9.887.501 €
Electric mobility	22.453.389 €
Public transport network improvement	3.367.607 €
Efficient driving force equipment	193.849 €
Open systems of energy management	2.676.270 €
LEDs and efficient luminaries in lighting	2.087.514 €
Thermal solar energy	11.697.872 €
Efficient het pumps	18.383.705 €
Efficient boilers	1.784.774 €
Biomass and forestry residues	3.271.332 €
Biofuels by transports	7.613.615 €
Urban rehabilitation and improvement of the energy and climate dimensions of urban planning	1.005.589 €
Sustainable water management	3.712.972 €
Sustainable residues management	297.365 €
Distribution and fleet improvement	250.612 €
Efficient office equipment	1.083.614 €
Natural gas	131.341 €
Efficient domestic equipment	16.183.602 €
Awareness and education for climate sustainability	2.093.163 €
Biomethane	**29.162.720 €**
Integrated renewable	85.601.937 €
Voluntary carbon reduction	564.495 €
Increase on pedestrian and cycling facilities	612.271 €
Improvement on professional and mobility	568.157 €
Public ecological shopping	554.901 €
Small hydro power stations	30.416.667 €
Urban sustainable investment and entrepreneurial support	927.287 €
Improvement on professional performance	387.396 €
TOTAL	**280.699.886 €**

5.2 Gdynia and Rzeszow, Poland

In Poland, the most common way to threat municipal waste is to dump it on landfill sites. Composting is only made very rarely and only for single households. Only very few projects are on-going on waste separation and adjacent biological processing. In Poland, waste water plants and landfills still burn off most of the biogas in flare stacks. If biogas is retrieved, it is usually used to produce electric and thermal energy.

The initial target city in Poland was Rzeszow, but due to political changes backing in the project was completely lost. Thus, UrbanBiogas project partners identified Gdynia as new target city.

Rzeszów is a city in south-eastern Poland with a population of 172,813 (2009). Currently no bio-waste is separately collected in Rzeszów. The wastes from the city area are transported to the landfill in Ostrów (about 60 km). Initially, Rzeszów was the target city of UrbanBiogas.

The municipal authorities in Rzeszów have commissioned a study researching alternative paths of waste disposal in the city. As a direct consequence of the study, a concept of thermal-disposal of municipal waste (incineration plant) has been officially adopted and thus became a guideline for local authorities involved in waste management. Thus, the authorities do not support a biogas project which is in their eyes much more expensive and in competition with the Waste – Incineration Plant. Moreover, there is strong conviction among the decision makers in Rzeszów that biogas plants and incineration plants exclude each other as solutions of waste management. The political backing for implementing the UrbanBiogas activities in Rzeszów was lost, although the UrbanBiogas partners tried very much to consider a biogas plant in Rzeszów.

As a consequence, the UrbanBiogas consortium decided in 2012 to implement its activities in a new target city in Poland: in Gdynia in the north of the country. This city was selected as the local framework seems to be promising and the political support available. Due to the introduction of new nationwide regulations the city introduced in 2013 source sorting of waste. There are two bins available for wet and dry waste. The test phase and the analysis of the source-separated waste provided valuable input on the implementation of suitable waste treatment for the organic MSW. The UrbanBiogas project assisted in this process with its expertise on anaerobic digestion technologies and defined a concept for the set-up of a biogas plant.

The waste in Gdynia is collected and managed by the company Ekodolina recycling or landfilling the waste. Besides the interest of Ekodolina on the WtB concept, also the transport company has signalled interest, as about 20 buses are already fuelled with CNG and could be also operated with biomethane.

Due to the difficult framework conditions for biogas development in Poland, also the UrbanBiogas partner, the Polish Biogas Association is weakened, so that not all tasks in the UrbanBiogas project could be finalised.

5.3 Graz, Austria

Waste management situation in Graz:

Graz has about 270,000 main residences and 30,000 second residences. The area is about 128 square kilometres with 40% green spaces. There are 57,000 buildings with 110,000 households. The waste separation system in the city of Graz is well established. The separated waste collection started more than 25 years ago.

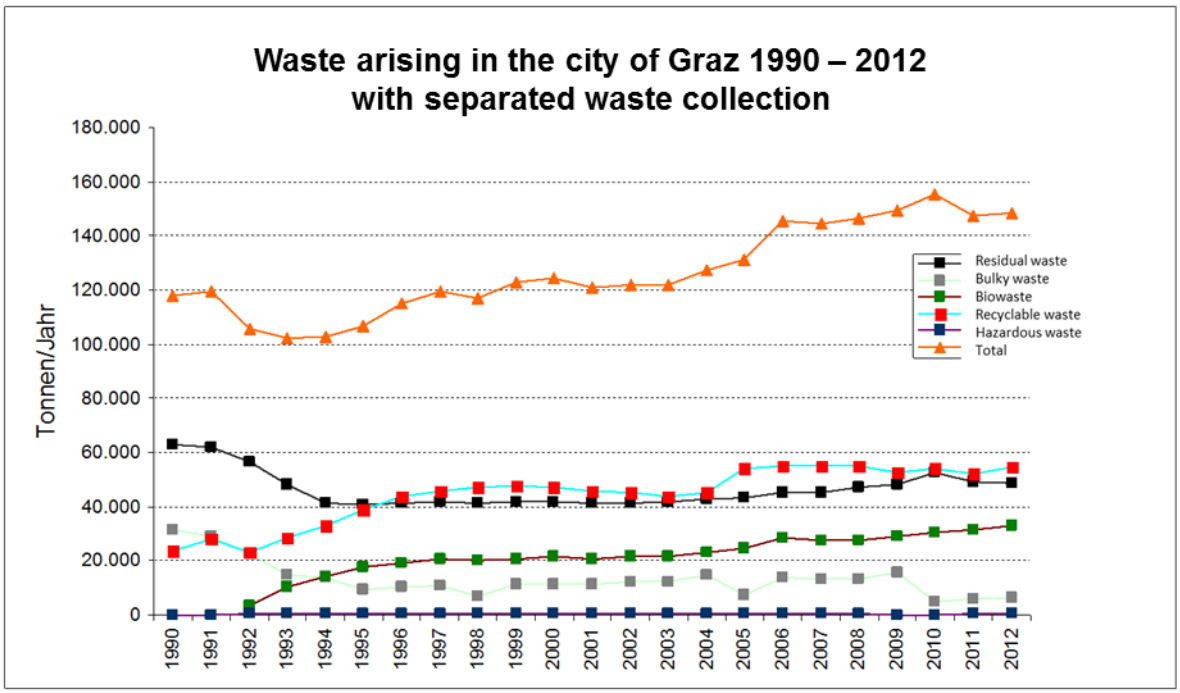

Figure 11: Separated municipal solid waste collection in Graz (Source: Stadt Graz - Umweltamt, 2013) – "bio-waste" is the brown line with the green dots

On more than 34,000 sites in Graz (properties, households and public collection centers) the waste containers are positioned. For the following waste-fractions different waste containers are foreseen: residual waste, paper, light packaging, organic waste, glass and metal. Textiles, bulky waste, hazardous waste, building rubble, waste oils etc. can be disposed at special collection centers. The collection of bio-waste started in 1992 and the yearly collected amount of bio-waste per inhabitant constantly increased to about 145 kg/year in 2012. It contains compostable municipal solid waste, like kitchen waste, garden rubbish, tree cut, waste resulted from food market and cemetery waste. More than 90% of the population of Graz use the separated organic waste collection ("Biotonne" in German). Only 8% of the households are composting their organic waste themselves. These ones get a reduced price for the waste disposal but they have to make sure that they really compost their organic waste and they are also controlled.

At the moment separate collected organic waste from households and green waste (waste from gardening and landscape maintenance) are mixed and pre-treated at the organic waste treatment plant Sturzgasse Graz and then treated in the composting plant nearby Graz (bio-mechanical organic waste treatment plant). Unfortunately, the energy content of the organic waste is not used at the moment (as the material is only composted). However, landfill gas from the existing landfill site is used in two CHP plants for electricity and heat generation.

The waste separation by the population in Graz is quite good compared with the Austrian average. Concerning the percentage of the separated collected organic fraction in the municipal solid waste Graz is with 21% two percentage points above the Austrian average. An evaluation of the remaining residual waste figured out, that with the remaining organic fraction in this residual waste and optimal waste separation behaviour this percentage could theoretically be increased to about 30 to 34%.

The population is quite satisfied with the existing waste separation system, there are only few people not accepting the system. As already mentioned there is a potential for optimisation and so there are special trainings for different target groups organised by the city of Graz/department of environment. These are especially for:

- Citizens in residential areas

- Migrants
- Children in kindergarten's and primary schools
- Companies with high amounts of residual waste and bio-waste like restaurants, food markets, etc.

Status WtB plant Graz:

The estimated potential of organic waste, which could be utilized in the potential WtB-plant Graz, accounts for approximately 48.000 t/a and consists of about 70% organic waste from the brown organic waste bins and the remaining part comes from food waste from restaurants caterings and the food industry, expired food from supermarkets and suppliers and old bread from bakeries. About 70% of the organic waste arises directly in Graz and the rest comes from its surrounding districts.

For the WtB-plant in Graz a wet fermentation process is foreseen. With the above mentioned substrates about 6 Mio. Nm³ biogas can be produced per year. After upgrading to biomethane about 3.6 Mio Nm³ biomethane would be available per year. A connection to the natural gas grid is foreseen. The following use for biomethane is planned in Graz:

- For public transport in Graz (busses, taxi, etc.)
- For the fleet of the waste collecting trucks, the company cars of the involved companies/stakeholders and in general for corporate fleets
- Product "Naturgas" for industry and households – "green gas" and attractive feed-in tariffs for green electricity when CHP-systems are operated with this fuel

The stakeholders of the WtB project of the city of Graz are the City of Graz/Holding Graz, the local energy supplier and gas provider Energie Steiermark and local waste disposal company/companies. It is foreseen, that the biomethane should be shared between these partners.

The decision about the location for the WtB-plant figured out as one of the most critical and challenging ones. After several evaluations of different potential plant-locations, a municipality was found at the end of 2013/ beginning of 2014, which is interested in the WtB project of the city of Graz. Negotiations about the land site started. For Q3/Q4 2014 the start for the detailed planning for the WtB-plant is scheduled.

With the UrbanBiogas-project it was possible to assist the process towards the realisation of the WtB-plant in Graz significantly. A consortium between the stakeholders was founded and the players in this consortium are highly interested in the realisation of the WtB-concept in Graz. Additionally the publicity of the product biomethane was increased through several info-events, meetings and workshops within the UrbanBiogas project and cooperation's with other cities started which are interested in such a WtB-concept.

5.4 Valmiera, Latvia

Valmiera is a biggest city in the North Vidzeme region in Latvia. Approximately 30-40% of the total waste generated in the region is collected in Valmiera. Source separated waste collection system was introduced in the region in 2001. Today, the system offers collection for packaging (PET, glass, paper, cardboard etc.), bulky waste, construction waste, garden and park waste and Waste Electrical and Electronic Equipment (WEEE). There are 18 sorting stations ("ECO field"), 232 - packaging containers, and 163- PET containers in the region. In average, there are placed 8 containers per 1 km^2 for source separate waste collection in populated areas.

Figure 12: Location of "Eco fields" for source separated waste collection in North Vidzeme region

Regarding bio-waste management the municipality of the Valmiera city approved (04.01.2012.) local binding regulations for waste management providing that legal persons such as catering services, shops, food processing companies and other entities that generate bio-waste must have a legal contract for source separate bio-waste collection services. Till now only 15 legal clients in Valmiera city have signed contracts for such a service with ZAAO, the waste management company in the region.

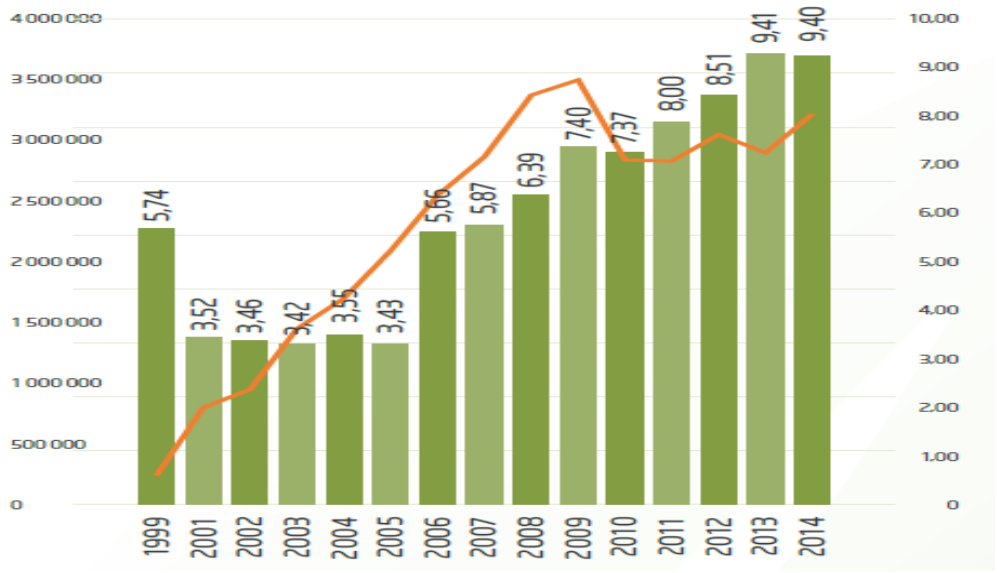

Figure 13: Collected MSW (t/a, green bars) in North Vidzeme region and average waste tipping fee (LVL/m^3 brown line)

Currently, organic waste is not separated in the households, but collected together with municipal solid waste (MSW) and brought to the mechanical treatment facility in regional landfill "Daibe".

The Waste Management Concept for Valmiera city, elaborated in the UrbanBiogas project, offers 2 scenarios for organic **waste collection**:

1. Scenario (base scenario) – collection of unsorted MSW
2. Scenario – collection of source separated organic waste.

In mid-term, the baseline scenario is preferred as the second scenario is currently economically not feasible. The introduction of the source separated organic waste collection has many obstacles: 1) lack of national-level regulatory framework, 2) waste management tariff increase for residents, 3) additional costs for waste management company for installation of separate organic waste collection bins and 4) increase in waste transportation costs.

Furthermore, for the organic **waste treatment** 3 scenarios were evaluated:

1. Scenario (base scenario) – mechanical treatment of unsorted MSW at regional waste treatment centre located at Daibe landfill site by using the existing waste treatment infrastructure (MBT). Composting of the organic fraction and using the compost for daily cover of the landfill.
2. Scenario – Mechanical treatment of unsorted MSW at regional waste treatment centre and using the organic fraction for dry fermentation. Digested substrate is further aerobically stabilised and used for daily cover of the landfill.
3. Scenario – Source separated organic waste collection and treatment in wet Anaerobic Digestion plant.

In the mid-term, the 2nd scenario was selected as feasible in the given situation.

Calculations for biogas and biomethane production were based on the estimation that the total amount of organic waste generation in Valmiera and North Vidzeme region will increase from 9.86 thousand t in 2012 to 10.75 thousand t in 2020, and reaching 14.65 thousand t in 2030. Two scenarios were considered for **biogas and biomethane** production:

1. Combined scenario – unsorted MSW collection, mechanical treatment at Daibe landfill site, dry fermentation of organic fraction, use of biogas in existing CHP plant and use of biogas for upgrading starting from 2020. Digestate would be used for the daily cover of the landfill.
2. Resource-efficiency scenario – source separated organic waste collection from households from 2017, wet AD, use of biogas in existing CHP plant and use of biogas for upgrading starting from 2020. Digestate would be used as high quality fertilizer.

In a mid-term the combined scenario was selected as economically most feasible.

During the UrbanBiogas project a concept for the use of biomethane was developed as provisional future opportunity. Biogas upgrading and biomethane use under existing framework conditions is not economically feasible. Biomethane production (biogas upgrading and compression) and use is evaluated in a perspective starting from 2020. Three alternatives for biomethane use were considered:

1. Biomethane use as fuel for waste collection trucks of ZAAO
2. Biomethane use as fuel for public busses in Valmiera city
3. Biomethane use in public filling stations for private transport and municipality transport

From all these 3 alternatives the biomethane use in ZAAO waste collection trucks and setting-up a biomethane filling station next to the biogas upgrading plant at Daibe landfill site was proposed as most feasible. In order to be able to use biomethane for public busses, the long term planning is required. The city should plan in future a procurement of CNG busses and construct appropriate biomethane transportation and filling infrastructure.

Three potential locations of the new WtB plant were evaluated: (1) biogas/biomethane plant at Daibe landfill site, (2) new biogas plant in the vicinity of Valmiera city, and (3) delivery of collected organic waste to one of existing biogas plants near Valmiera. Since for the mid-term the combined scenario was selected and it is foreseen to use the existing waste collection system and infrastructure of Daibe waste management centre, the biogas upgrading facility also should be located at Daibe landfill site. Besides availability of the infrastructure this location has other benefits, e.g., distance from residential areas and therefore the public acceptance for this alternative is expected to be positive.

The following organisational model was selected for the implementation of WtB project in Valmiera: collection of unsorted municipal solid waste, mechanical treatment at "Daibe" landfill site (owned by ZAAO), using organic fraction of the waste for dry fermentation. Biogas will be used for CHP and after 2020 – upgraded to biomethane and used for transport or injected into the natural gas grid (see Figure 14).

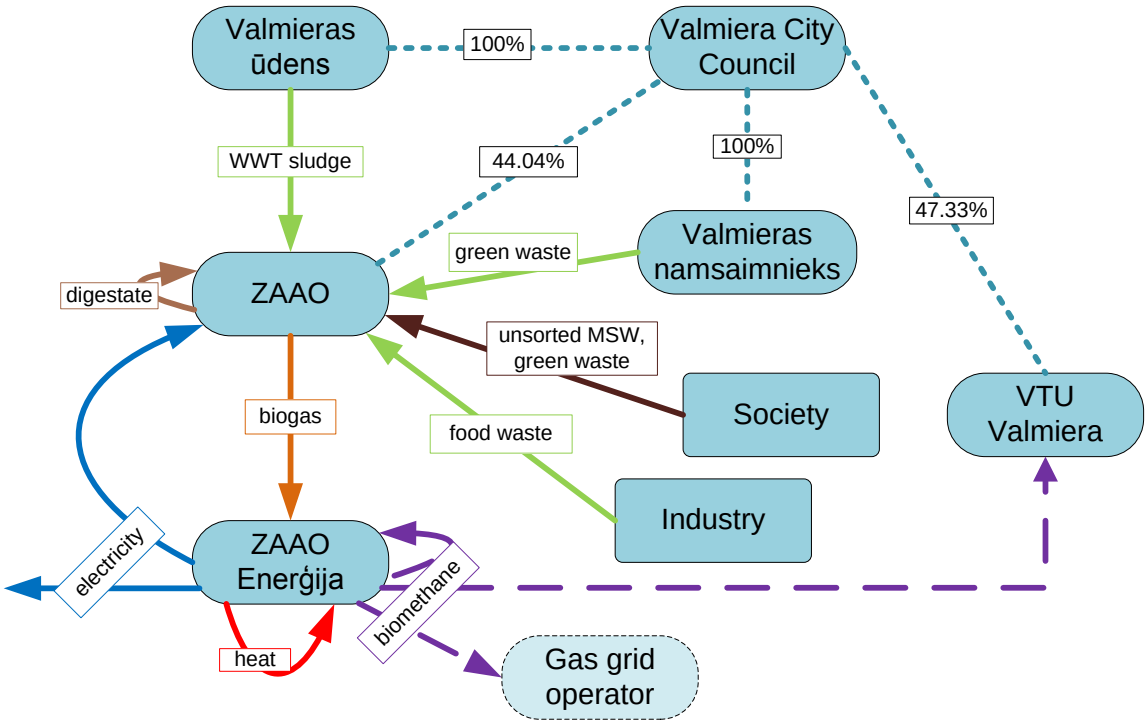

Figure 14: Dry fermentation organisational model for Valmiera

The main investor that is foreseen in the current organisational model is ZAAO Ltd. ZAAO has started the first steps in order to make an investment. In the end of 2013 ZAAO has applied a project application for EU Cohesion Fund programme and have got approval for construction of anaerobic digestion dry fermentation plant. The technical specification of the project has been prepared and the call for applications for potential technology providers was announced. Unfortunately by the end of April 2014 the tender for construction works was cancelled because of external risks analysis results: mainly risks for project realisation time frame and raw material long term supply security. Currently the implementation of the project is postponed.

5.5 Zagreb, Croatia

The City of Zagreb is producing around 250,000 tonnes of municipal solid waste (MSW) per year which is mostly being landfilled (92.6% in 2011) at the landfill site Jakuševec – Prudinec. Recently the life span of this landfill site has been extended even though most of

the landfilled waste is biodegradable (paper, cardboard, kitchen and green waste - approx. 62%).

The Republic of Croatia has to divert 65% of biodegradable municipal waste of the total amount (by weight) of biodegradable municipal waste produced in 1997 from landfills by the end of 2020 according to EU legislation. Furthermore, the City of Zagreb must meet the goals of the Landfill Directive and has the obligation to placing biofuels on the national market. Implementation of the waste-to-biomethane (WtB) concept in the City of Zagreb would meet these requirements, increase biofuel consumption, reduce GHG emissions, and contribute to the development of sustainable urban transport.

A pre-requisite for introducing a source separated bio-waste system, constructing a biogas plant and to establish mid to long term contracts for bio-waste delivery, is the adoption of the Waste Management Plan that is still pending. In that sense, the City of Zagreb and its Office for Energy, Environmental Protection and Sustainable Development are the main stakeholders in deciding in overall WtB framework in organisational, ownership, financing and operational aspects.

Developing a separate waste collection system along with the increased number of recycling yards will significantly increase the quantity of separately collected bio-waste suitable for biogas production. The part of the currently collected bio-waste (e.g. from gardening) is used in a composting plant. Compared to composting, the emissions to the air are significantly lower and easier to control in anaerobic digestion (AD) process than in a composting facility, as AD is conducted in closed reactors.

Bio-waste is separately collected from restaurants, schools and kindergarten canteens, market places, shopping centres and green waste from households. Even though it is questionable if the total potential amount of the bio-waste that could be collected is sufficient for the AD, the WtB concept can be closed regardless on the waste management concept implemented for the City of Zagreb as biogas can be produced from both, source separated bio-waste and bio-waste collected as mixed bulk in the remaining MSW. From the point of energy sustainability, less energy is needed if bio-waste is collected separately.

Also, the lack of education and awareness among citizens and inadequate penalties for polluters, could contribute to the unsatisfactory results in waste separation. However, the survey implemented in the UrbanBiogas project showed that citizens support the WtB concept. Therefore, constant communication with the public seems to be the most important non-technical assignment. Namely, if source separated collection is chosen as waste management concept, its collection rate and quality of the bio-waste will depend on the willingness of the citizens to contribute.

One of the advantages of the overall implementation of the UrbanBiogas project in Zagreb has been the support of all important stakeholders. An additional advantage is that the beginning as well as the end of the WtB value chain could be implemented by different branches of Zagreb City Holding, a company in 100% ownership of the City. The waste management could be operated by the Čistoća branch, the biomethane use in transport could be implemented by the ZET branch, the urban public transport company that currently has 60 public transport busses powered by CNG, or the biogas injection in the natural gas grid could be implemented by the GPZ branch, the city gasworks company.

Criteria for choosing the location for biogas plant construction should be: road access, neighbourhood acceptance, access to sufficient electrical power capacity, access to low or medium pressure natural gas grid, economic feasibility of the investment via maximisation of biogas production, availability of (additional) substrate, maximisation of useful energy obtained from biogas, sufficient space for the plant, the distance of waste water treatment facility, and minimal spatial alterations. The Spatial Plan of the City of Zagreb defines locations for overall waste management systems in the City of Zagreb:

- **Location 1:** Prudinec - area of existing land-filling site - overall plausible location
- **Location 2:** Resnik - joint areas of existing waste water management site and considered thermal waste processing plant - overall plausible location
- **Location 3:** Markuševac - area of existing composting plant
- **Location 4:** Dumovečki Lug

From technical, energy and economic point of view, it seems that organizing thermal (solid) and anaerobic (wet) waste treatment adjacent to the waste water treatment facility would create so called "industrial symbiosis" where the sum of performance of this symbiosis would be higher than adding each of the individual performances to the other. Industrial symbiosis is a subset of industrial ecology, with a particular focus on material and energy exchange. Given the efforts of the City of Zagreb on its green and sustainable profile already made, forming an industrial symbiosis while implementing WtB concept would be added value not only to the waste management, but to the overall life standard of the citizens.

A biogas upgrading plant will depend on the hourly production of biogas and the desired quality of biomethane. The produced biomethane should be injected in the natural gas grid or used in transport. Expected biomethane productions for all concerned scenarios are too little for capacities of planned filling stations of ZET. Consequently, the optimal solution could be to inject biomethane into the high pressure distribution grid. Due to the consumption patterns and gas grid features, pressurised water scrubbing or pressure swing adsorption (PSA) is proposed as upgrading technologies, suitable for high pressure distribution grid injection.

The sales concept for biomethane could include an agreement between the biomethane production company and the waste management company (Čistoća), but also with GPZ (City Gasworks Company) and ZET (Urban Public Transport Company for the City of Zagreb).

The actual time frame for the biogas plant construction, however, is difficult to predict. ZCH Čistoća and EIHP have made a lot of efforts in finding truly interested investors and some of them negotiated with the ZCH and city officials (Vienna Holding). As a result of EIHP's and ZCH's efforts, other potential investor Austep SPA (Milano) has also expressed interest by signed Letter of interest.

6 Conclusion

The UrbanBiogas consortium has achieved important results that helped to kick-start WtB projects in the UrbanBiogas target cities. A major effort was put on the implementation of so called local Task Forces in each target city which are working groups consisting of local stakeholders from different sectors involved in the WtB value chain. These include representatives from the administrative sector of the cities, waste management sector, energy utilities, renewable energy agencies and associations, researchers, consultancies and other stakeholders. This participatory approach was important to get the necessary support from the various actors in the WtB value chains.

Thereby, it has to be mentioned that the achievements in the target cities differed considerably, as also the starting points at the beginning of the UrbanBiogas project were different. The largest success can be reported for the cities of Graz in Austria and Valmiera in Latvia where the processes for public procurement have started.

All investigated cities, except Graz, do not yet have implemented separate waste collection systems for organic waste from households. In these cities, a major challenge was to convince local decision makers, that the set-up of a separate waste collection system with a biogas plant for bio-waste treatment is currently the most sustainable option from the environmental viewpoint. Furthermore, as the example of Rzeszow showed, it is very difficult to convince local decision makers about the benefits of AD. In that case, local authorities and politicians opted for an incineration plant and once the decision was made, it was not

possible to reconsider other options. Therefore, the new target city Gdynia was selected in Poland in late 2012.

The UrbanBiogas Project clearly promoted biogas production, which allows nutrient recovery, carbon storage in soils, renewable energy generation and other related benefits. With the proposal of dedicated WtB concepts for the UrbanBiogas target cities, the consortium suggests AD as a sustainable alternative to other less sustainable treatment options such as composting or incineration.

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