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Smart Biogas Grid:

biogas utilization to operate diffused micro-generation solutions in urban areas

through the bio-waste exploitation

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To my Ladies

ABSTRACT - ENG

'*Smart Biogas Grid*' investigates the potential, the opportunity and the applicability of biogas systems as renewable energy source within urban district. The research uses a multi and inter-disciplinary approach inside a systemic view to analyze aspects that affect biogas promotion and diffusion within existing urban patterns. Urban biogas involves considerations that, starting from bio-waste separated collection of household waste, garden waste and wastewater, sets solution to use biogas as energy vector suitable to activate processes of local engagement with results in environmental, energy, normative, technological, social and economic fields. The result of the research is the promotion of a systemic vision in which biogas technological components set a valuable network of actions, relations and skills that modify district and its community. '*Smart Biogas Grid*' is a technological innovation system that directs the promotion of a socio-technical transition using local material and immaterial resources, supporting stakeholders with decision-making tools.

ABSTRACT - ITA

'*Smart Biogas Grid*' indaga l'applicabilità dell'utilizzo del biogas come sistema di approvvigionamento energetico da fonte rinnovabile all'interno dei quartieri urbani. Attraverso un approccio di tipo multi and interdisciplinare, la ricerca analizza in una visione sistemica le diverse componenti disciplinari che caratterizzano e influenzano la diffusione del biogas all'interno dei tessuti consolidati urbani. L'utilizzo del biogas alla scala del quartiere è studiato all'interno di un processo che, partendo dalla raccolta differenzia del rifiuto organico domestico e delle aree verdi, sviluppa un sistema che sfrutta il biogas come vettore energetico capace di avviare processi di partecipazione di prossimità che permettono di giungere a considerazioni e di individuare benefici di tipo ambientale, energetico, normativo, tecnologico, sociale ed economico. Il risultato è un progetto che promuove e diffonde la *vision* di un sistema in cui le componenti tecnologiche del progetto legate alla filiera del biogas, diventano occasione per creare una rete di azioni, relazioni e conoscenze che modificano il quartiere e la sua comunità. '*Smart Biogas Grid*' si configura come un sistema di innovazione tecnologica che individua uno scenario di transizione che utilizza le risorse materiali e immateriali dell'ambiente antropico dove si concretizza, supportando gli *stakeholders* del progetto attraverso riflessioni che ne supportano il processo decisionale.

KEYWORDS

Biogas, Smart Grid, Technological Innovation System, energy, micro co-generation, bio-waste, social innovation, community

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1. INTRODUCTION OF SMART BIOGAS GRID RESEARCH

ORGANIZATION OF CHAPTER

This chapter introduces the research topic "*Smart Biogas Grid: biogas utilization to operate diffused micro-generation solutions in urban areas through the bio-waste exploitation*". The aim is to define the boundaries of present research in the scientific framework of reference, underlining the aspects of interest for the topic in the architectural context, in order to anticipate the features and analysis carried on in the next chapters.

1.1. Introduction

Fighting climate change and increasing security of energy supply, are key points in the European Union (EU) framework. Since the White Paper in 1997 (European Commission, 1997), EU has constantly updated its strategies to find an answer to global questions on energy consumption and Greenhouse Gas (GHG) emissions. European Directives in the last 20 years with this aim have strongly addressed development and implementation of new models for energy consumption reduction, GHG emissions decrease and improvement of renewable energy (European Commission, 2009; European Parliament, 2010, 2012). In line with expected 2020 targets (European Commission, 2010), the new challenge for EU in energy topic is the vision at 2030 and 2050 (European Commission, 2014). The challenge has enhanced solutions able to merge technical and non-technical aspects to address innovative energy strategies to go beyond the simple installation of high performance energy systems. In this scenario, the utilization of Renewable Energy Sources (RES) finds a good opportunity to improve efficiency and reduce environmental impact in small power plants and distributed generation.

If the European strategies have focused on such topics in line with the whole international community ("Kyoto Protocol," 1997, "The Paris Agreement," 2016; United Nations, 1994), the challenge for researchers in architectural and energy contexts is to read the current conditions and find key strategies, not only for existing problems, but especially for future imaginable barriers and problems, identifying solutions able to anticipate the future needs. At this aim, today it appears to be of meaningful concern with the perspective to become an emergency in the future, the containment of energy consumption and the development of new energy systems in cities.

Urban areas are indeed a wide debated topic in architectural and urban disciplines, especially if confronted with energy efficiency strategies, energy consumption reduction and energy production implementation. The present research takes place in this framework to contribute in the discussion on possible solutions which could diffuse models for low-carbon and self-energy producers and asses a possible strategy in ***Smart Biogas Grid*** (SBG) system.

1.2. Smart Biogas Grid: a strategy to promote '*energy efficiency and micro-cogeneration*'[1]

The research goal is to *study models to operate diffuse micro-generation solutions using biogas, from urban bio-waste, in urban areas*. 'Urban areas' is the first subject to be taken into consideration to understand the architectural space where this work is carried on, but also the major research limit of the research. Despite biogas is an energy solution widely applicable, working in 'urban areas', a specific spatial limitation, compels to understand the reasons for this boundary because it affects all the aspects studied in the research with its multiple components.

Nowadays urbanization is one of the most debated subject of energy topic, because of billions of people who live in cities. Since 1970, urbanization has grown up (Figure 1-1) and has had a deep impact in people life style, affecting their behaviors and their energy consumption (Figure 1-2). Actually cities host, in or around, the greatest part of energy consumption (transport, industrial and commercial activities, buildings and infrastructure, water distribution, food production) for about 75% of global primary energy consumed and 50-60% total GHG emissions ("Energy – UN-Habitat," n.d.). Having a look at the World data, urban population was 36,73% in 1970 (1.340.317.753 of total 3.684.765.870) while was 52,25% in 2012 (3.708.167.010 of total 7.097.400.665) with a progress of 176,77%; this growth has contributed in the GHG emission increase from 27.660.218 kt of CO2 equivalent in 1970 to 53.526.303 in 2012, with an advance of 93,51%.

[1] The present research has been funded by a scholarship of Italian Ministry of Education, Universities and Research (MIUR) on 'energy efficiency and urban cogeneration'

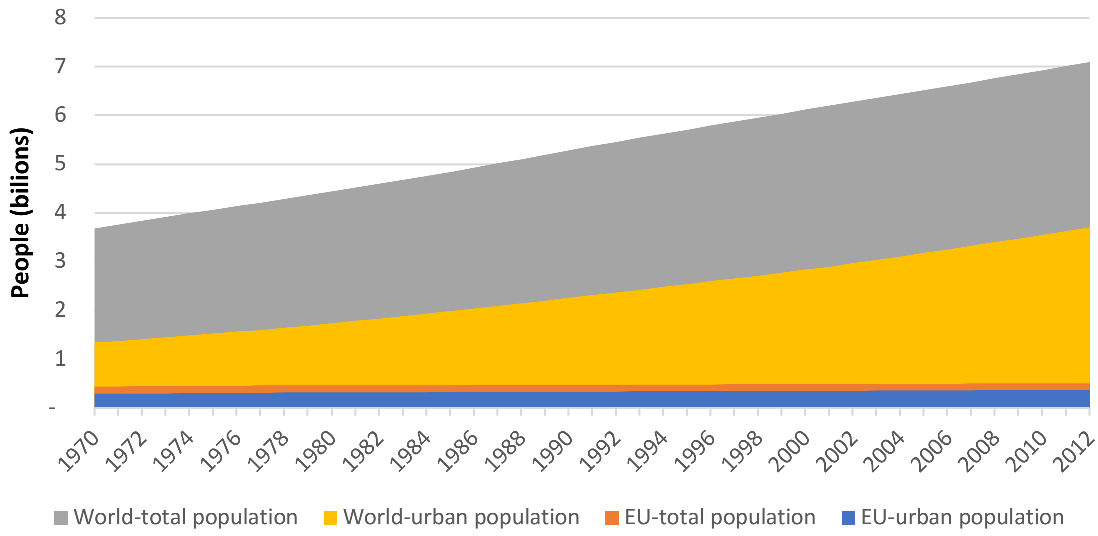
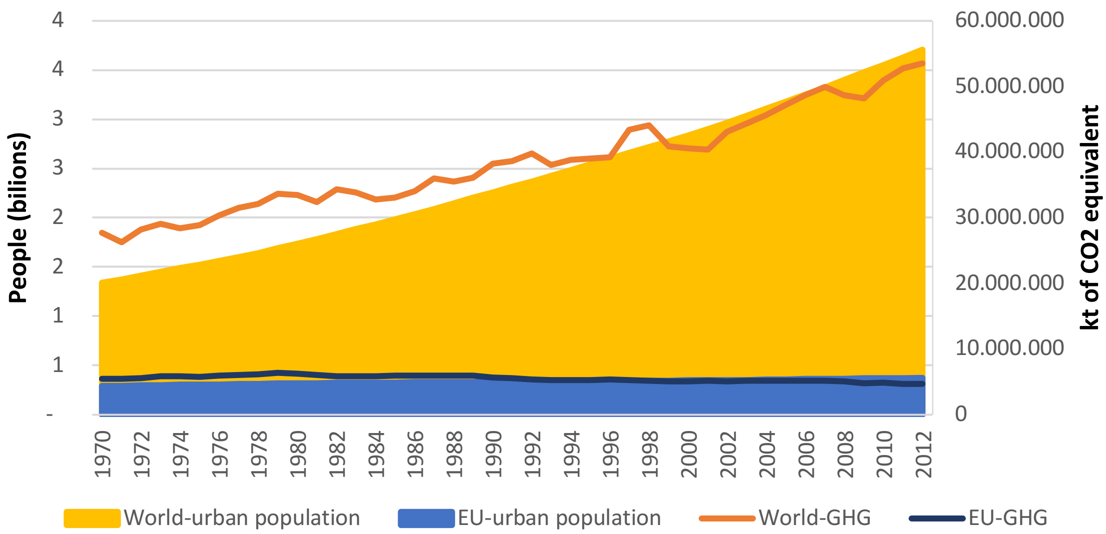


Figure 1-1: EU and World population (total and urban) since 1970 to 2012. Data elaborated from ("World Bank Group - International Development, Poverty, & Sustainability," n.d.)

Figure 1-2: EU and World urban population in comparison with GHG (kt of CO2 equivalent) since 1970 to 2012. Data elaborated from ("World Bank Group - International Development, Poverty, & Sustainability," n.d.)

Differently from world trends, also thanks to climate change policies adopted in last 20 years, EU data opens to a better scenario. Indeed, despite urban EU population has passed from 65,68% in 1970 (290.332.763 of total 442.062.266) to 74,16% in 2012 with +29,01% (374.563.831 of total 505.104.334), GHG emissions have decreased, since 1997, with a total diminution in relation to 1970 of 13,49%. At this point, considering that World urban population is estimated to be 66% of total by 2050 (United Nations, 2014), adopting new energy strategies in urban areas appears to be a need at worldwide scale. The rising of urban population underlines the importance to take care of cities from an energy point of view, because they host the major part of human activities and, for this reason, strategies for energy reduction and supply should involve urban areas, both in western countries as well as in the rest of the world, to develop new sustainable models. Indeed,



cities manage interdependent services and utilities and they can enable the necessary integration among solutions to face energy issue and related GHG emission; here the interest for urban Smart Biogas Grid solution, to locally produce and use the energy requested for activities, exploiting local sources.

1.2.1. Meanings and advantages of a Smart Biogas Grid

In the next paragraphs is underlined what ‘Smart Biogas Grid’ is, to specify the research features carried on.

The first element to be presented inside ‘Smart Biogas Grid’ topic is ‘smart grid’ concept. With the term ‘grid’ the scientific community means the electric grid network composed by all those components (transmission lines, substations, transformers, etc.) that have the aim to supply electricity from the power plant to energy demand places by using new advanced technologies to create a smarter, more efficient and sustainable grid (Gharavi & Ghafurian, 2011; Tobias Persson et al., 2014; “What is the Smart Grid?,” n.d.). This definition opens the way to move forward towards a new model of electric grid, built from a bottom-up approach to better handle energy demands. The new ‘grid’ generates a resilient power system going beyond the centralized energy production model, to develop and increase local sources for more energy efficiency and safe systems, boosting the potential of renewable and distributed power sources. With this in mind, ‘grid’ becomes a network of multiple ‘microgrids’, small and local distribution systems, crucial in the development of the new asset (Yoldaş, Önen, Muyeen, Vasilakos, & Alan, 2017).

The installation and utilization of digital technology helps to create a new ‘grid’ of ‘microgrids’ able to interact with energy demand as set of tools that connect in a two-communication the energy producer with its consumers, sensing variation of energy demand and consequently managing differently the energy supply case by case; this digitalization contributes to introduce the concept of ‘smart’. Aim of a ‘smart grid’ is moving energy sector into a new efficient model of energy supply, able to integrate and better answer to local demand and expanding the interest around energy over the energy provider. Indeed, energy becomes the key to develop and implement best practices for technological applications, consumer education strategies, new regulatory framework and standards implementation, ensuring the assessment of ‘smart grid’ model. In such a way, local projects become testers of ‘smart grid’ solutions which contribute in the creation of ‘microgrids’ network that implement the whole ‘smart grid’. The benefits are numerous (“What is the Smart Grid?,” n.d.) and a diffuse application of ‘smart grid’ solutions can allow to restore, upgrade or replace an aged energy infrastructure. This is not all the matter about the function of a ‘smart grid’. In the deep meaning of ‘smart’, there is indeed the need to go beyond the only improvements of technologies and regulatory frameworks: energy consumers are part of ‘smart grid’ concept. People are indeed involved into new ‘smart’ behaviors and a new awareness on energy issue, affecting with their choices about consumption, being able to manage their demand with energy supply. A ‘smart grid’ should assess new level of participation in energy behavior, thanks to strategies that give responsibility to consumers in their own energy consumption, helping to save money thanks to this ‘smart’ applied at energy. In such a way, towards a diffusion of ‘smart grid’ and its consequent energy network, there is a convergence of technologies for energy production, distribution and consumption that finds new aware actors in energy consumers. This reading underlines how ‘smart’ concept is connected to ‘smart grid’ model and it opens directions to a more comprehensive approach to the topic, going beyond the simple electrical energy and digital technologies, but including considerations on cities, people, local source and energy awareness; biogas topic is applied to this aim.

1.2.2. Biogas in/for Smart Grid

Biogas is a mixture of methane and carbon dioxide produced by the bacterial decomposition of organic matter, a process of organic decay which generates energy fuel (biogas) and natural fertilizer (digestate) from different types of biomass (sewage, manure, garbage, crop), produced under anaerobic conditions, with the production of a gas composed by 50–75% methane, 25–50% carbon dioxide and 2–8%

other gases – nitrogen, oxygen and trace gases. The main component that determines its energy content is methane (CH4), flammable and used in 2014 in energy production with an European average of 15,2% of gross production (Eurostat, 2016) with 10,5 kWh/m^3 of Higher Heating Value (HHV) (Murphy & Thamsiriroj, 2013); therefore biogas has a huge potential from an energy point of view. In addition to methane HHV, biogas is an energy vector with very interesting perspectives inside a Smart Biogas Grid strategy. It is a gas fuel that can be used as base load in energy supply being a substitute for natural gas (injecting upgraded biogas into gas grid), but it can also be used during electricity peak load through process of co-generation, facing grid variability. Biogas is a demand driven resource which can increase electricity production at times of high electricity demand or reduce electricity production at times of low demand varying the time, and rate, of feeding of the biogas plant (Tobias Persson et al., 2014). In this way biogas can compensate the fluctuation of other renewable power sources, which have less managing potential as in the case of photovoltaic, thermal solar energy and wind energy. In addition, biogas can be used as biofuel for vehicle or also for cooking or lighting.

Biogas is not only an energy vector easy to adapt to consumer demand, but it can be provided by all existing organic local sources. Biogas is derived by anaerobic decomposition of biomass and it is possible to find organic fraction worldwide for this purpose. The advantage is to overcome biomass energy restriction (it is mainly used as thermal source and its storage is more difficult than the one of biogas), offering a larger range of energy solutions (electric or thermal energy, biofuel for transport, cooking, lighting). Among biomass producers in the perspectives of a biogas production and utilization, there are urban areas.

1.2.3. Biogas: an urban energy source

As mentioned previously in this chapter, cities already host the greatest part of urban population and the percentage is estimated to grow up in the next decades. Cities do not represent only the major energy consumption for activities carried on, but also an incredible biomass producer, because they are waste generators, having a high organic biogas potential. Municipal waste[2] is estimated to be 477kg/capta ("Municipal waste statistics - Statistics Explained," n.d.) in EU and around 46% is organic fraction (Baxter & Al Seadi, 2013).

This waste is an urban biomass, valuable for biogas production, introducing reflections related to *circular economy*[3] and *urban metabolism*[4], concepts that implement sustainable actions towards the development of *smart city*. Indeed, the utilization of bio-waste locally is a readily available decentralized and flexible system that allows to supply, as result of anaerobic digestion, both energy as well as digestate, contributing in closing the nutrient chain inside cities. In addition, Smart Biogas Grid opens to a multi-disciplinary need to involve professional stakeholders as well as citizens, in order to promote sustainable urban development and alternative energy generation. Going beyond the energy and technological issues, SBG project allows to promote an economic more valuable model for waste treatment, reducing waste transport and providing reliable, baseload on-site energy, offering the break to design new environmental, educational, employment and training strategies (WRAP, 2015), as expected in the concept of 'smart' project.

For all these aspects involved, despite the fact that literature on biogas is deeply developed from an engineering and energy point of

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[2] "Municipal waste is defined as waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities. This indicator is measured in thousand tons and in kilograms per capita." ("Waste - Municipal waste - OECD Data," n.d.)

[3] "In a circular economy the value of products and materials is maintained for as long as possible. Waste and resource use are minimized, and when a product reaches the end of its life, it is used again to create further value. This can bring major economic benefits, contributing to innovation, growth and job creation." ("Circular economy - Growth - European Commission," n.d.)

[4] "Urban Metabolism is a framework for modeling complex urban systems' flows – water, energy, food, people, et cetera – as if the city were an ecosystem. It can be used to analyze how urban areas function with regard to resource use and the underlying infrastructures, and the relationship between human activities and the (natural) environment. What is more, it can be used to shape the urban environment in a more sustainable way."("What is Urban Metabolism?," n.d.)

view, there are very few considerations, marginally investigations and a few experiences on biogas application in cities. The reasons are multiple and despite the fact that 'biogas' as 'energy fuel' is produced by a quite easy anaerobic digestion process to put in place, 'biogas' as 'issue' includes a series of features which must challenge city complexities in the management of the full process, from waste collection to energy supply. The need is to connect the technical (for instance methane yield, system design, odor reduction) and non-technical (for instance people acceptance and participation) aspects involved. For this reason only rare cases of urban biogas have been realized until now, often used as prototype of study for possible further wider application ("Join the green revolution in urban food waste mangement : Local Energy ADventure Partnership," n.d.).

1.2.4. The role of district[5] in Smart Biogas Grid

Despite the goals described in 'Smart Biogas Grid', a remark is due to the scale of intervention inside urban areas: *district scale*. District is the focus of this work, because it hosts similar building and urban morphologies that assess specific context features – infrastructural, technological and functional – and that usually generates a community within its boundaries. In addition, as previous mentioned, a smart grid is the sum of micrograms which interact and are connected to each other, joining different projects and their energy outputs in a unique network; the district is the scale of application. The size of district, a small scale in relation to the entire urban context of belonging, is an elementary cell helpful to have limited case studies with their peculiarity and specific needs (Figure 1-3). District is the opportunity to bridge the theoretical framework of smart grid in a smart city with practical steps through a measurable scale of impact. District offers the chance to develop local integrate energy systems (UNEP, 2015), thanks to its numerous

[5] District is constituted by a set of blocks – smallest urban component characterized by the urban morphology and bordered by streets, that is the element of cohesion between household and community – with a structural common morphology that has a specific urban space, a social fabric and a specific function. District is considered in this research as functional, morphological and social homogenous characterization.

Figure 1-3: district is the elementary cell of city, characterized by similar urban morphology, same function and that is settlement for homogenous group of citizens, joined by culture and/or economic conditions that form a community. In the image four districts – compact district, peri-urban district with multifamily buildings, suburban district with multifamily buildings and suburban district with single-family buildings – are identified within city of Rimini

advantages and sources, that allow to carry out projects in a vision of smart grid.

The benefits of district scale are:

- integrate and test systems and infrastructures that conventionally operate separately (for instance energy supply, source collection, mobility strategies, etc.);
- small enough to be compact to concentrate resources, improve efficiency (shorter energy supply chain reducing heat losses), focus on priorities and issue an effective scheme of achievable objectives;
- utilize local energy sources and harness economies of scale;
- large enough to have noticeable impact on city;
- overcome urban lack of integrated policy and implementation framework, meaningful municipal barriers;
- test new models of financing and contracting for these emerging integrating systems (for instance joint ventures, partnerships, community engagement, consortium, new governance models, etc.);

- stimulate a wide collaboration and engagement of different stakeholders (for instance citizens and community groups, private developers, local associations, experts, governments, etc.)

The management of all these benefits of district scale in smart grid, determines a passing from pilot projects to a model helpful to widespread and replicate the achievements. The result is to accelerate the introduction of sustainability topics in built area and in local population, enhancing environmental, energy and social performances helpful for the whole city development.

Indeed, district allows to have a resilient system managing different technological systems (RES, waste stream collection, energy demand managements, etc.) in an integrated way, achieving locally reduction of GHG, air-quality improvements through specific energy, environmental and social actions that are a contribution in city energy and emissions targets. The experience conducted until now demonstrates how district energy systems represent a best practice approach to provide local, affordable and low-carbon energy supply, being a significant contribution for cities to move towards climate-resilient, resource-efficient and low-carbon pathways (UNEP, 2015).

1.3. Conclusion

The frame over mentioned assesses new challenges in energy efficiency practice and for biogas application in urban areas. The challenge of this research is to improve actions which can join in new ‘smart’ solutions, with technical as well as non-technical features, to create new energy network, as ‘Smart Biogas Grid’ aims at being, to assure reliable, efficient and cost-effective energy supply solutions, helpful to afford climate change issue as well as generate new virtuous social changes. The project aims at implementing solution for micro-cogeneration systems which offer the possibility to produce locally the whole or a part of energy needed by the cities, especially at district scale, thanks to the use of renewable sources as biogas, from the collection and utilization of local bio-waste, green waste and sewage, to energy supply. From the economic program of the district, through the behavior of the residents, until the definition of the limits of a biogas production system and its integration with other systems of sustainable energy production, many issues have to be analyzed, realizing a new energy, economic and social model. Smart Biogas Grid aims to create urban energy independent districts in communication with each other, where householders are virtuous producers of energy, through their own waste sharing; people engaged in such a project are not only energy consumers, but become energy 'prosumers', energy consumers who are also energy producers ("Prosumer - Oxford Reference," n.d.). Biogas offers the possibility to create micro-generation urban centers in an energy chain at zero kilometer, in line with energy European programs, but creating models valid also at World scale. The role of population is for this aim crucial: people are not anymore only energy consumer, but participate in the definition of Smart Biogas Grid.

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2. Methodology to research Smart Biogas Grid

Organization of chapter

The aim of this chapter is the analysis of the methodology adopted. The chapter underlines the importance to work on SBG complexity in a systemic view, highlighting the disciplinary aspects involved and the need for a multiple strategy to investigate properly each topic; for these reasons biogas is treated and researched as Technological Innovation System. The chapter anticipates the methodological organization of the work, deeply presented in its tools and specific methods in 'methodology' section of each chapter.

2.1. Introduction

As previously mentioned in the SBG introduction chapter, urban biogas is more than only an energy vector easy to produce and widely usable. Biogas is an opportunity to afford, develop and implement different sets of features, not classifiable in its traditional framework of scientific community. There are many aspects in SBG to consider, aspects proper of different disciplines and interrelated one with the others. For this reason, despite the biogas topic is usually treated by engineering disciplines – optimization of production, technologies of anaerobic digestion, energy performances, etc. –, this research investigates the topic from an atypical point of view, proper of architectural training, helpful to bridge the different topics related to biogas. Therefore, the challenge is to go beyond the typical disciplinary aspects of biogas, and to figure out the quantities and the qualities of features involved in SBG and how they can be afforded and developed in a parallel and collateral way. The proposed methodology aims at involving and connecting solutions, tools, typical of different disciplinary contents, not homogenous if considered from the usual scientific and academic perspective. For this fact, it is necessary to conceive a strategy of research that, starting from the emerging questions of the systemic vision of SBG, could allow to reach an original contributor in this research matter. Different disciplines ask for different concerns to be faced, looking for linkages capable to go beyond the respective scientific fields. Despite usual difficulties of overlapping these aspects, this research has tried to merge aspects and find a common knowledge among the disciplines involved. In front of an overspecialization of training program and professional experts, the real challenge for specialized expertizes appears to be the connection of these contents, finding mutual interests for applications and developments. At this aim, the multidisciplinary of SBG has addressed to multiple strategies and approaches, keeping in mind the final expected outputs: join disciplines in a common analysis to offer an original contribution inside the wide issue of energy efficiency and urban micro-cogeneration through biogas utilization. The thesis affords with this approach biogas topic, offering subsequent and linked developments of its contents.

2.2. Methodology

SBG's contents and significates could not be confined in a single specific scientific field or, more generally speaking, in academic discipline. Smart biogas grid needs to be studied understanding disciplines involved and their connections, linking biogas and energy goals to other foundational objectives which affect the success or the failure of SBG perspective, understanding the full complexity of elements and relations involved. With the aim to identify an energy solution, comprehensive of holistic concept around sustainability and smart concepts able to address new opportunities in energy production and consumption in urban areas, SBG marks for city and for energy models a transition process (Turnheim et al., 2015) to be understood, developed, implemented and guided, opening the direction to a socio-technical development with its continuous dynamicity of action and reaction (Hofman & Elzen, 2010) that describe the transformation of district with technological, environmental, normative, economic, social changes, as part of a complex co-evolutive scenario. As a consequence SBG has to be faced in a 'systemic view' (Guido Nardi, 2004), a vision which includes different aspects without excluding any possibility of investigation, assessing a process that permits to go inside each discipline, exploring their specificities, their tools, their methodologies, to generate an integrated research and connect its multidisciplinary and interdisciplinary contents.

Classifying SBG in such a view, proper of Architectural Technology (Italian Disciplinary Scientific Sector ICAR/12), allows to study each discipline as part of a set of interacting and parallel components. The systemic view is helpful to demonstrate the role of biogas as renewable energy source in urban district transformation process able to answer a set of questions regarding the knowledge the opportunities and the direction of this process. In such a way emerges the complexity of SBG that, starting from a technological system as biogas technology, asses a perspective for an innovative system.

Therefore, biogas technological system and other connected urban systems with their specific features, become the chance to found a transition process between an existing energy system, based on uninformed consumers, to aware 'prosumers', directing innovative changes in many aspects of daily lives. For this reason biogas can be included and considered in the frame of Technological Innovation System (TIS) (Carlsson & Stankiewicz, 1991; Jacobsson & Johnson, 2000; Bergek, Hekkert, & Jacobsson, 2008) useful to implement biogas aspects in a systemic analysis.

2.2.1. Biogas as Technological Innovation System[6]

Biogas production does not require complex or with a steep learning curve technologies to be applied. Indeed, experiences developed in many countries demonstrate how it is possible a diffusion of this system meaningless of economic conditions, deep specific expertizes, also in small context on of application (Ashden, 2006; Cook, 2010; "Build a Biogas Plant - Home," n.d.; IEA, 2013; Rauf, 2013; "Anaerobic Digestion (Small-scale) | SSWM," 2014). Despite these examples, in western and 'industrialized' countries biogas technology is mainly used as centralized energy solution realized to optimize and improve existing entrepreneurial profit. While small applications of biogas system, especially in urban areas, are only few, usually conducted by individuals because of their personal know-how, awareness and source opportunity, there are a lot of known cases – landfill, waste water treatment, crops cultivations – which collect sources and produce biogas in a logic of economy of scale to maximize the income of a core system. In this scenario, biogas as intended in SBG project (small plant at urban scale conducted by local people) is today exemplified by unique cases ("Join the green revolution in urban food waste mangement : Local Energy ADventure Partnership," n.d.; WRAP, 2013), experimental areas where biogas technology is applied,

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[6] "*network(s) of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks*" (Carlsson & Stankiewicz, 1991)

promoted and evolved thanks to favorable conditions that allow to understand its full potential, not only from a technological point of view, but through the involvement of all possible actors: these cases can be classified as *niches* (Geels, 2002). Biogas system examples represent good practices for the aspects they involve and implement, helpful for the vision they suggest, for the connection between technologies and other systems, achieving results in their specific context of application. Therefore, these few cases of biogas in urban areas are niches to be studied in their uniqueness as well as in relation to other sustainable solutions applied which usually mark complex transformations that involves the development and diffusion of a whole range of technological, energy, social and economic innovations. SBG research aims at understanding the potential of biogas in this holistic view and embracing solutions going over technical applications, but including features not normally considered in biogas study of feasibility, underlining linkages offered by this energy solution inside city context in its systemic perception. For this reason SBG is studied as Technological Innovation System (TIS), "*a configuration of parts connected and joined together by a web of relationships*" (Bergek et al., 2008), helpful to address this unusual reading of biogas.

No single technology, biogas is not an exemption, can be applied in an extensive and direct way. Indeed, despite innovative, quality and performance of a technology better than the existing ones, actors involved in technological transition (producers, users, authorities, policy makers, etc.) need the right space and time for its introduction (Schot & Geels, 2008), so that they can mature right conditions for its application, develop their perception – positive or negative –, change their behaviors, their believes on the technology and evaluate the adherence to their needs. For these reasons, to achieve the expected sustainable development through the technology application, Schot and Geels have identified the need of interrelation between technical and social change. With this in mind, it appears clear as a technology application goes beyond the usual "*developing, testing and optimizing*" (Schot & Geels, 2008) typical of common technological installation, but asks to consider the context of application since its first steps.

Starting from this vision of niche, technology is not anymore only a technical solution, but contributes in the specification of a set of rules, technical and infrastructural (design rules, odors, noises, emissions, etc.), institutional and social (skills, acceptance, user practices, regulatory framework, etc.), assessing a new socio-technical regime (Schot & Geels, 2008; "EU FP7 project PATHWAYS," 2015) that emerge from this niche, replacing and transforming the exiting regime. Application and diffusion of technologies can not only be meaningful for the degree of innovation introduced by a single technology, but represent the synthesis of the interaction between different niche technologies, developing their synergetic effects ("EU FP7 project PATHWAYS," 2015). Biogas applied in urban district fits perfectly this logic. Indeed, biogas cannot be only considered as a technology to be applied, but it involves a series of features, crucial to be studied to exploit their full potential of application. Existing cases are not exhaustive, but they can be studied as initial niche with the potential to address larger dissemination. In this way, biogas as TIS can address a socio-technical transition comprehensive of its elements of complexity.

Thanks to this kind of approach emerges "*a set of interrelated actors and institutional structures in a specific technological domain that contribute to the development of a focal technology*" (Bergek et al., 2008), that includes aspects (also niches connected to other niches) which can be studied in their systemic view, understanding the single component, as well as the relations among them, important to comprehend how biogas, as a urban energy solution, can be linked up with other new or existing technologies, working in symbiosis (Geels, 2002). The introduction of new technologies can have hard time because of existing components which can affect regulations and sets of elements (opportunities as well as limitations) which characterize the context of application; understanding their rules can direct the diffusion of new models from niche technology to TIS solution both as individual as well as a collective act, as SBG research aims at addressing.

For this reason, SBG as Technological Innovative System includes a large number of variables that have to be comprehended because they affect its feasibility, its development and its outputs, transforming consequently the results and the district where SBG is applied; TIS usefulness of the approach is to identify means that speed up or slow down the diffusion of biogas at urban district scale. Through an empirical mapping and analysis of biogas and sustainable aspects related to SBG, relevant stakeholders can know strengths and weakness of the system in their specific district, choose factors to pay attention and to develop. The approach typical of TIS is not considered only suitable because of the ability to understand the existing relations, but also it identifies unique features in terms of structure and elements. These can be simplified in the following categories (Jacobsson & Johnson, 2000):

- *actors and their competence* – stakeholders and shareholders who are technically, financially, politically, socially trained and powerful that they can initiate, promote, diffuse, use and maintain SBG.
- *networks* – web of relationships among actors which constitute primary stakeholders involved in SBG project, increasing the opportunities, the desirability, the knowledge of SBG.
- *institutions* – comprehensive of legislator, market and educational system, their roles vary dependent on district of application of SBG, enabling or obstructing the system and influencing its development, affecting its path development.

The understanding of these features contributes in the full comprehension of SBG potential, analyzing components which support biogas technology at urban scale, and understanding the features positively affected by biogas technology utilization. The next paragraphs focus on specific questions, limits that will be deepen in this research.

2.2.2. Methodologies of Smart Biogas Grid Technological Innovation System

From a methodological point of view, TIS is an analytic framework based on complementary ways of capturing system dynamics using a functional approach (Bergek et al., 2008), that it is used as frame to study and further implement SBG, tailored in line with the aim of the present research. Three ways can be identified and will be developed in the next chapter with the peculiarity of each discipline, here shortly presented:

1. ***longitudinal analysis*** – draw of maps with the functional patterns of technological system, capturing changes, results over time. Mapping can express the interaction of different technologies, functions, limits and opportunities through a number of different indicators. For this analysis, a mapping method redesigned from Forrest and Wiek (Forrest & Wiek, 2014) has been adopted, able to map multi-scale and interdisciplinary aspect of project taken into consideration, thanks to a structured interactions system between different processes (Figure 2-1). *Annex 1 – Case Studies*, reports case studies analyzed with this method.
2. ***system performance*** – evaluation of the functionality of specific technological systems. This phase (adopted for instance in technological chapter as well as in regulatory framework one) has been designed to merge different features, context, solutions (for example Table 2-3 adopted for analysis of technological systems included in SBG to understand the applicability and the integration of technologies each other).
3. ***link between functional pattern and evolution*** – empirically analysis can be linked and explained by the specific set of driving forces and blocking mechanisms which characterize the TIS. Key elements are categorized in set of actors/conditions/actions/outputs to allow the identification of strategy for the development and diffusion of SBG model. This phase is a synthesis of the specific analysis and research conducted during the work and two approaches have been used: at first maps have been produced to connect by discipline SBG features (each chapter report a map for each discipline involved); in a second phase, these maps, not easily readable for a not qualified user, have been embodied in a thinking tool, a decision support instrument useful for all actors typologies to understand the potential of SBG in their own district and address

further actions (the chapter 9 analysis in detail the genesis and the function of this tool).

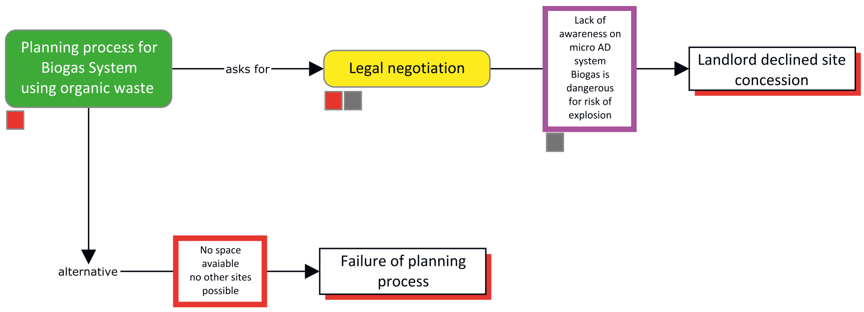
Defined shortly and partially the methodology of the SBG research inside TIS frame – a deepen analysis of methodology adopted discipline by discipline introduces each further chapter – it is now important a step back to focus on which are the elements object of investigation in this work.

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

NAME, location, State	#

TOPICS	**REFERENCES**
biogas micro size, co-generation, community, etc	sites, articles, surveys, etc

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved

- LEAP - Local Energy ADventure Partnership
  The Community Composting Network
  Methanogen UK Ltd
  Guy Blanch - research engineer for Alvan Blanch
  Musetopia Enterprises Ltd
  Community by Design – Camden-based community organisation
  Mark Walker and Davide Poggio – PhD researchers from Leeds University
  Dr David Neylan and the Bridport Renewable Energy Group
  Aleka Designs – specialists in electronics design, prototyping and commercialisation
- Site landlord

LEGEND

ACTORS	**ACTIONS**	**REQUIREMENTS/BARRIERS**
Core group	Networking	Infrastructural/technological
NGO	Mobilizing	Energetic
Business-SME	Planning	Economic
Government	Organizing	Institutional
Educational institution	Fundraising	Environmental
Community Group	Publicizing	Social/behavioral
Community Member	Monitoring	
Other	Executing	

CORRELATIONS
++ Strong positive
\+ Positive
\- Negative
-- Strong negative
o Alternative

OUTPUTS NO output
Infrastructure
Institutional
Products
Knowledge
Services

NOTES
notes

#-1

Figure 2-1: legend and exemplification of case study. Annex 1 reports the case studies analyzed.

Abbreviation	Label	Technology	Aim	ID	Relation	
BWC	Bio-waste collection				→	Autonomous components
BP	Biogas production				↔	Complementary components
PU	Products utilization				=	Supplementary components

Table 2-1: part 1 of the table. Classification and relation of technologies in SBG

Technical aspects									
size	**capacity**	**cost**		**odor**		**noise**		**emission**	
different units	different units	●●●	expensive	●●●	high	●●●	high	●●●	high
		●●	medium	●●	medium	●●	medium	●●	medium
		●	cheap	●	low	●	low	●	low
		○	no cost	○	no odor	○	no noise	○	no emission

Table 2-2: part 2 of the table. Technical aspects of technologies in SBG. The parameters are classified with a qualitative scale

Scale of installation					Functional complexity		
household		building		district	installation	use	management
intern	external	intern	external				
			●●●	preferable		3	difficult
			●●	possible		2	medium
			●	not advisable		1	easy
			○	impossible		0	no complexity

Table 2-3: Scale of installation and usability of technologies in SBG. The parameters are classified with a qualitative scale

2.3. Smart Biogas Grid: main aims and research questions

Once defined the width the width of SBG topic and the aim to pursue, it is in this phase to focus on what investigate and research. Despite the perspective to analysis biogas in a systemic view, all matters are not eligible, neither for the competences of the writer nor for the research goal. For this reason, it is requested a preliminary, but evolving, identification of research questions on SBG topic, to direct further phases; this step is a first moment of reflections and analysis. Indeed, these questions are not merely the queries of the initial idea, but they are a developing step, mediated with the progressive literature review and revision of case studies; the result is the identification of disciplines involved in SBG subject.

However, questions are not classified simply on discipline. As previously mentioned, SBG asses a set of connections which is not possible to categorize in a specific scientific area, but are an overlapping of matters part of a unique frame, precisely as demanded by the systemic view methodologically pursued. This step has specific applicability to SBG contexts such as urban districts. In fact, city includes a set of features typical of urban context that affect biogas question and all reflections related, addressing transition process of SBG at district scale.

Following, the questions that have directed the research activity:

- What is biogas potential (energy field) at district scale?
- It is possible to identify connections between biomass and biogas production and urban morphology?
- What are the district parameters which can affect biogas systems application and energy utilization?
- What are pitfalls of biogas in urban area?
- What is people acceptance of biogas and community system in their district?
- What is regulatory framework of reference for urban biogas application?
- How can the city council foster and develop SBG?
- What are the incentive policies to promote biogas among RES?
- How can incentives, policy frameworks and tariff structures better serve SBG?
- What are the common positive/features of success/failure of sustainable project in different domains and in different countries?
- What is biogas potential (environmental) at district scale?
- How organic waste can be collected?
- How can digestate contribute at closing the urban metabolism of city?
- What is the cost of biogas system in comparison with other renewable energy technology?
- What is the role of biogas in share of renewable energy technologies?

- How new initiatives are challenging the existing regime and how the regime can respond?
- What are multi-level and multi-actor interactions?
- What is biogas potential (social) at district scale?
- What are the main challenges for the governance of SBG?
- There are innovative models to go beyond the as usual business scenario to be translated into a range of options and priority setting to support decision-making?
- How is it possible to promote SBG model widespread?
- When SBG should be developed and what are the catalysts that take SBG from vision to reality?
- What steps need to be taken to begin development of a SBG project in urban district?

These questions have guided the further steps of SBG research. The result of these early and preliminary research phases, is a disassembly of SBG topic in components considered valuable for the development and implementation of the research inside the wide scientific scenario of reference. Thanks to this process, the expected outputs of the research are selected, directing the next research stages as well as being a constant verification step by step and for the final results.

Some contents are frequent and refer to specific disciplines, other are transversal and create cross relations between contents usually processed separately, directing the research on multi and inter-disciplinary approach.

2.3.1. Multi and interdisciplinary approach: features in Smart Biogas Grid research

SBG research is the summa of many different aspects and focus on these topics has been useful to direct further analysis and organize the research work. Questions over mentioned described features to be studied in this PhD thesis. Features studied and related to specific fields are:

- ***environment*** – set of aspects related to environmental features: waste production, collection and management, digestate utilization, biogas utilization and dispersion prevention, emissions reduction;

- ***energy*** – set of aspects related to energy features: biogas energy potential, biogas utilization, energy saving;

- ***regulatory framework*** – set of aspects related to normative features: regulatory framework at different institutional scale (European, national, regional, local), policy, financial incentives;

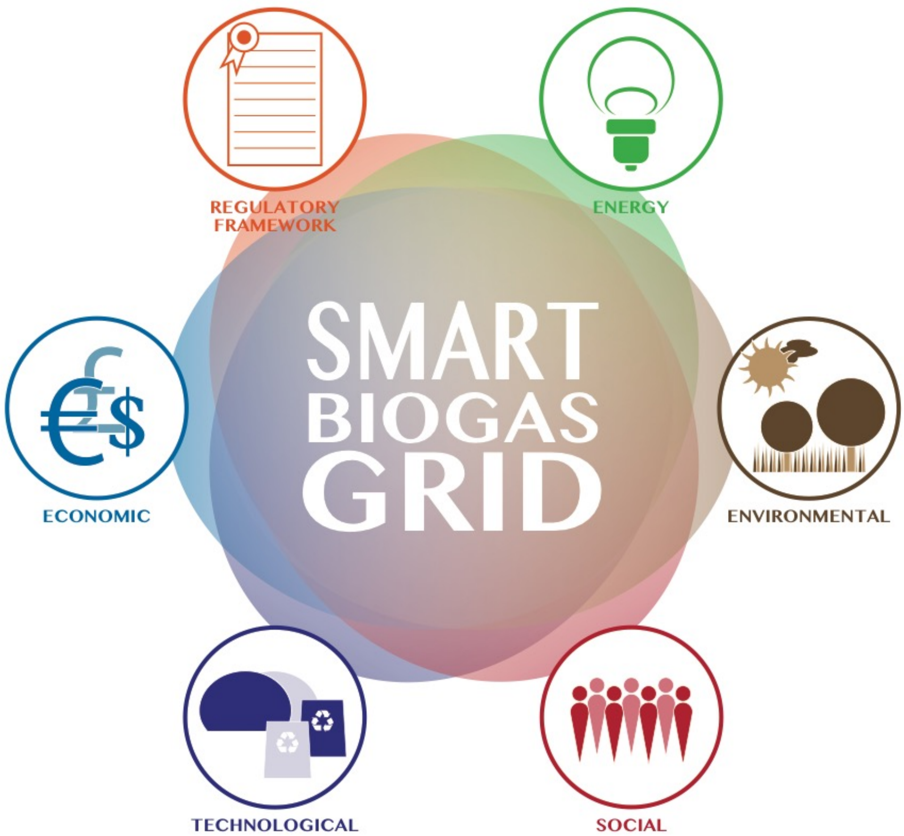
- ***technological*** – set of aspects related to technological features: classification of technologies involved, applicability at district scales, evaluation of correlation between energy and urban morphology, technological legitimacy of biogas at district scale;

- ***social*** – set of aspects related to social features: social legitimacy of biogas among people, solutions of social innovation, behavior and engagement in SBG, community energy system;

- ***governance and economy*** – set of aspects related to governance and economic features: model of governance, not as usual business scenario, cost, incomes.

Therefore, SBG includes these six disciplines, here shortly presented and embodied of a holistic vision of sustainability and smart practices; this thesis assigns each topic to a different chapter because of their peculiarity, with the aim to organize the work underlining multidisciplinary aspects of the research in their complexity. The order of disciplines is not random, but it marks a progressive development of research, including contents previously treated. In this way, the 'systemic view' is implemented going over the only organic matter for biogas production usually discussed, but including, in addition to material source, also immaterial ones typical of the district (and its different scales of interest) where SBG is promoted. The systemic view is supported by a full comprehension of features involved, studied through specific methods directly recovered and skilled for each discipline. This process allows to adopt a multi-scalar approach and apply a requirement-performance strategy helpful to join and read together different segments of the research. In such a way, there is a collaborative evolution (co-evolution) that direct towards the promotion of interdisciplinary aspects of the topic. In addition to multidisciplinary approach, SBG replies the need for an integration between disciplines, their features, projects, solutions, perspectives, essential to go beyond systems that usually operate separately and are not networked, in order to optimize their outcomes and research in a multi-level perspective. Environmental, energy, normative, technological, social, economic features, can enhance SBG differently, but they are part of this unique scenario. Research conducted in the frame of transition process, demonstrates the importance to relate different aspects from different contexts of background ("EU FP7 project PATHWAYS," 2015), to help meet ambitious performance goals using a "*an analytical and heuristic framework to understand Technological Transition*" (Geels, 2002). With this approach, SBG methodology overcomes the current lack of joined-up actions to find common strategies and solutions.

Figure 2-2: systemic view of the research join aspects of different disciplines



With the aim to join disciplines inside TIS framework and allowing a homogenization of contents with a common and transversal language despite their different scientific source, disciplinary aspects are developed mapping the following elements:

- ***actors*** – stakeholders involved with their potential role in SBG project.
- ***context*** – set of limitations and opportunities typical of a context of application to define and precise which are the elements of local success and failure of SBG features.
- ***actions*** – set of actions practicable by actors in the specific context in the specific disciplinary field they are divided in three transversal typologies evaluated as distinctive of SBG project:
  - ***Bio-waste collection*** – including collection and transportation, this step depends on waste collection typology and connected fuel energy consumption by the transport used. Experience and model calculation affirm that this is not an inssue in terms of energy consumption aspects, but it is in terms of costs (Scholwin & Nelles, 2013).
  - ***Biogas production*** – including energy required for the operation of production
  - ***Products utilization*** – including post-processing, transportation biogas and digestate can be used treated and used in different was and therefore there are different energy consumption expected.
- ***outputs*** – set of results achievable by actions to be confronted with stakeholders needs and expected requirements in SBG project.

These characteristics are identified in each chapter for each discipline, in order to create areas of overlapping among different scientific field and the possibility to set that network of relations researched in SBG.

2.3.2. Research boundaries

For the extent of the topic, and the specialization requested by each feature, it is fundamental to define boundaries of SBG research. Indeed, if research questions direct to topics to investigate, it is crucial to bound these topics to have clear limits to research. A limitation of the research helps to focus on precise parts of the general research having in mind the final aims of the work.

First limitation considered in the research it is the previous disciplines identification that bound partially the research. A second limitation is one of the main characteristic of SBG: application in *urban areas*. Indeed, urban areas strongly affect biogas application, advising boundaries of the research:

- ***Spatial*** – SBG is a model proposed at district scale. The reason is that cities are summa of districts, that can be considered as basilar cell. Small scale of district directs the involvement of local people in the project, thanks to a communitarian dimension. If the space of application of this system appears to be preferable new districts, the research aims at studying existing districts with their morphologies and typologies to introduce biogas system within consolidate urban patterns.
- ***Energy field*** – SBG assumes to use urban biomass available. The aim of the research is to identify an energy model for urban area in the scenario of renewable and local sources; for this reason, the utilization of urban biomass is considered priority and food waste, wastewater and green waste are biomass expected to be used.
- ***Density*** – SBG is expected to be realized in districts that host different number of people in relation to historical foundation or degradation. People quantity is a parameter to estimate urban biomass production; district urban morphology affects its quantity and understanding its rules is crucial for the research.

In addition to these urban limitations, other boundaries have been set:

- ***Technological*** – SBG does not invent new technologies, but it is based on existing ones, different from discipline to discipline involved, but considered as part of 'biogas system', set of technological systems and sub-systems subject of the research. Technological products are read independently of their degree of complexity or innovation, but as functional to SBG scheme development. It is not the aim of this research to find new chemical and engineering solutions to optimize biogas production.

- ***People awareness*** – SBG is investigated from point of view of people (actors of the system) role. It is central for the goal of the work to develop new energy models able to have people aware, engaged and involved in waste practice and energy utilization. People are not passive in SBG, but enroll an active role.
- ***Small and local generation*** – SBG aims at developing system at small and local scale to have decentralized generation system. For this reason, only technologies and energy generator applicable at district scale are studied having small cogeneration (<1 MWe) or micro small cogeneration (<50 kWe).
- ***Context*** – SBG does not work only on infrastructural context of application, often the only physical and territorial limits pondered (Bergek et al., 2015), but, as typical in TIS (Markard, Wirth, & Truffer, 2016), the context of application here considered has is larger and has a central role for the success or failure of a TIS. The context is the set of features typical for each different application and it includes infrastructural, social, economic and institutional aspects. For the complexity of the feature involved, defining the context is a set of infinite possibilities, a repertoire which is the same independent of the technology applied, but which can address the better application of a TIS rather than another.

2.3.3. Expected outputs

Defined what is SBG, disciplines involved and boundaries of the research, in this phase the expected outputs are highlighted. The objective of this research is to add a level of quality in the application of biogas technological system to promote an improved energy, social and economic business model that enables people to be aware producer and consumer of energy in their urban districts. At this aim, the expected direct outputs of the present research are:

- promote urban biomass utilization at urban scale, through bio-waste practices collection and recycling, to eliminate road transportation of the waste, promote waste utilization in the community district so to reduce waste management cost;

- promote a model of decentralized generation energy system, to have microgrids model as part of smart grid system;
- promote biogas solution in urban area among stakeholders, to have people aware on energy produced and consumed;
- evaluate biogas feasibility (multidisciplinary considerations) in existing urban areas:
- integrate energy biogas evaluation based on logic of people density and green area surfaces with an original decision-making process that includes a reading of the context, beyond the only energy aspects;
- creation of a predesign tool as decision support instrument to direct actions and development of Smart Biogas Grid within interested stakeholders.

In addition to these direct outputs of the present research, the perspective opened by this work, allow to include also indirect outputs based on further actions to take place and pilot demo cases to realize. The following outputs are expected to be achieve:

- develop new energy efficiency models for urban area, reducing current electric and heat district energy costs, towards the independence from fossil fuel thanks to installation and integration among Renewable Energy Sources (RESs);
- contribute in reduction of GHG emissions from urban areas, to face growing urbanization and emission from human urban activities;
- involve private and public authorities in the definition of new strategies for promotion of regulatory framework, policy and financial instrument to sustain sustainable practices;
- use local material (organic matter, existing systems, etc.) and immaterial (human expertise, behaviors, etc.) sources in tailor made models in energy, technological fields as well as in governance and business models.

In this paragraph, it is also relevant to underline the importance of dissemination of research results. Indeed, it is considered significant to asses a strategy to diffuse the results of this type both in scientific community as well as among people. The goal is double: firstly, testing the quality of the research conducted step by step, through Congresses, Seminars and Journals presenting single parts of the research to finally have an evaluation of final global quality (see *Annex 2 – Scientific published contributions*); secondly, communicate research to not specialized persons to diffuse and promote new energy and sustainable models. Both elements are considered crucial for dissemination strategy because without a scientific relevance and its evaluation, research has not a legitimacy; otherwise on topics such biogas and new practices to produce and consume self-produced energy, people have to be trained, prepared and informed on all possibilities they can be involved to attend project of this typology. Research is made by scientists, but people are final users, and SBG aims at having a symbiotic system between experts and citizens. With this goal, the final product of this research, the decision support tool tries to offer an answer, moving from a theoretical consideration to a practical instrument useful for different stakeholders interested in SBG.

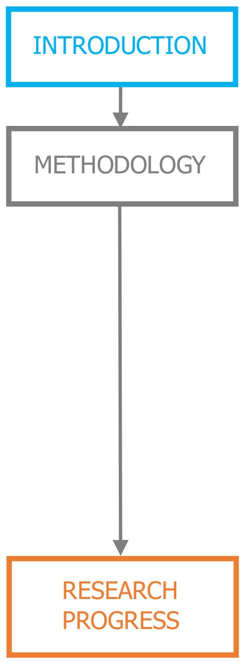
2.4. Organization of the thesis

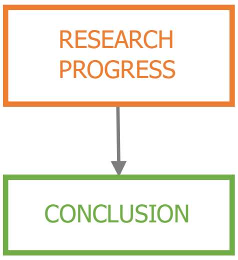
Within the framework of reference set in this chapter, this section underlines some aspects of organization arranged in this work.

Chapter from 3 to 9, the ones connected to specific aspects of SBG are organized in 4 main parts:

- ***Introduction*** – presentation of chapter's role of the topic within SBG and its aspects faced.
- ***Methodology*** – presentation of methodology used to face chapter's aspects. Being SBG developed within different disciplinary fields with their specific aspects, it is important to set a specific methodology for each research part. Despite some elements are in common and transversal at the topics – literature review, case studies, mapping of components – other aspects are typical for each disciplinary field and a clarification on methods and phases of the research applied are helpful for a better understanding of the work.

Figure 2-3: organization of thesis' chapters





- ***Research progress*** – presentation of the research conducted in the specific disciplinary field in line with aspects presented and methodology assessed.
- ***Conclusions*** – final considerations on aspects treated in the chapter within SBG.

Other element here underlined is related to citation and reference style adopted in the thesis. The referencing style used is the '*American Psychological Association (APA)'*, commonly considering as an appreciated standard within scientific community. Every reference cited in the text is also present in the reference list where it is arranged alphabetically and then chronologically if necessary. Citations in the text report the author surname and year of publication (author Surname, year), while the most used references are for journal publication:

Van der Geer, J., Hanraads, J. A. J., &Lupton, R. A. (2000). The art of writing a scientific article. Journal of Scientific Communications, 163, 51-59.

and for chapter in an edited book:

Mettam, G. R., &Adams, L. B. (1994). How to prepare an electronic version of your article. In B. S. Jones, &R. Z. Smith (Eds.), Introduction to the electronic age (pp. 281-304). New York: E-Publishing Inc.

For each other reference APA style is applied.

2.5. Conclusions

SBG is, from a methodological point of view, classifiable as an experimental research that has the ambitious aim to understand and operate within multidisciplinary, interdisciplinary and inter-sectorial domains. Biogas is not treated merely as RES, but as an opportunity to join features proper of different disciplines, expertizes and institutions. SBG aims at being a methodological sample for further and more detailed research on energy and architectural issue, able to include systemic considerations. The complexity of SBG is not rare in architectural practice and system design, and nowadays it is a model to pursue to connect experiences typical of different scientific disciplinary affiliation with the aim to produce sustainable solutions for people, environment and cities emergency.

SBG tries to overcome existing barriers for biogas system realization in urban areas, with the aim to identify the elements to promote a transition (energy field, technological, social, environmental, normative and economic) exploiting biogas as energy vector in a transition. The success of such work is in the connection of aspects that usually does not interact enough and properly, and SBG offers the opportunity to join go beyond specific problems typical of transition scenario ("EU FP7 project PATHWAYS," 2015):

- only attention on technologies and too little on wider socio-technical systems, including aspects often excluded in technical consideration as infrastructural, normative, social (cultural and behavioral) which affect the result of the transition and limited its full comprehension; narrow focus on economic constraints.
- insufficient attention to endogenous dynamics, causing a lack of attention on actors and social groups, their decisions, interactions and learning processes.

For this reason, the present research tries to overlap different disciplines using instruments typical of different scientific area and deepen chapter by chapter from disciplinary point of view. With this in mind, SBG aims to reposition biogas by shifting the attention on its multiple dimensions to direct the thinking and the further development of local energy system conducted by local stakeholders and community, thanks to a pre-existing and added awareness, using biogas as a momentum to support and stimulate wider sustainable initiatives and projects towards a smarter city.

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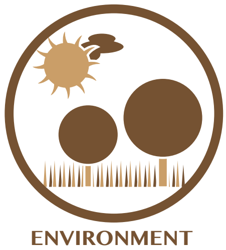
3. ENVIRONMENTAL ASPECTS IN SMART BIOGAS GRID



ORGANIZATION OF CHAPTER

Aim of this chapter is the investigation of SBG's environmental aspects. This chapter highlights the environmental prospects represented by the utilization of urban biomass inside a logic of Smart Biogas Grid through the construction of micro Anaerobic Digesters in city area. Anaerobic process advantages, role of biogas chain, waste collection systems are presented in line with EU environment strategies and as contributor in the debate on circular economy and urban metabolism (waste-biogas-energy). The chapter presents solutions for digestate application in cities and estimate emissions reduction.

3.1. Introduction

Environment is one of the pillar of sustainability and strategies promoted in last two decades have the goal to reduce emissions by human activities and prevent environmental damages, as issued by European policies on waste strategies (European Commission, 2017). Total amount of waste produced yearly in EU is 2,5 billion and from this only a 36% is recycled, with the rest landfilled or burned; it is considered a priority to revise this percentage and turning waste into a resource is one key to achieve this goal. Manage waste differently is one of the main focus of European research programs ("Environment Action Programme - European Commission," n.d., "Waste - Horizon 2020 - European Commission," n.d.) with the idea to promote and develop strategies of circular economy and have more sustainable cities. In the set of European environment actions, SBG finds its place and the role of urban waste is central and basic in the research here conducted. Despite SBG is not only an action on waste prevention, it puts waste inside a logic of reuse of its potential, in a way to promote new solutions in waste management practices to reduce landfill and incineration and support recycling and nutrient recovery (Al Seadi, Rutz, Janssen, & Drosg, 2013). Urban biomass, composed by all organic materials as food waste, wastewater and garden waste, is indeed a precious local source to afford environmental, energy and social issue. The use of urban organic waste as substrates among the categories of biomass documented in biogas scenario (Al Seadi, Rutz, et al., 2013), answers to characteristics of suitability and local availability for Anaerobic Digestion (AD) plant's feedstock, guaranteeing a good content of methane.

In this framework, this chapter underlines the opportunity to realize district AD systems to exploit local urban biomass especially highlighting the environmental aspects – waste diverted from landfill, emission reduction and digestate utilization – involved in SBG project.

3.2. Methodology

Environment is a transversal matter to disciplines and, as in chapter 2 has been underlined, not all competences have been subject of the research. Three main aspects of this chapter – waste, emissions and digestate – are adressed considering four different methodological phases:

- ***Literature review*** – papers, documents, law, regulations, have been read to focus on environmental aspects deepen in this chapter (waste, emissions, digestate) to understand scientific community scenario and international framework of reference;
- ***Case studies analysis*** – contained in *Annex 1 – Case studies*, this analytic instrument is useful to understand existing urban biomass systems, AD applied in urban area, digestate application, as well as other sustainable solutions with environmental benefits applicable in SBG projects.
- ***Environmental benefits identification*** – analytic analysis of environmental results of SBG application, through calculation of expected waste diverted from landfill, emissions reduction and digestate opportunity to be used in city. In this part the calculation of GHG emissions though waste life-cycle assessment and digestate utilization in city are presented.
- ***Mapping of components*** – synthesis of information collected to schematize actors, context, actions and outputs previously collected. This map is a partial contribute to the full understanding of SBG in its complex.

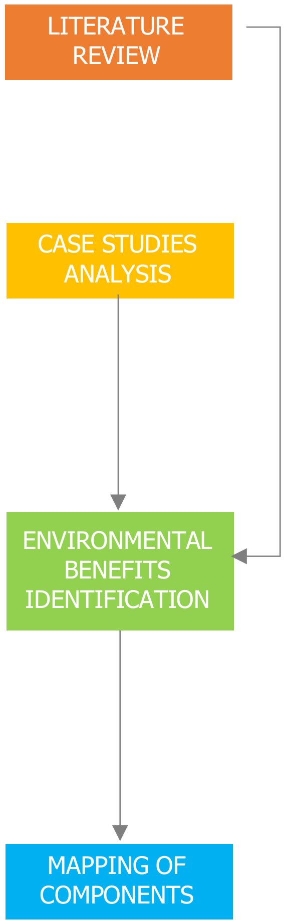


Figure 3-1: synoptic framework of methodology adopted for environmental aspects of SBG

3.3. Urban biomass for biogas production: urban waste use

Management of waste is a priority in the worldwide scenario. The current model based on consumption of goods and their quick end of life, has created a system which use 16 tons of material per person per year, of which 6 tons become waste (European Commission, 2017); find a way to recover this waste is fundamental for environmental quality preservation and restoration. Municipal waste represents 10% of this total waste, a small part compared to the total, but with a very high environmental profile because of its composition, distribution and link to consumption patterns (Eurostat, 2016). In 2015, 477 kg/capta (Eurostat, 2016) was produced inside urban areas in EU, and 247 kg have been incinerated or landfilled; this amount, despite it is lower than the data surveyed in 1997, is still a high percentage of waste. Waste legislations challenges this handling of waste, setting targets for progressively reducing the amount of organic waste landfilled (European Parliament and Council, 2008); the amount of organic waste provides a powerful motivation. Energy utilization of bio-wastes – food waste, garden waste, paper and woody residues – constitutes up to 80% of MSW (Caló & Pongrácz, 2014), and on this basis, it is not also mandatory to treat differently bio-waste to extend its life identifying strategy for its reuse, but it also a qualifying solution for waste management; SBG yields in this framework using organic fraction of municipal waste as urban biomass usable to produce biogas. Biogas is indeed produced in anaerobic digestion process which is possible through the utilization of organic fraction of municipal waste.

Figure 3-2: bio-waste potential is currently dispersed in landfill disposal process, with a loss of biogas and money expenses for producers

3.3.1. Bio-waste in municipal waste

First consideration is related to municipal waste suitable as feedstock for anaerobic digestion treatment, among wide range of different substrates accepted by the system. MSW is composed by different waste – papers, plastic, glass, food waste, garden waste, etc. – and a standard generalization on amount of organic fraction is not possible because of features that affected its quantity. Culture, standards of living, local policies, system collection are characteristics that deeply change MSW composition at district as well as national scale. For this reason, it is important a preliminary analysis on Organic Fraction of Municipal Solid Waste (OFMSW) collectable at district scale for a full comprehension of SBG suitability, evaluating parameters as food waste in waste streams, separated food waste collections, mixed organic waste collections – targeting garden and food waste –, food waste sent to the sewer – drink and liquid foods – or home composting solution.

For the goal of this research, data collected in different researches have been used to be representative of reflections and analysis conducted (Åsa Stenmarck et al., 2016; "Comparing grass silage harvesting: production differences and cost considerations," n.d., "EU FUSIONS," n.d.; Hao, Novotny, & Nelson, 2010), aware that they are not exhaustive and perfect matching indicators for each peculiar SBG district application. Indeed, estimating potential of bio-waste is a challenging aspect to be evaluated. To have a precise evaluation of urban biomass potential is imperative a survey district by district to understand which is the rate of organic waste produced in the area, because there are many features that affect organic waste production: people density – dependent also on season variation for touristic reasons – catering activities, food facilities, green areas, all contributors to waste amounts. In this scenario among MSW, three categories of urban biomass are classified and are considered as part of Smart Biogas Grid.

3.3.1.1. Food waste

FOOD WASTE

Food waste is composed by primary production, processing, wholesale and retail, food service, households, and its total is estimated to be 173 kg/capta/yr in EU (Åsa Stenmarck et al., 2016). It represents the major contributor in urban bio-waste because it is connected to human feeding. The expectation of EU strategy is to reduce this amount of food waste generated by better policies and behaviors on catering activities and new destination of unconsumed food in order to challenge alimentary poverty and not loose food still eatable (UNEP, FAO, & WRAP, 2014). Even though this is a goal of EU that is expected to reduce food waste amount, a zero-food waste perspective in not predictable neither possible; for this reason, it is important to asses strategies as SBG. Smart biogas grid uses food waste at district scale engaging local people and their awareness on issue through a set of actions stimulating for actors involved. In particular householders have a crucial role because they provide the greatest contribution at food waste, 92 kg/capta/yr (53% of total food waste) (Åsa Stenmarck et al., 2016), marking an opportunity to engage citizens in reutilization of their discarded matter.

Estimate the precise amount of food waste produced is not easy. The most efficient and cost effective methodology to estimate food waste generation at district scale, is population density. Despite this method is not the best and the most precise, it is not affordable to survey household by household for a relative long period and survey each production so to sum the contribution of each householder. Engagement of local waste collector is however a good suggestion. Updated data on organic fraction collected at district scale is not always available, but at least a percentage data at municipal scale should be available and cross-referred to resident population would allow to estimate district actual food waste collection. Food waste is central in bio-waste total evaluation because it is the greatest contributor and population is an active part of SBG scenario.

3.3.1.2. Wastewater

Other waste obtained by human activities, is wastewater. Wastewater is water that has been used in the home, in a business, or as part of an industrial process ("wastewater - definition of wastewater in English | Oxford Dictionaries," n.d.) and in urban areas it is generally collected in sewage systems. Collection of black water among wastewater is the most appealing because it is composed by only urine and faeces, human waste, and represent a huge part of whole wastewater. The average amount of urine produced by human is 1,40 l per person and day, 1,4 kg/capta/day, while the amount of faeces is 140 ml per person and day, 0,14 kg/capta/day (Hao et al., 2010). This quantity, apparently low at day, it is a significant during the year. In particular, it can divert from wastewater treatment plant a consistent part of the waste and prevent further intervention of expansion of existing plant.

3.3.1.3. Garden waste

Last waste used in SBG scenario is garden waste. It is produced in garden and park areas and it includes garden waste, trees waste, flowers and all waste derived by green area management. Its evaluation is maybe one of the most complex because it is affected by green design, vegetation adopted and management practices. It is not possible to standardize evaluation of garden waste, but in this research yards areas are considered producer of 50% grass – 2 kg/m^2/yr of grass ("Comparing grass silage harvesting: production differences and cost considerations," n.d.) – , 25% leaves , and 25% tree with a yearly production of. Garden waste is surely underestimated in such a way, but it can be useful to make some considerations on role of this waste in SBG. It is demanded at study case by case for precise quantification of garden waste collectable.

The strategy proposed by SBG is to use differently from common waste end-of-life the bio-waste collected with the aim to produce biogas where waste is produced and collected at district scale; the process that produces biogas using bio-waste is anaerobic digestion.

3.3.2. Micro anaerobic digestion: from waste to energy (and digestate)

The possibility to use Anaerobic Digestion (AD) for organic fraction of bio-waste is a viable technology, with a huge potential treatment method to turn urban biomass into useful commodities.

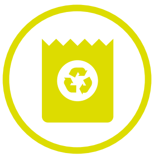
AD practice involves the breakdown of biodegradable material in absence of oxygen by micro-organisms called methanogens in a period that takes from two to five weeks. Among all technical components involved in the biochemical process which affect the quality and quantity of the final product – input substrate, pH, temperature, nutrients, microbes, process configuration and time of retention –, AD for this research is simplified in two main types (Banks & Heaven, 2013; Tomperi, Luoma, Pongrácz, & Leiviskä, 2014; WRAP, 2016):

- ***thermophilic*** – system reaches temperatures of up to 60°C and processes 'high solid materials', such as a garden and food waste mixture, using a batch system. The rate of methane generation in thermophilic systems may be 25–50% higher than in mesophilic ones, allowing shorter retention times.
- ***mesophilic*** – system normally run at about 30-40°C and processes 'low solid materials', such as household food wastes, using a continuous flow system, it is considered more stable and less energy consumptive than thermophilic digestion.

These two processes have some differences but, despite both are eligible for urban biogas system, the more interesting is mesophilic one, both for energy issue – lower temperatures are more achievable and cost effective at small district scale than higher ones – as well for feedstock typologies expected to be used in SBG – mainly household food waste with low solid material concentration. However, the choice should be evaluated case by case by chemical and energy expertizes, because of peculiar local feedstocks available – food or drinking facilities, large green areas, etc. – or context conditions favorable for thermophilic system – local heating system recovery (for instance wastewater treatment plant) with possibility to integrate digester heating demand with heating recovery.

Regardless of AD system applied, the process guarantees to organic waste processed to be used beyond its usual life, exploiting its potential suitable for energy production. Since organic waste is broken down in AD, there is the conversion of chemically bound of organic matters in two products:


BIOGAS


DIGESTATE

- ***biogas*** – a mixture of gases with high energy content;
- ***digestate*** – a semi-liquid stabilized product rich of nutrients.

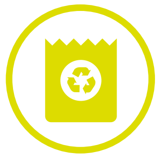
These are the products of AD process, one with an energy potential and environmental consequences, the other with an environmental relevance. In this frame, reflections on urban metabolism should be included. Indeed, if SBG takes waste and transform them into profitable products, affecting and improving current urban metabolism to a more sustainable environmental impact, their correct utilization is mandatory to avoid loss of products and their components, because of undersigned solutions despite their predictability, dispersing their full potential.

3.3.2.1. Biogas


BIOGAS

Biogas is the most valuable, at least for this research, product of anaerobic digestion. It is a mixture of different gases – methane (CH4) and carbon dioxide (CO2) and small amounts of nitrogen nitrous oxide (N_2O), and ammonia (NH_3), hydrogen, hydrogen sulfide (H_2S) and oxygen – mainly composed by methane and carbon dioxide which content is between a range of 55-70% and 30-45% (Tomperi et al., 2014). Its energy potential is dependent on methane yield and it can be used alternatively for energy specific needs as heating, Combined Heat and Power (CHP), upgrade and injected into the grid. Next chapter on energy aspects of SBG, goes deep inside energy potential of biogas, its utilization and related aspects.

3.3.2.2. Digestate



The other product of AD is digestate. Speaking about AD, the attention is usually focused on biogas, but digestate is an other valuable commodity of the process. During AD process, bio-waste degradation releases a semi-liquid component dehydrated and sanitized, deodorized and rotted without having lost original nutrients of feedstock (Tomperi et al., 2014). In fact, the process increases the nutrient efficiency of bio-waste by solubilizing nutrients (nitrogen) and, despite it is commonly considered as a secondary product of anaerobic digestion, its utilization is a valuable solution to be used as (Al Seadi, Drosg, Fuchs, Rutz, & Janssen, 2013):

- ***fertilizer*** – considered the most sustainable utilization if digestate, is an alternative for artificial and mineral fertilizer in green and agricultural growing, and the limit nitrate input a maximum of 170 kg/ha per year is applied;
- ***soil conditioner*** – obtained by the separation of solid fraction of digestate, it is a compost which can improve soil quality, improving water retention capacity.

The real issue on digestate is the certification of its quality depending mainly on feedstock used. Regulatory frames rules on digestate utilization combining different legislations - soil protection legislation, fertilizer and waste legislation – which have in single countries stricter regulations than European ones. In many cases, positive lists of materials suitable as AD feedstock to guarantee digestate certification and high quality have been issued (Al Seadi, Drosg, et al., 2013). The problem is that digestate by bio-waste derived by activities that produce waste (for instance food waste and wastewater) is a 'waste'; this is an obstacle for a whole digestate utilization as fertilizer. The legislation is made to simplify the digestate management and end-of-waste products: if a digestate is produced by waste is a waste. The reason is that waste has a wide composition and a strict control is difficult to achieve, but also waste is a business and a self-management of this waste is an economic loss for operators of waste management. However, regulation and law can be changed and, for this reason, it is here important to evaluate urban bio-waste for its environmental opportunity even though nowadays some norms can affect its utilization. Urban biomass, through separated collection of organic fraction of municipal waste, is potentially free of physical impurities (plastic, glass, non-digestible matter, etc.), and for this reason further regulation development should consider this eventuality to review end-of-waste products. Despite these political issues and regulation restrictions, digestate by urban bio-waste cannot be generally classified as unsuitable for utilization, but its mandatory an analysis of its chemical composition and concentration of nutrients, to evaluate its quality; these aspects are demanded to disciplinary experts. Indeed, the whole process should include a constant quality management. From feedstock quality to digestate nutrients, the quality process provides assurance that the digestate is suitable and safe as fertilizer, subsequently improving the perception of safe product by actors involved in its utilization – population, food growers and sellers, politicians, decision makers, etc. (Al Seadi & Lukehurst, 2012).

The initial step of this quality chain to face waste contamination and have good quality digestate is bio-waste collection. Source separated organic household waste and food waste are valuable feedstock materials for the production of quality digestate (Al Seadi, Drosg, et al., 2013); the way they are collected and their origin is important. In fact, feedstock cannot contain non-digestible materials – plastic, rubber, metal, glass, large pieces of organic material – and control of origin, as the first collection phase, cannot be undervalued. The presence of impurities in the bio-waste could cause damages in AD plant and it will decrease the quality of digestate, causing hazardous environmental impact. For this reason, in this process, the involvement of population and their awareness on recycling for AD plant is fundamental to guarantee a correct collection of bio-waste and consequently assure that the feedstock is not polluted with any unwanted matter that is able to pass unchanged into the digestate.

A more controversial and debated feedstock is digestate from wastewater (Al Seadi, Drosg, et al., 2013). Urban wastewater treatment generates a sewage sludge which can be used on green and food growing area as farm land, as a cheap disposal solution. Divergent opinions are sustained because there is not a common judgement on chemical composition. For this reason, in case of use of digestate by sewage sludge is important a constant monitoring control of its chemical composition, even if its use as fertilizer do not create any human or environmental risk.

A high-quality digestate can be used directly once removed from the digester. This fact allows to have cost savings because there is no need to store, transport or post-treat the digestate. However the European nitrate directive restricts the utilization to precise seasons to reduce the uncontrolled spread of nitrate, highly present in the digestate, in agricultural land (Al Seadi, Drosg, et al., 2013). Therefore, the quantity of nitrate can influence digestate application to protect environment and requesting the redistribution of nutrients somewhere else with consequent cost of transportation costs. Differentiate the possibilities in using digestate locally is important to optimize products utilization.

3.3.3. Waste chain: from waste producer to AD feedstock

To be suitable as AD feedstock for biogas production, household waste has to be collected separately at the place of production and utilization. Many studies have indeed show that low-purity (maximum 0,1% of not organic material) can cause technical malfunctions of biogas plant, having bad consequences on biogas and fertilizer, products of the anaerobic digestion (Al Seadi, Rutz, et al., 2013). Therefore, it is important to identify best practices for waste separated collection in urban areas enhancing the quality of AD feedstock to reduce contamination rate. In contamination prevention strategy, practices of waste collection and management are key points.

3.3.3.1. Waste management

Management of municipal waste, in particular food waste in SBG perspective, is challenging due to increasing per capita waste generation and thinking of other utilization of its organic fraction is an alternative to incineration and landfilling (Piippo, Saavalainen, Kaakinen, & Pongrácz, 2015). Urban biomass used in a perspective of Smart Biogas Grid to use locally organic waste and offering alternative to current waste management plans following EU Directives prescription and expected results. Using waste as urban biomass exploit separation strategies to use material amounts not diffusely recovered, offering the chance to evaluate costs and emissions. Definition of a strategic municipal solid waste management in SBG is priority.

A good Municipal Solid Waste Management (MSWM) is an important activity in waste chain and it is the instrument to pursue principles of sustainable development, integrating waste management with waste hierarchy and policies issued at different institutional levels, from national to municipal one (Piippo et al., 2015). In particular, municipal government is responsible for the implementation of municipal MSWM programs, deciding on strategies to chase, setting targets, using an in-house management as well as licensing companies to provide these services. To assess principles and program MSWM is requested to issue a strategic planning – 6 phases (general considerations, status part, planning part, consultation proves, implementation, plan revision) (Piippo et al., 2015). The strategic plan is essential to meet expected demand, to be suitable to needs, and to be cost-effective and it is the combination of political decisions and experienced solutions:

- *strategy* – presents the overall framework for MSWM systems and standards. It is mainly demanded to political decision in line with different institutional levels;
- *action plan* – specific options to be realized, in order to meet the requirements and expected outputs set out in the strategy part.

SBG directs decisions in *strategy* as well as in *action plan* in line with last perspective of waste and sustainable resource management ("Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.). SBG *strategies* can be set in three key operational strands, as expected by environmental EU strategy (European Commission, 2017):

- *urban metabolism* – SBG aims at identifying a model to facilitate the analysis, description and utilization of organic waste flows and derived energy within cities;
- *circular economy* – SBG aims at being an economy model which extends waste life thanks to reusing bio-waste to exploit its potential with the aim to close cycle of bio-waste nutrients where waste is produced;
- *blue economy* – SBG aims at stimulating relative low investments using an innovative way local bio-waste to obtain multiple income streams, local job opportunity and ownership of new solutions adopted.

Adopting these strategies, affect the waste chain and MSWM. These practices are indeed different than conventional and diffuse approach to urban waste management, mainly focused on recycling in a logic of green economy. The consequent *set of actions* of MSWM has to be thought starting from these strategies. Three aspects to implement these strategies and crucial for further actions assessed in SBG are here underline.

Figure 3-3: SBG waste treatment processes are part of possible circular economy strategies

3.3.3.2. People engagement in bio-waste plan

The role of local people is central to SBG and it starts with bio-waste collection. Households produce large quantities of food waste and pay charges, or taxes, for the collection of their waste. Despite increasing awareness on environmental issues related to waste prevention and separate collection, involvement of household in food waste collection is lower than participation in dry recycling services (plastic, glass and paper) (WRAP, 2016). The factors influencing food waste collection are multiple and depend on:

- *collection profile* – if food is collected separately or mixed with garden waste with a frequency of collection weekly or fortnightly, different results are achievable:
  - separate weekly collections: 1.5 kg/pp served/week;
  - weekly mixed food and garden waste collections: 0.8 kg/pp served/week;
  - fortnightly mixed food and garden waste collections: 0.5 kg/pp served/week.
- *property types* – typology of property and number of people resident can affect food waste collection, because of social pressure and goals sharing.
- *quality of service* – clear and good quality information is crucial to:
  - provide information on containment;
  - introduction of new service;
  - time schedule collections.
- *participation* – full participation is not possible and even the best performing services achieve participation rates of less than 70%. For a separate weekly food waste collection – the most efficient – data on participation are:
  - poor participation ≤35%;
  - average participation = 35-55%;
  - good participation ≥55%.

A right planning of these aspects directs a waste management plan with a good engagement.

3.3.3.3. Communication in bio-waste plan

Other feature to be considered is the one of communication. Even the best waste service can fail if it is not properly communicated. For this reason, a communication plan should be provided in MSWM in order to provide right information to the users, but also to the staff involved. Leaflets, posters, workshops are part of a communication strategy that needs to be planned in detail to underline the benefits of bio-waste collection in SBG. Communication should be clear, with simple language and appealing graphically, but overall should report information on waste service – waste that can and can not be included (emphasis on the wide range of food that can be collected to help address consumers' belief that they do not produce enough food waste to use the service), the importance of eliminating contamination, bin/caddies and liners to use, solutions to maintain hygiene and eliminate odors, the importance to take part in the service (local benefits, food waste final aim and utilization or not-utilization, tips on how to make food waste collection convenient), message on how much food residents have collected after program starting with environmental and energy results achieved. A wide range of communication possibilities are used and can be implemented ("WRAP Resource Library," n.d.), but it is important to always target it on people to involve them in the project.

3.3.3.4. Waste collection system in bio-waste plan

Not marginal in waste planning is the collection system adopted. Collection system is the set of components – more or less technological and better treated in the next chapter – that people have to collect bio-waste and to manage it properly. Collection system solution depends on many factors:

- *infrastructural context* – not all waste collection systems can be installed everywhere, but it depends on characteristics of site of installation (*Chapter 6 – Technological* goes deep inside the issue of context and components application);
- *contamination control* – food waste needs to be collect and managed properly to maximize the amount of bio-waste collected for SBG (WRAP, 2016) and the aspect of

contamination is of particular matter. Contamination is indeed a risk for bio-waste quality, and consequently digestate utilization, but also for the component of digester as well as mill or other technological system; control contamination at different phase it is important and collection system is a first moment to monitor and address contamination actions. If contamination is:

  - *minimal* – caddies are collected, contamination removed manually by operators and feedback is given to food waste producers if necessary;
  - *substantial* – caddies are not collected and a note is left to explain why.

  In such way contamination prevention reduces operational costs and prevent further efficiency issues.

- *budget amount* – collection system depends on budget available in MSWM. Indeed, technological solutions – as well as people engagement or communication – needs to face economic possibility to afford also in consideration of fee charge for waste collection. Not only as usual business scenarios have to be investigated (*Chapter 8 – Economic* goes deep inside the issue of economic feasibility and governance solutions)

Depending on these features different collection system can be used with difference potentials and personalization possibilities (Envac, n.d.; "Join the green revolution in urban food waste mangement : Local Energy ADventure Partnership," n.d.; WRAP, 2016). Aim of these system is collecting food waste from resident to district area, to arise people awareness on amount of food waste collectable and affecting their behavior to reuse residual food waste. Affirming that a collection system is better that another is not possible. Their success can indeed affect differently the engagement and the contamination control – the systems are presented with a gradual improvement of performances –, but they depend on conditions of applications, communication provides and revision of ongoing waste management plan. The systems are here presented in their environmental impact, but should be integrated for a full understanding with technological analysis of *Chapter 6*. The collection systems are:

- *collection from a communal area* – residents use a small kitchen caddy (5–10 liters with caddies lined with a biodegradable liner or newspaper) and transfer the food waste to larger caddies which are presented in a communal area for collection;
- *bank collection schemes* – residents use a small kitchen caddy in their homes (as above) and periodically transfer their food waste to a larger communal collection container;
- *door-to-door collection scheme* – residents use a small kitchen caddy in their homes (as above) and present their food waste in a larger (e.g. 23 liters) caddy outside their front doors (in the corridor of the block of flats) on a regular collection day;
- *pneumatic system collection* – residents use a small kitchen caddy in their homes (as above) and transfer their food waste in inlets installed at floor level, building area or at ground level. The system pressurized bring to a communal area the bio-waste collected for further treatment.

3.4. Environmental benefits of SBG in urban area

Identified the environmental components, it is time to identify the potential benefits associated with SBG realization in urban areas. Treating bio-waste in SBG scenario allows to increase food waste collected, reducing the amount to landfill disposal and consequently decreasing its transportation; in addition, the two products of AD, biogas and digestate, reduce fossil fuels used in generation systems and the related greenhouse gases associated, and integrate nutrients in urban green solutions. Two environmental benefits are reported:

- *Greenhouse Gas (GHG) emissions analysis;*
- *Digestate urban utilization*.

3.4.1. GHG emissions analysis

Environmental impact of SBG is firstly related to GHG emissions and, the benefit, associated with its reduction. Producing biogas by bio-waste is a positive contributor in GHG reduction because it converts

CH_4 formed naturally in landfill into a product of a controlled process and usable as RES. In line with last study conducted (Daniel-Gromke, Liebetrau, Denysenko, & Krebs, 2015), environmental benefits take into biogas components and convert their value by using characterization factors based on 100-year Global Warming Potential (100-yr GWP) into CO_2 equivalents (CO_2e) (Table 3-1). There are many advantages on using SBG rather than landfilling and the following contributors are to be considered:

- *diverting waste from landfill* – bio-waste used in SBG is not moved to landfills, but is treated locally, with a double result:
    - *reducing waste transportation* – waste treated locally makes waste transportation drops. Travel to landfill is excluded for food waste share. In addition, the need for shorter transportation – district is not wider than an half kilometer – allows the utilization of smaller and less energy consumptive collection systems (for instance cargo bicycles (WRAP, 2013)). Cumulative distance travelled by vehicles and the associated fuel economy of differing vehicle types allow to estimate precisely emission reduction.
    - *avoiding methane dispersion* – food waste disposed in landfill disperses methane directly in atmosphere (if not gas collection systems are installed), while SBG allow its utilization locally as biogas.
- *Renewable Energy Generation* – using biogas (RES and consequently considered with '*0*' emissions) allows to reduce fossil fuel for energy production.

Table 3-1: data on biogas components and global warming potential expressed in CO_2e

Biogas composition	**100-yr GWP (1kg of CO_2e)**	**Reference**
CO_2	1	("Bioverse energy," n.d.; IPCC, 2007)
CH_4	25	("Bioverse energy," n.d.; IPCC, 2007)
N_2O	298	("Bioverse energy," n.d.; IPCC, 2007)
NH_3	NH_3 = 0,01 N_2O	("Bioverse energy," n.d.; IPCC, 2007)
O_2	-	("Bioverse energy," n.d.)
H_2O	-	("Bioverse energy," n.d.)

CO_2e contributions on SBG MSWM solution is a summa of elements and for its estimation Life-Cycle Assessment (LCA) methodology has been used MSWM (Da Costa Gomez, 2013; OAR US EPA, 2015; OSWER US EPA, 2016a) (see Annex for elements used and calculation made are presented). Results of GHG emissions for different bio-waste management strategies – landfill, incineration, composting, anaerobic digestion – in comparison with SBG, are reported in Table 3-2.

Bio-waste	**Waste management strategy**	**CH_4 produced (m^3/ton)**	**Net GHG emissions ($kgCO_2e$/ton)**
Food waste		44,00	
	AD		-136,10
	Composting		-86,34
	Incineration		26,39
	Landfilling		1.707,83
	Smart Biogas Grid		-137,39
Garden waste		204,75	
	AD		-1.099,16
	Composting		423,36
	Incineration		23,39
	Landfilling		327,18
	Smart Biogas Grid		-1.100,45
Wastewater		15,00	
	Wastewater treatment		0,96
	Smart Biogas Grid		-314,46

Table 3-2. GHG emissions for different waste mangement strategies. See Annex to deepen formula and data used. negative values denote a decrease in carbon storage.

3.4.2. Soil (and vegetation) health

In addition to GHG emissions calculation, SBG needs to take into consideration solutions for digestate utilization. Digestate can be used in urban area in site and, with possible change in fertilize regulation, also sold to be used off site. Therefore, digestate is an opportunity to increase organic matter content of soil representing also a possible income for SBG project. Digestate can reduce the need to apply chemical fertilizers and pesticides, improve plant growth, reduce soil erosion and nutrient runoff, alleviate soil compaction help increase the soil's water retention ability, increasing water permeability to green areas. Urban areas embrace this possibility and contribute in the closure of waste chain. Cities can host activities of:

- *Gardening and food growing* – digestate makes nitrogen, phosphorus and other valuable nutrients available in renewable form and studies have shown it to increase germination and overall plant growth rates by up to 30% (LEAP - Local Energy ADventure Partnership, n.d.; "Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.). Gardening as well as food growing offer the same opportunity for environmental improvement of urban areas where they are located because, in addition to digestate application, they improve urban quality and human health. From a designing point of view, gardening and food growing can be developed in two models:

- *on-plot* – used typically for small contexts and applications (balconies, terraces, façade refurbishment), it produces green practices for vertical garden, roof-top, allotment plot or other solutions designed case by case by architects;
- *off-plot* – typical for larger green areas and public spaces, it produces green practices for vertical garden, roof-top as well as communal site, playground, school yard, golf field or other solutions designed case by case.

In addition to these chances, digestate can be used also in algae cultivation processes, to produce biofuel (WRAP, 2013). Cultivation of algae is considered expensive, due to current cultivation techniques – harvesting methods and downstream processing – but new approaches are investigated to increase the economic feasibility of algae as a source of biofuel. Algae cultivation is a suitable solution if integrated with algal production process, growing an algae as '*Chlorella sorokiniana*' on wastewaters, specifically upon effluent from anaerobically digested material (LEAP - Local Energy ADventure Partnership, n.d.; "Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.), but it works if climate conditions guarantee good lighting and heating as typical of central-south Europe.

3.5. Conclusions

Environmental aspects analyzed in SBG show an alternative MSWM strategy to traditional solutions. Collecting bio-waste from different district producers and move this source to one place at neighborhood scale, waste is treated locally with reduction of waste transportation emissions and diverting bio-waste from landfilling; in this way AD plant closes waste cycles locally. Indeed, waste is treated on-site or near to the point of generation, supplying to district activities energy, through biogas, and nutrients, through digestate; these 2 commodities have both an important positive environmental impact. GHG emissions analysis shows as SBG is the most performing solutions and only anaerobic digestion is a comparable, but the advantages of SBG emerge in the other disciplines researched in this work. SBG closes urban metabolism because bio-waste is treated where it is produced and it is processed in anaerobic digestion process offering to the district products usable at local scale. If energy is better deepened in the next chapter, the role of digestate is underlined. Despite it could be sold if only a more positive regulation on waste would be issued – not affecting environmental safety – digestate can be nowadays used for urban gardening and food growing, developing solutions of urban agriculture. These practices are architectural and urbanistic solutions that are not only appealing from an aesthetic point of view, but are extremely positive from environmental aspects – soil health, water retention, CO_2 challenging – but also because they are reasons to direct new social behaviors and face food poverty.

In conclusion, adopting bio-waste collection systems inside SBG strategy allows to rethink MSWM towards sustainable models in line with waste European directives and reusing sources otherwise lost. All environmental considerations and analysis highlighted in this chapter offer an initial set of actions, solutions to direct SBG environmental development. To order these actions and achievable results, a map of synthesis has been realized and classifies elements:

- *context elements* – set of features derived by context analyzed that affect SBG;

- *actions for waste collection* – set of actions to realize bio-waste collections in SBG;
- *actions for biogas production* – set of actions to promote biogas production in SBG;
- *actions for products utilization* – set of actions to use products in SBG;
- *actions of connection between disciplines* – actions that are key points for connections among disciplines involved in SBG;
- *outputs* – results achievable by actions of SBG.

Maps are realized for each aspects of SBG.

Annex – LCA assessment of GHG

This annex reports elements, data and formula used for life-cycle GHG calculations; conversion factors used are referred to Carbon Trust (2008).

Bio-waste management strategy	Bio-waste collection	End of Life	
	Emissions	**Emissions**	**Offsets**
Landfilling	Baseline waste collection system and transport to landfill	Landfilling operation Landfill methane	Avoided utility emissions due to landfill gas combustion Landfill carbon storage
Incineration	Baseline waste collection system and transport to waste-to-energy facility	Combustion-related nitrous oxide	Avoided utility emissions
Composting	Baseline waste collection system and transport to compost facility	Compost operation	Increase in soil carbon storage
Wastewater treatment plant	Sewer system	Wastewater treatment Wastewater discharge in water bodies	
Anaerobic digestion	Baseline waste collection system and transport to anaerobic digester	Equipment use and biogas leakage at anaerobic digester CH4 and N2O emissions during digestate curing N_2O emissions from land application of digestate	Avoided utility emissions due to biogas to energy Avoided synthetic fertilizer use due to land application of digestate Increase in soil carbon storage from application of digestate to soils
Smart Biogas Grid	Alternative transport to anaerobic digester Sewer system	Equipment use and biogas leakage at anaerobic digester CH4 and N2O emissions during digestate curing N_2O emissions from land application of digestate	Avoided utility emissions due to biogas to energy Avoided synthetic fertilizer use due to land application of digestate Increase in soil carbon storage from application of digestate to soils

Table 3-3: life-cycle GHG emissions for MSWM strategy with emissions and offsets evaluated

Bio-waste	Waste management strategy	CH_4 produced (m^3/ton)	Net GHG emissions ($kgCO_2e$/ton)	GHG emissions (kg CO_2e/ton)														
				Sewer system	Transport to landfill	Landfilling operation	Landfill methane	Transport to incineration facility	Combustion-related nitrous oxide	Transport to anaerobic digester	Anaerobic digester operation: equipment use and biogas leakage	CH_4 and N_2O emissions during digestate curing	N_2O emissions from land application of digestate	Transport to compost facility	Compost operation: fugitive emissions, energy required for composting, fugitive	Wastewater treatment: screening and grit removal, primary	Wastewater treatment: aeration, sludge incineration	Wastewater discharge in water bodies
Food waste		44,00		na	1,29	20,00	1785,74	1,29	44,09	1,29	151,12	39,28	77,48	1,29	152,37	na	na	na
	AD		-136,10							x	x	x	x					
	Composting		-86,34											x	x			
	Incineration		26,39					x	x									
	Landfilling		1707,83		x	x	x											
	SBG		-137,39								x	x	x					
Garden waste		204,75		na	1,29	20,00	892,87	1,29	44,09	1,29	608,42	49,88	44,70	1,29	182,07	na	na	na
	AD		-1099,16							x	x	x	x					
	Composting		423,36											x	x			
	Incineration		23,39					x	x									
	Landfilling		327,18		x	x	x											
	SBG		-1100,45								x	x	x					
Wastewater		15,00		0,01	na	na	na	na	na	na	68,62	na	na	na	na	0,14	0,80	0,01
	Wastewater treatment		0,96	x												x	x	x
	SBG		-314,46	x							x	x	x			x		x
id		(1)	(2)	(3)	(3a)	(3b)	(3b)	(3a)	(3d)	(3a)	(3e)	(3f)	(3g)	(3h)	(3i)	(3j)	(3k)	(3l)
Reference				(US EPA, 2014)		(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)		(OSWER US EPA, 2016b)			(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)		(OSWER US EPA, 2016b)	(US EPA, 2014)	(US EPA, 2014)	(US EPA, 2014)

Table 3-4: LCA for GHG emissions.

Bio-waste	Waste management strategy	CH_4 produced (m^3/ton)	Net GHG emissions ($kgCO_2e$/ton)	GHG offsets (kg CO_2e/ton)							
				Alternative collection system	Increase in soil carbon storage	Increase in soil carbon storage from application of digestate	Avoided utility emissions due to landfill gas combustion	Landfill carbon storage	Avoided utility emissions	Avoided utility emissions due to biogas to energy	Avoided synthetic fertilizer use due to land application of digestate
Food waste		44,00		0,00	-240,00	-11,00	-12,13	-99,21	-19,00	-383,25	-11,02
	AD		-136,10			x				x	x
	Composting		-86,34		x						
	Incineration		26,39						x		
	Landfilling		1707,83				(x)	x			
	SBG		-137,39	x		x				x	x
Garden waste		204,75		0,00	240,00	-9,00	-12,13	-586,98	-22,00	-1783,43	-11,02
	AD		-1099,16		-240,00	x				x	x
	Composting		423,36		x						
	Incineration		23,39						x		
	Landfilling		327,18				(x)	x			
	SBG		-1100,45	x		x				x	x
Wastewater		15,00		na	na	na	na	na	na	-383,25	na
	Wastewater treatment		0,96								
	SBG		-314,46			x				x	x
id		(1)	(2)	(4a)	(4b)	(4c)	(4d)	(4e)	(4f)	(4g)	(4h)
Reference				(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)	(OSWER US EPA, 2016b)

Table 3-5: LCA for GHG emissions

(1) $CH_4\, produced = Waste\, amount \cdot DM \cdot VS\,\%\, of\, DM \cdot Methane\, yield$ (m^3/ton)

Values used are reported in Table 3-6.

Type of bio-waste	DM	VS % of DM	Methane yield	Reference
	%	%	$m^3\, CH_4/$ kg VS	
Food waste	10%	80%	0,55	(Al Seadi, Rutz, et al., 2013) (Åsa Stenmarck et al., 2016)
Wastewater	5%	75%	0,40	(Al Seadi, Rutz, et al., 2013) (Hao et al., 2010)
Garden waste	65%	90%	0,35	("Comparing grass silage harvesting: production differences and cost considerations," n.d.) (Al Seadi, Rutz, et al., 2013)

Table 3-6: values on biogas production by different bio-waste used: Dry Matter (DM), Volatile Solid (VS) and methane.

(2) $Net\, GHG\, emissions = (3) + (4)$ $(kgCO_2e/ton)$

(3) $GHG\, emissioins = \sum_n^{n+1}(3n)$ $(kgCO_2e/ton)$

(3a) $Transport = \frac{(a+b)}{c} \cdot d/e$ $(kgCO_2e/ton)$

Value used are reported in Table 3-7.

Label	Unit	id	Value	Reference
Waste vehicle distance travelled during collection	km	a	30	Estimated
Distance to landfill (/incineration/compost facility/anaerobic digester)	km	b	50	Estimated
Vehicle (diesel) efficiency	km/l	c	21,7	(WRAP, 2010)
Diesel GHG emissions	kg CO2e/l	d	2,63	(Carbon Trust, 2008)
Waste vehicle capacity	ton	e	7,5	(WRAP, 2010)

Table 3-7: values used for traditional MSWM solution, with a diesel vehicle of 7,5 tons direct to waste end-of-life destination

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(3e) $Digester\, operation = (1) \cdot f \cdot CO_2e_{CH_4} + g \cdot CO_2e_{EU27} + h \cdot CO_2e_{EU27} + i \cdot CO_2e_{diesel}$

Label	Unit	Id	Value	Reference
Percent methane loss to leaks	%	f	2	(OSWER US EPA, 2016b)
House electricity demand	kWh/ton	g	18,10	(OSWER US EPA, 2016b)
Dewatering electricity use	kWh/ton	h	0,00	(OSWER US EPA, 2016b)
House diesel fuel use	l/ton	i	5,89	(OSWER US EPA, 2016b)

Table 3-8: anaerobic digester operations (dry digestion - dry matter between 15-30% - usable for all bio-waste considered in SBG)

(4) $GHG\, emissions = \sum_n^{n+1}(4n)$

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4. ENERGY POTENTIAL IN SMART BIOGAS GRID

ORGANIZATION OF CHAPTER

This chapter investigates energy aspects of SBG. This section studies urban land uses that can generate, directly or indirectly, bio-waste to define connection between destination uses of areas with bio-waste potential. Chapter provide also identification of biogas importance in management energy fluctuation, as well as providing perspectives for its utilization.

4.1. Introduction

Key role of Smart Biogas Grid (SBG) is played by biogas. This chapter goes inside SBG, underlining energy aspects, possibilities of biogas utilization in urban context. Indeed, biogas offers a set of opportunities for challenging energy urban utilization in electricity and heating demand for buildings, fuel for transport, opening the way for new energy solutions at urban scale. It is here important to focus on factors that make biogas be a valuable perspective in scaling up energy efficiency and renewable energy, as well as in reaching targets for zero or low greenhouse gas emissions as expected in European directive (European Parliament, 2012). Biogas has numerous end-use applications compared with other renewable energy resources (Urban, 2013; Kaparaju & Rintala, 2013) and in this is where the major potential for it application at district scale lays. District has many different energy demands and the application of RES in urban scenario is marginal despite the highest request (UNEP, 2015). Biogas by bio-waste, exploiting the High Heating Value (HHV) of methane present in biogas, can partially, but in a responsive way, answer at this energy demand. The creation of a district energy system based on biogas thanks to high-density and mixed-use areas typical of cities allow to collect different bio-waste collections and answering to types of energy consumers demand – residential, retail, public buildings – that are located within its boundaries. This is not all. In fact, goal of SBG is beyond the creation of biogas district system, but aims at networking districts to answer promptly at different energy demand profiles of different districts. Mixed-use district is useful to respond to energy demands without high loads for energy grid, but, where district has similar energy demand profiles, networking with other districts is useful to answer to energy requests. In this reflection, RESs have a central role and their contribution must be designed with attention; biogas can help to balance energy fluctuation on renewable sources. SBG opens different perspectives useful to have a balanced and district customized utilization. Biogas, with the chance to provide different energy outputs, allow to personalize its utilization case by case. Understanding these possibilities, it useful to target final aim of biogas production and addressing its utilization at district scale as well as network level. This chapter investigates this potential.

4.2. Methodology

Energy topic in SBG has been investigated in its peculiarity – energy value, energy utilizations – at district level as well in the perspective of network on biogas systems. Chapter contents have been deepened with three different methodological phases:

- ***Literature review*** – papers, documents have been read to focus on energy potential of biogas, its uses and its opportunity to be used in district, both in existing system as well as in sub-systems of district.
- ***Case studies analysis*** – contained in *Annex 1 – Case studies*, this analytic instrument is helpful to analyze existing examples that have used biogas exploiting its potential and other energy efficiency solutions that can be integrated with biogas in SBG projects.
- ***Energy benefits identification*** – analytic analysis of environmental results of SBG application, through calculations of expected biogas energy produced in district. A comparison among possibilities of biogas utilizations and existing energy consumptions are studied.
- ***Mapping of components*** – synthesis of information collected to schematize actors, context, actions and outputs collected on energy issue. This map is a partial contribute to the full understanding of SBG in its complexity.

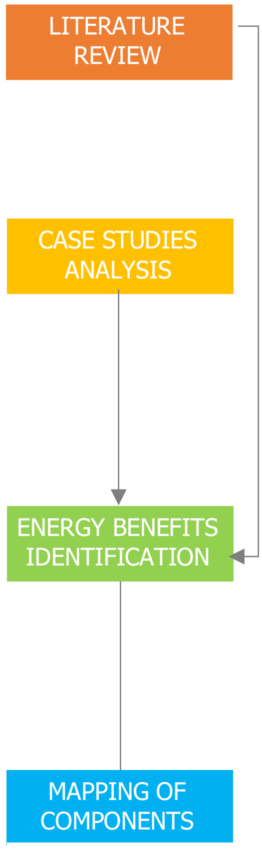


Figure 4-1:synoptic framework of methodology adopted for energy aspects of SBG

4.3. SBG energy product: biogas

Biogas is produced by anaerobic digestion of bio-waste and biogas production is limited by urban bio-waste amount, depending on human and natural reasons as well as by the annual natural biomass regrowth (Al Seadi, Rutz, Janssen, & Drosg, 2013). Food waste, wastewater and garden waste are valuable for AD, but their viability for biogas depends on local characteristics and collection capacity of suitable biomass feedstock within district. Understanding availability of feedstock at district scale is mandatory to ensure continuous, stable and economically sustainable operations of biogas plant and having an energy vector, as biogas, widely usable. At this aim, some elements are to be considered to quantify biogas production potential:

- ***typologies of bio-waste producers*** – district users affect bio-waste production because they direct people and green presence in the district. Built area uses – residential, retail, public activities, factories, etc. – and other land uses – green rather than brown fields, or infrastructural areas – addresses bio-waste production; a direct analysis of these land uses can address decisions to district to study on a SBG perspective.
- ***amount of bio-waste collectable*** – bio-waste assesses the potential of AD plant at district scale, but its amount is subject to percentage of waste collectable. People of the district must be weighted with people attending SBG project to estimate food waste and wastewater, as well as garden property – public, private, semipublic – that affect yard waste collectable.
- ***bio-waste's methane yield*** – different bio-waste has different methane yields. Methane, as energy component of biogas, should be evaluated case by case, testing in laboratory bio-waste composition and consequently methane yield in biogas.

This research, recognizing the importance to estimate case by case biogas potential, in line with aim to understand SBG at urban scale, generalize the consideration on bio-waste produced and methane yield contained, independently of location, people behaviors and vegetation planted; it is demanded to specific further steps understanding the true energy potential of specific district identified for the realization of SBG.

4.3.1. Bio-waste from land uses: meanings related to energy district morphology

Energy subject of this research is biogas system inside urban areas; understanding which districts are the most suitable on SBG perspective is crucial. Considering bio-waste typologies, it appears clear that population density is a major factor to determine biogas bio-waste potential for food waste and wastewater as well as green areas are for garden waste; from an energy point of view this is the right approach, but it is interesting to understand which district typology is more suitable to produce biogas, going beyond the simple population density, to better understand the relation between energy potential and other factors that can affect SBG development. Realizing SBG where bio-waste is produced, district has to be considered in its full set of characteristics because waste is not brought somewhere else for AD, but it is treated, and used locally for its potential; a deeper study on district typology can addresses these analyses.

Despite different uses, here it is considered important to restrict analysis to residential district; the reason it is high-density of these urban areas. Four district typologies, considered typical for European, and Italian one in particular, urban planning are taken into considerations (Pracucci & Theo Zaffagnini, 2016):

- ***Compact district*** – typical of historical nucleus and central city area, compact form is a consolidated urban pattern with high density built area. The buildings are based on aggregation from the fundamental cell of 5/6 with a depth of from 10/12 m to 15/18m, with single-family and multifamily buildings which host 1 or 2 household's units. A maximum of 4 floors with the ground floor designed to service activities. (Figure 4-2)
- ***Peri-urban district*** – part of the city of nineteenth century developed around the historical nucleus, with mean density building. The buildings have a width of 20/22 m and a depth of 10/12m, maximum 4 floors with 2 housings for each store. (Figure 4-3)
- ***Suburban district with multifamily buildings*** – urban cluster characterized by a mean density built area, but high inhabitants concentration, with multifamily high rise buildings (4/6 floors), with 4 housings for store. (Figure 4-4)
- ***Suburban district with single-family buildings*** – urban cluster characterized by a low density with single or double houses on 2 or 3 floors, which host maximum 1 or 2 household's units. (Figure 4-5)

Figure 4-2: Compact district.

NOTE: In the bar on the upper right, the total district area is in a black frame and land uses are in colors. In red (or darker grey) the floor area and the percentage reported is the ratio between floors area to district area (that is why the value can be more than 100%)

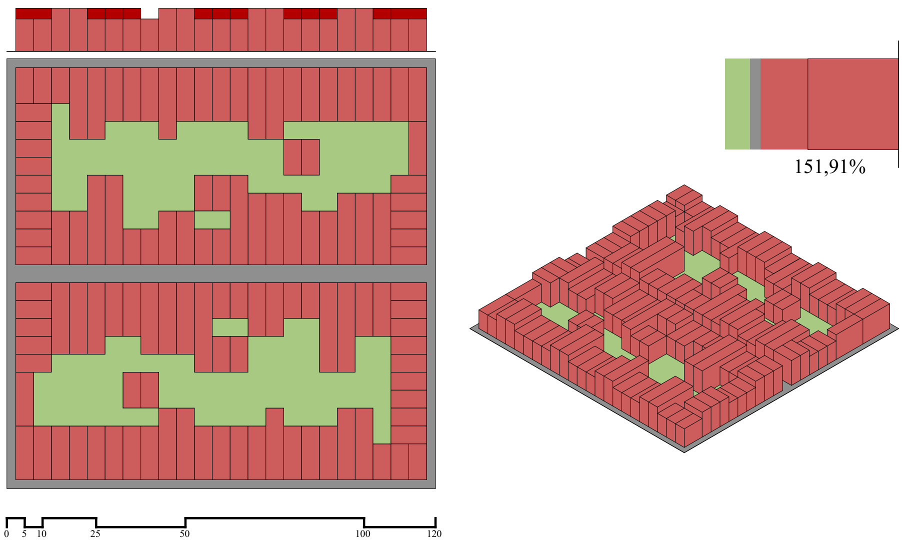
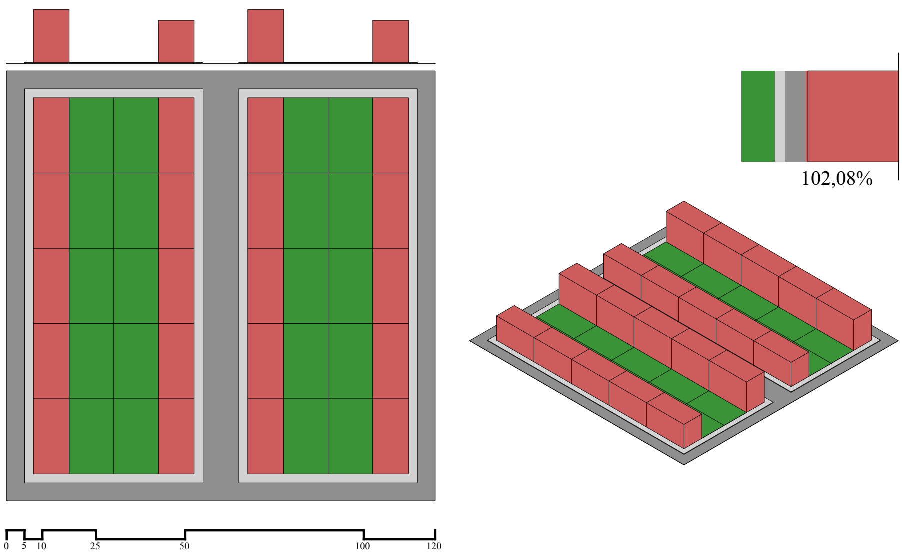


Figure 4-3: Peri-urban district.



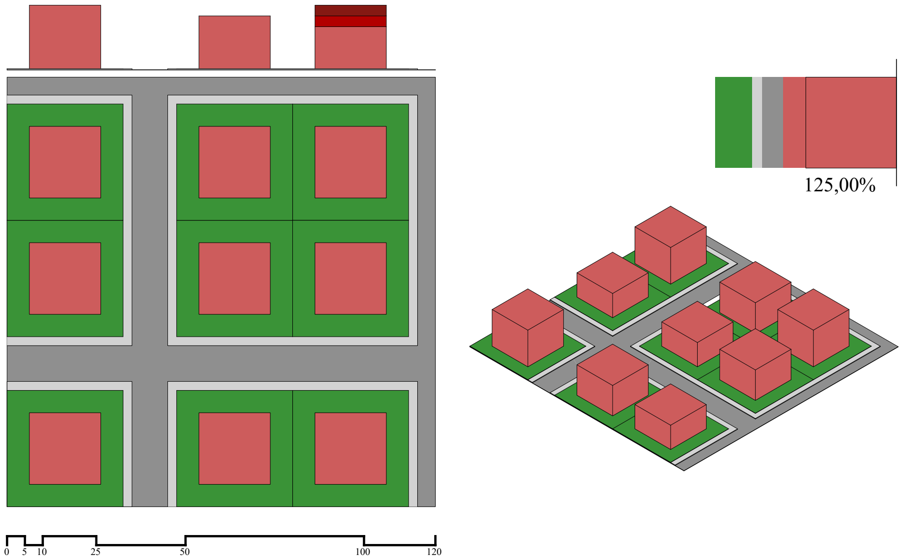


Figure 4-4: Suburban district with multifamily buildings

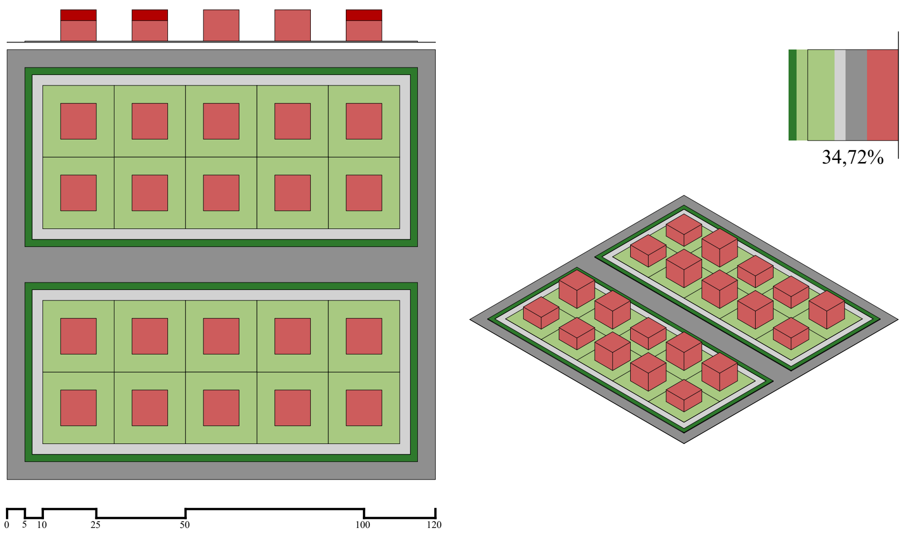


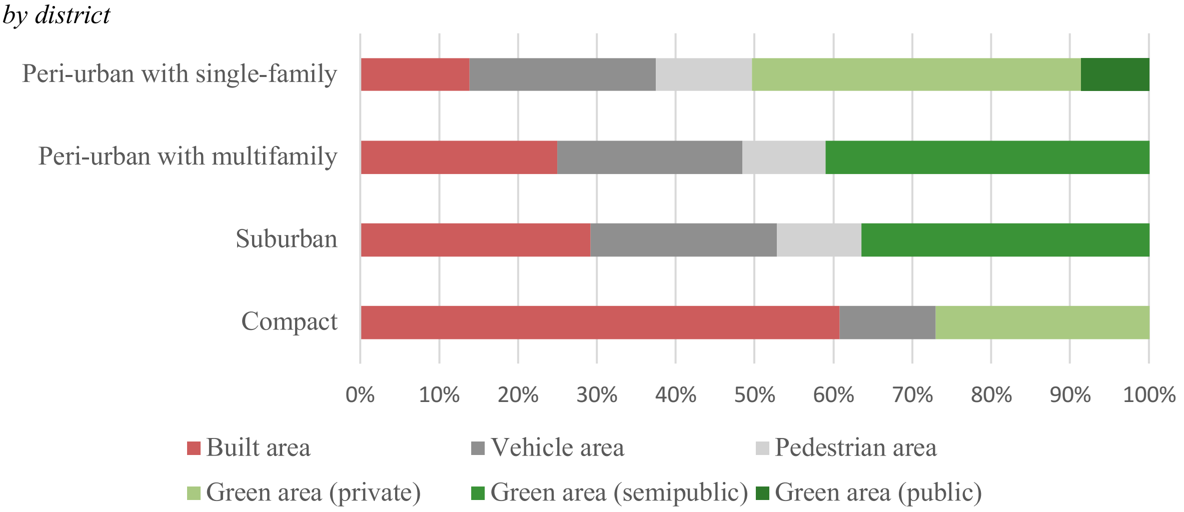
Figure 4-5: Suburban district with single-family buildings

Districts as models of reference used are not exhaustive, but they describe a set of parameters helpful for preliminary and general considerations on energy potential in relation to parameters – built, green areas, population density – that affect biogas production. *Table 4-1* reports measures typical of district models based on a common matrix of 120x120m, equal to 14.400 m^2; Figure 4-6 is a useful graphic to show differences between districts studied.

Table 4-1: land uses and their amount district by district.

	Label	Unit	District typology			
			Compact district	**Peri-urban district**	**Suburban district with multifamily buildings**	**Suburban district with single-family buildings**
District geometry	District area	m^2	14.400,00	14.400,00	14.400,00	14.400,00
	Built area	m^2	8.750,00	4.200,00	3.600,00	2.000,00
	Average building height	m	10,50	10,50	15,00	10,50
	Building volume	m^3	91.875,00	44.100,00	54.000,00	21.000,00
	Vehicle area	m^2	1.750,00	3.400,00	3.375,00	3.400,00
	Pedestrian area	m^2	0,00	1.550,00	1.518,75	1.752,00
	Infrastructural area (total roads)	m^2	1.750,00	4.950,00	4.893,75	5.152,00
	Green area (private)	m^2	3.900,00	0,00	0,00	6.000,00
	Green area (semipublic)	m^2	0,00	5.250,00	5.906,25	0,00
	Green area (public)	m^2	0,00	0,00	0,00	1.248,00
	Green area (total)	m^2	3.900,00	5.250,00	5.906,25	7.248,00
Land uses	Built area (share)	%	60,76%	29,17%	25,00%	13,89%
	Vehicle area (share)	%	12,15%	23,61%	23,44%	23,61%
	Pedestrian area (share)	%	0,00%	10,76%	10,55%	12,17%
	Infrastructural area (total roads) (share)	m^2	12,15%	34,38%	33,98%	35,78%
	Green area (private) (share)	%	27,08%	0,00%	0,00%	41,67%
	Green area (semipublic) (share)	%	0,00%	36,46%	41,02%	0,00%
	Green area (public) (share)	%	0,00%	0,00%	0,00%	8,67%
	Green area (total) (share)	m^2	27,08%	36,46%	41,02%	50,33%

Figure 4-6: graphic to show distribution of land uses district by district



The aim of this part of the research is understanding district energy potential only going over the population density. Even if bio-waste production derives by population density, this is a variable parameter depending on economic and social cycles, but affected by urban morphology. Cities patterns change more slowly than population density and for this reason a general analysis on urban morphology and population density is an interesting approach to energy potential identification because it is an out of time study useful to appreciate the district area where SBG is realized. Therefore, starting from district physical characteristics, population density, fundamental to know bio-waste production, and green area are considered as parameters to quantify bio-waste. Some reflections are made considering calculation presented in *Table 4-2* and estimated in *Table 4-3*.

Table 4-2: formula and data used in Table 4-3

Label		Unit	Id	Reference
District	Area	m2	(1)	model survey
Land use	Built area	m2	(2)	model survey
	Share built area	%	(3)	(1)/(2)
Population density	Avg. residential floors	nr	(4)	model survey
	Housings for floor	nr	(5)	model survey
	Housings for buildings	nr	(6)	(4)*(5)
	Tot. buildings	nr	(7)	model survey
	Tot. housings	nr	(8)	(6)*(7)
	Floor area	m2	(9)	(2)*(4)
	Floor ratio	%	(10)	(9)/(1)
	Household size	pp/hsg	(11)	(Eurostat, 2014)
	Population	nr	(12)	(8)*(11)

Table 4-3: data on district parameters

Label		Unit	District typology			
			Compact district	**Peri-urban district**	**Suburban district with multifamily buildings**	**Suburban district with single-family buildings**
District	Area	m^2	14.400	14.400	14.400	14.400
Land use	Built area	m^2	8.750	4.200	3.600	2.000
	Built area	%	60,76%	29,17%	25,00%	13,89%
Population density	Avg. residential floors	#	2,5	3,5	5	2,5
	Housings for floor	#	0,75	2	4	0,75
	Housings for buildings	#	1,875	7	20	1,875
	Tot. buildings	#	122	20	9	20
	Tot. housings	#	228,75	140	180	37,5
	Floor area	m^2	21.875	14.700	18.000	5.000
	Floor area	%	151,91%	102,08%	125,00%	34,72%
	Household size	pp/hsg	2,3	2,3	2,3	2,3
	Population	pp	526	322	414	86

'*Compact district*' has the higher density, but the less amount of green area; otherwise '*suburban district with single-family buildings*' has the minor density, but the greatest green surfaces. '*Peri-urban district with multifamily buildings*' join high density with the presence of green area; this is interesting because it can provide more bio-waste typologies and spaces for installation of technological components of the systems (presented in chapter 6).

Next step is the analysis of bio-waste potential of districts. Table 4-4 reports data of bio-waste production divided into bio-waste typologies with the specific methane yield of reference.

Table 4-4: feedstock of AD. Data on Dry Matter, Volatile Solid and methane yield of urban bio-waste. This data are useful to estimate energy biogas potential used in SBG

Type of feedstock	**Origin**	**Yearly production (kg/pp(m^2)/yr**	**DM (%)**	**VS % of DM**	**Methane yield (m3 CH4/ kg VS)**	**Reference**
Food waste	Household	92	10%	80%	0,55	(Al Seadi et al., 2013; Åsa Stenmarck et al., 2016)
Wastewater	Black water	562,1	5%	75%	0,40	(Al Seadi et al., 2013; Hao, Novotny, & Nelson, 2010)
Garden waste	Grass	2	65%	90%	0,35	("Comparing grass silage harvesting: production differences and cost considerations," n.d.; Drosg, Braun, Bochmann, & Al Saedi, 2013)

Bio-waste amount, estimated in Table 4-5, is expressed in tons and offers some first considerations. The major contributor in bio-waste management derived by people wastewater, and secondly by food waste. A consideration is about garden waste, considered in calculation only grass because of the impossibility to standardize model of reference with garden design – grass, bushes, trees, flowers – the research underestimated for sure quantity of garden waste. Another parameter to consider is seasonal variety that should be taken into consideration in the case of a feasibility study. Food waste can indeed vary due to seasonal changes with consequential effects on whole bio-waste collection and, consequently, on biogas potential (Drosg et al., 2013). For these reasons, a case by case analysis should be conducted to understand the potential of garden waste as well as the one food waste and its seasonal valuation.

Label	Unit	District typology			
		Compact district	**Peri-urban district**	**Suburban district with multifamily buildings**	**Suburban district with single-family buildings**
Food waste	t/pp/yr	48,40	29,62	38,09	7,94
Wastewater	t/pp/yr	295,74	181,00	232,71	48,48
Garden waste	t/m^2/yr	7,80	10,50	11,81	14,50

Table 4-5: bio-waste production district by district

4.3.2. Biogas from bio-waste

Defined bio-waste collectable, the amount of methane produced and contained in biogas should be estimated. This process needs to be accompanied with a specific study on chemical composition of bio-waste, in particular the one related to human waste. While in fact for garden waste the identification area of interest, its extension and its vegetation are enough to have a precise estimation of bio-waste and methane yield, food waste and wastewater are affected by local food diet and it is necessary a precise analysis of waste composition to define the methane yield. As already mentioned, this is not a research focused on analysis of different bio-waste from a chemical composition, and for this reason DM, VS and methane yield reported Table 4-4 are considered valuable for analysis here conducted. With these limitations, methane produced by different wastes in each district is estimated and reported in the following Table 4-6.

Table 4-6: methane produced district by district

Label	Unit	District typology							
		Compact district		**Peri-urban district**		**Suburban district with multifamily buildings**		**Suburban district with single-family buildings**	
Methane from food waste	m^3	2.129,77	26%	1.303,46	21%	1.675,87	22%	349,14	9%
Methane from wastewater	m^3	4.436,07	54%	2.714,94	44%	3.490,64	46%	727,22	18%
Methane from garden waste	m^3	1.597,05	20%	2.149,88	35%	2.418,61	32%	2.968,06	73%
Total methane	m^3	8.162,89		6.168,27		7.585,12		4.044,41	

The results offer some considerations. '*Compact district*' is the model with highest methane production. This data is affected by higher density and indeed '*suburban district with single-family buildings*' has the lowest amount of methane. Wastewater has, for data of reference used, highest methane yield concentration and for this reason is a major contributor in total methane produced. Garden waste, despite it is underestimated, represents 73% of total methane produced in *suburban* *district with single-family buildings*', underlining as green area can be a precious resource. Indeed '*methane from garden waste*' can increase its amount in the analysis with case by case survey, while food waste and wastewater cannot be maximized in no way. In this perspective, '*suburban district with multifamily buildings*' could achieve better performances being actually at 32% of methane produced by garden waste.

In energy evaluation, a non-role is the one of infrastructural areas. In fact, they are no bio-waste producers and their presence affect the final results. However infrastructural areas can have a central role to host AD plant and other technological components of SBG, and therefore their contribution should be evaluated as important as the ones of built or green areas, allowing systems and sub-systems installation and improvement; *chapter 6* takes care of these aspects.

4.3.2.1. Solutions for methane yield increase

Increase of methane yield does not depend only on bio-waste collected. Indeed, there are some solutions helpful to increase methane yield during AD; this section underlines these opportunities, demanding to deep disciplinary studies the performances achieved with different solutions adopted. Two strategies to increase methane yield are realizable (Banks & Heaven, 2013; LEAP - Local Energy ADventure Partnership, n.d.):

- ***Mechanical*** – solutions to improve degradability of bio-waste through the increase of feedstock surface area thanks the installation of breaker mill or in pre-feed system to store feedstock in caddies for a few days;
- ***Chemical*** – improvement of carbon stored in bio-waste treated in AD to have higher yield of methane. In this case bio-waste used is not limited to food waste, wastewater by households or garden waste from green areas utilization in AD, but it includes utilization of natural booster from food and beverage industry – soya bean oil and margarine, fish oil from fish processing industries, alcohol and sugar residues, waste from

juice, oil from grapes, olives, apples and other fruits – that can be activities done close to district where SBG is realized.

In this two ways, through technological components and involvement of local activities of district other than householders and catering ones, SBG improves its methane potential and, consequently, the perspective in its energy utilization.

4.3.3. Energy from Biogas

SBG is a set of possibilities and energy utilization is part of this frame. Working on specifics of each district it is important to respond to peculiar district energy demand to exploit in the most efficient way the methane energy value – HHV of 10,5 kWh/m^3 (Murphy & Thamsiriroj, 2013). Therefore, it is central to understand the full energy potential of biogas utilization in different energy systems that can be run using biogas in its multiple facets. As energy vector, biogas can be used with various energy outputs ("Natural and biogas filling stations," n.d.; Pöschl, Ward, & Owende, 2010; Verhoog, 2013; Wellinger, Murphy, & Baxter, 2013):

- ***electric generation*** – primary energy source, it can be used as alternative to electricity supplied by traditional grid network for functions of electric devices;
- ***heat generation*** – HHV of methane is ideal to for heat generation to warm spaces – public or private spaces – as well as provide the thermal energy requested by AD;
- ***biofuel*** – upgraded and clean, biogas becomes a biomethane useful for injection into grid, as well as for biofuel for methane vehicle.

With these energy different opportunities, biogas is a useful source to respond to district energy demand assuming to neighborhood needs can be identified and consequently establish the most valuable solutions.

4.3.3.1. Energy systems generation

The over mentioned energy outputs are obtained by a set of energy generation systems that are below indexed and which efficiencies are synthetized in Table 4-7 (Da Costa Gomez, 2013):

- ***Biogas boiler*** – low efficiency system with possibility to modify a traditional boiler;
- ***Combined Heat and Power (CHP) plants*** – produce electricity and heat, and its efficiency is the sum of electrical and thermal efficiencies is 85-90%, with an electrical efficiency around 35%. Three generators systems for small scale plant are valuable: *CHP engines*, *CHP stirling engines*, *CHP micro turbines*.
- ***Fuel cells*** – system that generate only electricity is a zero emissions generator. Actually, it is in a phase of development, but it is commonly considered as the energy generation system of the future.
- ***Upgrading system to biomethane/biofuel*** – installation of gas upgrading system that generate a gas with approximately 98% of methane usable in all applications known for natural gas and sent in *grid-injection into a natural gas grid*, or with a percentage of methane of 70% and used in *vehicle fuel supply*.
- other minor use – these are direct utilization of biogas produced, but not represent profitable solutions. These uses are:
    - *cooking* – direct utilization in burco tea urn or coking hob;
    - *lighting* – direct utilization to light spaces;
    - *refrigeration* – perspective of utilization of biogas in refrigerating systems, but not yet investigated properly.

Among these generation systems, two different models of utilization of biogas emerges and settle two answer at energy demand (Kaparaju & Rintala, 2013):

- *stationary* – model based on energy generation where biogas is produced in systems like boilers, CHP, fuel cell or refrigeration system;
- *non-stationary* – model based on energy generation moving biogas from where it is produced through vehicle run by biomethane or injecting gas in network or distributed in mobile storage units.

These two models are not necessarily independent from each other, but can be integrated, in order to maximize full utilization of biogas depending on seasonal variability of energy demand (Svensson, 2013), alternating heat production and electricity demand with e-mobility or grid injection. Indeed, energy demand needs to be compared with the opportunity to use an energy output rather than another one, considering also related efficiencies[7]. Indeed, energy demand needs to be compared with the opportunity to use an energy output rather than another one, also considering related efficiencies, with evaluations done in relation to needs and context factors than address SBG promotion.

Table 4-7: biogas energy systems and efficiency in biogas utilization Established the amount of waste is possible to design biogas system.

Energy generator	Energy system efficiency				Reference
	Electricity	Heating	Methane	Other	
Boilers		33%			(Pandolfi, 2016)
CHP engines	37%	53%			(Kaparaju & Rintala, 2013)
CHP stirling engines	25%	70%			(Kaparaju & Rintala, 2013)
CHP micro turbines	30%	70%			(Kaparaju & Rintala, 2013)
Small-scale fuel cells	50%				(Pandolfi, 2016)
Refrigeration					(“Technology Radar - WISIONS of Sustainability,” n.d.)
Grid injection: natural gas equivalent			100%		(Urban, 2013)
Biofuel for transport			100%		(“Natural and biogas filling stations,” n.d.)
Biogas cleaning/upgrade - methane loss			10%		(Urban, 2013)
Cooking			100%	0,6 m^3/pp/day	(“Anaerobic Digestion (Small-scale) | SSWM,” 2014)
Lighting			100%	0,1m^3/hr	(“Biogas Appliances - energypedia.info,” n.d.)

4.3.3.2. SBG (sub-)systems

To conclude this section dedicated to energy utilization of biogas, some aspects related to systems and sub-systems involved have to be taken into consideration. While indeed to use biogas there are energy systems over mentioned, other existing or realizable systems and sub-systems should be used to support its uses. The network of systems

[7] For example, the efficiency of clean biogas production is higher than that of electricity and heat production from biogas, because it uses all the energy potential of methane contained in biogas. However, its utilization should be evaluated and its only practicable for new districts because a separate biogas network is needed and it is not economically feasible to create a biogas network when there is already a natural gas network present and it is too expensive to justify switching to clean biogas consumption (Verhoog, 2013).

depends on energy outputs and its final use. Considering for example heating produced by biogas, it can supply directly building for heating or hot water or be part of district heating/cooling systems; while in the first case heating it is used where it is produced, in the second one there is a system of underground pipelines from a central station that brings hot water where needed. District heating systems can be integrated with other systems – renewable energy plants – to fully satisfy energy demand. In such a case the existence of a district heating system in a district can affect biogas utilization.

In the same way, an integration between different systems is requested for biofuel utilization. The upgrading plant necessary for biofuel generates biogas for methane vehicles, but it is requested also to a biomethane supply station, that could be complemented with a car pooling station.

SBG goes beyond the only AD plant system, but needs for energy utilization to integrate components one with another to use in the best way the energy output achievable by biogas opportunities. The choice of which energy outputs depend on local systems and sub-systems still available because they can reduce capital and management costs, on district citizens needs and on benefits expected by energy use.

4.3.4. Energy savings

Estimating energy savings guaranteed by biogas energy outputs allows to weigh better the choice to make, because not all biogas utilizations achieve the same results. Here it is interesting to provide a comparison among energy systems' savings to frame their usefulness in district in line with *calculation of GHG emissions saved*, of Chapter 3. Following this approach (Pracucci, 2017), it is proposed an evaluation between biogas energy systems. Emissions of these systems are "0" and savings are estimated in comparison with source emissions they replace – grid electricity, methane utilization, gasoline vehicle[8]

[8] As vehicle of reference has been considered a gasoline vehicle ("Volkswagen," 2017) with 0,252 kg of CO_2/kWh of emissions.

and lighting emissions[9]. Emissions saved using biogas is calculated with formula below.

$$GHG\ emissions\ saved\ (CO_2e) = \sum energy\ output\ (kWh) \cdot source\ emissions \left(\frac{CO_2e}{kWh}\right)$$

GHG emissions are a first comparison among energy outputs; a more visual description of results achievable by each output is made with energy equivalences. GHG emissions measurement equivalent emissions are translated into tangible terms understandable by not specialized person, useful to communicate SBG strategy to people engaged in the project. Energy equivalences are:

- ***Kilometers driven by a methane vehicle*** – calculation of kilometers driven by a vehicle run by methane with consumption of 5,31/100km ("Volkswagen," 2017),

$$km\ driven\ (km) = \frac{GHG\ emissions\ (CO_2e)}{methane\ vehicle\ emissions(\frac{CO_2e}{km})}$$

- ***Homes' energy use for one year*** – calculation of homes supplied by energy produced considering 4,15 CO_2e/dwelling ("CO2 emissions per dwelling, climate corrected (EU-27)," n.d.),

$$home\ supplied\ (\#) = \frac{GHG\ emissions\ (CO_2e)}{household\ emissions\ (\frac{CO_2e}{dwelling})}$$

- ***Number of light-emitting diode bulbs (LED) replaced*** – considering European ban of incandescent bulbs, biogas is considered as substitute of LED bulbs; the positive results is underestimated if compared with other part of the world where incandescent bulbs are allowed. For calculation of this contribution, has been considered a LED power of 9 watts assuming an average daily use of 3 hours per day,

$$LED\ bulbs\ (\#) = \frac{GHG\ emissions\ (CO_2e)}{LED\ (W) \cdot hours\ on\ \left(\frac{hrs}{yr}\right) \cdot electric\ grid\ emissons\ \left(\frac{CO_2e}{kWh}\right)}$$

[9] In the case of GHG emissions from biogas used for lighting, the light hours allowed by biogas utilization are calculated considering 0,1/0,15 m^3 of biogas per hours requested and a comparison with LED bulbs (mandatory in EU) energy demand for the same amount of hour is done.

$$GHG\ emissions\ (CO_2e) = LED(W) \cdot \left[\frac{biofuel\ (m^3)}{\text{lighting demand}\ \left(\frac{m^3}{hrs}\right)}\right] \cdot grid\ emissions\ (CO_2e)$$

- ***Calculation of people fed*** – calculation of people fed per day in a year is estimated, considering that there is a daily methane consumption for cooking of 0,6 m^3 per person ("Anaerobic Digestion (Small-scale) | SSWM," 2014), equal to 425,41 kg of CO_2e per person per year.

$$People\ fed\ (\#) = \frac{GHG\ emissions\ (CO_2e)}{cooking\ request\ \left(\frac{CO_2e}{pp \cdot year}\right)}$$

The following tables report energy outputs and energy equivalences for each district taken into consideration.

Independently of the district considered, GHG emissions are a good parameter to standardize energy positive results of different energy generation systems. For this reason, CHP systems appear to be the most proficient system to exploit biogas better the other generation system. The production of electricity and heating in CHP generator optimize biogas and improves the life cycle assessment of that plant in particular following daily and season variability of energy demand. Relevance of CHP does not exclude the utilization of other generations systems, especially the ones that produce biomethane and biofuel. In fact, in a logic of SBG and reading of district context and needs, it is important an evaluation case by case to design energy systems in line with district necessities.

Energy equivalences offered an interesting scenario that shoe how profitable are different energy systems in substitution of existing energy sources used with the same aim. It is confirmed the efficiency of CHP – engines CHP in particular – other than other systems. The results show that the amount of biogas produced can not supply all the district energy demand, but it can provide energy for some dwellings, why not offering solutions to face some specific energy, as well as economic or social, poverty conditions. For sure it is possible to consider not prosecutable boiler and lighting uses that are not efficient systems, in particular lighting that must be discarded.

Compact district									
Energy system	**Unit**	**Energy saved**			**GHG emissions saved (MTCO$_2$e)**	**Energy equivalence**			
		Electricity	**Heating**	**Biofuel**		**Km driven**	**Homes supplied**	**LED bulbs**	**People fed**
Boilers	kWh/yr		27.856		5,15	45.807	1,24	974	12
CHP engines	kWh/yr	31.284	44.998		25,12	223.327	6,05	4.747	59
CHP stirling engines	kWh/yr	21.428	59.997		22,61	200.943	5,45	4.272	53
CHP micro turbines	kWh/yr	25.285	59.569		24,60	218.649	5,93	4.648	58
Small-scale fuel cells	kWh/yr	42.855			23,01	204.562	5,55	4.349	54
Refrigeration					not available				
Grid injection: natural gas equivalent	kWh/yr			77.139	14,27	126.851	3,44	2.697	34
Biofuel for transport	kWh/yr			77.139	19,44	172.792	4,68	3.673	46
Cooking	kWh/yr			85.710	15,86	140.946	3,82	2.996	37
Lighting	kWh/yr			85.710	0,32	2.805	0,08	60	1

Table 4-8: energy outputs and energy equivalences of Compact district

Suburban district									
Energy system	**Unit**	**Energy saved**			**GHG emissions saved (MTCO$_2$e)**	**Energy equivalence**			
		Electricity	**Heating**	**Biofuel**		**Km driven**	**Homes supplied**	**LED bulbs**	**People fed**
Boilers	kWh/yr		21.049		3,89	34.614	0,94	736	9
CHP engines	kWh/yr	23.640	34.003		18,99	168.757	4,57	3.587	45
CHP stirling engines	kWh/yr	16.192	45.337		17,08	151.842	4,12	3.228	40
CHP micro turbines	kWh/yr	19.106	45.013		18,59	165.222	4,48	3.512	44
Small-scale fuel cells	kWh/yr	32.383			17,39	154.577	4,19	3.286	41
Refrigeration					not available				
Grid injection: natural gas equivalent	kWh/yr			58.290	10,78	95.855	2,60	2.038	25
Biofuel for transport	kWh/yr			58.290	14,69	130.570	3,54	2.776	35
Cooking	kWh/yr			64.767	11,98	106.506	2,89	2.264	28
Lighting	kWh/yr			64.767	0,24	2.120	0,06	45	1

Table 4-9: energy outputs and energy equivalences of Suburban district

Peri-urban district with multifamily									
		Energy saved			GHG emissions saved ($MTCO_2e$)	Energy equivalence			
Energy system	Unit	Electricity	Heating	Biofuel		Km driven	Homes supplied	LED bulbs	People fed
Boilers	kWh/yr		25.884		4,79	42.565	1,15	905	11
CHP engines	kWh/yr	29.070	41.813		23,35	207.520	5,63	4.411	55
CHP stirling engines	kWh/yr	19.911	55.751		21,01	186.720	5,06	3.969	49
CHP micro turbines	kWh/yr	23.495	55.352		22,86	203.173	5,51	4.319	54
Small-scale fuel cells	kWh/yr	39.822			21,38	190.083	5,15	4.041	50
Refrigeration					not available				
Grid injection: natural gas equivalent	kWh/yr			71.679	13,26	117.873	3,20	2.506	31
Biofuel for transport	kWh/yr			71.679	18,06	160.562	4,35	3.413	42
Cooking	kWh/yr			79.644	14,73	130.970	3,55	2.784	35
Lighting	kWh/yr			79.644	0,29	2.607	0,07	55	1

Table 4-10: energy outputs and energy equivalences of Peri-urban district with multifamily

Peri-urban district with single-family									
		Energy saved			GHG emissions saved ($MTCO_2e$)	Energy equivalence			
Energy system	Unit	Electricity	Heating	Biofuel		Km driven	Homes supplied	LED bulbs	People fed
Boilers	kWh/yr		13.802		2,55	22.696	0,62	482	6
CHP engines	kWh/yr	15.500	22.295		12,45	110.650	3,00	2.352	29
CHP stirling engines	kWh/yr	10.617	29.726		11,20	99.560	2,70	2.116	26
CHP micro turbines	kWh/yr	12.528	29.514		12,19	108.333	2,94	2.303	29
Small-scale fuel cells	kWh/yr	21.233			11,40	101.353	2,75	2.155	27
Refrigeration					not available				
Grid injection: natural gas equivalent	kWh/yr			38.220	7,07	62.850	1,70	1.336	17
Biofuel for transport	kWh/yr			38.220	9,63	85.612	2,32	1.820	23
Cooking	kWh/yr			42.466	7,86	69.834	1,89	1.485	18
Lighting	kWh/yr			42.466	0,16	1.390	0,04	30	0

Table 4-11: energy outputs and energy equivalences of Peri-urban district with single-family

4.3.5. Biogas as opportunity to overcome RES fluctuation

Biogas is limited by human activity and natural green regrowth, but among other RES applicable in urban context, it is production does not depend on variability of natural elements. While photovoltaic and solar collection depend on daily light, wind on ventilation currents, biogas is available at any time of da day, responding punctually to consumers' demand in particular when used in CHP plant (UNEP, 2015). This is a great advantage in a district and network level and it is particularly connected to '*on-grid*' as well as '*off-grid*' systems. European policies issued by countries for the promotion of RES, usually guarantee a connection to existing grid both for electricity grid and in such a way, certainty to use all the energy produced is achieved and the producer has guaranteed his economic profits. Systems so identified are '*on-grid*' and represent the most appealing solutions because prevent to lose energy produced by renewable sources. Otherwise in some cases and context conditions, it is mandatory the realization of '*off-grid system*' '*Off-grid system*' answer to some conditions – isolated villages from network in remote places, islands – and can find a good support for their energy generation and use. SBG strategy supports both scenarios. Biogas can compensate '*on-grid*' or '*off-grid*' energy fluctuation in energy production answering at energy demand in efficient way. Even if biogas can be used as base energy load to guarantee a minimum energy production, its peak load potential is more interesting. '*On-grid*' as well '*off-grid*' systems based on RES, suffer of energy fluctuation because photovoltaic depend on daylight while wind energy is affected by ventilation condition. Electricity produced, but not use by RES is sold in '*on-grid*' system to energy provider through grid network with loss typical of network, while is stored in batteries in '*off-grid*' system, having an energy cost related to battery efficiency. For this reason, it is preferable to use RES energy when it is produced; this is not for biogas. As gas energy vector, biogas can be stored without loss of its energy potential and be used when needed. This means that when other RES cannot answer at energy demand – for natural condition or for system production limit –, biogas can cover energy peak load through its utilization. Consequently, SBG can join different district energy sources, using biogas as key instrument to integrate energy produced by other RES – photovoltaic, solar collector, wind – creating a network of RES that exploit biogas when requested. Biogas is the only versatile energy renewable source and it should be considered as part of a more complex system of sustainable renewable energy supply; SBG works at this aim guaranteeing a synergy between biogas energy outputs – especially for CHP case, but also for fuel cell – and energy demand, provide energy when other RES are less able to.

4.4. Conclusion

Energy aspects to support SBG are relevant. Biogas can be converted into electricity, heat, biomethane and biofuel and used locally where it is produced or wherever grid network – gas or electricity – is able to bring it. Biogas thanks to the possibility to be used also for peak energy load, can pursuit energy efficiency practices in an efficient way independent of daily and season variability of energy demand or natural context conditions, integrating in such way existing (or designed) RES – photovoltaic, solar collector wind – and sustainable projects – car sharing, e-mobility. Among these perspectives, the evaluation of which energy systems installed is demanded to specific district conditions and energy demand analysis. In particular a study of district bio-waste amount identify compact district and suburban district with multi-family buildings as the most appealing to have higher amount of biogas produced; chapter 6 should investigate the possibility to host technological components properly.

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5. Regulatory framework in Smart Biogas Grid

REGULATORY FRAMEWORK

Organization of chapter

Aim of this chapter is the analysis of regulatory framework that concerns SBG design, development and diffusion. The chapter analyses the vertical interconnections of normative from European to local governments, taking into consideration waste norms, as well as energy ones.

5.1. Introduction

Complex and uncommon technological systems as SBG, need to find in regulatory framework their legitimacy and support. Since its very beginning, SBG works on specific goals and strategies assessed by environmental and energy aspects that have been issued by institutions at different scales; understanding their role, importance and implementation perspectives is a step helpful to adress SBG development. Regulatory framework does not concern only an institutional level, but it is the result of overlapping and challenge of different scale – European, national, regional, local – that should interact and be integrated one with the other. The development of new Energy Efficiency practices, as fixed by 2020 EU guidelines towards the "20-20-20" European targets (European Commission, 2011), finds in the regulatory framework key points, strategies, schemes to support goals set. Understanding regulatory framework that involves SBG is not secondary in this research. Indeed, SBG is a complex district energy system that must face different norms, regulations, targets, limitations, because of its complexity and completeness that move attention to multidisciplinary aspects. As already mentioned, SBG is uncommon approach in RES, and biogas is used as tool to develop and implement features characteristic of disciplines other than energy ones (European Commission, 2015). For this reason, this chapter, starting with an analysis of the energy regulatory framework, tries to go deep down the whole regulatory framework that affects SBG, its design, its promotion and its realization. Different disciplinary aspects are treated – waste, energy, fertilizer, authorization, urban plans –, all set of norms that can contribute and obstruct biogas development and diffusion. SBG works in the middle among these norms, obliging to challenge specific frameworks and institutional jurisdiction in the research of a vertical and horizontal integration between normative frames set.

5.2. Methodology

This chapter takes into consideration regulatory framework that affects SBG, both at disciplinary level as well as to intuitional level of issuance. The methodological instruments used are:

- ***Literature review*** – papers, law, regulations, resolutions have been read to focus on norms deepen in this chapter (energy, waste, taxation, incentivizing schemes) to understand normative frame of reference of SBG. A research at different scale has been conducted – European, national, local – to enlarge considerations and offer a wider understanding of regulatory framework.
- ***Case studies analysis*** – contained in *Annex 1 – Case studies*, this analytic instrument is useful to understand how and which regulatory framework have been applied and have affected at AD in urban area, digestate application, as well as other sustainable solutions. Beyond regulatory framework review, the real implementation is valuable to evaluate norms' efficiency marking success or failure of projects.
- ***Institutional legitimacy and regulatory guidelines*** – an analysis on aspects that support SBG among institutions has been elaborated to focus on aspects that governments at different scale should provide. Some guidelines derived by literature review experience are elaborated and propose to support SBG regulatory framework.
- ***Mapping of components*** – synthesis of information collected to schematize actors, context, actions and outputs previously analyzed. This map is a partial contribute to the full understanding of SBG in its complex.

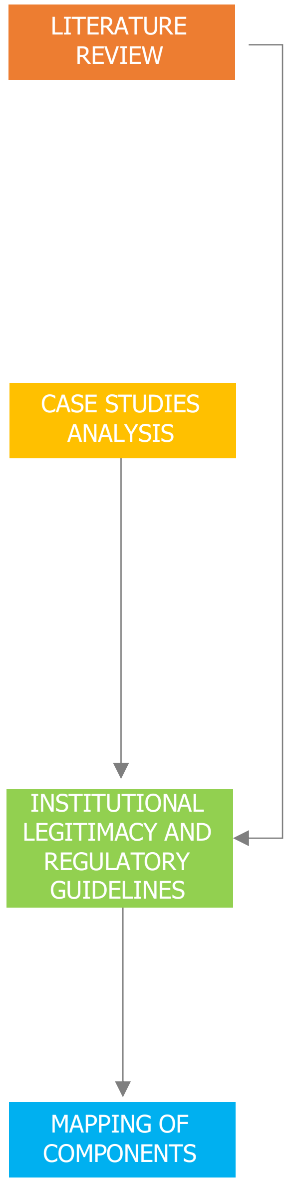

Figure 5-1:synoptic framework of methodology

5.3. SBG regulatory framework

Regulatory framework is issued by different institutions, each with its own jurisdiction in specific fields. However, researching SBG in EU scenario, the first level for importance to be analyzed in this chapter is the European one. Since the beginning of this century, EU has focused its attention in the development of energy policies able to contribute for a deep transformation in the Community (Lyons, 1998) and the whole EU regulatory framework has been created to create the conditions for new sustainability concepts, based on environmental, economic and social implementation; SBG fits perfectly this frame. Indeed, the advancement of new technologies and the emerging topics of energy efficiency and sustainability are meaningful issues in the European Union debate and the aspects involved in SBG are legitimately part of this scenario. Climate and energy packages of binding legislation have to ensure that EU meets 2020 energy targets, but while the greatest part of RESs depends primarily on two directives – energy Directive 2009/28/EC and Energy Taxation Directive 2003/96/EC – biogas is framed in a more complex normative situation, that include aspects treated for instance in Waste Directive 2008/98/EC and Fertilizer Regulation 2003/2003. The need to relate directives, policies and regulatory is primary to better understand opportunities and limitation of in SBG.

Secondarily there are aspects related to support schemes and authorization processes that are assess by national and local institutions that affect SBG. This section, starting with analysis of European framework, pass to below institutional levels, offering a comprehensive scenario of specific topic treated at different scales.

5.3.1. Energy framework

Key European Directive in RES debate is the energy Directive 2009/28/EC (European Parliament and Council, 2009). This Directive, which replaces the previous 2001/77/EC, defines an important policy based on the control of European energy consumption and increased of RES with the aims to save energy, increase energy efficiency and reduce GHG emissions, in line with international Kyoto Protocol (“Kyoto Protocol,” 1997). Biogas, as decentralized renewable energy technology developed in SBG, answers to all characteristics requested to Directives' performance policies thanks to its multiple benefits – utilization of local bio-waste energy sources, opportunities for employment and local development through local small and medium-sized enterprises, formation of local security of energy supply, shorter transport distances and reduction of energy transmission losses (Wellinger, Murphy, & Baxter, 2013).

Other norm to consider in this frame is the Energy Efficiency Directive 2012/27/EU, that sets for each Member State binding national targets for raising the share of renewable energy in gross energy consumption with the aim to achieve EU targets by 2020. Directive provides National Energy Efficiency Action Plan (NEEAP) as an instrument to set policies and direct national strategies to reach expected goals. NEEAP, starting from national energy benchmark, defines renewable energy targets and biogas is diffusely part of these national plans, because it allows to increase RES share in national energy mix thanks also to its many different energy outputs.

In energy policies framework Energy Taxation Directive 2003/96/EC (Table 5-1).

Table 5-1: Energy taxation Directive 2003/96/EC's key points that support and are developed in SBG

EU issuance	Energy taxation Directive 2003/96/EC			
Policy	FLEXIBILITY: taxation as flexible instrument for Member State to define and implement policies appropriate to national circumstances	TAXATION AS ENERGY COMPETITION: suggestion to base the tax minimum level on the energy content	CHP PREFERENTIAL TREATMENT: Combined Heat and Power generation to promote use of alternative energy	ENVIRONMENTAL BACKDOOR : minimum taxation level could not be respected for reasons of environmental
Support schemes: taxation and incentives	MINIMUM TAXATION LEVEL (art.4): "level of taxation" is the total charge levied in respect of all indirect taxes (except VAT) calculated directly or indirectly on the quantity of energy products and electricity at the time of release for consumption	TOTAL or PARTIAL FISCAL EXEMPTIONS OR TAXATION REDUCTION (art14): pilot projects for technological development of environmental products or for fuels from renewable resources; electricity generated from biomass; CHP generation	TAX REFUND (art.15): some or all amount of tax paid by the consumer on electricity produced from biomass	ELECTRICITY TAXATION: 1,0€ per MWh for non-business use, 0,5€ per MWH for business use
Authorization and plan	Not present			
Public Role	Not present			

This directive must also be considered, especially because nowadays it is much more an obstacle than a positive element for Europe's 2020 targets. The Directive, issued earlier than energy directives, has been designed primarily to avoid competitive distortions in the energy sector within the EU internal market, overcoming differences of national levels on taxes applied by Member States, considered damaging for functioning of communitarian energy economy. Even if the Directive recognizes that taxation of energy products and electricity as one of instruments available for achieving sustainable targets, it is totally outdated. The Energy Taxation Directive did not consider RES incoming importance, taxing RESs at the same rate as the traditional energy they are intended to replace; the possibility provided was a partial/total exemption of Value-Added Tax (VAT) for electricity from renewable energy. Other barrier of this directive is taxation based on volume consumed, strongly penalizing because it does not consider GHG emissions. For these reasons, a revision of the Directive is an yearly open discussion ("Excise Duties," n.d.) with the aim to issue new taxation rating on CO_2 emissions and energy content, giving to RES economic advantages on fossil fuel.

5.3.2. Waste framework

The Waste Directive 2008/98/EC (European Parliament and Council, 2008) offers other direction for biogas application in urban district because urban waste in SBG is the main matter for energy production. Urban biogas can be technological, environmental and economic efficient measures to achieve high quality standards in waste collection as required by the Directive. In fact, anaerobic digestion using bio-waste are more appreciated than landfilling, representing a valuable strategy to decrease the amount of waste landfilled. At this aim, Member States should support separated collection of bio-waste with anaerobic – and aerobic – digestion perspective, in other to achieve expected level of environmental protection through these treatments; the result is not only avoiding landfilling, but reaching energy efficiency thanks to biogas production and utilization. In addition to these possibilities, biogas from bio-waste can encourage policies based on citizens' sensitivity to prepare for waste re-use, waste energy recover, decrease waste disposal, all parameters required by the Waste Directive for waste hierarchy. (Table 5-2)

From general goals issued by European regulatory framework that frame SBG, it is mandatory a reception at each institutional sub-layer level. Indeed, waste directive asks for a national reception that addresses final statutory requirements in bio-waste quality and recycling target able to asses valuable MSWM. For this reason, for what concerns waste regulation, MSW management has three-fold other than European one (Piippo, Saavalainen, Kaakinen, & Pongrácz, 2015):

- *national government* – it needs to develop and enact legislation and policies, which assist and confirm the protection of the environment in line with European goals;
- *national agency/department* – it executes programs and perform essential research and development;
- *local government* – it needs to guarantee local regulation of solid waste management practices.

Table 5-2: Waste Directive 2008/98/EC's key points that support and are developed in SBG

EU issuance	Waste Directive 2008/98/EC			
Policy	**Waste Hierarchy (art.4):** Member states should take measures to encourage policies based on priority order in waste prevention: (a) prevention (b) preparing for re-use (c) recycling (d) energy recover (e) disposal	**(NON) legislative responsibilities (art. 10):** waste producer responsibility extended to all natural or legal people who use waste	**Separate waste collection (art. 10):** Member states shall take measures to achieve separated waste collection if technically, environmentally and economically practicable, without mixing materials with different properties, achieving high quality standards.	**Bio-waste collection (art. 22):** Member states should promote the separate collection of bio-waste with a view to composting and digestion, so to achieve an high level of environmental protection trough the treatment of bio-waste
Support schemes: taxation and incentives	*Not present*			
Authorization and plan	**Waste disposal (art. 24):** Member states may exempt from disposal permit in case of disposal of their own non-hazardous waste at the place of production or for waste recovery		**Waste management plan (art. 28):** measures to improve environmentally sound preparing for re-use, recycling, recovery of waste, so to support the implementation of the Directive's objectives	
Public Role	**Participation (art. 31):** Member states should ensure the opportunity to participate in the elaboration of the waste management plans especially if these have relevant environment effects			

These levels are interconnected and direct the planning process to allow that general goals could find good practices in MSWM, improving the research and developing pilot projects in waste field; SBG could be a further contribution in this scenario.

Despite these considerations, the real question on SBG is compelling with Directive that defines '*waste*' the '*products by-waste*', marking a problem connected to its utilization.

5.3.3. Fertilizer framework

Digestate considered '*waste*' is a limitation that affects its utilization in urban areas. As still mentioned in chapter 3, digestate by bio-waste is a complex matter of discussion and despite it could replace the use of artificial fertilizer and could represent an income for producers, its classification as '*waste*' obliges to send it to landfills with a cost for producers and high environmental impact. Actually, legislation allows some treatment processes to classify digestate as '*end of waste*' status (WRAP, 2015), through *pasteurization* – digestate is ready to be sold, but this is an expensive treatment not intended by regulatory framework for small AD systems –, *permit or local agreement with the Environment Agency* – long and expensive process that only a network of SBG that connect biogas plant management could afford for expense –,classifying bio-waste as '*low risk matrix'* – cheaper strategy that directs utilization without further chemical analysis, using digestate for green area both '*on-site*' as well as '*off-site*', but without selling. These are actions that can be realized in SBG. Further considerations are demanded to specific studied that includes chemical analysis of digestate to verify environmental impact of its use.

5.3.4. Policies of support schemes: taxation and incentives systems

The role of financial and economic aspects is basilar to promote SBG and support its perspectives. It is demanded to national policies issued by Member States to create address support schemes, adequate subsides and other economic measures to promote biogas, at least until the biogas sector could become commercially viable (European Parliament, 2008) and reported in Table 5-3. These schemes are important because biogas, and RES in general, are not competitive yet with traditional fuels – natural gas, fossil oil, coal. For this reason, financial incentives and tax exemption support policies issued sustain NEEAP in supporting biogas. European Member States (MS) have not the same support schemes because of different interests or opportunities in developing biogas. The instruments structured to support biogas have studied (Table 5-4) (European Commission, 2015) – *Feed-in-tariff (FIT)*, *premium tariff*, *subsidy*, *quota system*, *loan*, *net-metering*, *taxation*, *Contract for difference (CfD)*. Next paragraphs analyze potential of incentivizing scheme.

<table>
<tr><th>EU issuance</th><th colspan="3">European parliament resolution of 12 March 2008 on sustainable agriculture and biogas: a need for review of EU legislation</th></tr>
<tr><td>Policy</td><td colspan="2"><u>Biogas potential:</u> Economic viability and support schemes stresses that it would be best for biogas installation operators to combine and use all available organic matter both from an environmental and an economic perspective</td><td><u>Further development:</u> EU legislation urges to develop a coherent biogas policy to underline the necessary changes in Community and national laws so to point out the most efficient ways of using EU funds and programs</td></tr>
<tr><td>Support schemes: taxation and incentives</td><td><u>Positivity in incentives:</u> Member states that are providing extra incentives for 'green energy', by means of adequate price subsidies or through other measures, are also the most successful in promoting biogas; a support scheme of this way should only last until the biogas sector has become commercially viable</td><td><u>Need for funding:</u> research and development, promotion of specific projects are possible only with additional funding by Member States</td><td><u>Funding destination:</u> Member states and Commission should guarantee that funding go to the most efficient and sustainable installations, especially to CHP plant</td></tr>
<tr><td>Authorization and plan</td><td colspan="3"><u>AVOID HINDRANCE:</u> Member states' support scheme should draw attention not to create unnecessary hindrance trough their approval procedures, regional planning, granting of license and approvable schedule. Support scheme should call for simplified planning permission procedure in biogas construction installations</td></tr>
<tr><td>Public Role</td><td colspan="2"><u>Cooperation:</u> support schemes encourage frames cooperation</td><td><u>Member states' cooperation:</u> EU legislation calls need to ensure cooperation and collaboration between Member states, to learn about best practices; regulatory can be part of this cooperation to better understand best possible laws applied</td></tr>
</table>

Table 5-3:Resolution 12/03/2008's key points that support and are developed in SBG

Incentives schemes \ Member States	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	The Netherlands	United Kingdom
Feed-in-tariff	•		•	•						•	•	•	•	•	•	•	•	•			•		•	•				•
Premium tariff							•	•	•		•				•									•	•		•	
Subsidy	•	•					•	•	•	•	•	•					•	•		•		•	•	•				
Quota system		•																		•		•				•		•
Loan			•	•							•	•					•			•				•				
Net-metering		•					•						•		•	•											•	
Upgrading tariff										•													•					
Taxation		•				•						•			•	•	•			•			•			•	•	•
Contract for difference																												•

Table 5-4: incentives schemes adopted in EU Member States

5.3.4.1. *Feed-in-tariff*

The most diffused financial incentive in EU is feed-in-tariff (Table 5-5). The success of this instrument is dependent on a fixed energy price to cover the biogas energy production, independent of energy market spot, in order to be able to guarantee a certain amount of money for biogas producers by providing investment security for further 15/20 years. A successful FIT policy should include typically three key provisions: guaranteed access to the grid; stable, long-term purchase agreements; payment levels based on the costs of energy generation. FIT reflects the total production costs, from which energy market prices for conventional electricity should be subtracted to get the extra costs of biogas electricity, but it is useless if it is not supported by prioritized grid access and a purchase obligation of the grid operator, to effectively guarantee tariff payment in the expected period of time and validate the investment executed. The analysis presents different feed-in tariff schemes depending on biogas origin – AD is supported more than biogas from landfill and sewage gas –, size plant – small plants have higher tariffs rather than the biggest ones –, or feedstock – household waste and biomass are sustained –, providing further bonus for cogeneration systems. SBG fit perfectly this logic of FIT schemes.

Table 5-5a: feed-in-tariff schemes in EU's Member States

Biogas feed-in-tariff				
Member state	**Biogas plant**	**Tariff**	**Payment period**	**Notes**
Austria	Biogas plant	12,93/19,5€ct/kWh	15 years	Since 2014, tariffs reduced by 1%
	Sewage gas	5,94€/kWh		
	Landfill	4,95€/kWh		
Bulgaria	plant and animal waste	19,8/23,2€ct/kWh	12/15 years	
	household waste	10,5/11,5€ct/kWh		
	household wastewater	4,6/6,4€ct/kWh		

Biogas feed-in-tariff				
Member state	**Biogas plant**	**Tariff**	**Payment period**	**Notes**
Croatia	≤ 300 kW	17,4€ct/kWh	14 years	
	300 kW < P ≤ 2 MW	16,4€ct/kWh		
	> 2 MW < P < 5MW	15,3€ct/kWh		
	> 5MW	dependent on reference price		
Czech Republic	Landfill and sewage gas	7,1€ct/Kwh	20 years	until 31/12/2013
	>100kW	12,9€ct/kWh		
Denmark	< 6 kW	11/16€ct/kWh	10 years	Since 01/01/2014 tariff reduced by 2€ct/kWh annually until 01/01/2018
France	Landfill gas	8,121/9,745€ct/kWh	15 years	BONUS: CHP 0/4€ct/kWh Manure 0/2,6€ct/kWh (no landfill)
	Anaerobic Digestion	11,19/13,37€ct/kWh		
Germany	Biomass	5,85/27,73€ct/kWh (plant size and fuels) Minus 0,2€ct/kWh	20 years + 1 year system operative	after 01/01/2014
	Landfill gas	5,83/8,42€ct/kWh (plant size and fuels) Minus 0,2€ct/kWh		
	Sewage gas	5,83/6,69€ct/kWh Minus 0,2€ct/kWh		
Greece	Landfill gas ≤ 20 kW	13,1€ct/kWh NS 11,4€ct/kWh WS	20 years	NS: No financial Support WS: With financial Support
	Landfill gas > 20 kW	10,8€ct/kWh NS 9,4€ct/kWh WS		
	Biomass ≤ 20 kW	23€ct/kWh NS 20,9€ct/kWh WS		
	Biomass > 20 kW	20,9€ct/kWh NS 19€ct/kWh WS		
Hungary	< 20 MW	4/12€ct/kWh	not exceed the pay-off period	Tariff dependent on daily period
	20 MW < P < 50MW	3/9€ct/kWh		
	> 50 MW	5/7€ct/kWh		
Ireland	Landfill gas	8,54€ct/kWh	15 years and not beyond 31/12/2032	
	Anaerobic Digestion CHP≤500kW	15,7€ct/kWh	15 years and not beyond 31/12/2030	
	Anaerobic Digestion CHP>500kW	13,63€ct/kWh	15 years and not beyond 31/12/2030	
	Anaerobic Digestion no CHP≤500kW	11,53€ct/kWh	15 years and not beyond 31/12/2030	
	Anaerobic Digestion no CHP>500kW	10,48€ct/kWh	15 years and not beyond 31/12/2030	
Italy	1 kW < P < 5 MW	14/23,6€ct/kWh	20 years	100 kW < P < 5 MW need to be listed in a register
Latvia		17/23€ct/kWh	20 years	

Table 5-5b: feed-in-tariff schemes in EU's Member States

Biogas feed-in-tariff				
Member state	**Biogas plant**	**Tariff**	**Payment period**	**Notes**
Lithuania	Landfill gas < 10kW	11,6€ct/kWh	12 years	
	10kW < P ≤ 500kW	11,3€ct/kWh		
	> 500kW	9€ct/kWh		
	Anaerobic Digestion or biodegradable organic waste or substrates < 10kW	15,3€ct/kWh		
	10kW < P ≤ 500kW	13,9€ct/kWh		
	500kW < P ≤ 1MW	13,3€ct/kWh		
	1MW < P ≤ 2MW	12,7€ct/kWh		
	> 2 MW	12,2€ct/kWh		
Luxembourg	500 kW < P ≤ 2,5 MW	19,2€ct/kWh	15/20 years	
	300 kW < P ≤ 500 kW	18,1€ct/kWh		
	150 kW < P ≤ 300 kW	17,1€ct/kWh		
	≤ 150 kW	15,3€ct/kWh		
Portugal	MSW, sewage, waste water, waste from agricultural and food industries	11,5/11,7€ct/kWh	15 years	
	Existing landfill	10,2/10,4€ct/kWh		
	miniproduction units	60% of the reference tariff		
Slovakia	Landfill and sewage gas	7,03€ct/kWh	15 years	Plant < 500 kW are entitled to the payment of the price electricity to cover grid losses for the entire plant lifetime
	Anaerobic Digestion ≤ 250 kW	12,53€ct/kWh		
	Anaerobic Digestion 250 kW < P ≤ 500 kW	11,94€ct/kWh		
	Anaerobic Digestion 500 kW < P ≤ 750 kW	11,06€ct/kWh		
	Anaerobic Digestion ≥ 750 kW	10,73€ct/kWh		
	Thermochemical conversion	12,26€ct/kWh		
	Anaerobic Digestion of bio-degradable waste	11,89€ct/kWh		
Slovenia	Biomass	16,18/16,56€ct/kWh	15 years	
	Bio-degradable waste	13,92€ct/kWh		
	Digester gas	6,61/8,56€ct/kWh		
	Landfill gas	7,44/9,93€ct/kWh		
United Kingdom	≤ 250 kW	14,22€ct/kWh	20 years	for electricity production
	250 kW < P ≤ 500 kW	10,37€ct/kWh		
	> 500 kW	11,44€ct/kWh		
	Biogas injection	10,22€/kWth	20 years	for heat production
	≤ 200 kWth	10,22€/kWth		
	200 kWth < P ≤ 600 kWth	8,04€ct/kWh		
	> 600 kW	3,00€ct/kWh		

Table 5-5c: feed-in-tariff schemes in EU's Member States

5.3.4.2. Premium tariff

Alternative solution provided by European Member States that have not established FIT policies, is premium-tariff. In fact, as shown in Table 5-4, among the 28 actual, 16 Member States have FIT, 8 MS have Premium-tariff, only 5 MS have neither FIT, neither Premium tariff. FIT is preferred because premium-tariff is demonstrated to provide higher total payments than FITs (Toby D. Couture, Karlynn Cory, Claire Kreycik, & Emily Williams, 2010) and for this reason it is not considered cost-effective by national governments. While in feed-in-tariff approach, energy purchase is guaranteed in order to keep renewable energy generation separate from spot market fluctuation, in premium tariff scheme energy is sold on spot market and producers receive a premium above the market price; this is much more expensive solution. Some Member States offer both feed-in-tariff as well as premium-price option, therefore producers can choose support schemes on most convenient solution for their business plan. As for FIT, also premium-tariff needs a guaranteed incentivizing period from 10 years to 20 years, or based on plant useful life as in Spain case. Investments on biogas CHP is supported by additional premium for heat energy production as provided in Finland national policies since its introduction in 2011. Table 5-6 resumes premium tariff in EU's Member States.

Biogas premium tariff				
Member state	**Biogas plant**	**Tariff**	**Payment period**	**Notes**
Czech Republic	Landfill and sewage gas	4,1€ct/Kwh	20 years	CHP plant using no more than 70% energy crops, at least 50% of the biomass primary energy operation until 31 December 2013
	≤ 550 kW	9,8€ct/kWh		
Denmark		Maximum bonus 11€ct/kWh	10 years 10 years	60% market price at 01/01/year
		Guaranteed bonus 6€ct/kWh		
		3,50€+1,340€ per GJ		For heat production
Estonia		5,37€ct/kWh	Maximum 12 years	For heat production BONUS: 3,2€ct/kWh <10MW from waste
Finland		0,835€ct/kWh	Maximum 12 years	For heat production BONUS: 0,50€ct/kWh
Germany	Biomass	5,85/27,73€ct/kWh (plant sieze and fuels) Minus 0,2€ct/kWh	20 years	Calculated every calendar month Operative after 01/01/2014
	Landfill gas	5,83/8,42€ct/kWh (plant sieze and fuels) Minus 0,2€ct/kWh		
	Sewage gas	5,83/6,69€ct/kWh Minus 0,2€ct/kWh		
Italy	1 kW < P < 5 MW	10,9/23,6€ct/kWh	20 years	100 kW < P < 5 MW need to be listed in a register
The Netherlands	Biogas basic price	4€ct/kWh 19,444/31,40€/GJ (max 5735 Full Load Hours)	12 years	
	Sewage gas	3,30€ct/kWh (max 8000 Hours)		
	Extension of operating period	19,44/28,20€/GJ (max 5855 Hours)		
	fermentation heat	14,70/6,40€/GJ	12 yrs (15 yrs for existing waste-to-power plants)	For heat production
	fermentation CHP	19,44/26,30€/GJ		
	th. conversion heat	6,40/19,44€/GJ		
	th. conversion CHP	18,10/40,90€/GJ		
Slovenia	Biomass	16,18/16,56€ct/kWh B factor = 0,88/0,92	15 years	Premium = Reference costs) – (Market Price for electricity)*B factor
	Bio-degradable waste	13,92€ct/kWh B factor = 0,88/0,92		
	Digester gas	6,61/8,56€ct/kWh B factor = 0,92		
	Landfill gas	7,44/9,93€ct/kWh B factor =0,92		
Spain	Tariff based on parameter: return on investment and operation; incentive for investment; min/max number of operating hours; top and bottom limits of market prices; Average yearly price of (intra)daily market		useful regulatory life	

Table 5-6: premium tariff schemes in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.3. Subsidy

Subsidy is a support scheme that guarantee incomes for design, commissioning, installation costs, depending on State or local funds issued by each Government related to specific periods of time (Table 5-7). The period predicted for funds represents the main problem. In fact, the large part of Member States have annual funds, established by yearly financial programs. This is an obstacle for enterprises and their willingness to develop existing plants as well as realize new plants in further years. A possible strategy is providing budget for long periods – as typical for EU programs with 7 years budget – issuing a framework self-assured and steady.

Subsidies are meanly based on incentive for heat generation especially related to CHP, with further covering costs for application of new technological systems as in Finnish case.

Table 5-7a: subsidy schemes in EU's Member States (2015). Elaborated from (European Commission, 2015)

Biogas subsidies		
Member state	**Tariff**	**Notes**
Austria	30% of installation cost PLUS: 5% for installations in areas higher than 1.200 m or in ecologically sensitive areas; 5% implementation of different measures; 5% or a maximum of€ 10.000€ for EMAS and eco-label	for CHP
Belgium	For BRUSSEL Micro and small ent.s: 40% of the costs Medium ent.s : 30% of the costs Large ent.s, 20% of the costs PLUS: 5% if ent.s is EMAS certified For WALLONIA 30% of investment costs 15% if combined with other support schemes for more than 20% of costs	for CHP and trigeneration if al least 5%/10% (dependent on region) CO2 is saved compared with conventional heating, cooling and electricity generators MAX: 80.000€ per year
	MAX: 30% of installation cost	for CHP > 4kW feasibility study for trigeneration
Denmark	coverage of: Consultancy, commissioning, investment, preparation or installation plant costs; finance and operation costs	biomass gasification plants eligible BUDGET: 3,35 M€ until the end of 2015
Estonia	Construction renovation of CHP, including infrastructure; Boiler-houses reconstruction; district heating networks energy raising	for CHP BUDGET: 32,000/3,2 M€
Finland	MAX: 30% of installation cost, 40% using new technologies	At least 25% financed from non-state funding
France	For household: 3.000€ + 500€ (depending on local authorities) For landlords: 2.000€ For associations of co-owners: 1.500€ 40% can be granted at renovation work beginning	For heat production

Biogas subsidies		
Member state	**Tariff**	**Notes**
Germany	130€/kW per year for 10 years	FLEXIBILITY PREMIUM MAX: 1.350 MW additional installed
	40€/kW per year	FLEXIBILITY SURCHARGE if FIT or premium tariff are eligible
Greece	Small ent.s: 25/50% of the costs, minimum 200.000€ Medium ent.s : 20/45% of the costs, minimum 500.000€ Large ent,s,15/40% of the costs, minimum 1.000.000€	Maximum 100% of investment cost is tax deductible Maximum 80% of technological development is tax deductible Maximum 70% for regional convergences tax deductible Plus 10% for newly established ent.s
Lithuania	MAX: 200.000€ ≤ 80% of the costs 60% payable with operating plant, 40% payable with environmental compliance achieved and submitted	Lithuanian Environmental Investment Fund – LEIF Demonstration of funding provision possibility
	MAX: 80% of the project costs MAX: 1.447.270€ for not engaged in economic and commercial activities applicants MAX: 199.723€ for engaged in economic and commercial activities applicants	Fund for the Special Program for Climate Change Mitigation BUDGET: Annual cost estimation
Luxembourg	MAX: 40% of the costs PLUS: 10% for small-medium ent.s 10% for self-sufficient community supply	Help for middleclass Medium ent. less than 250pp and annual turnover ≤ 40 M€ Small ent. less than 50pp and annual turnover ≤ 7M€
	MAX: 45% of the costs arising from the use of RES as compared to non-renewable sources PLUS: 20% for small ent.s 10% for medium ent.s	Help for environmental protection and rational use of natural sources
	33% of the investment cost	Funding for environmental protection

Table 5-7b: subsidy schemes in EU's Member States (2015). Elaborated from (European Commission, 2015)

Biogas subsidies		
Member state	**Tariff**	**Notes**
Poland	20% of the loan received, maximum 16% of the cost, not exceed twice the amount of annual energy cost saving	For heat production Thermo-modernization grants
	≤ 40 kW (micro co-generation installations) MAX: 30% of the costs (for years 2014-2015 40%) Maximum 72.810€	National Fund for Environmental Protection and Water Management – Prosumer PERIOD: 2014/2020 BUDGET: 36,4 billion€
Romania	depending on annual call for proposal For family farms 40/70% of the costs Minimum 5.000€, maximum 125.000€ For other farms depending on sector Maximum 700.000/2.000.000€	PERIOD: 2014/2020 BUDGET: 7,14 billion€
	depending on annual call for proposal For micro, small, medium ent.s MAX: 50% of the costs, maximum 2.000.000€ For associative structures MAX: 50% of the costs, 3.000.000€ For project in Bucharest region MAX: 40% of costs For other ent.s MAX: 25% of the costs, 2.000.000€	PERIOD: 2014/2020 BUDGET: 7,14 billion€
	Annual call for applications MAX: 90% of the cost, maximum 100.000/890.000€ (depending on legal entity applying)	For heat production
Slovakia	Individual call for applications	For heat production
Slovenia	State aid: MAX: 30% of the costs, maximum 200.000€ Exceptional project 40% of the costs	Awarded subsides

Table 5-7c: subsidy schemes in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.4. Quota system

Quota-system is based on production/purchase of a certain amount of green electricity certificates established by countries' Governments in order to fulfill renewable energy targets issued by energy Directive. (Table 5-8) Not many Member States have quota system. The main problem is the value of the certificate to buy with price for the green certificates that is usually determined by market and for this reason affected by fluctuation being not attractive. For this cause, enterprises need to have sureness of their investment, preferring FIT, premium-tariff or subsidy schemes; only green certificate with price fixed by legislation could represent an investment for energy suppliers. The quota could however be a good instrument for what concerns penalties to pay in case of missing certificate. As for tax exemption, penalties are a good instrument to encourage renewable energy production, despite of paying a penalty up to 150% of certificate value as in Sweden scheme.

Member state	Biogas quota system prescription	Notes
Belgium	For BRUSSELS certified since max 10 years CO_2 savings at least 5% compared with conventional installations < 1MW, 1 certificate per MWh For FLANDERS > 200kWh shall be certified by an authorized body For WALLONIA K-factor 0,25/1 depending on plant size	
Poland	RE percentage of the total electricity sold 2014 – 13%, 2017 – 16%, 2021 – 20% Annual payment fee set Penalty per missing certificate	quota independent of the technology used
Romania	annual quota established by energy regulator For CHP: 2 certificates per MWh CHP high efficiency receive 1 plus certificate Energy crops 1 plus certificate per MWh For Anaerobic Digestion of waste and sewage: 1 certificate per MWh CHP high efficiency 1 plus certificate Energy crops or deadwood 1 plus certificate 27/55€ certificate cost in 2008/2025 period Penalty of 110€ per missing certificate	plant supported under government-fund program have number of certificates lower than the number usually awarded but with no funds
Sweden	2014 – 14,2%, 2017 – 15,2%, 2020 – 19,5% 2023 – 17,0%, 2026 – 13,7%, 2029 – 9,2% 2032 – 4,5%, 2035 – 0,8% 1 certificate per MWh Penalty of 150% of certificate value per missing certificate	
United Kingdom	power > 5 MW 01/05/2014 – 31/03/2015 – 24,4% 01/05/2015 – 31/03/2016 – 15,4% 01/05/2016 – 31/03/2027 – 15,4% Penalty of buy-out price plus 5% above Bank of England base rate per missing certificate	Renewables Obligation Certificates – ROCs 31/03/2017 RO systems will be replaced by CfD

Table 5-8: quota system in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.5. *Loan*

Another incentive strategy is the loan scheme, because it is not common that enterprises have enough cash flow to realize biogas plants, and currently the profit logic of bank system provided does not fit sustainable targets, because loan concession usually depends on interests subjected to free market. Some Member States throughout their National Banks promote loan to realize biogas plants to incentivize sustainable targets and international goals, assessing advantageous interests for plant realization guaranteed by national funds.

Table 5-9a: loan scheme in EU's Member States (2015). Elaborated from (European Commission, 2015)

Biogas loan		
Member state	**Tariff**	**Notes**
Bulgaria	MAX: 400.000€ of approved bank credit PAYBACK PERIOD: ≤ 5 years 15.000€ ≤ INVESTMENT ≤ 1.500.000€ INTERESTS: 6/9% for Municipalities 7/10% for Corporate clients and private persons 10/25% of equity contribution	For heating production Bulgarian Energy Efficiency Fund – BGEEF At least 50% of a project's benefits must come from energy savings Commitment fees amount to 0,5/2% per year
Croatia	MIN: 13.100 € MAX: depending on the HBOR's financing capability, the specific investment program, the creditworthiness of the end borrower(s), the value and quality of the security offered INTERESTS: 4% year or three-month EURIBOR + 2% year If Environmental Fund approved plant, Interest can be reduced by further 2%	HBOR – Croatian Bank for Reconstruction and Development owned by the Republic of Croatia HBOR covers 75% of estimated investment (no VAT)
Germany	MAX: 50% of installation cost INTERESTS: Depending on bank consortium agreement, 20 years period Repayment-free start-up period of 3 years	KfW - Kreditanstalt für Wiederaufbau FINANCING INIZIATIVE ENERGIEWENDE BUDGET: 25/100 M€ Commitment fees amount to 0,25% per month
	MAX: 100% of installation cost (no VAT), maximum 25M€ INTERESTS: 1,31/7,56%, 5/10 years fixed interests, 20 years if technical and economic co-financed investment is longer than 10 years	KfW - Kreditanstalt für Wiederaufbau RENEWABLE ENERGY PROGRAMME - STANDARD Commitment fees amount to 0,25% per month
	80€ per kW minimum 10.000€, maximum 50.000 Biogas pipelines investment 300m long ≤ 30% of the investment cost	For heating production KfW – Kreditanstalt für Wiederaufbau RENEWABLE ENERGY PROGRAMME PREMIUM

Biogas loan		
Member state	**Tariff**	**Notes**
Greece	MAX: 15.000€ of the installation cost INTERESTS: Interest-free loan 30/85% (depending on applicant income) or SUBSIDY: 70/15% (depending on applicant income) PERIOD: 4 years	For heating production PERIOD: 31/12/2012-2017 BUDGET: 396 M€
Italy	MAX: depending on nature of the subject and plant size INTERESTS: 0,5% per year	Fondo Kyoto For CHP plants, with C ≤ 50 kWe PERIOD: 2012/2014 BUDGET: 600 M€
Lithuania	Plant financed part from program's budget, part at least 20% from the funds of a credit institution NO MAX amount	Fund for the Special Program for Climate Change Mitigation
Poland	MAX: 75% of the installation costs INTERESTS: WIBOR 3M – 100 base, but at least 2%, 15 years period	National Fund for Environmental Protection and Water Management PERIOD: 2014/2020 BUDGET: 102 M€ NOT compatible with other National Fund for Environmental Protection and Water Management supports
Slovenia	loan depends on: the amount of eligible costs; the type of investment; the evaluation of the environmental criteria; the credit rating of the eligible party and the debt insurance; the total budget available for a specific call, as defined in the public call document; the relevant state aid and "de minimis" limits For residents: MAX: 8M€ (deadline 30/05/2015) For individuals: 1.500/20.000 € (40.000 € in special circumstances) INTERESTS: Three-months EURIBOR + 1,5% 10 years period	Eko Fund

Table 5-9b: loan scheme in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.6. Net-metering

Net-metering is the priority access – and consequent selling – to grid network. In such a way electricity produced in SBG is injected into grid and the producer receives the same quota introduced for free.

Biogas net-metering		
Member state	**Tariff**	**Notes**
Belgium	For BRUSSELS and WALLONIA: Compensation mechanism for the period between two meter-reading, Electricity fed can not exceeded the taken For FLANDERS: Power ≤ 10 kW Compensation for the injected electricity, Electricity fed and not taken is not reimbursed	
Denmark		exemption by Public Service Obligation: whole for Plants ≤ 11kW For RE partially Power > 11kW
Hungary	Power ≤ 40 kW (household size plant) Energy received as much for free as produced Surplus electricity fed into grid remunerated with retail electricity price	
Italy	Energy received as much for free as produced Surplus electricity fed into grid remunerated	
Latvia	Energy received as much for free as produced Surplus electricity fed into grid transferred to next billing period	
The Netherlands	apply for an offer from the grid operator for injecting electricity to the grid and required to pay a grid use charge	

Table 5-10: net-metering scheme in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.7. Upgrading tariff

In the perspective of injection of biogas with high percentage of methane in the grid, a motivating possibility is the utilization of an upgrading tariff to support.

Biogas upgrading tariff			
Member state	**Biogas plant**	**Tariff**	**Notes**
France	Landfill	45/95€/MWh	
	Anaerobic Digestion	69/125€/MWh	
Slovakia	Anaerobic Digestion ≤ 1MW	10,75€ct/kWh	

Table 5-11: upgrading tariff in EU's Member States (2015). Elaborated from (European Commission, 2015)

5.3.4.8. Taxation

In addition to the different incentives schemes over mentioned, another important instrument is taxation, solution that demonstrates a preference for a long-term market solution rather than a specific project support. In fact, above the minimum rates established by EU framework, especially through Energy Tax Directive (Council, 2003) to allow open energy market through the Community, Member states are free to set their own national taxes. Energy Tax Directive 2003/93/EC predicts total or partial fiscal exemptions, or taxation reduction, for pilot projects for technological development of environmental products, for electricity generated from biomass – one of the matter for biogas production, or CHP generation. In this way, the taxation can be controlled and decreased for virtuous environmental projects, as long as to be refunded if it produced from biomass. Energy taxes are part of the (not)incentivizing policies of each Member States, free to set rules on what should be taxed, when and what exemptions are allowed. Taxation role can be a persuasive instrument in order to influence consumers' behavior or promote certain political, social and cultural aims. In this perspective, taxes applied in fossil fuels affects citizens behaviors and can be considered an indirect subsidy for green energy development (Bye & Bruvoll, 2008) exploiting Member States' faculty to increase taxes on energy generated from non-renewable resources. Countries as Sweden, Finland, Denmark, Ireland have carbon tax in place, but fixed at very different levels and not in line with the carbon price under the Energy Tax Directive. Currently the result is a patchwork of national policies that allow to achieve the sustainable national.

Waste taxation is an other tax that can be issued, as provided by waste directive (European Parliament and Council, 2008). Currently recycling practices are not economic incentivized nor penalties are provided; the result is that a huge part of waste is still landfilled with a great loss of methane yield of bio-waste.

Biogas taxation		
Member state	**Tariff**	**Notes**
Belgium	14,5% of the investment value for the fiscal year (2014 data)	
Bulgaria	Property tax exemption using RESs 10 years for building "A" certificate 5 years for building "B" certificate	
Czech Republic	Exemption from Real Estate Tax for property used for environment purpose	
Denmark	RESs are exempt from taxes on mineral oil products, coal, lignite and coke, carbon dioxide	
Greece	Small ent.s: 25/50% of the costs, minimum 200.000€ Medium ent.s : 20/45% of the costs, minimum 500.000€ Large ent,s,15/40% of the costs, Minimum 1.000.000€	Max 100% of investment cost is tax deductible Maximum 80% of technological development is tax deductible Maximum 70% for regional convergences tax deductible Plus 10% for newly established ent.s
	Tax emption MAX: 10% of the costs, maximum 3.000€	
Italy	real estate tax less than 0,4% MAX: 5 years period	tax determined at city council level
Latvia	Exemption from: exercise tax of natural gas; value added tax at 12%	Exercise tax 1,007€ct/m3 Value added tax 21%
Lithuania	Exemption equal to the amount of tax a person is exempt	Electricity tax 0,1€ct/kWh for business 0,52€/MWh
The Netherlands	tax payable per 12-month period: consumption ≤ 10.000 kWh: 11,21€ct/kWh 10.000 kWh < c ≤ 50.000 kWh: 4,08€ct/kWh 50.000 kWh < c ≤ 10.000.000 kWh: 1,09€ct/kWh c > 10.000.000 kWh: 0,05€ct/kWh	Reduction of environmental protection tax Self-consumption is tax exempt
	tax benefit enables entrepreneurs based in the Netherlands to write off investments in renewable energy plants against tax tax credit ≤ 41,5% of the investment per year MAX: 116 M€ per year	Energy Investment Allowance, EIA scheme NOT eligible costs <450€ BUDGET: 2.300€/116 M€ per year
Poland	Electricity from RES is exempt from consumption tax Exemption equal to the amount of tax a person is exempt	Electricity tax 0,5€ct/kWh
Slovakia	Electricity from RES is exempt from consumption tax Exemption equal to the amount of tax a person is exempt	Electricity tax 0,132€ct/MWh
Sweden	Total exemption from: nitrogen oxide emissions tax (5,34€ per kg of nitrogen oxides); carbon dioxide tax (11€ct/kg of CO2)	For heat production
United Kingdom	Electricity from renewable sources is exempt from Carbon Price Floor – CPF	TAX until 31/03/2016 Gas tax 0,417€ct/kWh Petroleum gas, Hydrocarbon liquid state 6,633€ct/kg Coal and other taxable solid fuels 2,03134€/GJ
	Electricity from renewable sources is exempt from Climate Change Levy – CCL	TAX until 31/03/2016 0,707€ct/kWh

Table 5-12: tax scheme in EU's Member States (2015). Elaborated from(European Commission, 2015)

5.3.4.9. Contract for difference

In the frame of support schemes, new policies are issued: Contract for Difference is one. Emanated by UK Government it is a private law contract between a RES generator and a Low Carbon Contracts Company - LCCC, owned by the UK Government. The CfD is based on a difference between the market price and an agreed '*strike price*' and the payment of this difference to the contractor with payable credit. The CfD scheme started with the first allocation round in October 2014 and from April 2017 the CfD scheme will be the only support scheme for all new RES projects over 5MW. The efficiency of this support scheme need to be testified during next years to understand if it can increase RES and biogas scenario, following the sole rules of free market.

5.3.5. Authorizations and plans

Last aspect to take into consideration for SBG realization is the role of authorizations and plans on municipal level, being often an obstacle to diffusion of such system. Despite European Parliament recognizes that Member States' support schemes should draw attention not to create unnecessary hindrances through their approval procedures granting of license and approval schedule (European Parliament, 2008), Member States' have not simplified enough planning permission procedures in biogas constructions, except for more exceptional cases of "*urgent works in the public interest*" ("D.lgs. n. 387 del 2003 (fonti rinnovabili)," n.d.), Indeed, among different national authorization regulations – different for efficiency standards, environmental impact, pollution limits, noises and odors emissions, but guarantors of public control and safety, preservation of urban landscape – the real problem is multiplicity and overlapping of norms that are not integrated one with other, generating a non-necessary complexity. Simplify these norms and provide exceptions to common procedures, should be pursued by institutions for those projects that introduce multidisciplinary innovations, profitable for governments as well as for populations.

Another aspect is the revision of existing urban planning. SBG is not a project that work on built parameters, but on a vision of district that includes technological, infrastructural, urbanistic aspects to direct environmental and social innovations. Urban plans should be assessed with zoning that promote mix-used zones, new infrastructural systems, area for experimental missions, agricultural and green projects. At this aim, the role of integration among municipal departments is central to have plans that considered complex systems in a systemic view.

Another authorization process to review in SBG, is the MSWM approval. Waste Directive 2008/98/EC compels Member States to take appropriate measures to establish an integrated and adequate network of waste disposal solutions, considering the best available techniques; these aspects constitute MSWM and SBG needs precise plan. Indeed, SBG improves environmental measures for re-use of bio-waste to support the implementation of the Directive's objectives and to exempt from disposal permit in case of disposal at the place of production for waste recovery; issuing norms that support MSWM with these targets is necessary. In the same way, rules should also include processes for local participation and engagement of citizens to share solutions and direct approval path of MSWM.

5.4. Towards definition of SBG regulatory framework

Define the best regulatory framework for SBG is not easy, because of multiple norms and institutions involved; however, some guidelines can be set, ensuring development of biogas through a continuous and clear-cut support policy (Da Costa Gomez, 2013). It is necessary to go beyond Member States’ regulatory framework pitfalls – not coherent policies integrated and interacting among institutional scales, electricity and heat by biogas not directly supported, difficulties for stakeholders to have economic sources, energy price not supported by regulation to challenge existing regime, complicate incentivizing systems, absence of long-term policies, long procedure for authorization. At different institutional scale – European, national, local – is fundamental regulatory framework needs to ensure stability for stakeholders involved in SBG.

5.4.1. Vertical and horizontal integration of regulatory framework

Integration and interaction among regulatory frameworks is primary for a regulatory framework that support SBG.

Vertical integration is the first to consider. A wide institutional collaboration make multi-governance approaches cooperate each other for the same goals, and an effective vertical integration is indispensable to optimize targets, planning, coordination and monitoring of different levels of governments. From the European one, through national and regional to local, each level has its specific functions and only a clear vertical integration allows to join targets, actions and results. Reception of over-institutional targets, coordination of strategies, policies and planning should be pursued.

The second integration is the horizontal one, that shares goals, policies, actions inside the same institutional level into a systemic view. The greatest impact is the one of national policies – incentives, national regulation on tariffs, incorporation of district energy into building efficiency standards and labels, tax regimes, planning guidance and regulations that provide local governments with a mandate to act (UNEP, 2015) – that have to interact to achieve optimal results. Despite the chief role of national level, municipal level is where SBG districts are and where it is really developed. Local institutions move goals and strategies into actions embodied by planning and policies, setting solutions from land use organization to investment into district infrastructural systems, from bio-waste collection management to new energy efficiency practices, from gardening projects to engagement of population. Local institutions direct the realization of SBG and have the normative instruments, but they must manage and coordinate different local departments towards this common aim. Coordination is basilar to have norms and plans integrated that support the achievement of targets assessed.

5.4.2. Foster measure to promote SBG

Regulatory framework should also include measures to promote public engagement. Stakeholders – citizens, SME, energy distributors – are key components of technological innovation system projects, as

SBG, and for this reason a set of facilitations – bonus, norms exemptions and shortcut – should be set to guarantee a wide participation. Projects with valuable innovative aspects – environmental, economic, social, energy field – should be supported by partial or total removal of administrative obstacles to guarantee SBG development and implementation, keeping safe parameters of quality expected by norms. Exception at authorization processes, connection to public sewer, increase of densities to support brownfield redevelopment through bonus, free assignation of public sites, are only some instruments to encourage actions that support SBG. In this frame, economic and financial aspects play a central role to support capital expenses, programs and contractors. Primary importance is issuing rules that could liberalized market to open competiveness, fostering shorter contacts in waste and energy management and enabling stakeholders to change operators in line with shifted expectations. Another element is providing instruments that could ensure economic and financial resources to support SBG – incentives to support RES projects, fiscal policy in community project, tax exemption, funding to support training dedicated staff, ethical finance, microcredits, mutuality, community bonds, facilitations at loans and financial coaching for charitable and non-profit sectors, community enterprise support and funding, crowd sourcing. In this frame, promotion of grants and scholarships in Research & Development to promote topic of SBG – energy efficiency, waste recycling, food and green growing or in the promotion of small scale experimental Start Up – are precious solutions.

Other measures for public engagement is the promotion of public and civic debate. The local government is perceived by stakeholders to have legitimacy and capacity to support and lead the development and implementation of complex project, but the conditions to credit this potential among actors have to be built. This is possible only if there is a clear and shared policy agenda, that uses collective planning to focus on population needs and answers with practices that integrate multi and inter-disciplinary features directing towards grassroots initiatives. Actors engagement in policies development is crucial to promote local active/passive engagement in further phases. Engagement means clear understanding of actions that actors involved can implement to support plans and their implementation. In this scenario, public authority skills must emerge and only a trained staff can highlight advantages and solutions offered by regulatory framework in case of promotion of SBG. The ability of public authorities to support technically and coordinate SBG projects build sense of safety and the coordination among departments and offices is a resource to make it available. Technical expertise in managing infrastructure and experience in programs elaboration, development and implementation of an energy plan, funding knowledge, set of energies and GHG reduction targets, integration into local plans and authorization processes, are aspects that an institution can provide to support projects as SBG and have a positive impact on actors.

5.4.3. Guidelines for SBG regulatory framework

In line with considerations made in the chapter and two principles assessed to manage SBG regulatory framework, some guidelines for institutions at different level are proposed:

- *at **European level***:
    - *review Energy Tax Directive* – introduction of tax based on CO_2 and energy content, to prevent a patchwork of national policies that could obstacle and distort European Internal Market, to guarantee the promotion of those resources able to generate alternative energy with low CO_2 – '*next zero*' – emissions and high energy content.
    - *set common national guidelines* – aligning existing policies and transfer experiences among Member States.
- *at **national level***:
    - *schedule long-term budgetary plan* – a defined period for budget of 7 year program can allow a schedule for investments, overcoming the uncertainty of unknown future economic resources both for public municipalities both for private enterprises.

  - *Guarantee political stability* – a longer-term predictability of regulatory framework is necessary because absence of stable framework discourages investments and energy innovation.
  - *Introduce incentives in re-use and AD treatment* – despite diffused recycling practices, nowadays there are not economic incentives nor penalties for virtuous behavior and waste collection solutions. SBG's stakeholders that produce and collect separately bio-waste should be supported through financial incentives.
  - *Support policies focused on decentralized plants* – local small cogeneration plants are more sustainable than nationwide projects and can contribute through self-production and self-consumption – '*prosumer*' concept – at the energy independence that represents an environmental and a social opportunity.
- *At **local level**:*
  - *Review of authorization process* – local authorities should favor, in the respect of all environmental factors, those sustainable projects based on cooperation that join multidisciplinary aspects, simplifying authorization processes and providing shortcuts.
  - *Coordinate municipal departments* – set a departmental organization that reduces the time for having answer to projects problems through a coordination of departments.

5.5. Conclusion

Regulatory framework in SBG is a complex set of rules that direct its development and implementation. Norms affecting different disciplines – energy, waste, taxation, fertilizer – need to be joined in SBG project. At this aim evolution of regulatory framework should provide an integration of norms both vertically among institutions to standardize targets with strategies and actions, as well as horizontally to have a vision of disciplines as part of a unique system view aimed at sustainability goals. This integration will not support only SBG, but all projects that do not affect specific disciplines, but develop scenario not commonly considered in emanation procedures.

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6. TECHNOLOGICAL COMPONENTS IN SMART BIOGAS GRID

ORGANIZATION OF CHAPTER

Aim of this chapter is the investigation of SBG technological components. This chapter highlights components usable in SBG project, focusing on their function and applicability at different scales of the district. The chapter aim is to evaluate the appliances of these components on urban areas in relation to available space and technological limitations. Two complementary approaches are used: analysis of technological components related to their role in technological innovation system – waste collection, biogas production, products utilization – and their applicability in district.

6.1. Introduction

This research investigates the utilization of biogas in urban area with the aim to realize a '*smart biogas grid*' as technological innovation system, that could move from an existing regime to a new one; this chapter focuses on which are the technological components involved in SBG. To modify existing regime and its characteristics, introduction of technologies is needed and therefore framing their typologies and characteristics is important, also for SBG.

First key point is defining what is here considered as '*technology*' or '*technological component*'. With these terms, this research includes all those physical components related to SBG that answer to projects' needs through their performances. In this perspective with '*technology*' term, all components of SBG are checked independent of the grade of complexity they have. From a kitchen caddy to CHP generator, there are many components that needs to be classified, analyzed, compared underlining their performances, their spatial needs and applicability at different scale as well as in different district typology, their environmental and social sustainability; all these are architectural technological aspects to be studied in SBG project. Technological components are fundamental in architectural process and this work takes into consideration cities, districts, built areas that are the expression of architecture. In the frame of architectural technology, the components studied are solutions able to answer humans needs and expectations in the most effective way, changing the context where there are applied. For this reason, understanding the role of technologies related to SBG is not a merely act of rating, but it is the comprehension of which is the role of these technologies in district scenario and in TIS perspective with social, environmental and infrastructural consequences derived.

First part of this chapter takes into considerations technological components involved in SBG, through a ranking base on their functional roles in SBG; second analysis how other technologies RES and energy efficiency practices, can be integrated with SBG' components presented; third frames the role of context, as technological set of characteristics that are capable to host components analyzed, taking into consideration district typologies with their characteristics.

6.2. Methodology adopted

These chapter has been developed with following methodologies:

- ***Literature review*** – papers, documents, have been read to investigate technological components that affect waste collection, biogas production and products – biogas and digestate – utilization;
- ***Case studies analysis*** – contained in *Annex 1 – Case studies*, this analytic instrument is used to study case studies realized in urban areas that include bio-waste collection, biogas production and utilization, food and green growing practices as well as other sustainable solutions that could be included in SBG projects.
- ***Technological components classification*** – analytic analysis of technological components of SBG application, through division in three macro categories – waste collection, biogas production and products utilization. Components are classified and presented for their characteristics – technical aspects, scale of installation, functional complexity – in relation to SBG as TIS. Components are highlighted for their autonomy, complementary and alternative in relation to other.
- ***Technological legitimacy identification*** – over classified technologies are presented for their applicability in different district scales – household, building, district – as well as in different district typologies – compact, peri-urban, suburban districts. In the frame of approach requirements-performances (Mario Zaffagnini, 1981) applied at district for SBG's technological components, this analysis directs the utilization of technological components in specific urban areas.
- ***Mapping of components*** – synthesis of information collected to schematize context, actions and outputs previously collected. This map is a partial contribute to the full understanding of SBG in its complex.

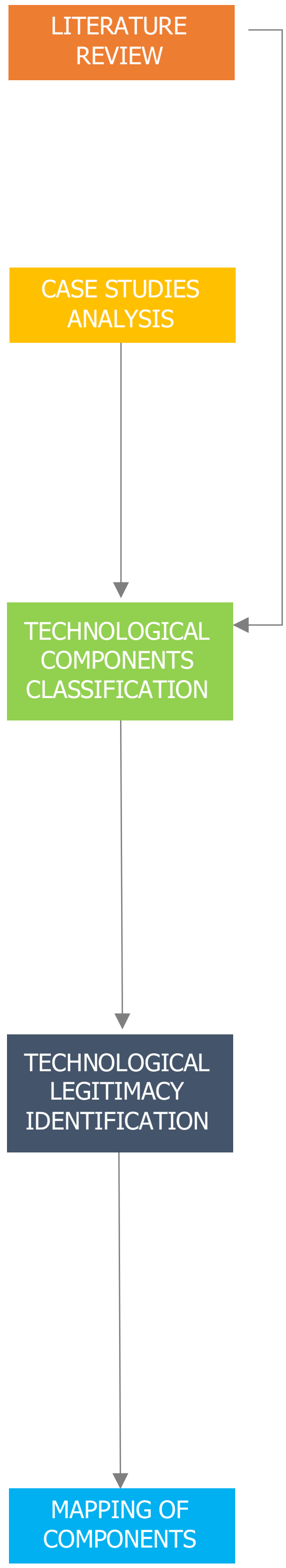


Figure 6-1: synoptic framework of methodology adopted for technological aspects of SBG

6.3. SBG's technological components

Identifying SBG's technologies inside a TIS, means firstly, understand which are complexities involved. Indeed, TIS as SBG is not merely the application of single components, but it is the result of the interconnections, overlapping of components that work as part of a complex system. Comprehension of all these technological components is mandatory to go beyond the only biogas plant system, identifying number of components, heterogeneity of their functions, complexity of their network (Cayford & Scholten, 2014). For this reason, this section presents a rating of SBG's technological components that is indicative of possible components applicable to this project. All disciplinary topics emerged in previous chapters – environmental, energy field, normative – are here resumed as characteristics of different technologies. Indeed, a full comprehension of technologies faces aspects other than technological applicability, including elements that can preclude success of SBG and independent of their possibility to be installed. In this framework, among aspects involved, SBG's technological components are studied excluding engineering aspects, not treated in this research.

To direct analysis of technologies in SBG, different classifications are provided. The first is based on categories on role of technological components in SBG:

- ***Bio-waste collection (BWC)*** – this category involves the technological components related to the collection and management of bio-waste from its production to its collection. This category is classified in sub-categories: food waste collection (FWC), green waste collection (GWC), wastewater collection (WWC), food waste pre-treatment (FWPT), food/green waste movement (WM), waste storage (WS).
- ***Biogas production (BP)*** – this category involves the technological components related to the biogas production system. A simplification is made, considering anaerobic digestion plant, as an unique system of more technologies. This category is classified in three sub-categories: waste storage (WS), digestate reactor (DR), gas storage (GS).

- ***Products utilization (PU)*** – this category involves the technological components related to utilization of anaerobic digestion products: biogas and digestate. This category is classified in two sub-categories: biogas utilization (BU), digestate utilization (DU).

Components presented are classified using the category subdivision over mentioned (for instance '*bio-waste collection for green waste collection*' is identifiable as '*BWC GWC*'), and they are analyzed through their main characteristics in line with following classes:

- ***technical aspects*** (Table 6-1) – set of features that affect direct component application – size, capacity, cost, odor, noise, emission. Except for '*size*' and '*capacity*' that are quantitatively described, the other features are evaluated qualitatively; considered acceptable by norms all parameters defined, differences among components' aspects can affect economic and social sustainability in SBG perspective.

Table 6-1: technical aspects of component are classified following the present quantitative and qualitative ranking

Technical aspects									
Size	**Capacity**	**Cost**		**Odor**		**Noise**		**Emission**	
specific units	specific units	●●●	expensive	●●●	high	●●●	high	●●●	high
		●●	medium	●●	medium	●●	medium	●●	medium
		●	cheap	●	low	●	low	●	low
		○	no cost	○	no odor	○	no noise	○	no emission

- ***scale of installation*** (Table 6-2) – this category takes into consideration where technological components should be installed: household – internal and external –, building – internal and external –, or district scale. This classification has a double goal: from one side, direct further classification at district scale to understand if technologies can be applied independently of district typologies; on the other it frames technologies into a logic of actors engagement, directing social innovation for different stakeholders (analyzed properly in next chapter).

Table 6-2: scale of installation of technological component is classified following the present qualitative ranking

Scale of installation				
household		**building**		**district**
internal	**external**	**internal**	**external**	
	●●●	preferable		
	●●	possible		
	●	not advisable		
	○	impossible		

- ***functional complexity*** (Table 6-3) – in line with scale of installation, this classification helps to understand the grade of complexity of technological components for installer, user and maintenance technician. In the perspective to generate through SBG, a logic of prosumers, engagement of non-professional actors has to be evaluated starting with functional complexity of technologies in installation, use and maintenance. Classification is made on necessary training requested to operator.

Table 6-3: functional complexity of technological component is classified following the present qualitative ranking

Functional complexity		
installation	**use**	**management**
●●●	high training	
●●	medium training	
●	low training	
○	no training	

Among technological components classified, different types of relationships can be identified and here presented (Table 6-4):

- ***Autonomous*** – technological component works autonomously without necessity to be related with other technologies;
- ***Complementary*** – technological components need to be installed in collaboration with others to be effective;
- ***Substitute*** – technological components play the same role in SBG and are alternative of other components.

Table 6-4: relationship typology between technological components

Relationship typology	
⟶	Autonomous
⟷	Complementary
=	Substitute

Next paragraphs present technological components investigated.

6.3.1. SBG's technological components: bio-waste collection

First set of components analyzed are those that are connected to '*bio-waste collection*'. Process of urban collection and its advantages have been presented in environmental chapter; this section takes into consideration those technologies necessary to achieve bio-waste separate collection at household, building and urban scale. Table 6-5 reports components analyzed and their technical aspects, while Table 6-6 reports scale of application and functional complexity. Some considerations can be done. Components related to sub-category FWC and GWC are generally typical of post-production phase: after food and green waste are produced in food or in cutting activities, waste is collected separately in lidded containers that are positioned in places depending on their capacity and (Figure 6-2, Figure 6-3, Figure 6-4). These components have a very low degree of technological complexity, but their role is important because they direct engagement of bio-waste producer waste management practices.

Figure 6-2: kitchen caddy (BWC FWC 1.1) for food waste collection used to stock temporary inside household (emptied twice a week) residual food intended to be wasted

Figure 6-3: curbside caddy (BWC FWC 1.2) for food waste collection used to stock temporary at household/building level (weekly emptied to prevent odor) residual food intended to be wasted

Figure 6-4: wheeled container (BWC FWC 1.3 and BWC GWC 2.1) for food and green waste collection used to stock temporary at building level (weekly emptied to prevent odor) residual food and garden waste to be wasted, once moved from caddies. It can be contained in wheeled container housing (BWC GWC 2.2,Figure 6-6)

Figure 6-5: bin (BWC FWC 1.5) for food waste collection used to stock temporary at building/communal area level (weekly emptied to prevent odor) residual food to be wasted, once moved from caddies

Figure 6-6: wheeled container housing (BWC GWC 2.2) to have a greater control and protection of wheeled container

Pre-treatment technologies are considered in 'bio-waste collection' section. Before the arrival to AD plant, food can be treated to increase its degradability and, as a consequence, improve its methane yield through mechanical pre-treatments (Bochmann & Montgomery, 2013). Different technologies can be used to increase the specific surface area of bio-waste with the effect to reduce particle size, accelerate further AD process and increase biogas amount. Household, building as well as district macerator can be provided adopting technologies that macerate bio-waste at different scale represent a solution depending on willingness of actors in be engaged in the project (Figure 6-7, Figure 6-8, Figure 6-9).

Figure 6-7: household macerator (BWC FWPT 3.1) to install under kitchen's sink increase biogas yield up to +33%

Figure 6-8: building waste macerator (BWC FWPT 3.2) reduces volume by up to 80% and weight by up to 50%

Figure 6-9: district macerator (BWC FWPT 3.2) to be used close to AD plant

Not considered in this research is the wastewater collection system. The reason is that sewage infrastructure is usually a system already existing in EU cities. Wastewater contribution is very important in biogas production and for this reason it is important to channel black water into anaerobic digestion process also through dedicated black sewage systems to reduce amount of cleaners and soap present in other wastewater. In addition, AD process can be optimized reducing percentage of water derived by flushing; at this aim the utilization of vacuum toilet (BWC WWC 4.1) decrease water quantity in wastewater (0,5/1,5 liters used against 10 liters of traditional toilets).

A further important phase of bio-waste collection is movement of bio-waste to anaerobic digestion plant. The choice of vehicle to collect waste is not secondary. Its design is affected by technological district characteristics, efficiency, cost-effective and, also, engagement of district citizens. Different solutions can be applied, each one with its legitimacy, but to be tested case by case (WRAP, 2016). In addition to usual solutions that provide garbage truck suitable to move tons of waste and should be managed in a network of districts to recoup their cost and justify their acquisition in MSWM practice, smaller solutions are particularly interesting in SBG perspectives. This is the case of cargo bike (Figure 6-10), small vehicle activated by human force that can collect food with zero emissions and through engagement of local citizens, voluntary or paid, as well as charity organizations.

Figure 6-10: bike cargo (BWC WM 5.1) is a small cycling vehicle that collect up to 100 kg of food waste with an average speed of 15/20 km/h

Figure 6-11: cargo bike allows to collect household waste within a radius of 2 miles (3,2km) in the AD plant in Camley street natural park, London, UK.

Similar is the utilization of electric vehicle (Figure 6-12) that can be used for the collection at district scale despite their low autonomy (70km), and with zero emission expect for those derived by electricity generation – in case of RES generations is a zero-emission vehicle.

Figure 6-12: small electric vehicles (BWC WM 5.2) with a capacity of 655 kg (2.200 liter) has an autonomy of 70 km and a max speed of 35/44 km/h

In addition to collection system that provide a movement by crew, market proposes also pneumatic system that move automatically bio-waste from collection point to district collection point. Through installation of inlets (Figure 6-13) installable indoor – household floor as well as building communal area – or outdoor – street level, park – with a density of 1 each 150-250 people, waste collected can be moved without any manual operation except the one of waste producers that bring bags and liners to collection point. System, through underground pneumatic pipelines of diameter 500 mm and at a depth of 2 m, move bio-waste to a district collection area at maximum distance of 2km.

Figure 6-13: Pneumatic collection inlets (BWC WM 5.5.1) are emptied automatically when full or at times. 1 each 150-250 people at streetscape, indoors floor, doorway, street level or outdoors, wall-mounted as well as freestanding. Pneumatic system needs for infrastructural intervention in district underground and, for this reason, only bio-waste collection would not be cost effective if not connected to other waste streams

Once moved to district collection area, two solutions of station are provided:

- ***stationary station*** (Figure 6-14) – collection area covers an area of 150/400m^2 and it is usually in district periphery. This area, in the case of SBG, can host AD plant and systems demanded to biogas production and utilization.

Figure 6-14: pneumatic collection stationary station (BP WS 5.5.3)

- ***moving station*** (Figure 6-15) – collection area covers an area of 150m^2, in district periphery and it can be also underground. Collection point must grant the access to vehicles to move waste where it is treated.

Figure 6-15: pneumatic collection mobile station (BWC FM 5.5.4)

Components presented in this section offer a set of possibilities that, integrated in MSWM, allow to achieve the expected results in bio-waste percentage collection, actors engagement and cost-efficiency. There are no components considerable more valuable than other, but they should be measured case by case, crossing exiting waste management practices with district technological boundaries, as well as level of population awareness and willingness to be engaged.

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
kitchen caddy	BWC	FWC	1.1	separate and store food waste temporary before transferred to the external container	⟶		≅252 x229 x234mm	7/10 l	●	●	○	○	twice a week emptied to prevent odor	(“Waste Recycling Products,” n.d.; WRAP, 2016)
curbside caddy	BWC	FWC	1.2	separate and store food waste before its collection	⟷ =	1.1 1.3 1.5	≅320 x400 x405mm	23 l	●	●●	○	○	weekly emptied to prevent odor	(“Waste Recycling Products,” n.d.; WRAP, 2016)
wheeled container	BWC	FWC	1.3	collection of food waste in building or communal areas	⟷ =	1.1 1.2 1.5	≅480 x550 x1060mm	120/240 l	●●	●●	○	○	multiple weekly emptied to prevent odor	(“Waste Recycling Products,” n.d.)
wheeled container housing	BWC	FWC	1.4	protects the container, controls access and keeps the container secure	⟷	1.2 1.3	≅580 x660 x1280mm	140/240 l	●	○	○	○		(“Waste Recycling Products,” n.d.)
bin	BWC	FWC	1.5	collection of food waste in communal areas	⟷ =	1.1 1.2 1.3	≅1270 x720 x1100mm	500l	●●	●●	○	○	garbage truck requested to collect waste	(“Waste Recycling Products,” n.d.)
external collection point	BWC	FWC	1.6	area dedicated to collect multiple bins and curbside caddies	⟷	1.2 1.3 1.5	≅4000 x6000mm	# bins and curbsides	●	●●	○	○	garbage truck requested to collect waste	(“Waste Recycling Products,” n.d.)
wheeled container	BWC	GWC	2.1	collection of food waste in building or communal areas	⟶		≅480 x550 x1060mm	120/240 l	●●	●●	○	○	multiple weekly emptied to prevent odor	(“Waste Recycling Products,” n.d.)
wheeled container housing	BWC	GWC	2.2	protects the container, controls access and keeps the container secure	⟷	2.1	≅580 x660 x1280mm	140/240 l	●	○	○	○	greater control and protection of wheeled container	(“Waste Recycling Products,” n.d.)
household waste macerator	BWC	FWPT	3.1	increasing waste surface area reduce volume	=	3.2 3.3	≅173 x173 x318mm	980ml	●	○	●	○	increase biogas yield (+33%) power 3-4 kWh per year cost 150,00€	(InSinkErator UK, n.d.; Salihu & Alam, 2016)

Table 6-5a: technical aspects of bio-waste collection components

Component	Component id		Goal	Relation		Technical aspects						Notes	Reference
						size	capacity	cost	odor	noise	emission		
building waste macerator	BWC FWPT	3.2	increasing waste surface area reduce volume	=	3.1 3.3	≅635 x 762 x1041mm	19l	●●	●	●	○	reduction of volume by up to 80% reduction of weight by up to 50%	(“Dehydra Food Waste Dewatering System,” n.d., “SO5ES Stainless Steel Food Grinder | Hoover Ferguson Group, Inc,” n.d.)
district waste macerator	BWC FWPT	3.3	increasing waste surface area reduce volume	=	3.1 3.2	≅1949 x502 x279mm	7,7m^3/hr	●●	●	●	○	included in AD plant area	(“Industrial Shredders & Waste Grinders Size Reduction Equipment,” 2016)
vacuum toilet	BWC WWC	4.1	wastewater collection	⟶		≅525 x365 x465mm	/	●	○	○	○	high concentration of biomass low water requirement (0,5/1,5l) reduce water consumption by up to 90%	(“Vacuum Toilet | SSWM,” n.d., “Vacuum toilets for buildings - Sanitary Systems made to please - JETS™,” n.d.)
wastewater collection system	BWC WWC	4.2	wastewater movement to treatment plant	⟷	4.1	/	/	●●●	○	○	○	existing system in urban area	
small food waste only collection vehicles (bike cargo)	BWC WM	5.1	collect food/green waste	=	5.2 5.3 5.4 5.5	≅190 x90 x110cm	100 kg	●	○	○	○	average speed 15/20 km/h	(“Cargo-Bike Furgoncini a pedali di qualità 100% made in Italy,” n.d.)
small collection vehicles (electric)	BWC WM	5.2	collect food/green waste	=	5.1 5.3 5.4 5.5	≅385 x131cm	655 kg 2.200 liters 70 km	●●	○	○	○	max speed 35/44 km/h	(“Electric vehicle for waste collection,” n.d.)

Table 6-5b: technical aspects of bio-waste collection components

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
medium collection vehicles	BWC	WM	5.3	collect food/green waste	=	5.1 5.2 5.4 5.5	≅4200 x3000	2,5–3 tons	●●●	●●	●	●●	€ 68.000	(“Autobren Srl,” n.d., “Waste Collection Vehicle,” n.d.; WRAP, 2016)
Co-collection vehicles	BWC	WM	5.4	collect all waste	=	5.1 5.2 5.3 5.5	8000 x3900	1 tons of food waste	●●●	●●	●	●●	€96.000/€130.000 18,9/22,9m turning circle	(“Autobren Srl,” n.d.; WRAP, 2016)
Pneumatic collection	BWC	WM	5.5		=	5.1 5.2 5.3 5.4								(Envac, n.d.)
Pneumatic collection: inlet	BWC	WM	5.5.1	collect separately all waste	⟷	5.5.2 5.5.3 5.5.4	≅80x 80 x110cm # of inlets	emptied automatically when full or at times	●	○	○	○	inlet point 1 each 150-250 people streetscape, indoors floor, doorway, street level or outdoors wall-mounted or freestanding	(Envac, n.d.; “Waste Collection Vehicle,” n.d.)

Table 6-5c: technical aspects of bio-waste collection components

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
Pneumatic collection: pipeline	BWC	FM	5.5.2	bridging inlet with waste tank	↔	5.5.1 5.5.3 5.5.4	Ø500mm	based on # waste	●●●	○	○	○	pipeline of 500mm 2m underground pneumatic air at 70-80 Km/h 2km from the waste inlets added to underground infrastructure	(Envac, n.d.; Oppent, n.d.)
Pneumatic collection: stationary station	BWC	WS	5.5.3	collect district waste	↔ =	5.5.1 5.5.2 5.5.4	150/400 m^2	based on # waste	●●	●	○	○	charcoal or fabric filter smells and emissions reduction periphery or underground	(Envac, n.d.)
Pneumatic collection: mobile station	BWC	FM	5.5.4	collect district waste	↔ =	5.5.1 5.5.2 5.5.3	150 m^2	based on # waste	●●	●	●	●	waste vacuumed into closed screw tanks and emptied by vehicle	(Envac, n.d.)

Table 6-5d: technical aspects of bio-waste collection components

Component id	Scale of installation					Functional complexity			
	household		building		district	installation	use	management	average
	internal	external	internal	external					
BWC FWC 1.1	●●●	●●●	○	○	○	○	○	●	○
BWC FWC 1.2	●	●●	●●	●●●	○	○	○	●	○
BWC FWC 1.3	○	○	●●	●●●	●●●	○	●	●	●
BWC FWC 1.4	○	○	○	○	●●●	●	○	○	○
BWC FWC 1.5	○	○	○	●●	●●	●	○	●●	●
BWC FWC 1.6	○	○	○	●●	●●●	●	○	●●	●
BWC GWC 2.1	○	○	●●	●●●	●●●	○	●	●	●
BWC GWC 2.2	○	○	○	○	●●●	●	○	○	○
BWC FWPT 3.1	●●●	○	○	○	○	●	○	●●	●
BWC FWPT 3.2	○	○	●●●	○	○	●	●	●	●
BWC FWPT 3.3	○	○	○	○	●●●	●	●●	●	●
BWC WWC 4.1	●●●	○	●	○	○	●●	○	○	●
BWC WWC 4.2	○	○	○	○	●●●	●●●	○	●●●	●●
BWC WM 5.1	○	○	○	○	●●●	○	●	●	●
BWC WM 5.2	○	○	○	○	●●●	○	●	●●	●
BWC WM 5.3	○	○	○	○	●●●	○	●	●●	●
BWC WM 5.4	○	○	○	○	●●●	○	●	●●	●
BWC WM 5.5.1	●	●	●	●	●●●	●●●	○	○	●
BWC FM 5.5.2	○	○	●	●	●●●	●●●	●●●	●●●	●●●
BP WS 5.5.3	○	○	○	○	●●●	●	●	●●	●
BWC FM 5.5.4	○	○	○	○	●●●	○	●●	●●	●

Table 6-6: scale of installation and functional complexity of bio-waste collection components

6.3.2. SBG's technological components: biogas production

Once bio-waste has been collected, it is time for anaerobic digestion. This section presents components related to '*biogas production*', that can be included in biogas plant design, with Table 6-7 that reports components analyzed and their technical aspects and Table 6-8 that reports scale of application and functional complexity. AD plant cannot be installed with the relatively easiness of solar systems, but it includes a set of components with specific dimensions in relation to amount of bio-waste treated (Figure 6-17).

Figure 6-17: AD plant in Camley street natural park, London, UK. AD plant covers an area of about 60m2 treating an average of 14kg of food waste at day, producing 4,2 m3 of biogas used in a strirling engine of 1kW (WRAP, 2015)

Figure 6-16: plan of preliminary project of AD plant in Camley Street park. Acknowledgment to Rokiah Yaman, Director at Community by Design, London, UK, for the material provided on the project

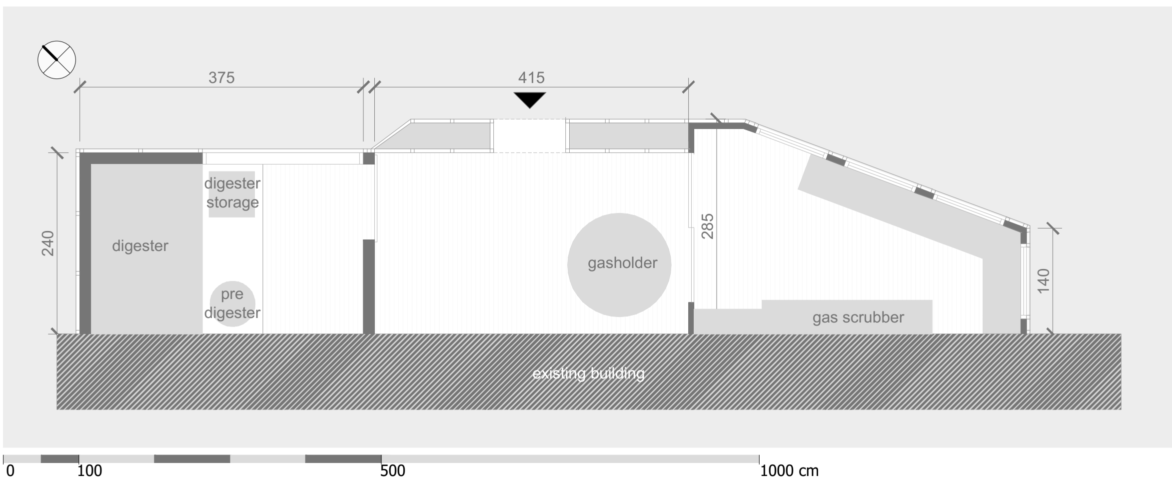
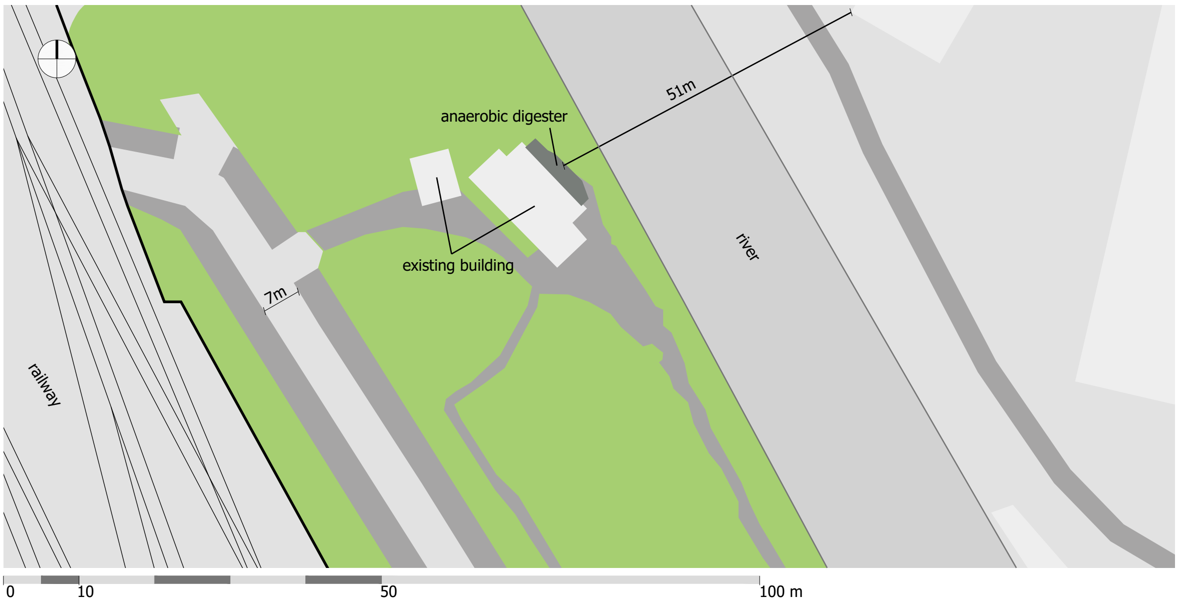


Figure 6-18: localization of AD plant of Camley Street park within the district where it operates

Figure 6-19: AD distances with closer buildings. The AD located inside the park guarantees am adequate distances to prevent eventually unpleasant odors



For this reason, more than the evaluation of engineering components – pipes, pumps, valves – this section considers components that mainly affected size of AD plant:

- *digestion reactor (BP DR 1.0)* – technological component that is composed by feeding systems, reactor – classifiable for type volume and material – insulation and agitators. Different types of reactor can be used (Figure 6-20, Figure 6-21, Figure 6-22) and their size depend on waste treated.
- *gas storage (BP DR 2.0)* – technological component that differs for type, volume, material and space available for location (Figure 6-22, Figure 6-23, Figure 6-24).

Figure 6-20: rubber-balloon reactor (BP DR 1.1) is an off-ground digester simple and cheap, that achieves high temperature under sunny sky and is easy to clean and empty. Being an inflatable balloon exposed to natural event, possible damaged has a short life span

Figure 6-21: fixed-dome reactor (BP DR 1.2) has constant volume, usually is an underground digester that has) minimal temperature exploiting ground insulation. Made of concrete and buried, it has a long-life span

Figure 6-22: floating-drum reactor (BP DR 1.3) with integrated gas storage (roof double-layer BP GS 2.1). Reactor has expandable a volume that compensates biogas fluctuations

Figure 6-23: stand-alone vessel (BP GS 2.2) is external to digester to compensates biogas

Figure 6-24: gas bag (BP GS 2.3) is external to digester to compensate biogas fluctuations

Among these two components related to biogas production process, it is important to size correctly biogas reactor to host the waste feed in. Two parameters are used to calculate the digester volume (Nathalie Bachmann, 2013):

- *Organic Loading Rate (OLR)* – that describe the amount of volatile dry matter (VDM) introduced in the digester, considered for our purpose to $3\frac{kg_{VDM}}{m^3dd}$, to maintain a reduced organic load and not be the system too much sensitive (specific design should be assessed for each plant);
- *Hydraulic Retention Time (HRT)* – the theoretical time that substrates stay in the digester and it must not be below 10 days.

To determine reactor volume two following formula are used

$$Digester\ volume\ (m^3) = \frac{Substrate\ input\ \left(\frac{kg}{dd}\right) X\ DM(\%)\ X\ VDM\ (\%\ od\ DM)}{OLR\ \left(\frac{kg_{VDM}}{m^3dd}\right)}$$

or

$$Digester\ volume\ (m^3) = Substrate\ input\ \left(\frac{m^3}{dd}\right) X\ HRT\ (dd)$$

The major among the two volume is the size expected for biogas reactor.

Parallel to digestion reactor, size of gas storage should be calculated considering biogas utilization. Indeed, in the perspective to not use all quantity of generated biogas immediately in generation system or in its injection into gar grid, a gas storage should be provided calculating m^3 needed as difference between biogas produced and biogas used.

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
Digestion reactor	BP	DR	1.0		→									
rubber-balloon reactor	BP	DR	1.1	bio-waste degradation	=	1.2 1.3	based on # waste treated	based on # waste treated	●	○	○	●	off-ground digester simple and cheap higher temperature under sunny sky easy to clean and empty short life span	("Anaerobic Digestion (Small-scale) | SSWM," 2014)
fixed-dome reactor	BP	DR	1.2	bio-waste degradation	=	1.1 1.3	based on # waste treated	based on # waste treated	●	○	○	○	constant volume (underground) minimal temperature changes long life span	("Anaerobic Digestion (Small-scale) | SSWM," 2014)
floating-drum reactor	BP	DR	1.3	bio-waste degradation	=	1.1 1.2	based on # waste treated	based on # waste treated	●●	○	○	○	expandable volume (underground) minimal temperature changes long life span	("Anaerobic Digestion (Small-scale) | SSWM," 2014)
Gas storage	BP	GS	2.0		→									
integrated in digester: roof double-layer	BP	GS	2.1	compensate biogas fluctuations in production and consumption	=	2.2 2.3	Ø 10-40m h 2,1-8,5m	60-3.000 m³	●	○	○	○	double-shell biogas roof withstands all external loads	(Sattler Ceno Biogas GmbH, n.d.)
external to digester: stand-alone vessel	BP	GS	2.2	compensate biogas fluctuations in production and consumption	=	2.1 2.3	Ø 4,9-23,5m h 3,7-17,6m	50-5400 m³	●	○	○	○		(Sattler Ceno Biogas GmbH, n.d.)
external to digester: gas bag	BP	GS	2.3	compensate biogas fluctuations in production and consumption	=	2.1 2.2	based on space available	based on # waste treated	●	○	○	○	depressurized bag or steel or concrete tanks	(Sattler Ceno Biogas GmbH, n.d.)

Table 6-7: technical aspects of biogas production components

Component id			Scale of installation					Functional complexity			
			household		building		district	installation	use	management	average
			internal	external	internal	external					
BP	WS	1.0	○	○	○	○	●●●	●	●	●●	●
BP	DR	2.0									
BP	DR	2.1	○	○	○	●	●●●	●	●	●	●
BP	DR	2.2	○	○	○	●	●●●	●●	●●	●●	●●
BP	DR	2.3	○	○	○	●	●●●	●●	●	●●●	●●
BP	GS	3.0									
BP	GS	3.1	○	○	○	○	●●●	●●	●	●●	●●
BP	GS	3.2	○	○	○	●	●●●	●●	●	●	●
BP	GS	3.3	○	○	●●	●●	●●	●	●	●	●

Table 6-8: scale of installation and functional complexity of biogas production component

6.3.3. SBG's technological components: products utilization

Last components to take into consideration are those related to AD products utilization: biogas and digestate. Components taken into consideration are classified in Table 6-9 for technical aspects and in Table 6-10 for their scale of installation and functional complexity.

The most appealing product in SBG is biogas. Indeed, many are the possibilities that biogas opens and technological components that allow its utilization have been investigated in energy chapter. In this technological analysis, the concentration is in understanding the amount of space requested for installation of these systems that need dedicated locations to be separated from AD plant and guarantee correct installation, management without interfering with bio-waste collection or biogas production (Figure 6-25, Figure 6-26). These components connected to small AD plant needs for relative small spaces of installation depending on power and energy outputs expected. Generators are bigger that normal household boilers or engines, but, considering energy producible by bio-waste treated at district scale, their size is generally hosted in an area of around 10m^2.

Figure 6-25: boilers (PU BU 1.1) produces hot water

Figure 6-26: CHP stirling engines (PU BU 1.3) produces heat and electric energy

In addition to generation system, biogas utilization can provide also system to clean (Nathalie Bachmann, 2013) (Figure 6-27), useful to remove gas compounds – water, hydrogen sulfide, particles and siloxanes – which can cause corrosion and increase in management cost in biogas technologies – boilers, gas engines and turbines, CHP, fuel cells (Petersson, 2013; Kaparaju & Rintala, 2013). Also biological, physical or chimical removal are used for hydrogen sulfide; filters or solutions before or after the digester absolve this goal. Other process is the upgrading treatment (Nathalie Bachmann, 2013), that allow to biogas to be injected into the gas grid or used directly as vehicle fuel, its quality has to be equal to natural gas used and have methane concentration >96 (Beil & Beyrich, 2013). However, before biogas is upgraded, a previous cleaning is requested to prevent some impurities to be harmful, as in the case of hydrogen sulfide, and only in a second phase compression or scrubber (Figure 6-28) technologies are used to upgrade biogas into biomethane.

Figure 6-27: membrane separation system (PU BU 1.9)

Figure 6-28: scrubbing technology (PU BU 1.9)

Once upgraded biogas became biomethane that can be used as alternative to natural gas and be injected into grid without other technological systems needed, or used as biomethane in natural gas vehicle. In this case, in addition to vehicles to be used depending on district requirements, urban areas must provide a place for methane station (Figure 6-29) to supply vehicles; for this reason, a dedicated area, at least 8 m^2, should be provided.

Figure 6-29:methane station (PU BU 1.11.2)

Final reflection is on digestate utilization. Considering the opportunity to use on-site digestate produced in AD process, some components can be applied placing next to green area increasing areas available for digestate utilization. Among these components, appliances to be installed inside homes are the last development (Figure 6-30) and occupy a space typical of other domestic tools as ovens or dishwashers. At district level to develop communitarian project and contribute in manage green areas, vertical (Figure 6-31) or horizontal (Figure 6-32) different – forms, material – boxes typologies can be used to contribute in brown field refurbishment or in promoting social activities and training on plant and food growing.

Figure 6-30: garden home appliance (PU DU 2.1) for home food growing

Figure 6-31: vertical box (PU DU 2.2) for plant and food growing

Figure 6-32: horizontal box (PU DU 2.3) for plant and food growing

<table>
<tr><th rowspan="2">Component</th><th colspan="3" rowspan="2">Component id</th><th rowspan="2">Goal</th><th colspan="2" rowspan="2">Relation</th><th colspan="6">Technical aspects</th><th rowspan="2">Notes</th><th rowspan="2">Reference</th></tr>
<tr><th>size</th><th>capacity</th><th>cost</th><th>odor</th><th>noise</th><th>emission</th></tr>
<tr><td>boilers</td><td>PU</td><td>BU</td><td>1.1</td><td>produce hot water</td><td>=</td><td>1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.10
1.11</td><td>≅2,4x
2,0m</td><td>199/500k
W</td><td>●</td><td>○</td><td>○</td><td>●</td><td></td><td>(“Biogas Boiler | Renewable Heating | Bioenergy Specialists,” n.d.; Kaparaju & Rintala, 2013)</td></tr>
<tr><td>CHP engines</td><td>PU</td><td>BU</td><td>1.2</td><td>produce mechanical energy</td><td>=</td><td>1.1
1.3
1.4
1.5
1.6
1.7
1.8
1.10
1.11</td><td>≅3,80x
1,65x
2,75m</td><td>100–350
kW_{el}</td><td>●●</td><td>○</td><td>●</td><td>●●●</td><td>36-37% electricity efficiency 51-54% thermal efficiency</td><td>(“Gas engines - Products - Biogas Systems,” n.d., “Kraft Energy Systems: Generators, Gas and Diesel Engines, Power Transmission Equipment, Swichgage, Parts and Accessories. For home, industrial, mobile use,” n.d., “Technology Radar - WISIONS of Sustainability,” n.d.; Kaparaju & Rintala, 2013)</td></tr>
<tr><td>CHP stirling engines</td><td>PU</td><td>BU</td><td>1.3</td><td>produce heat and electric energy</td><td>=</td><td>1.1
1.2
1.4
1.5
1.6
1.7
1.8
1.10
1.11</td><td>≅3,0x
1,2x
1,8m</td><td>2-9 kW_{el}
8-26 kW_{th}</td><td>●●</td><td>○</td><td>●</td><td>●</td><td>25% electricity efficiency 70% thermal efficiency <18% methane yield in biogas</td><td>(Clean Energy, n.d.; Kaparaju & Rintala, 2013)</td></tr>
</table>

Table 6-9a: technical aspects of products utilization components

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
CHP micro turbines	PU	BU	1.4	produce heat and electric energy	=	1.1 1.2 1.3 1.5 1.6 1.7 1.8 1.10 1.11	≅0,76-3,0x 1,5-9,1x 1,8-2,9m	30–1000 kW_{el}	●●	○	●	●	26-33% electricity efficiency 57-64% thermal efficiency	(Capstone, n.d.; Kaparaju & Rintala, 2013; “Technology Radar - WISIONS of Sustainability,” n.d.)
refrigeration	PU	BU	1.5	use the heat produced from biogas for refrigerate	=	1.1 1.2 1.3 1.4 1.6 1.7 1.8 1.10 1.11	≅0,50x 0,50x 0,85m	100l	●	○	○	○	not yet commercial expected cost 700€/1500€ 100 l refrigeration volume/2000 l of biogas per day	(“Biogas Appliances - energypedia.info,” n.d., “Technology Radar - WISIONS of Sustainability,” n.d.)
small-scale fuel cells	PU	BU	1.6	convert the chemical energy of a fuel source, as biogas, and an oxidant, as air, to electrical energy and by-products including heat	=	1.1 1.2 1.3 1.4 1.5 1.7 1.8 1.10 1.11		300–1500 kW_{el}	●●●	○	○	○	not economically competitive (10.000€/kW; 2.396€/kW by 2050) not commercially mature	(“Fuel Cell FAQ | Pure Energy Centre,” n.d., “Technology Radar - WISIONS of Sustainability,” n.d.; FuelCellsEtc, 2015; Kaparaju & Rintala, 2013)

Table 6-9b: technical aspects of products utilization components

<table>
<tr><th rowspan="2">Component</th><th colspan="3" rowspan="2">Component id</th><th rowspan="2">Goal</th><th colspan="2" rowspan="2">Relation</th><th colspan="6">Technical aspects</th><th rowspan="2">Notes</th><th rowspan="2">Reference</th></tr>
<tr><th>size</th><th>capacity</th><th>cost</th><th>odor</th><th>noise</th><th>emission</th></tr>
<tr><td>cooking</td><td>PU</td><td>BU</td><td>1.7</td><td>utilization for food cooking</td><td>=</td><td>1.1
1.2
1.3
1.4
1.5
1.6
1.8
1.10
1.11</td><td></td><td></td><td>○</td><td>○</td><td>○</td><td>○</td><td>0,3 to 0,9 m3/person per day</td><td>(“Anaerobic Digestion (Small-scale) | SSWM,” 2014)</td></tr>
<tr><td>lighting</td><td>PU</td><td>BU</td><td>1.8</td><td>utilization for food lighting</td><td>=</td><td>1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.10
1.11</td><td></td><td></td><td>○</td><td>○</td><td>○</td><td>○</td><td>0,1 to 0,15m3/h</td><td>(“Biogas Appliances - energypedia.info,” n.d.)</td></tr>
<tr><td>-pressure swing adsorption (PSA)
- scrubbing
- membrane separation</td><td>PU</td><td>BU</td><td>1.9</td><td>cleaning biogas</td><td>↔</td><td>1.10
1.11</td><td>≅2 ×2 ×2,24m</td><td>40-80 Nm^3/hr</td><td>●</td><td>○</td><td>●</td><td>○</td><td>methane loss 0,05-15% (scrubber 0,5-2%) (scrubber water demand of 2.1 to 3.3 liters per day per cubic meter)</td><td>(“Camda Biogas Scrubber Precheatment System For Biogas Generator - Buy Scrubber,Perifying System,Precheatment System Product on Alibaba.com,” n.d.)</td></tr>
</table>

Table 6-9c: technical aspects of products utilization components

Component	Component id			Goal	Relation		Technical aspects						Notes	Reference
							size	capacity	cost	odor	noise	emission		
grid injection	PU	BU	1.10		=	1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.11			○	○	○	○		(Urban, 2013)
transport system	PU	BU	1.11		=	1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.10								(Svensson, 2013)
transport system: Natural Gas Vehicle (car, bus)	PU	BU	1.11.1		⟷	1.11.2		based on NGV used	●●●	○	○	●		(Svensson, 2013)
transport system: biogas fuel station	PU	BU	1.11.2		⟷	1.11.1	≅2 ×4m	1/2 vehicles	●●	○	●	●		(“Natural and biogas filling stations,” n.d.)
garden home appliance	PU	DU	2.1		⟶				●●	●	○	○		(“plantCube,” n.d.)
vertical gardening	PU	DU	2.2		⟶				●	●	○	○		(“20 Vertical Gardening Ideas for Turning a Small Space into a Big Harvest,” 2015)
horizontal gardening	PU	DU	2.3		⟶				●	●	○	○		

Table 6-9d: technical aspects of products utilization components

Component id	Scale of installation					Functional complexity			
	household		building		district	installation	use	management	average
	internal	external	internal	external					
PU BU 1.1	○	○	●●	●●	●●●	●●	●●	●●●	●●
PU BU 1.2	○	○	●●	●●	●●●	●●	●●	●●●	●●
PU BU 1.3	○	○	●●	●●	●●●	●●	●●	●●●	●●
PU BU 1.4	○	○	●●	●●	●●●	●●	●●	●●●	●●
PU BU 1.5	●●●	○	●●●	○	●●●	○	●	●●●	●
PU BU 1.6	○	●	○	●	●●●	●●●	●	●●●	●●
PU BU 1.7	●●●	○	●	●	●●●	●	●	●	●
PU BU 1.8	○	○	○	○	●●●	●	●	●	●
PU BU 1.9	○	○	○	●	●●●	●●●	●●	●●●	●●●
PU BU 1.10	○	○	○	○	●●●	●●●	●	●	●●
PU BU 1.11									
PU BU 1.11.1	○	○	○	○	●●●	○	●	●●	●
PU BU 1.11.2	○	○	○	○	●●●	●●●	●	●●	●●
PU DU 2.1	●●●	○	●	○	○	●●	●	●	●
PU DU 2.2	○	●●●	○	●●●	●●●	●	●	●●	●
PU DU 2.3	○	●●●	○	●●●	●●●	●	●	●●	●

Table 6-10: scale of installation and functional complexity of products utilization component

6.4. Energy efficiency practices and RES for technological integration

Among previously mentioned SBG's technological components, some solutions can be provided to improve system performances. Both in existing technological components as well as in new technologies applied, application of SBG's technologies can find a valuable support. Among energy efficiency practices, it is possible to include a set of technological solutions that can integrate SBG's components reducing installation and operative energy demand as well as costs by installing and using contemporary different technologies.

Components that have energy demand – heating or electrical – or that share similar worktable, are technologies that are more interesting to be integrated with other products.

In this scenario, the most appealing energy interventions are those on biogas reactor. AD system, has a relevant heating energy demand that can be reduced with some good energy practices. At this aim *insulation improvement* – a thickness around 10-18 cm with heat transfer values between 0,2-0,3 W/m^2K (Nathalie Bachmann, 2013) – and *greenhouse* – capable to save 51% of heat loss (WRAP, 2013) – are solutions considered valuable. If insulation is clearly a practice that reduce heating loss, and consequently energy demand and costs, creation of greenhouse – or polytunnels – is even more fascinating in SBG perspective. Indeed, greenhouse offers different opportunities (LEAP - Local Energy ADventure Partnership, n.d.) in SBG perspective more than the only reduction of heating loss, providing to AD pant of a cost-effective insulation that also guarantee solar gain, furtherly reducing energy demand. Greenhouse improves internal thermal condition also because it hosts food and plant growing, that, especially during colder periods, can exploit emissions released during biogas burning (CO_2 and sulfur), creating a more positive environment for digestion process as well as for plant growth itself. The consequences are overcoming odor problems being greenhouse interior odorless, evaporating surplus moisture from the AD operation. Therefore, greenhouse is an energy efficiency practice that positively contributes in SBG, enhanced performances of biogas production, contemporary reducing energy demand and costs. In parallel, greenhouse can provide a place for growing activities useful for digestate utilization as well for serving as a location for district and community activities (next chapter goosed deep inside the topic).

In addition to AD plant integration with greenhouse, also other interventions can better integrate technologies installable in SBG; this is the case of underground utilities. SBG includes different technologies that can be integrated in infrastructural planning optimizing worktable and solutions realization. Pneumatic waste collection, district heating/cooling, biogas upgraded grid network, are technological systems that should be complementary planned to optimize interventions. Organizing projects' operations to work simultaneously and with a holistic vision as the one predicted by SBG, would allow to work on street underground positioning the requested pipelines only once, with economic, infrastructural and social advantages. In the same way, this solution should provide building connections opportunity to pipes, designing pipeline systems in order to ensure the efficiency of the network in arranging further connections at the system by stakeholders.

In addition to these good practices proposed, a key element is integration with RESs. RESs are not only important in SBG energy outputs, but also to optimize SBG energy demands. Digester reactor is a crucial component. Thermal energy needed by AD treatment, can be generated from different sources, but, RESs are the most appealing in this way. Biogas and biomass combustion (Murphy & Thamsiriroj, 2013), solar collection, geothermal can represent good opportunity to supply digester reaction. In the same way, RES can run pneumatic underground systems, supply electric vehicles for waste collection, being source for district heating and cooling energy demand working with biogas energy outputs. Therefore, the presence of renewable energy systems at district scale offer opportunities to integrate SBG technological components with energy outputs and optimize the whole SBG system.

6.5. Technological legitimacy of components

Urban morphology is characterized by different patterns each one with a different degree in accommodating SBG's technologies. There are indeed technological characteristics typical of different urban morphologies, which can affect the introduction of technological solution and understanding these features is important to verify technological legitimacy of SBG in urban areas. Indeed, technological context sets spatial limitations and opportunities to install and use SBG's components, defining a legitimacy (Markard, Wirth, & Truffer, 2016) that a context analysis based on built aspects and urban morphology helps to verify applicability at different scales of technologies analyzed. With this aim, identification of features that characterize district directs evaluation on legitimacy of SBG addressing further steps and strategies. While in previous chapters the energy potential of SBG in district and regulatory framework of reference has been analyzed, in this section the focus is on buildings and district features that affect SBG's technological components installation.

As already studied in '*scale of installation*' for each technology presented, components need specific spaces where to be installed. This is the case of AD plant, that can be located in a wide range of different district sites – park, brown field, community gardens and allotments, transport depots, street markets, social housing flats, hospitality businesses, universities, prisons, hospitals, etc. –, but this rule is also applied for all the other components according to their requirements. Another element to consider is the presence of existing systems that can be used by SBG or can be integrated with it. For instance, existing underground tubes and tunnels no more used or historical remains can affect the introduction of technological components as pneumatic collection system or district heating. Therefore, knowing technological characteristics frames legitimacy for components to be applied.

6.5.1. District legitimacy classification

All technologies previously analyzed are evaluated and classified to fit district typologies (Pracucci & Theo Zaffagnini, 2016). District have specific characteristics depending on building characteristics, green area presence and infrastructural elements. Reading these components from a technological point of view, helps to understand how many technologies can be installed in line with district typologies features. Indeed, districts have building typological models depending on geographical location technologies, historical foundation moment and cultural heritage; framing districts technological possibility to host components can direct SBG development. At this aim, district typologies have been classified considering components at their scale of installation, evaluating district technological legitimacy on technological applicability of SBG's technologies. Technological legitimacy is evaluated on a qualitative scale (Table 6-11) considering as requisite *usability*, *adaptability*, *integrability,* of district areas considered.

Table 6-11: rank of technological legitimacy of SBG's components for district areas

●●●	high
●●	medium
●	low
○	not legitimate

To evaluate the degree of technological legitimacy for districts, a benchmark centered on a '*new district*', designed to host all SBG's technologies is set and compared to district typologies. Based on ranking presented in Table 6-12, at each classification is assigned an increasing point from '*0 – not applicable*' to '*3 – high legitimacy*'. Summa of technological legitimacy of '*new district*' determines an upper limit of points that is a benchmark value for district typologies, allowing to evaluate their technological responsivity. A note should be made for this classification: considered scale of installation presented in tables above, correspondence with built, green and infrastructural is in bellowing table.

Table 6-12: correspondence between scale of installation and district's areas

Scale of installation		District areas
household intern	=	built area
household external	=	built area
building intern	=	built area
building external	=	green area
district	=	green area
district	=	infrastructural area

Table 6-13 reports results of this evaluation. The most interesting district typologies appear to be '*peri-urban district*' and '*suburban district with multifamily buildings*', urban patterns that can host technological components and their different configuration. With 79%

of legitimacy in relation to benchmark district, these typologies have few problems in hosting, for their technological characteristics, SBG's components. However, an highlight is needed: SBG project works at district scale, especially in public and semi-public areas, and for this reason many technologies are not considered legitimated to be installed in areas that are private and not serve at least a part of district population. Therefore, results have to be read considering district typologies limitations set – residential and small pattern size – that for this reason do not provide places – public or private, built or green, etc. – that can be designed or indented to be used for technological installation of SBG. This element affects particularly BP technologies in a negative way, especially in '*compact district*' and '*suburban district with single-family building*' that appear to have 0% possibility to host biogas production systems. This data derives from the fact that private green areas, typical of compact and sub-urban with multifamily buildings districts, do not allow to host AD plants – digester reactor and gas storage – because it is difficult to install components on private areas for the reason that it is not credible that private stakeholders could grant their property for a district activity. However, AD plant can be host in a set of possibilities – building to refurbish, brownfield, public park, etc. – that are not included in districts typologies as modelled. For this reason, identifying right spaces of installation can be crucial to allow applicability of SBG's components.

This evaluation on district legitimacy in hosting SBG, in connection with energy district potential focused on chapter 4, underline how the most appealing district to invest in SBG is '*sub-urban with multifamily district*', for good population density, as well as for built areas that can better host and integrate technological components and because there are semipublic sites that can serve AD plant and other community systems.

Component id			New designed district			Compact district			Peri-urban district			Suburban district with multifamily buildings			Suburban district with single-family buildings		
			built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area
BWC	FWC	1.1	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/
BWC	FWC	1.2	●●●	●●●	/	●●	●●	/	●●	○	/	●●	○	/	●●●	●●●	/
BWC	FWC	1.3	●●●	●●●	●●●	●	●●●	●	●	●●●	●●	●	●●●	●●	●	●●●	●●
BWC	FWC	1.4	/	●●●	●●●	/	○	○	/	●●	●●	/	●●	●●	/	●●●	●●
BWC	FWC	1.5	/	●●●	●●●	/	○	●	/	●●	●●	/	●●	●●	/	●●	●●
BWC	FWC	1.6	/	●●●	●●●	/	○	●	/	●●	●●	/	●●	●●	/	●●	●●
BWC	GWC	2.1	●●●	●●●	●●●	/	○	○	/	●●	●●	/	●●	●●	/	●●●	●●
BWC	GWC	2.2	/	●●●	●●●	/	○	●	/	●●	●●	/	●●	●●	/	●●	●●
BWC	FWPT	3.1	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/
BWC	FWPT	3.2	○	○	/	●●	○	/	●●●	●●	/	●●●	●●	/	○	○	/
BWC	FWPT	3.3	/	●●●	●●●	/	●	●	/	●●	●●	/	●●	●●	/	●●	●●
BWC	WWC	4.1	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/	●●●	/	/
BWC	WWC	4.2	/	●●●	●●●	/	●●	●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●
BWC	WM	5.1	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●
BWC	WM	5.2	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●
BWC	WM	5.3	/	●●	●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●
BWC	WM	5.4	/	●	●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●	/	●●●	●●●
BWC	WM	5.5	●●●	●●●	●●●	●	○	●	●●●	●●	●●	●●●	●●	●●	●	●	●●
BWC	WM	5.5.1	●●●	●●●	●●●	●	○	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●	○	●●
BWC	FM	5.5.2	●●●	●●●	●●●	●	○	●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●	●●●
BWC	WS	5.5.3	/	●●●	●●●	/	○	●	/	●●	●	/	●●	●	/	●	●
BWC	FM	5.5.4	/	●●●	●●●	/	○	●	/	●●	●	/	●●	●	/	●	●
BWC points achieved			***126***			***64***			***108***			***108***			***95***		
Degree of tech. leg.			***100%***			***50%***			***85%***			***85%***			***76%***		

Table 6-13a: degree of technological legitimacy for district typology

Component id			New designed district			Compact district			Peri-urban district			Suburban district with multifamily buildings			Suburban district with single-family buildings		
			built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area
BP		0.0	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	DR	2.0	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	DR	2.1	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	DR	2.2	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	DR	2.3	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	GS	3.0	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	GS	3.1	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	GS	3.2	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP	GS	3.3	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
BP points achieved			***27***			***0***			***18***			***18***			***0***		
Degree of tech. leg			***100%***			***0%***			***67%***			***67%***			***0%***		

Table 6-13b: degree of technological legitimacy for district typology

Component id			New designed district			Compact district			Peri-urban district			Suburban district with multifamily buildings			Suburban district with single-family buildings		
			built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area	built area	green area	infr.al area
PU	BU	1.1	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.2	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.3	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.4	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.5	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.6	●●●	●●●	○	●●	○	○	●●	●●	○	●●	●●	○	●●	○	○
PU	BU	1.7	●●●	●●●	○	●●●	●●	○	●●●	●●	○	●●●	●●	○	●●●	●●	○
PU	BU	1.8	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
PU	BU	1.9	/	●●●	○	/	○	○	/	●●	○	/	●●	○	/	○	○
PU	BU	1.10	/	○	●●●	/	○	●●●	/	○	●●●	/	○	●●●	/	○	●●●
PU	BU	1.11	/	○	●●●	/	○	●●	/	○	●●	/	○	●●	/	○	●●
PU	BU	1.11.1	/	○	●●●	/	○	●●	/	○	●●●	/	○	●●●	/	○	●●●
PU	BU	1.11.2	/	○	●●●	/	○	●●●	/	○	●●	/	○	●●	/	○	●●
PU	DU	2.1	●●●	○	○	●●●	○	○	●●●	○	○	●●●	○	○	●●●	○	○
PU	DU	2.2	●●●	●●●	○	●●	●●●	○	●●	●●●	○	●●	●●●	○	●●	●●●	○
PU	DU	2.3	●●●	●●●	○	●	●●●	○	●	●●●	○	●	●●●	○	●	●●●	○
PU points achieved			***75***			***39***			***55***			***55***			***40***		
Degree of tech. leg			***100%***			***52%***			***73%***			***73%***			***53%***		
Total points achieved			***228***			***103***			***181***			***181***			***135***		
Degree of tech. leg			***100%***			***45%***			***79%***			***79%***			***59%***		

Table 6-13c: degree of technological legitimacy for district typology

6.6. Conclusion

Knowing which components of SBG, what are they useful for, why can they be used, where can they be installed is mandatory to fully understand technological limits of SBG at urban scale. The study here conducted directs the utilization of components of SBG project that can modify areas where they are applied, combining different technological components in an integrated model that bring new relevance to these elements, from a technological point of view, as well for usability, safety and aesthetic. Except for component proper of bio-waste collection containment – caddy, curbside, bins – other components taken into consideration are mainly to be read at infrastructural level, need installation at district scale – pneumatic waste collection, AD plant, etc.. For this reason, SBG technologies integrate existing scenario better where there are less infrastructural boundaries – historical remains, private areas – and urban patterns provide larger public and semi-public space. These considerations open the possibility to work on contexts where there are areas to be renovated and restored, and owners – private or public – share SBG's aims and perspective for the whole district.

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7. Social innovation in Smart Biogas Grid

Organization of chapter

The present chapter investigates and integrates the previous chapter with social features involved in the promotion and diffusion of a biogas system inside communities. The aim is reading social features involved in biogas system investigating individual and communitarian predisposition to accept and share systems of these type to open opportunities of social innovation.

7.1. Introduction

Since the introduction of sustainable topic with the white paper of 1997 (European Commission, 1997), governments have realized and promoted policies, strategies and practices for sustainable transition, facing their environmental, social and economic problems. However, in this scenario, a lack of adequate actions at all levels, local, regional or national, has led to the development of semi-spontaneous answers to overcome specific problems related to sustainability issues; individual citizens and whole communities have contributed to the definition of new models of social innovation able to realize sustainable transformations. Indeed, as demonstrated by Turnheim et al. (2015), the "*diffusion of new technologies alone, assumed to be within a given socio-technical configuration, may not be sufficient to describe a process of transition*", and for this reason, beyond the only installation on technological components, implementation of interdisciplinary project as SBG should include strategies that concern the role of actors involved, their relationships and wider social logics.

In this perspective, the role of population is crucial to assess an evolution, and revolution, on an energy matter. It is important to assess new models of energy production and utilization where population has a key role in developing strategies; SBG can offer this opportunity. People are commonly considered as energy consumers for supplying their daily activities, but SBG can mark an energy transition that mobilizes a wider range of energy-users, moving population from energy consumers to energy producers, promoting the vision of population as '*prosumers*' (Süsser, 2016). In this frame SBG technological aspects contribute in the implementation of social innovation initiatives through community actions, allowing to develop a biogas energy system that involves local people engagement – community of practices, energy cooperatives and initiatives, energy independent district and energy self-sustaining households – building new aspects capable to generate a socio-technical transition.

In this context, social legitimacy of a biogas project cannot be underestimated. People are concerned on nuisance aspects as odor, noise and landscape changes, that often generate fears and rejections also because there is a wrong amplification by media supported by lack of know-how (Nathalie Bachmann, 2013). A clear identification of population expectations, fears on SBG, is basilar to direct information process within population and guide discussions to prevent further problems and obstacles in project development and implementation, as well as in authoritative processes. In the same way, involvement in bio-waste collection practices, as well as in managing project aspects, need to be included.

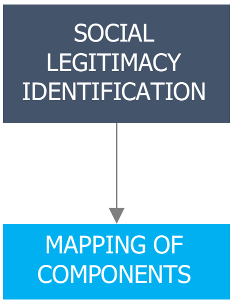
SBG opens to multi-agent, multidisciplinary actions and outputs that need to fit neighborhoods' requirements and needs, describing a set of possibilities that support the promotion of solutions in the scenario of social innovation. In such way, SBG helps single citizens and community to move to new models of energy and environmental behaviors, through active engagement into good practices in their own districts, raise awareness on the role of society in energy and technical transition.

7.2. Methodology

Figure 7-1: synoptic framework of methodology

These chapter has been developed with following methodologies:

- *Literature review* – papers, documents, have been read to investigate social components that direct social participation in sustainable projects as well as they are helpful for a wider engagement of stakeholders.
- *Case studies analysis* – contained in *Annex 1 – Case studies*, this analytic instrument is used to study case studies realized in urban areas that have included actions to engage different actors in bio-waste collection, biogas production and utilization, food and green growing practices as well as other sustainable solutions that could be included in SBG projects.
- *Population requirements survey* – among all stakeholders, SBG includes participation of local population. For this reason, understanding population willingness and perceptions on RESs and district scale energy solution, is considered a key element to define further SBG strategies and actions to implement in the project. Support of online survey is presented as operative tool



of preliminary evaluation.

- *Social legitimacy identification* – in this phase, a ranking of elements – actors, roles, social features – which contribute in social legitimation are issued, to direct evaluation of opportunity to realize SBG in an identified district.
- *Mapping of components* – synthesis of information collected are mapped to schematize context, actions and outputs collected. This map is a partial contribute to the full understanding of SBG in its complex.

7.3. Social innovation through community

Among disciplinary aspects developed in SBG, the role of social innovation is one of the most interesting to develop new generations of energy consumers and producers that are aware of their actions and their roles; the function of district's community is central because individual is a part of a society and common and effective results are achievable only by sharing objectives and programs. Role of population and degree of its engagement – active and/or passive – are key elements and SBG includes a set of aspects that implies participation of actors that live or work in urban districts. Community role in biogas consolidation, is already pursued by European Parliament with Resolution of 12 March 2008 (European Parliament, 2008), for which EU legislation urges to develop a coherent biogas policy to point out the most efficient ways of using EU funds and programs to achieve the necessary changes in community and national laws. If this consideration is valuable for agricultural communities, it is even more for urban community that have higher density and consequently generates specific social norms that are tools in society dynamics. In this perspective, the role of cooperation is basilar in SBG, to assess a shared scenario of actions within citizens and other local actors. As expected by European Parliament and Council (European Parliament and Council, 2008) communities should be involved starting with waste collection practices, Waste Directive highlights in article 31 that Member States should ensure the opportunity to participate in the elaboration of the waste management plans especially if these have relevant environmental effects; SBG fits perfectly this logic. This aspect is marked also by European Parliament (European Parliament, 2008), that asks to direct EU legislation to ensure cooperation and collaboration between Member States, to learn about each other best practices and export efficient biogas models.

Independently of geographical location – urban or rural areas – of size – small or large group – different communities have implemented their own initiatives (Turnheim et al., 2015), finding in social fabric the occasion for grassroots initiatives. Bottom-up initiative are indeed the most appealing because they have roots in local actors' interests and for this reason can go beyond institutional barriers and led to actions shared by population. These can be also defined as '*community-based initiatives*' that respond to local conditions with specific actions, assessed within the context of realization and on limitations and/or opportunities offered by local contingency, that empowers local community members to set actions that could not find the same success with a top-down approach. Social transition set with these experiences is commonly evaluated successful by actors involved. In the last decade, community-based initiatives have become fundamental experiences in green practices promotion with thousands of initiatives all over the world ("Community Energy Coalition," n.d., "Community Power," n.d., "Getting to Implementation - Community Energy Planning in Canada," n.d., "Global Ecovillage Network," n.d., "Transition Network," n.d.). In particular, community-driven initiatives are the most interesting experiences, that have been able to reduce emissions, to be energy independent and create autonomy from traditional energy networks, generate new incomes and promote new models of socialization. Actually, other appealing initiatives are also taking place and they are SME-driven initiatives ("Proficient," n.d.). Indeed, SMEs have the possibility to intercept people's requirements and concentrate resources towards common targets, thanks to their know-how and their financial capacities.

Despite variety of possible initiatives and their origins, there are common features which are recognizable and part of community projects (Turnheim et al., 2015): small-scale and place-based actions –

typically districts, neighborhoods, small towns, and villages; actions based on local sources and opportunities; initiatives that manage many different solutions going beyond single-issue actions, realizing multi-stranded projects. These projects underline the centrality of communities, both as population and other involved local actors, for the diffusion of a new technology, inside a context of application where it is legitimated and assessed in relation to community know-how, social cohesion and expected results. Community initiatives provide a set of possibilities that starts from populations' needs to develop specific transition paths.

7.3.1. Identification of community of practice

Despite achievable results, realization of community initiative is not simple neither automatic. Before issuance of projects at community level, it is requested an identification of a nucleus that shares goals and decides to find a way to pursue these objectives and identifies roots for a Community of Practice (CoP). '*Domain*' – identity defined by a shared domain of interests –, '*community*' – members of domain that build relationships and share information, activities and discussion –, and '*practice*' –shared practice of resources (experiences, stories, tools, ways of addressing recurring problems) – are elements that set a CoP (Wenger & Trayner, 2015). CoP is a combination of these factors and excluding domain, it appears clear that to create '*community*' and '*practice*', a certain time and interaction between actors are requested. SBG for its characteristics needs to be a CoP.

Without a common vision on district, SBG could not take place, and therefore it is important an initial effort to understand if premises for a CoP are present, investigating if there are any environmental, energy and social shared aspects. If there these conditions are present, members of community assessed a pathway that allow to learn with and from each other, becoming practitioners that take collective responsibility for managing knowledge they need and system they realize, creating a direct link between learning and performances. In this frame relies social innovation of SBG, promoting a solution at district scale that can support and implement community interests. SBG as community of practice allows to develop innovative models of governance (see next chapter) and education, to be considered an other products of SBG. Indeed, learning – waste chain, green/food growing, closed loop, etc. – is an end-product of education in SBG, developed inside the community. Peer-to-peer professional development activities, school guided tours carried on by actors involved, contribute in the promotion and diffusion of new education models, where education is not only provided by institutions, but also by a self-contained, closed experience in which students acquire knowledge that are applied in real world, outside classrooms. These points represent aspects of deep social innovation, considering that educational institutions have a slower attitude toward changes.

7.3.2. Towards biogas community energy

If over mentioned are social innovative aspects that are derived by CoP, shared interests in SBG also assess the promotion of biogas in urban areas as community energy. The term '*community energy*' covers a wide range of collective actions, with an emphasis on projects involving local engagement, leadership and control, and where there are benefits to local communities with an energy objective ("ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation," n.d.; QUEST – Quality Urban Energy Systems of Tomorrow, 2016). Community energy has had a step over in last years because in the context of low-carbon actions, it is now commonly accepted that low-carbon targets cannot be realized without the uptake of community energy that can offer wide social contribution. Case studies analyzed, especially in photovoltaic and wind community energy, demonstrate that there is an increased acceptance and awareness of renewable and sustainable energy technologies and issues, faster uptake of low carbon technologies and sustainable/pro-environmental behaviors, able to raise awareness on sustainable energy issues, on energy consumption practices and enhancing social cohesion. Despite these successful experiences, the development of bioenergy is low, because it includes, as already widely discussed in this work, a set of disciplines that need to be carefully interconnected and are not properly known by local actors. Despite this, biogas and community energy must be promoted with joined strategies. Indeed, community energy allows to maximize its potential – environmental, energy field and social – better than stand-alone solutions, and can also dissociate biogas from traditional governance structures – for example private energy companies or state-owned energy – that may be perceived as having conflicts with local interests. In this frame, actors engagement is the winning aspect of community energy. Studies conducted (Cayford & Scholten, 2014) show how community energy is a technical system which includes a high degree of participation within community it serves, as expected by CoP. This participation has its peculiarities depending on social fabric and its requirements in project, directing different community energy forms – specific initiatives, implementation, operations and expansion – generating a system connected and not independent of existing systems – social or technological –, operated entirely or partially by the community itself. SBG is a community energy based on biogas exploitation and possible engagement – passive and/or active – is crucial to define which strategies and actions take in place. For this reason, an analysis of social fabric and people's expectations is useful to frame the opportunity to realize CoP and community energy, evaluating actors attitudes to attend these communitarian solutions as well as their know-how to define the knowledge state of art to work on.

7.4. Social components in SBG

Considering all aspects and conditions previously mentioned, the identification of roots for CoP and energy community have to be investigates carefully. Infrastructural and institutional aspects discussed in the previous chapters, define only partially SBG legitimacy (Markard, Wirth, & Truffer, 2016), because it affected also by social components, causes of possible misalignments with context that could preclude the realization of SBG. Definition of elements that contribute to social legitimacy are here discussed and presented.

7.4.1. Actors

Core elements of social context and SBG are actors. With the term '*actors*' are considered all those individuals and collective players that are for various reasons part of domain where insists SBG and can perform different '*roles*' in the development of the project. Actors involved in SBG, are all practitioners of the project, players with a huge heterogeneity within districts because of different social, economic, professional conditions. Seven categories of actors have been identified by literature review, case studies analysis and survey conducted:

- ***community member*** – actors part of community for individual interests within district;
- ***community group*** – actors part of community that represent group of interests within district;
- ***business-SME*** – actors that have economic interests and are located within or close to district;
- ***educational institution*** – actors that have educational interests and are located within or close to district;
- ***government*** – public actors with normative and decisional authority on district;
- ***non-government organization (NGO)*** – actors that are organized in association/network that share some of SBG's specific targets;
- ***other*** – actors personally interested in being part of SBG project.

Table 7-1 reports in detail actors included in each category, players that can have roles in SBG development and further implementation of actions exploiting their competences, personal interests, time availability, social attendance or social relevance.

Table 7-1 (part 1): actors involved in

Community member	Community group	Business-SME	Educational institution	Government	Non-Government Organization	Other
Individual citizen interested Householder Gas station Hotel Café Restaurant	Housing managing association Voluntary association Charity association Parish	Fund sector Waste chain sector Real estate sector Energy supply sector Biogas industry	School boards Educational association University College Secondary school Primary school	Local Council Borough Municipality Regional National Over national	Social housing, citizens, consumers association Citizen assoc. Loc. chambers of commerce	Engineering and planning consultants Experts in disciplinary aspects

Community member	Community group	Business-SME	Educational institution	Government	Non-Government Organization	Other
		Food industry Agricultural firm			Assoc. of RES and/or biogas producers Consumer association Network for RES and/or biogas promotion	

Table 7-2 (part 2): actors involved in SBG

7.4.2. Roles

Independent of actors involved in SBG, there are recurring elements in development of the project that are roles that actors can play. In socio-technical transition project, role can be resumed in two moments of project elaboration (Walker & Devine-Wright, 2008):

- *Roles derived by* ***process dimension*** – phase of development of the project in its phase of design, realization and operation, that assesses who is project developer and runner and who is involved and has influence. In this process, following roles can be identified:
    - ***Instigator*** – actor that is the initiator of SBG, actor that has clear target to reach and knows innovation aspects achievable. The devotion to the project is important in order to deal with refusal, problems and to fight to have its vision become real.
    - ***Connector*** – actor - often institutions – that acts as a magnet and an enabler, attracting all relevant and motivated stakeholders, identifying local leaders, facilitating the exchange of knowledge and ideas, and supporting their implementation by empowering the community ("ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation," n.d.)
    - ***Interlocutor*** – actors that are involved in project development, through activities of information and planning of SBG. Usually interlocutors are all those actors that have interests in developing innovative solutions and introduce change with socio-technical transition assess.

- ***Opponent*** – actors that are usually supporters of existing socio-technical regime that could be damaged from introduction of new regimes. They can also be represented by actors that have a lack of awareness and know-how on disciplinary aspects faced in the project.
- ***Investor*** – actors that provide economic resources to afford technological components installation and eventually expenses for project development and implementation.
- ***Site landlord*** – actor that is landlord of site where AD plant – larger system to realize – is installed. Depending on site landlord, it could be provide for free – public property that recognize interest in project, or virtuous private landlord – or through an economic provision – rental, leasing, purchase, energy or digestate shares.
- ***SBG manager*** – actor that has the competences to manage aspects of the project, in its phases.
- ***Waste producer/feedstock supplier*** – actors that provide bio-waste source to SBG.
- ***Waste collector/manager*** – actors that collect and manage bio-waste source from collection point to AD plant.
- ***Biogas/digestate producer*** – actors that are responsible of digestion process of bio-waste and manage biogas and digestate utilization.
- ***Social innovation manager*** – actors responsible of managing activities to promote social actions and raise awareness, know-how as well as training on SBG's disciplines.

- *Roles derived by* ***project outcomes*** – phase of utilization of project's products – material and immaterial – that involve who benefits in energy, economic and social terms from project's outcomes. In this stage, emerges the role of stakeholders, actors that are users of SBG's products as well as the role of shareholders, actors that are owners of SBG. Roles of SBG are:

- ***Biogas user*** – actors that use energy by biogas in its different outputs.
- ***Digestate user*** – actors that use digestate for green and food growing.
- ***Social innovation users*** – actors that attend SBG's activities targeted for people engagement in social activities.
- ***Profit gainer*** – actors that, through energy and digestate selling, job opportunity incomes and SBG's shares, gain a profit in being owner of SBG.

The two different phases mentioned of SBG set specific roles, but actors can take over more than one roles independently of stages, thanks to possible connection among roles that are linked in a progressively and/or parallel way, one with the other. Opportunity for actors to take over specific roles, needs an evaluation of community and social fabric as well as individual expectations on developing project.

7.4.3. Expectations of social fabric in SBG

Many variables affect actors, their connection and ability to work together, defining a complex set of existing, but evolving rules that frame social fabric and need to be constantly considered (Cayford & Scholten, 2014). Within the development of the research, these variables have been firstly extrapolated by literature review and case studies analysis, secondly submitted to the stakeholders of SBG and lastly integrated with their observations. Results achieved show how SBG's expectations by actors cannot be framed in a simple identification of final results expected – energy safe, reduction of costs –, but involve a set of possibilities that depend on SBG's characteristics. For this reason, in initial phases of SBG development when meeting, surveys of social fabric are conducted, expectations are helpful to direct the further phase, marking a direction for project managers. Evaluating the weight of requirements is useful to direct outputs of the project and, consequently, fit SBG on specific social fabric settled in district.

Focusing on specific outcomes emerged, each disciplinary aspect developed in SBG – energy field, environmental, institutional, technological, social behavioral, economic –, coincides with a set of possible expectations that actors await from SBG. Table 7-3 reports actors' expectations from SBG and represents the complexity in developing, operating and managing stages of the project. Existence of group, size of group, lobbying capacity, social pressure, homogeneity and interpersonal dynamics are element to considered in expectations and elements to work to improve perspectives of SBG and, overall, contribute in the creation of social legitimacy of SBG within district. Only if there is a correspondence between actors' expectations and projects' outputs, SBG finds its legitimation in district's social fabric.

Table 7-3: expectations of social fabric in SBG

Energy field	Environmental	Institutional	Technological	Social behavioral	Economic
Develop energy system sited where local resource is available Disseminate innovative energy solution Implement of energy independence solutions Have a flexible energy system in meeting energy demand	Minimize urban impact of waste collection system Guarantee a full waste collection Manage different organic waste streams Optimize source utilization Demonstrate its benefits Promote waste recycle Respect environmental Use sources and products locally (2kms)	Be aligned to public strategy Have simplified authorization process Sureness of result of authorization process Shortness of authorization process Avoid sanction and reduce tax payment Receive public incentives	Being accessible and visible Being user friendliness Suing and replacing existing infrastructure Guaranteeing distance from residential property Having a compact size to have a human scale	Be construct and manage autonomously Promote social justice and fairness Create local value Empower citizens Have an aesthetic positive perception in urban landscape Be a share project Share project results	Reduce energy cost Reduce waste cost Have public investors Have a return investment Have multiple investors

7.4.4. Framing social fabric: the experience of "Energy for citizen"[10]

Studying aspects that are typical of social fabric are therefore important to assess a good development and implementation plan for SBG. For this reason, the realization of a survey was considered remarkable to better understand social aspects towards CoP and energy community. "*Energy for citizen*" (Pracucci, 2016) has the aim to focus

[10] Italian title 'L'Energia per il Cittadino'. Survey is available at link https://goo.gl/forms/0aZM7jZyeXVZ9G6f1.

on people perception on RES and waste management practices in the frame of cooperation strategies to be assessed at district scale. This can be considered a necessary preliminary phase for SBG evaluation that is useful to frame state of the art of social fabric.

7.4.4.1. Methodology

Within possibilities – public meetings and presentations, door-to-door communications – this research has chosen to experience the utilization of on-line survey as tool to investigate social position. Reason for this choice is the growing diffusion of mobile devices that can connect people and can represent tools to collect information and create network within district. Through the utilization of a common tool available by Google – '*Google forms*' – and usable by low digitalized people, a set of questions have been proposed. Questions fit the character of neutrality, transparency and clarity requested by survey within general segment of population to not direct their answers and, consequently, affect the results of survey. Topic is not only biogas and SBG – complex project not affordable without a previous introductory phase – but more in general issue on energy sources, their utilization at community level and opportunity to use bio-waste – household and garden waste in specific – for energy production.

Some statistical errors have to be considered in analysis of data collected. Two reasons for these errors: digital compilation and target group. Conducting a digital survey restricts population involved in survey because the utilization of e-mail and social media precludes compilation to a non-digitalized segment of population and select interviewed people by title of survey, that declares purpose of investigation and, consequently, address compilation or not by personal interests. These aspects contribute in definition of a target group that cannot fit perfectly the specific one of SBG. While indeed in SBG project, such a survey would be conducted within population of the selected district, "*Energy for citizen*" diffusion privileges a general target group. This choice depends on survey goal to test generally the quality of questions issued and frame citizens know-how on topics afforded. Surely, this '*undefined*' target group generates a statistical error to be taken into consideration in result analysis, but despite these aspects, survey can be considered indicative, even if not exhaustive.

7.4.4.2. Survey organization

Survey is organized in sections (13) that afford even more specifically the subject of the survey. Sections are:

- *Section 1* – survey on user profile, identifying residence, age, occupation status, qualification, household compositions and income;
- *Section 2-4* – survey on district and building typology of residence, energy provision systems;
- *Section 5-10* – survey on waste management practices and produced amount, green area management;
- *Section 11-12* – survey on perception of different RES (excluding nuclear energy, not applicable at district scale) based on safety, cos-effectiveness and environmental respect; questions to investigate what could direct change in behavioral attitudes for cooperation in waste management and energy production;
- *Section 13* – possibility to supply personal contact for further communication.

7.4.4.3. Survey dissemination and data collection

Survey has been conducted for 6 months between July 2016 and December 2016, and diffused to almost 200 contacts – Universities, Regions, Housing Associations – and the participation has achieved 1.158 people, of which 39% male and 61% female. Within 200 contacts that have received communication, only around 10% has accepted to share survey with their contacts. Two main reasons have been adduced: restrictive policies and not being partner of the project. It is clear how the involvement of institutions, associations since the evaluating phase is central to collect data on population exploiting official channels already developed within communities. However, despite a comparison with potential audience could appear that few people have been reached, the achievement of more than a thousand participations surely represents a good statistical parameter to assess considerations on results collected.

7.4.4.4. Results

In this venue, only few aspects related to development of energy community are evaluated, demanded to reference other considerations (Pracucci, 2016), in particular offering a comparison between data collected and district. As already addressed in previous chapters, district is central to define SBG potential because of differences within district typologies. Data have studied in the base of district typology of residence (Figure 7-2).

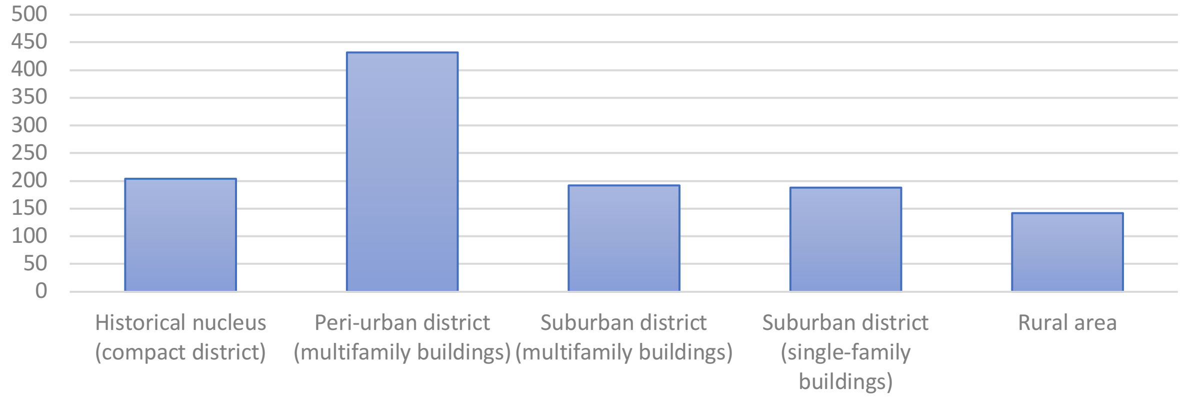
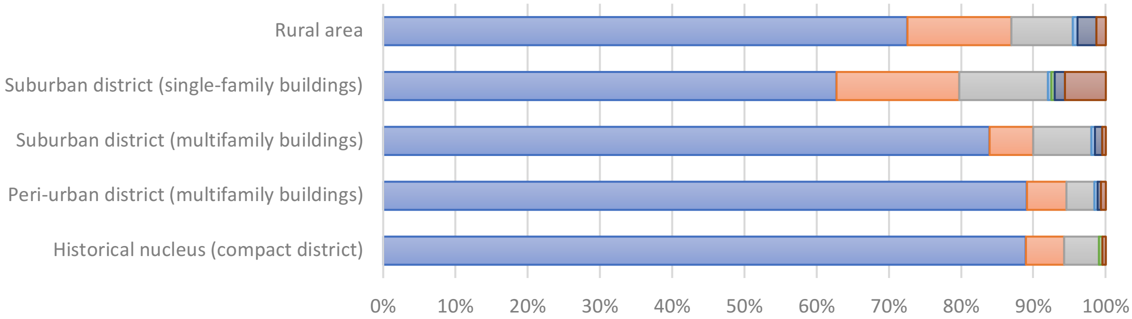


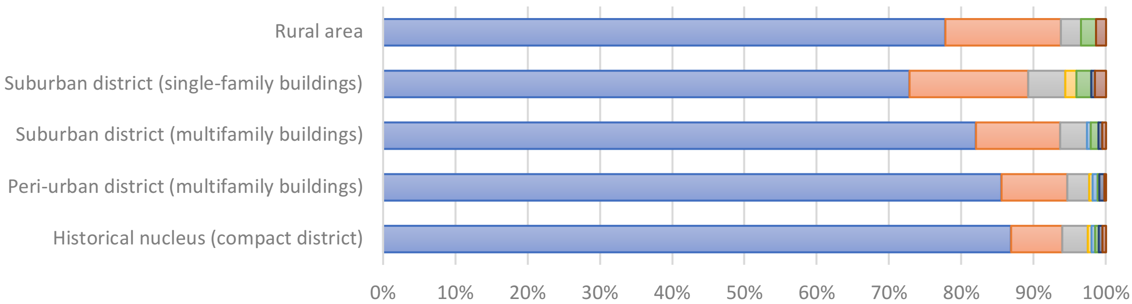
Figure 7-2: participation by district at "Energy for citizen" (Pracucci, 2016)

Records confirm that RES systems installed to serve single houses (Figure 7-3) are installed where there is a prevalence of single-family solutions, in particular in sub-urban area where there are single-family buildings. If this result was easily imaginable, it is interesting to analyze data on RES systems that serve district community (Figure 7-4). Indeed, there are already existing community solutions that supply energy, and despite the greatest number is installed in '*suburban district with single-family buildings*', statistic collected shows that also other districts have a certain predisposition for these systems: indeed, where there is a multiple ownership, share systems are the only affordable renewable solutions. These numbers appear to confirm the goodness of energy community proposal in district where there are mainly multifamily buildings and lower RES installed. Energy community could represent an option to install RES following a sharing logic.



	Historical nucleus (compact district)	Peri-urban district (multifamily buildings)	Suburban district (multifamily buildings)	Suburban district (single-family buildings)	Rural area
No, there are not RES systems	185	392	167	133	111
Photovoltaic	11	24	12	36	22
Thermal solar	10	17	16	26	13
Wind energy					
Geothermal		2	1	1	1
Biogas energy systems	1			1	
Biomass energy systems		2	2	3	4
Other	1	3	1	12	2

Figure 7-3: existing RES systems that serve individual house (Pracucci, 2016)

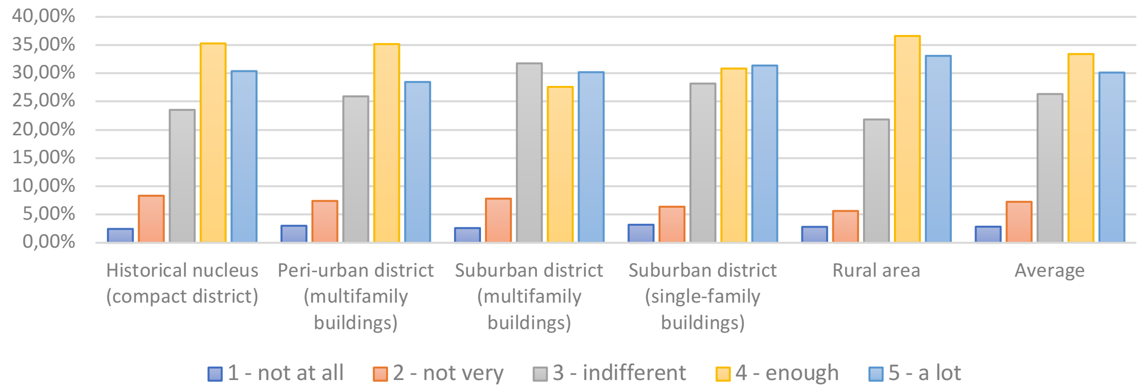


	Historical nucleus (compact district)	Peri-urban district (multifamily buildings)	Suburban district (multifamily buildings)	Suburban district (single-family buildings)	Rural area
No, there are not RES systems	172	367	155	142	112
Photovoltaic	14	39	22	32	23
Thermal solar	7	13	7	10	4
Wind energy	1	2		3	
Geothermal	1	3	1		
Biogas energy systems	1	1	2	4	3
Biomass energy systems	1	3	1	1	
Other	1	1	1	3	2

Figure 7-4: existing RES systems that serve district community (Pracucci, 2016)

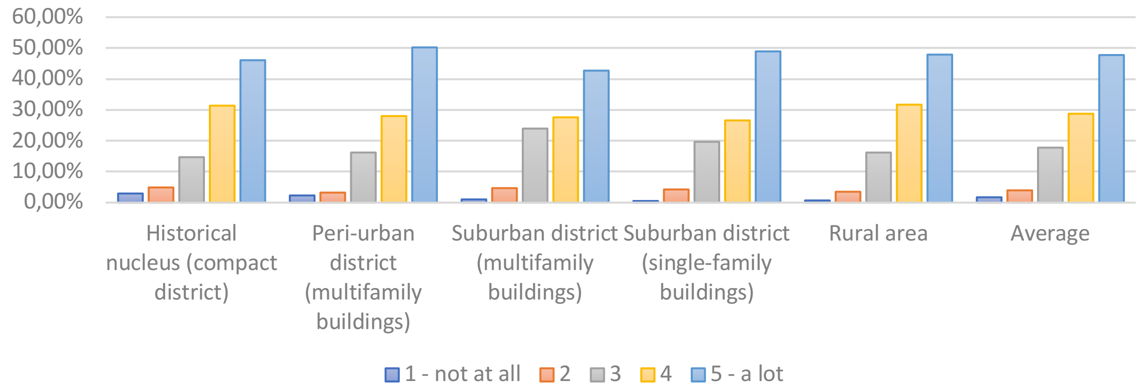
This consideration is confirmed also by disposal of interviewed people in cooperating for housing energy supply (Figure 7-5). Data collected shows a general predisposition independent of district: excluding negative answers (value '*1*' and '*2*') the average of willingness to cooperate is 63,46%, showing a wide availability in attending energy community project.

Figure 7-5: cooperation availability in House energy supply (Pracucci, 2016)



In the scenario of SBG potential, records support also a general acceptance of waste as possible energy source (Figure 7-6) with some peak value in *rural area* – where waste as already often used in burning, composting and anaerobic digestion treatments – and *peri-urban district (multifamily buildings)*; only an average of 5,70% appears to refuse waste utilization (aggregated data of value '*1*' and '*2*').

Figure 7-6: predisposition at waste utilization for energy purpose (Pracucci, 2016)



7.4.4.5. Conclusions

Analysis of data collectable by such survey demonstrates how valuable this tool could be to define operational boundaries for the development of CoP and energy community. However, this type of preliminary investigation needs the collaboration of local associations and public authorities to allow a wider diffusion of survey and, consequently, collect data from a larger sample of population and consequently offering better analysis of existing social fabric. At his aim, on-line survey is not enough and need to be supported by '*traditional*' tools – door-to-door, paper survey – to achieve higher attendance results.

7.5. Social legitimacy

Success in development of social innovative aspects of SBG, depend as shown on many aspects that are related and need to be evaluated to be challenged by actors to motivate and legitimate SBG system (Markard et al., 2016). Despite SBG can be legitimate from an institutional – meeting urban plans, emissions norms, energy targets, etc. – and technological point of view – district space availability and integrability, usable existing systems, etc. –, social legitimacy has the same importance. Social fabric is indeed a component that not only direct actions to realize, but set the context where SBG has its roots. In the scenario of CoP and energy community, social legitimacy is requested to not loose resource in project that have not legitimation among actors it should involve.

First social aspect that affect SBG legitimacy is lack of knowledge, as demonstrated by survey conducted that shows a low degree of awareness on biogas issues – and believes on biogas. First belief to be clarified is that biogas is dangerous. SBG and biogas plant in particular do not involve a particular safety risk for population or environment if applicable provisions are observed and construction and operation of the plants are state-of-the-art (Da Costa Gomez, 2013). Surely, if handled improperly, digester reactor or gas storage could be damaged, spill and cause environmental damage; following prescriptive rules all these risks are avoidable. Fear on biogas – it is however a bursting gas – needs to be faced with positive public relations to improve the public acceptance and explain the real, not presumed, risks ("Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.). Parallel is ethical issue on origin of feedstock of biogas in SBG. Crop is one of possible substrates for biogas, representing an alternative for food feeding and, consequently an ethical issue to be faced; proposing a biogas community energy can be affect by this evaluation, but, in the case of SBG, is a misunderstanding easy to face. Indeed, SBG uses household wastes as a feedstock for biogas and consequently does not compete for land use and does not have negative sustainability impacts (Al Seadi et al., 2013). SBG instigator should elucidate immediately on substrates used, underlining the positive results achievable by bio-waste – environmental and energy field – thanks to diversion to other waste treatment – landfill and incineration. A clear communication on SBG perspectives appear to be basilar to prevent misinterpretations and possible further resistances.

Another parameter that affect social legitimacy is complexity of technologies adopted. In fact, higher is the technology complexity, higher is the social complexity it involves and vice versa (Cayford & Scholten, 2014). These two complexities could compromise the legitimacy of SBG among their users and consequently it could be important to adopt strategies of technological integration and actors' involvement, as user friendliness as possible. Indeed, the pressure of complexities increase on local participants if they are the ones designing, implementing, or maintaining the governance of the system.

At this aim, the opportunity to provide training and activities which can be taken place inside a project developed around micro AD processes should be evaluated. The study of biogas closed loop waste-biogas-energy/food/green cycle can develop many chances for educational activities of communities, to stimulate changes in other context, and to address towards new unexpected social innovation processes. Through this action, community are provided by a better understanding on SBG features and its outputs, improving success possibility of energy community logic. In this scenario, the realization of built components as greenhouse can be used as instrument to place training activities that show the chain waste-biogas-energy/food/green (LEAP - Local Energy ADventure Partnership, n.d.). In addition to training activities, a greenhouse production is more social appealing for community business rather than the lonely AD plant, thanks to its potential in creating job opportunities for the work activity it requests in food and green growing activities as well as for eventual community café and/or community center with meeting and workshop areas which can be set inside. (LEAP - Local Energy ADventure Partnership, n.d.)

7.5.1. Strategies to improve social legitimacy in SBG

Social legitimacy is not evaluable by a mathematic formula, but it is described by a complex set of features that are related one another. Working on factors that affect its result is crucial to achieve success in SBG decision-making process. For this reason, following aspects should be promoted:

- ***Social fabric survey*** – study and analysis of local actors settled in district, to know their needs, expectations, goals, etc.;
- ***Communication*** – inform local actor of SBG vision, underlining energy, environmental and social benefits;
- ***Engagement*** – involve local actors interested in passive or active actions to be part of SBG project;
- ***Governance*** – provide instrument to support models of governance that support community appreciation.

7.5.1.1. Social fabric survey

Understanding the state of art of social fabric is an element to start and workshop meetings and survey within community are useful. These offer the possibility to present SBG project for its benefits – environmental, energy and social – and in this way opportunity of direct local actors participation in SBG towards the creation of local biogas communities. At this aim, population and other relevant stakeholders should perceive SBG as a project that supply biogas, and digestate, as a public good and associate its value with community-based structures. This target marks necessity of specific process of gradual change and convergence to capitalize existing perceptions and add necessary elements to show and stimulate communities to generate new models of waste and energy chain management, to achieve energy self-sufficiency and promote new sustainable practices, until become shareholders of community biogas energy itself. If this is the target of possibilities to communicate in SBG presentation, a planning of different phases has to be set progressively to raise awareness on this potential; SWOT analysis can work in this direction ("SWOT Analysis

| Better Evaluation," n.d.). Assess the Strengths, Weaknesses, Opportunities and Threats (SWOT) of social fabric where SBG is proposed at different stages, evaluate internal and external conditions that influence SBG and offer an upgrading transparent picture of the project helpful to set social pillars of further SBG and assess possible actions to enact its vision. Thanks to SWOT it is possible to verify the suitability of proposed solutions and test their effectiveness.

7.5.1.1.1. Communication

Social fabric is a preliminary evaluation useful to set further steps in SBG development: communication strategy is crucial. SBG project needs of people involvement and a training of SBG benefits is mandatory. Actors know-how about SBG occasions is necessary because it influences social legitimacy of the full project. Indeed, the introduction of new technical and behavioral attitudes at specific scale has to face a lack of awareness and resistance to environmental or behavioral changes. Changings needs to be prepared by SBG initiators and promoters to have local actors as partners and not opponents, and consequently have a community that works towards the same goals. Time is crucial and gradual information should be provided. Bio-waste collection that requires behavioral change of consumers is an example ("Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.; WRAP, 2016). Indeed, participation rates depends on waste collection systems adopted, but also on communication provided on waste processes to the population involved, achieving also high ranging between 74% and 97%. Therefore, in addition to specific collection solutions, it is crucial to think about actions of collective planning and share of bio-waste collection program through a specific communication plan that is composed by different communication systems valuable for district – leaflets, public meeting, worktable, face to face message, memorandum, etc. – help to challenge existing behavioral obstacles as well as nuisance – odor or noise emissions issues.

7.5.1.2. Involvement

As part of communication, there is the presentation of opportunity of actors involvement. Local participation goes beyond social context analysis and communication of the project, but provide a set of effective roles. The greater number of community's individuals are able to participate, the higher is the probability that a community is able to assess, achieve and capture expected resulting and related benefits. Population should be encouraged to be able to take action towards renewable energy, sustainable solutions, in order to become involved in energy production and consumption decisions (Walker, Devine-Wright, Hunter, High, & Evans, 2010). SBG success, because of its complexity, find in participation the necessary support of its success to create a more positive social context and, consequently, legitimate SBG. Population involvement in SBG begins with bio-waste collection, waste that, differently from usual, is locally processed, and allows its producers to benefit from its reuse in anaerobic digestion. The role of producer engaged in separated collection can be considered a passive role in SBG; higher degree of active participation is achievable and suggested to improve local engagement. For this reason, identification of actors that can manage SBG aspects also in designing, operational and management are important to be part of SBG from a technical point of view. In fact, active engagement passes from identification of actors involved in SBG – population, SME, institutions, etc. – that can provide such know-how in SBG development and implementation as well as provide communication to population, or specific training staff – paid or unpaid – hired in SBG functional activities. Creation of job opportunity is particularly interesting to improve level of social acceptance by actors. SBG provides a set of possibilities to offer also an income inside the project – waste collection, manual feeding of AD, pop-up café, food growing and consequent selling, etc. – that can face social poverty. Social benefits are also achievable through involvement of local institutions – district schools for instance – and associations in educational programs. The opportunity to present valuable effects of closed loop of SBG, or attending seminars on specific projects – urban agriculture as well as sharing mobility –implemented inside SBG, are useful to attest the goodness of the project.

Many actions can be provided to engage local actors in SBG and demonstrate how much importance they have to achieve social fabric's targets, showing that SBG is a socio-technical transition that contributes in biogas renewable-energy production, but also in promotion of social aspects.

7.5.1.3. Governance

SBG, fitting logic of community energy, represents also the opportunity to assess model of governance bases on sharing systems. Indeed, a community achieve the highest engagement in SBG when, from '*stakeholders*' become also a '*shareholders*', being owner of systems. This opportunity is better investigated in next chapter.

7.5.2. Evaluation of progress in SBG's social legitimacy

The real question is how to evaluate this legitimacy progresses. Indeed in SBG, while environmental and energy impacts can be easily defined and measured, social benefits can be hard to estimate and translate into numerical terms, as in the case of social legitimacy aspects – acceptance, community cohesion, raised awareness, built capacity, new partnerships, knowledge management tools, etc.. Indeed, many situation and '*unmeasurable*' parameters affect social innovation and only a work together with actors involved can demonstrate the success of certain actions. For this reason it is important to assess a process of Monitoring and Evaluation (M&E) (Hobson, Hamilton, & Mayne, 2014) that could periodically evaluate the achievement of expected outputs of SBG. Through the utilization of specific indicators assessed on expected outcomes of SBG, it is possible to measure and consequently evaluate actions implemented, both single and in their relations. A M&E process can help SBG promoters to support projects and redefine actions to better fit society expectations and, as a consequence, improve social legitimacy. At this aim an already established way of monitoring a project is through the development of a theory of change ("ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation," n.d.). Theory of change is a simplified description of connections among actions carried out, based on assumptions that actions are logically and causally connected. Built a proper theory of change on SBG, is based on stakeholders involvements during preliminary steps and in period updates to analyze if the planned interventions are appropriate to achieve the desired goals. Theory of change makes the interconnections explicit among actions to achieve the change expected, generating knowledge about SBG successful factors and also supporting what are the most efficient solutions. The sequential application of the theory of change and SWOT analysis applied to SBG, create a learning cycle that allows to understand and describe actions carried out. In this way, all actions are made '*measurable*' and permit to estimate clearly social legitimacy of actions within social fabric. In such a way, M&E enables SBG community to understand the impacts of its actions, eventually re-orienting them, allowing to cumulate data and experiences for further projects, based on learning by community stakeholders.

7.6. Conclusion

Social innovation is part of SBG. As community energy project, SBG triggers producer/consumer behavioral changes that generate alternative solutions as usual ones, a powerful way to work on complex challenges, combining local actors' resources and cooperation. SBG is a CoP, with community-based origin, based on biogas exploitation that has the potential to increase availability and usability of urban bio-waste, with multi practices actions. District of installation are described not only by infrastructural, technological and institutional aspects, but also by social features that direct to a '*tailor made*' strategies grounded on preliminary analysis, developed according to each individual case. In this frame, understanding local expertizes, existing know-how and innovation inclination are aspects that can be joined with ongoing similar experiences and are helpful to set SBG strategies with customized actions.

Strategy for participation appears to depend on different factors and cannot be standardized without considerations on context and population involved. It is therefore important to share since the very beginning the process to include actors to be involved in SBG project, to understand their expectations and assess time scheduled for development and implementation in line with their know-how, available tools and personal capacity to support the project. In this phase, it is important to identify expertizes available at district scale, to value their presence in designing, execution and managing phase, as well as in SBG activities at community scale as training on green and food growing, or in other recreational activities. In such way actors of SBG are included both in passive and in active way, each one for its peculiarities at neighborhood level.

To evaluate social innovation in district due to SBG is important to set processes of monitoring and evaluation, that collect and analyze information about the project and provide a clear understanding of results achieved, helpful to value the real contribution of a specific action and directing further implementation strategies.

Annex – 'Energy for citizen'

The annex reports questionnaire conducted within the survey "*Energy for citizen*". This is an original survey planned for this research work by Alessandro Pracucci, wrote in Italian language – and here translated in English – that has reached 1.171 people.

ENERGY FOR CITIZEN

This is survey for research created by Alessandro Pracucci, PhD candidate of the International Doctorate in Architecture and Urban Planning of University of Ferrara, Italy and Polis University of Tirana, Albania. Data collected will be used only for research's aims and, eventually, diffused within scientific community. For each information, contact e- mail *alessandro.pracucci@unife.it* or phone number +39 339 6469607.

*Mandatory question

---

section 1 – YOUR PROFILE

Where do you live? Your Region*

- ______________________

Where do you live? Your Province *

- ______________________

Where do you live? Your Municipality

- ______________________

Where do you live? Your District

- ______________________

How old are you? *

- <18
- 18–29
- 30–49
- 50–64
- 65–75
- >75

Your gender is*

- Male
- Female

What is your qualification? *

- Elementary School diploma
- Secondary School diploma
- High School degree
- Master Degree
- Post degree qualification (master, PhD, etc.)

- Other _______________

What is your occupational status? *
- Student
- Employed
- Free-lance
- Unemployed
- Retired
- Other _______________

How many people are in your household, including you? *
- 1
- 2
- 3
- 4
- 5
- > 5

What is your household income?
- < 7.500€
- 7.500€ – 15.000€
- 15.000€ – 30.000€
- 30.000€ – 60.000€
- > 60.000€

section 2 – YOUR HOUSING and YOUR DISTRICT
Some questions to know where you live

Which is your district typology? *
- Historical nucleus (compact district)
- Peri-urban district (multifamily buildings)
- Suburban district (multifamily buildings)
- Suburban district (single-family buildings)
- Rural area
- Other _______________

Which is your house? *
- Single-family house with yard
- Single-family house without yard
- Dwelling in multifamily building with communal yard
- Dwelling in multifamily building with private yard
- Dwelling in multifamily building without yard
- Other _______________

The house you live in, is:
- State-owned
- Rented
- Rented controlled
- Other _______________

Is your house equipped with RES systems? *
- Photovoltaic
- Thermal solar

- Geothermal
- Wind energy system
- Biomass energy systems
- Biogas energy systems
- No, there are not RES systems
- Other _______________

Is your District equipped with RES community systems? *

- Photovoltaic
- Thermal solar
- Geothermal
- Wind energy system
- Biomass energy systems
- Biogas energy systems
- No, there are not RES systems
- Other _______________

Who is your house energy provider? *

- Public energy network
- District energy network
- Self-production
- Other _______________

In your house, do you have a stand-alone energy generator for domestic water? *

- Yes – *go to section 3*
- No – *go to section 4*

Section 3 – WHICH ENERGY FOR YOUR HOUSE?

Some questions to know your domestic water and electricity provision

Which is your domestic water generator? *

- Domestic boiler/heating pump
- Building oiler/heating pump
- District heating
- Other _______________
-

Go to section 5 – HOW DO YOU MANAGE HOUSEHOLD WASTE?

---

section 4 – WHICH ENERGY FOR YOUR HOUSE?

Some questions to know your domestic water and electricity provision

Which is your heating generator? *

- Domestic boiler/heating pump
- Building oiler/heating pump
- District heating
- Other _______________

Which is your domestic water generator? *
- o Domestic boiler/heating pump
- o Building oiler/heating pump
- o District heating
- o Other _______________

section 5 – HOW DO YOU MANAGE HOUSEHOLD WASTE?
Some information on household waste collection

How your household waste is collected? *
- o Bins
- o Collection point
- o Door-to-door
- o Other _______________

Do you know final disposal of your household waste? *
- o Yes
- o No
- o I do not know, but I would like to
- o I do not know, but I would not like to

Do you collect separate household waste (answer "YES" if at least one waste is usually collected separately)? *
- o Yes – go to *section 6*
- o No – *go to section 7*

section 6 – YOUR SEPARATED COLLECTION
Some questions to analyze to deepen your separated collection

For which is do you make separated collection? (max 3 answers) *
- o Waste collection scheme
- o Habit
- o Civic awareness
- o Sanction risk
- o Decrease waste charge
- o Environmental protection
- o Other _______________

Which within following waste do you collect separately? (medium bag size 48x75cm) *

	<1	1	2	3	>3
o Glass					
o Organic					
o Paper					
o Plastic					
o Foil					
o Other ________					

How many GENERAL WASTE do you produce in a week? (medium bag size 48x75cm) *

	<1	1	2	3	>3
o General waste					

Do you have your ownership green area? (private and communal) *
- o Yes – go to section 8
- o No – go to section 9

section 7 – GREEN AREA MANAGEMENT
Some questions to know management of your and district's green area

Do you have your ownership green area? (private and communal) *
- o Yes – *go to section 8*
- o No – *go to section 9*

section 8 – GREEN AREA MANAGEMENT
Some questions to know management of your and district's green area

Who manages your ownership green area? *
- o Me and/or mu household
- o Neighborhood
- o Paid gardener
- o Other _______________

Where are disposed garden waste of your ownership green area? *
- o General waste
- o Organic fraction collection
- o Compost
- o Incineration
- o Abandoned
- o I do not know, but I would like to
- o I do not know, but I would not like to
- o Other _______________

Does your District have a green area? *
- o Yes – *go to section 10*
- o No – *go to section11*

section 9 – GREEN AREA MANAGEMENT
Some questions to know management of your and district's green area

Does your District have a green area? *
- o Yes – *go to section 10*

- No – *go to section 11*

section 10 – GREEN AREA MANAGEMENT. DISTRICT'S GREEN AREA
Some questions to know management of your and district's green area

Who manages District's green area? *
- Public authority
- Private enterprise
- Me and/or mu household
- Neighborhood
- Paid gardener
- Other _______________

Where are disposed garden waste of District's green area? *
- General waste
- Organic fraction collection
- Compost
- Incineration
- Abandoned
- I do not know, but I would like to
- I do not know, but I would not like to
- Other _______________

section 11 – ENGAGEMENT IN YOUR DISITRCT COMMUNITY FOR HOUSING ENERGY PRODUCTION
Some questions to know how you perceive housing energy

Which within these reasons could change your energy behaviors? (max 3 answers) *
- Economic profitability
- Environmental respect
- Sense of belonging to community
- Knowledge of real cases
- Partnership public-private
- Sanction risk
- No reason
- Other _______________

How do you evaluate these energy sources applied to your House? PHOTOVOLTAIC (solar light transformation in electricity) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

How do you evaluate these energy sources applied to your House? THERMAL SOLAR (solar heating transformation in heating energy) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

How do you evaluate these energy sources applied to your House? GEOTHERMAL (ground heating transformation in heating energy) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

How do you evaluate these energy sources applied to your House? WIND ENERGY SYSTEM (wind transformation in electricity) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

How do you evaluate these energy sources applied to your House? BIOMASS ENERGY SYSTEM (organic material burning for electricity and heating energy) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

How do you evaluate these energy sources applied to your House? BIOGAS ENERGY SYSTEM (organic material digestion to produce gas for electricity, heating energy, biofuel and domestic methane) *

	Not at all	Not very	I do not know	Enough	A lot
Safe					
Cheap					
Environmental respectful					

Would you like to cooperate with your neighborhood for your House energy supply? *

Not at all	*1*	*2*	*3*	*4*	*5*	*Yes a lot*

Which reason would motivate your engagement in neighborhood cooperation for your House energy supply? (max 3 answers) *

- o Economic profitability
- o Environmental respect
- o Sense of belonging to community
- o Knowledge of real cases
- o Partnership public-private
- o Sanction risk
- o No reason
- o Other ______________

Which is the best way to receive communication on energy cooperation activities? (max 3 answers) *

- o Mail
- o Information attached to bills
- o Public meetings
- o Information provided by district's meeting points (school, sport center, elderly/youth centers, etc.)
- o Web sites
- o Social Media
- o Other ______________

section 12 – ENGAGEMENT IN YOUR DISITRCT COMMUNITY FOR HOUSEHOLD AND GREEN WASTE MANAGEMENT

Some questions to know how you perceive housing energy

Would you like to cooperate in household waste management? *

Not at all	*1*	*2*	*3*	*4*	*5*	*Yes a lot*

How do you perceive household waste utilization as energy? *

Strongly negative	*1*	*2*	*3*	*4*	*5*	*Strongly positive*

Which reason would motivate your behavioral changes in household waste management? (max 3 answers) *

- o Economic profitability
- o Environmental respect
- o Sense of belonging to community
- o Knowledge of real cases
- o Partnership public-private
- o Sanction risk
- o No reason
- o Other ______________

Would you like to cooperate in garden waste management? *

Not at all	*1*	*2*	*3*	*4*	*5*	*Yes a lot*

How do you evaluate garden waste energy utilization? *

Strongly negative	*1*	*2*	*3*	*4*	*5*	*Strongly positive*

Which reason would motivate your behavioral changes in garden waste management? (max 3 answers) *
- o Economic profitability
- o Environmental respect
- o Sense of belonging to community
- o Knowledge of real cases
- o Partnership public-private
- o Sanction risk
- o No reason
- o Other ______________

Section 13 – KEEP IN TOUCH
Leave your contacts to communicate further progress of the research

Name and Surname

____

E- Mail

____

Other ways to contact you

____

Authorization to private data process *
- o I accept private data process for article 13 of D.lg. n.196/2003 (D.lg. n.196/2003 is Italian law)

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8. Financial and Governance opportunities in Smart Biogas Grid

Organization of chapter

The present chapter investigates economic aspects of SBG, including considerations on models of governance that contribute in its development following reflections conducted in previous chapters. In particular, the chapter investigates aspects of self-governance and frames costs and savings of cash flows that define business plan of SBG.

8.1. Introduction

According to SBG definition also economic, financial and governance aspects are to be considered. Economic aspects are a key point for actors engagement (Pracucci, 2016) and promotion of socio-technical transition finds an important support in innovative models of business. Economic sustainability as well as investments are catalysts for people involvement in project, to have profit and have lower risk. Within this framework, researchers conducted (UNEP, 2015) demonstrate as the most important actors to catalyze investments in district energy is local governments, followed by private sector thanks to its technical and operational support. It is clear how public investments can enough easily afford costs of SBG, but, in the perspective to develop and implement directly at district scale this project using locally resources – bio-waste as well as local actors expertize, awareness and willingness – identification of alternative solutions rather than as usual business, seems to be central. However, institutions need to set well-defined and supportive financial and fiscal policies that reduce project risk and increase sense of security in actors. This public economic support allows to assess robust economic business plan that include subsidies, grants, funds, environmental taxes and value-added tax reductions that can significantly improve the viability of SBG project, providing an alternative to direct public ownership of the project through involvement of local actors in managing economic and governance aspects. These business models should ensure that all actors involved – investors, owners, operators, suppliers, end-consumers, municipalities, etc. – could achieve economic sustainability and eventually having financial returns for their investment, in addition to any wider economic, energy, environmental and social benefits seek. SBG opens for optimized business solutions that, even if slightly more complex, can meet expectations of actors involved and resources available in the district, achieving higher standards of efficiency on financial and social point of view. These new governance models provide a platform for institutions, staff and stakeholders that allows to achieve higher success in energy community rather than as-usual business approach (QUEST

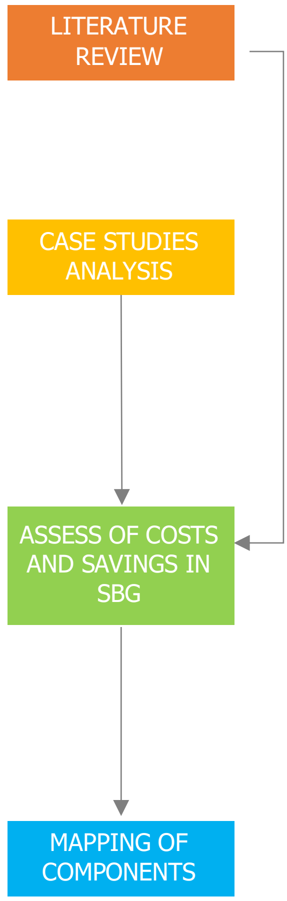
– Quality Urban Energy Systems of Tomorrow, 2016). This chapter, considering the role of community central in SBG development, investigates possibilities of self-governance and shared ownership that could contribute in the promotion of models of management using available local resources – actors' economic funds, know-how – for renewable energy community projects.

8.2. Methodology

This chapter has been developed with following methodologies:

- ***Literature review*** – papers, documents, have been read to investigate models of governance and ownership based on community involvement to share economic resources and investment risk.
- ***Case studies analysis*** – contained in *Annex 1 – Case studies*, this analytic instrument is used to analyze case studies realized in urban areas that provide governance solutions not typical of as-usual business strategy, in particular within projects that support sustainable and renewable energy solutions.
- ***Assess of costs and savings in SBG*** – thanks to disciplinary contents treated in previous chapters, it is possible to make a synthesis of costs and savings expected by SBG project. This phase defines general voices to assess possible business plan for the project, that need specific study of local costs to be considered valuable for each specific district.
- ***Mapping of components*** – synthesis of information collected are mapped to schematize context, actions and outputs collected. This map is a partial contribute to the full understanding of SBG in its complex.

Figure 8-1: synoptic framework of methodology adopted for economic and governance aspects of SBG



8.3. Governance and ownership models for SBG

To achieve direct involvement of actors and rootedness in district, SBG opens to possibilities to implement solutions of governance and ownership models, not common in traditional waste and energy scenario, creating alternatives to as-usual business solutions. SBG needs to have a high degree of actors involvement and for this reason, development of initiatives based on direct ownership and involvement of people concerned are preferable because they empower players ("Supurbfood. Towards sustainable modes of urban and peri-urban food provisioning.," n.d.). In line with blue economy philosophy, SBG generates income streams that contribute in innovate business models, where bio-waste offers the opportunity to implement governance and ownership in a not-common way. In addition to as-usual business plan based on expected payback period for the investment and internal rate of the project – parameters that assess the profit for SBG and, eventually, calculate the shares for investors –, other solutions can be pursued in a logic of community and shared interests, with financial surplus invested in implementing SBG as well as other sustainable projects on community and district level, with actors involved that are repaid by in-kind benefits of the project – digestate, food, etc. – instead of economic incomes. Alternatives should be evaluated and proposed to SBG attendants to understand which solution of governance and ownership can better fulfill their expectations.

First focus proposed is on governance models. Literature identifies three approaches of governance in socio-technical transition processes (Turnheim et al., 2015):

- ***command and control*** – typical of public projects issued by institutions, that achieve public policy targets but can face problems of legitimacy and effectiveness of actions within actors;
- ***public-private governance*** – it works on partnerships between institutions and business, leveraging dynamics in market and society with research, technology and innovation;
- ***adaptive governance*** – it responds to complex aspects of transition process creating cooperation among social fabric, institutions and businesses and providing a constant upgrade of project objectives, its actions, with an accent on social innovation aspects.

Despite each governance model has its advantages and its problems, in the scenario of SBG and within goals of the project, '*adaptive governance*' appears to be the most fascinating perspective, because it involves all actors for their specific role. Governance structure should indeed work for its specific shareholders and stakeholders, for the community and the district where it is implemented, fitting its peculiarities, and for this reason an adaptive governance is recommended. Problems of cooperation, assessment and interventions are challenges of such model of governance, but institutions, associations, businesses, SMEs can be interlocutors and facilitators of such model of governance because they can provide knowledge and capacity in structuring project to attract investments (UNEP, 2015) as well as offering their managing capacity to set cooperative actions, going beyond local actors' lack of awareness and know-how about technology application, creating valuable networks to share experiences, expectations and economic resources. However, assessing adaptive governance has its difficulties, and higher is the social and technical complexity higher is the pressure on actors involved, causing a greater demand for expertise. Adaptive governance has the huge advantage to consider the context of reference of the project and work on its potentiality, creating strategic partnership between actors. Number of actors, amount of community participants, know-how, economic sources are determinant variables for governance model (Cayford & Scholten, 2014) and for this reason actors involved in SBG appears to be a key element for their material and non-material available resources. Despite this a key point is to be set: district community can difficultly manage all aspects involved in SBG. Identifying within a district all disciplinary competences requested by the project is prohibitive, because SBG has demonstrated to include aspects of interconnections that are not of common knowledge. Good practices in socio-technical transition processes suggest that combination of community with entrepreneurial activities and businesses, municipalities and public authority, associations, academia and research centers, can set up networks that provide boosting results ("ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation," n.d.). Benefits of such cooperation can overcome community lack of knowledge and, consequently, assess the possibility to develop models of self-governance.

8.3.1. Self-governance opportunity in SBG

Self-governance seems to fit perfectly SBG's aim to involve community in all aspects of the project, including ownership and management and the question is if SBG is liable to have self-governance as a robust mode of governance depending on investigation of society features and actors involved. Many researchers conducted on overlapping socio-technical systems with self-governance (Cayford & Scholten, 2014) have demonstrated that the increase of social and technical complexity precludes an high degree of self-governance expected, an adaptive mode that can widely vary to fit a given context and its expectations in line with SBG development and implementation. Robustness of self-governance scenario depends on specific conditions affected by available resources and interests of community and actors in using governance as success factor for the project (Ostrom, 2005). The aim of SBG to combine a more liberalized waste and energy market, supported by the development of biogas as decentralized energy solution with a perspective to create a wider grid network, support forms of local operations and self-governance. In particular, the role of actors involved actively engaged in waste and energy practices, increase self-organized collective solutions. Actors can have different roles in SBG (see chapter 7) and here stands their techno-operational dimension in self-governance model. SBG's assets – waste, digester and energy components – need to be managed for operation and financial aspects – incomes and costs. It is important to arrange a board composed by a skilled or trained staff that can manage SBG operations and assess sustainable business plans, making decisions on investments to preserve systems operations and costs balance, handling proper solutions. This governance complexity opens two possibilities: the need for more financial resources assigned to external contracts (Cayford & Scholten, 2014) or identification of SBG actors within cooperative network previously created with expertise requested to set and manage governance. Adaptability of SBG at the context, emerges also in the identification of proper resources to manage the project and in the need to find more finances for external contracts or to create a network where partners can guarantee adequate management and/or train community for future governance. In such a way, SBG emerges as a credible alternative to centralize waste management and energy production, organizing it in small district businesses to manage and operate each project stages depending only on the network they have created.

8.3.2. Ownership opportunity in SBG

If self-governance represents the opportunity for actors to self-manage the project and its finances, promotion of such a model depends on the ownership of SBG. Different models of ownership of SBG are possible:

- *public and private venture* – company of private enterprises with or without public authority, that have common objectives and share know-how and investments in a joint venture – new enterprise – or in incorporate venture – parallel development of the project. In this case, local authority is usually the proponent of original project and still attract financing and grants for its realization, encouraging social or environmental objectives within community interested. A venture is organized by shares that empower actor of decisional power.
- *cooperative* – transparent and democratic legal form, one member-one vote principle for board election and decision making, independently of investment in society. Being a cooperative member derived by a financial interest, minimizing project risks sharing investment. In cooperative solutions, also the creation of common by law is a possibility. Differently from the traditional cooperation system that is mainly proposed and managed by private actors, common by law is defined as an individual property that is commonly managed and it is established by issuance of specific law by local authority. This solution make property indivisible despite its own share can be sold.

In this frame, the opportunity is the creation of a '*Special Purpose Vehicle*' (SPV) company, a legal entity that will operate and manage the system as a network of complementary local actors – public authorities, SMEs, interest citizens – to surmount existing economic barriers – bank loan or realization costs. SPV is a solution that can fit district's expectations and risk profile, offering at the same time the opportunity to share economic benefits with energy and social outputs, involving qualified companies such as Renewable Energy Service Companies (RESCOs) or proposing new business configurations commercial platforms to collect funds and resources.

If these ownership solutions provided for SBG are the most suitable, a strong network among private actors, business-SMEs and public authorities is needed to make synthesis of possibilities and identify the best possible solution for each district, and consequently optimize business model.

8.4. Economic and financial sustainability

This section of chapter considers expenditure items to assess ac SBG business plan that includes all different aspects of the project. Differently from renewable energy community, SBG involves a series of aspects that require specific expenditure items to be included to guarantee a correct economic and financial plan. Indeed, biogas by bio-waste demands to comprise cost and funding elements that go beyond realization of technological systems and, eventually, energy supply of other RESs as wind farms or photovoltaic systems. From waste costs, collection fee charges, passes from land acquisition, AD plant realization to social activities offered within district, a set of items affects economic balances. Having a clear understanding of all these components help governance structure in financial decision making especially with a medium-long term. If indeed, SBG operates in district based on initially characteristics, the context of reference changes during time and development of SBG stages; hypothesizing evolution of context of reference and, consequently, of the related market can allow to have an evolving business plan over years. This is particularly important in the initial phase to outline the financial model and pricing assumptions in detail, including initial costs, yearly costs and savings, to focus on funding needed. SBG's business plan in its economic components – personnel, technology, finances, distribution, promotion, products, services – allow to summarize risk of the project as well as expected rewards. This is especially remarkable not only to manage economically the project, but also to direct actions to realize. Business plan is a tool to evaluate solutions in the short term and long term, especially to seek adequate fundings for specific issues that require financial resources for resolution.

Table 8-1: expenditure items for SBG business plan

Costs		Savings	Funding	
Capital costs	**Operation and Management costs**		**Internal funding**	**External funding**
Site acquisition Permits Technological components	Project promotion Waste collection AD plant operations	Expenditure items are following presented. SBG costs. Waste fee charge savings Energy savings Digestate savings Social costs savings	Investor funding Waste fee charge Digestate selling Energy selling Social activities incomes	Financial support to RES Financial support for training Tax reduction

Expenditure items are following presented.

8.4.1. SBG costs

First items to assess in business plan are principally composed by costs of SBG. These can be classified in two categories: '*capital costs*' and '*operative and maintenance costs*'.

8.4.1.1. Capital costs

Capital costs are one-time expenditure items fundamental to achieve operational status of the project. These items include all those aspects of SBG project that allow to realize infrastructural and technological elements of the project and constitute SBG's assets. Following expenditure items should be considered:

- *site acquisition* – realization of SBG passes through the availability of a site – land, green or brown filed, building – in the district that allows the installation, at least, of AD plant. Presence of a site in line with sized necessity of the project is crucial and represent a cost to face and to insert in business plan. This process is linked to negotiation with the site landlord that can on the one hand share less or more SBG's aims and consequently decrease or reset its economic expectations of the site, or, on the other hand, aspire to maximize profit of its property; depending on the landlord, site can be an expensive or cheap cost in business plan, purchased or get leased. In addition to these possibilities involvement of public authority in SBG could allow to have site provided for free through a concession. Evaluation of sites availability is crucial because this item is one of the most significant cost, but its estimation is affected by local property market and, therefore it is not here quantified.

- *Technological components* – installation of technological components is the other relevant cost. In line with technological analysis and actions derived by district characteristics and actors' expectations, technological components costs have to be included in the business plan, following case by case study. Costs depend on technological components of waste collection, biogas production and products utilization to be installed. If some components have to be paid by project finances because are mainly district's components – bins, vehicles, AD plant, eventual pneumatic waste collection system, energy generators, etc. – some components can be supplied by project management choice or autonomously purchased by actors – kitchen caddy, curbsides. This choice depends on the degree of actors engagement as well as on project funding availability but also on external expertizes to be paid to develop the project.
- *Permits costs* – last costs to have operation status of project, are those of permits. These costs depend on planning, construction and emission authorizations to be requested to local authorities, as well as experts that certificate and sign the rightness of the project. Dependent on local regulatory framework they also have a relevance on time of execution of work and, consequently, can affect the operation start of the project.

8.4.1.2. Operation and Management costs

Achieved operational status, there are costs for running the project. Personnel, source collections, management, services, are included in this expenditure items, economic components that recur during a certain time – monthly, yearly – that have to be included to have systems that operate correctly. In these costs are considered:

- ***Project management*** – staff of the project with the task of running the project is the main responsible for the project to success or fail. Specific expertizes on different aspects of SBG should be provided and to contain this item is crucial to assess a network interested in the promotion of SBG, or identifying actors involved with needed professionalism. Medium-high expertizes requested by this personnel would increase this expenditure item and for this reasons identify alternative solutions within network or thanks to availability of public authority competences is crucial to reduce the incidence of this voice on the business plan.
- ***Project promotion*** – actions related to promotion of the project have to be run regularly to involve and update actors on status and results achieved by the SBG project. From launch of the project – leaflet, rent conference rooms, websites, etc. – to waste management practices explanation, a set of different activities that request communication materials or spaces to be used are requested and are costs for the project. Clearing what and when realizing such activities help to assess expenditure item within business plan.
- ***Bio-waste collection operator*** – operation of waste collection – household and green waste – have to be run by personnel that collect liners, cut vegetation and collect bio-waste produced in district close to AD plant. Personnel has a low formation and its cost is relative low. Involvement of charity group or voluntary partners can contribute in reduction of this voice.
- ***AD operator*** – AD system, central technological core of the system, need to be run properly from feeding to digestate

processing. All manual operations that need an operator could be saved in case of automatic process that, despite it increases capital cost, reduces operation and management costs to regular system control. AD operator is responsible for energy exploitation of biogas produced, taking care of energy generation and supply.

- ***Maintenance operator*** – all operations to preserve proper functioning of the project need for actions depending on components. Cleaning bins, digester maintenance, energy generators fumes control are some aspects to include in maintenance operations. As for other expenditure items, identifying operators within the actors involved in the project as volunteer helps to reduce this cost.

8.4.2. Savings

Savings are part of business plan and represent one of the most interesting voice in SBG. SBG opens many perspectives in savings scenarios because of many aspects it includes. Savings are all those expenses expected of previous regime not more necessary into new project because related outflows are ceased. In this way money are saved and have to be considered within business plan evaluation. Savings to be considered are:

- ***Waste fee charge savings*** – waste is normally a cost for producers (Dominic Hogg et al., 2011) that are charged by local waste company in form of a tariff for collection and management of waste; within SBG, the use of bio-waste as energy source can lead to revision of fee charges. Waste fee charge is summa of many costs – crew costs, supervisor, vehicle fuel, vehicle standing costs vehicle depreciations, overheads, treatment – that are involved in waste collection and expected profit seeking (WRAP, 2016). Within SBG project different solutions are imaginable for fee charge, depending on the population involvement in the project: on one hand if attendance in SBG is lower, a revision of fee charge should be asked actor by actor in relation to decrease of waste managed by waste company; on the other hand, in the case of waste collection completely managed within SBG, not organic waste is profitable for company that reuse and recycle and can represent an income for SBG business plan. As mentioned in environmental chapter, a liberalized market is necessary, but it is not easy to achieve because of business around waste management. This research frames a scenario where waste company provide a discount of 20% in the case bio-waste – almost 50% of total waste collected) is demonstrated not to be more collected by the company, but it is allocated to SBG project. Considering a waste fee charge of 295€ (Guglielmo Loy, 2017) per year for household, discount is 60€. This is a theoretical save, that should be compared with possibility to assess a fee charge to collect bio-waste within SBG, depending on vehicle, paid crew or other less expensive solutions.

- ***Energy savings*** – biogas produced in SBG can have different outputs, but it can generate a saving dependent on energy – electricity, heating or biofuel – no more purchased from traditional energy providers. In the case of an on-grid SBG project, there is a compensation between energy sold and purchased without being dependent on energy market costs variation; instead in the case of an off-grid project, direct utilization of energy outputs can vary the savings because there is a fluctuation in the energy market and consequently it affects the profitability of SBG's energy utilization.
- ***Digestate savings*** – utilization of fertilizer is normally a cost. For this reason, own production of digestate in SBG save money for its purchase. In particular, this is the case where there are urban agriculture activities that use nutrients to improve green and food growing.
- ***Social costs savings*** – if previously savings are mainly related to SBG's actors that produce waste, use energy and digestate, this item is helpful to decrease social costs of institutions. Social innovation provided by SBG through its activities of training –

workshops, laboratories and other activities that provide know-how –, diversion of waste – landfill, incineration and waste nuisances are not positive factors for population and closing property values –, use of bio-waste as energy source – greenhouse gas emission reduction with related improvement of the image of the area of the project – contribute in the raise of social cohesion as well as in the development of new social mindfulness on sustainable topics and direct promotion of waste, energy and social good practices. These aspects solve and anticipate problems resolutions of social difficulties in further projects, generating new transversal consciousness within society.

8.4.3. SBG funding

Considered costs and savings, last voice to be taken into consideration is the one of funding to afford costs of the project. Internal funding – provided by SBG – and external funding – provided out by SBG – assess the economic resources available to face costs to realize and run SBG.

8.4.3.1. Internal funding

Internal funding are those economic resources provided by the project organization. It is composed by:

- ***investor funding*** – funding provided by actors involved in SBG that become also investors of the project. Participation by shares is the most common, but some alternative solutions are here presented:
    - *freemium consortium* – local actors and companies supply specific items, labour for activities – construction, operation, management – in change of shares of SPV, allowing a widespread participation of local actors. The shared benefits are hence distributed within a large parterre and some of the revenues may be re-invested to further boost the adoption of clean technologies by the singular actors of the community assisted by the freemium consortium through specific

instruments such as e-commerce specific platforms.
  - *crowdfunding* – alternative funding schemes that can provide an extra economical value as a better return of investment and a risk reduction for both SBG actors involved.
  - *ethical finance* – financial support by microcredits, mutuality and community bonds that have low interest rate and are provided in the presence of ethical characteristics recognized and pursued in the project.
- ***Waste fee charge*** – collection operations can be supported by the request of a fee charge that can cover operators and vehicle costs. This fee charge should be calculated to provide a total discount considering savings for reduction of waste fee charge by waste company, otherwise waste producers could not join project because of increase of expenses.
- ***Digestate selling*** – certification of digestate and revision of regulatory offer the chance to sell digestate and generate an income from selling to users.
- *Energy selling* – if not used within SBG project, biogas and its energy outputs can be sold providing an income for SBG.
- ***Social activities incomes*** – activities organized can provide an income for the project. Visiting charge to know project activities, training charge for participants not members of the project, sponsored study tours, rent out meeting rooms, represent opportunity to collect funding for SBG. In addition, some experiences demonstrate that know-how acquired by renewable energy community projects can support the creation of an association or enterprise for consulting, planning and implementing similar plans, being an other possible incomes for SBG.

8.4.3.2. External funding

SBG provides only a share of necessary funding. Financial and fiscal support should be provided by public authorities because producing biogas is not profitable without any financial investment support (Tomperi, Luoma, Pongrácz, & Leiviskä, 2014). Identification of funding opportunities is needed to have SBG project appealing to actors since the very beginning both for involvements as for investments. The following fundings are possible:

- ***Financial support to RES*** – public authority should issue incentivizing scheme in medium-long period that can cover costs and support socio-technical transition from existing regime. Chapter 5 reports in details these aspects.
- ***Financial support for training*** – public authority can support training programmes for these social interests providing resources – human and know-how – to face SBG expertizes needs.
- ***Fiscal support*** – sustainable and renewable community energy projects could be supported by reduction of taxes and VAT reduction for environmental, energy and social sustainable results pursued by the project.

8.5. Conclusion

SBG financial and governance aspects are central to assess a project that could operate and run within district and its community. More than as-usual business perspective, CoP and energy community demands for business models that allow a direct involvement of actors in the governance of such projects. At this aim, self-governance gains prominence because it offers the opportunity to include the community in the decision-making process, involving local actors also in project management strategies; this can be a winning aspect to have a greater engagement and participation of people in the project. Despite this opportunity, self-governance should be considered as an opportunity to be used in specific circumstances where suitable competences are available or provided by a network assessed in line with SBG development and implementation. Therefore, despite community is center of SBG self-governance is not sufficient by itself. The role of institutions or business-SME can be determinant with structural or initial investments and coordination that can be particularly relevant to raise a sense of security in the project by potential actors. Governance assessed for SBG should ensure that all political, staff and community stakeholders are involved for their competences at the right stage, especially in the case of management staff that, in addition to specific skills, should mature a clear vision on the purpose of the project and should have the authority to implement it, making changes to the implementation plan. Management staff cannot however work alone, but should provide to the community regular reports of progress monitored, presenting to shareholders and stakeholders results and new perspectives to ensure a profitable dialogue.

In this perspective, business plan definition is not only demonstration of financial sustainability of the project, but also help to define optimized solutions between costs and results achievable. Business plan becomes an instrument to plan in medium-long run the actions in order to gradually develop aspects of SBG in relation to awareness of population and degree of engagement. However, assessing an accurate business plan could not be enough and a determining element. Within SBG there are also not rational and economic parameters in the decision-making process that are key drivers to be considered because they asses social benefits with a non-measurable economic profit; the examples of social cohesion, environmental and energy field raise awareness set in this frame. For this reason, business plan should be considered as economic planning, but also an evaluation instrument for self-governance and community choice within society.

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9. A THINKING TOOL FOR SMART BIOGAS GRID

ORGANIZATION OF CHAPTER

The following considerations aims at being a synthesis of the research work and connected reflections. The chapter presents an original thinking tool issued for SBG to support decision making process. The tool is based on analysis conducted during the research and it is modelled in line with systematic view developed in the research, connecting different features collected. This output summarizes considerations from context definition, to actors involvement, until possible solutions to assess and promote diffusion of SBG perspective.

9.1. Introduction

SBG research development has emphasizes systemic interdependencies of elements that contribute in the definition of smart biogas grid as TIS (Bergek et al., 2015), with a particular focus on environmental, energy, normative, technological, social and economic components. Various forms of possible synergies have emerged on which the different actors can draw if they do not work in isolation and keep in mind a whole vision of the complexities of the system. Actors must be able to perceive opportunities of this new TIS to enter into it and catch its positive results. This process must be driven to conduct potential SBG's players into a decision-making process to better fulfill their needs, their resources and their expectations. For this purpose, a Multiple Criteria Decision-Making (MCDM) methods should be assess, methodology characterized by making preference decisions over the available alternatives that are characterized by multiple, usually conflicting, attributes (Yoon and Hwang, 1995). These methods are designed for problems that are concerned with the evaluation of, and possible choice between, discretely defined alternatives as SBG project. MCDM is an interactive and cumulative process in which opportunities are dynamic and consequently, the factors inducing actors entry or influencing actions to place within SBG are controlled by a variety of system components as well as factors that go beyond technology specific components. This chapter investigates the adoption of a MCDM into a model to evaluate feasibility of SBG within urban district, in line with initial aim of this research. Models for such typologies of evaluation are frequent and support complex analysis. Models are applied widely across scientific disciplines including mental models, conceptual models, numerical models, statistical models and computer models (Süsser, 2016). Despite this wide application "*Essentially, all models are wrong, but some are useful*" (Box & Draper, 1987) and, for this reason, the model assessed for SBG prefer not to provide a perfect modelling of TIS, but a thinking tool with the aim to simplify the representations of the project itself serving to offer an instrument to help disclose, understand and set project's strategies perspectives. For this purpose, a Decision Support

Tool (DST) is realized fulfilling the necessity of being accurate, but simple enough, instead of being unnecessarily complex. DST as thinking toll provides a learning instrument base for the TIS and useful to diffused and combined knowledge in the system. The sources of knowledge development includes not only academic and firm level R&D, but also activities such as learning by doing, learning by using, imitation etc. (Bergek, Hekkert, & Jacobsson, 2008) and DST works in this context to share knowledge of SBG potential and perspectives out of traditional scientific sectors. Indeed, the present DST identifies actor opportunities in improving energy efficiency in district, cutting GHG emissions, achieving resilience and driving economic development. There is growing acceptance among stakeholders to provide pathway for communities to become energy communities (QUEST – Quality Urban Energy Systems of Tomorrow, 2016) and understanding this potential as well as raise people awareness on SBG's opportunities is the final purpose of the thinking tool.

9.2. Methodology

DST has been faced within the research as a synthesis of all activities carried on. Methodology to assess a thinking tool useful for SBG is here specified:

- ***Literature review*** – papers, documents, models have been read and studied to research modelling field among topics faced in this research – environmental, energy field, social – focusing on their usefulness to diffuse SBG perspective to the largest number of actors.
- ***Mapping components – SBG map*** – all the information and conceptual maps realized for each research's topics are summarized and overlapped to have a join map that gather all considerations obtained in the work.
- ***Creation of DST*** – using models studied and information collected, a DST is realized to fit characteristics of the project. In particular, following methodologies have been used for the thinking tool:

- ***Multi-criteria decision analysis (MCDA)*** – method of MCDA has been used to create a more efficient construction process that will produce a more effective outcome based on the logic of consequences. within MCDA, actors, roles and context are analyzed. Energy and emission issues are covered by estimating the current and future emissions as result of the users' choices of within SBG.
- ***Theory of Change*** – comprehensive description and illustration of how and why a change within a specific context should occur for players involved. Theory of change's maps put initial condition and components that can contribute in its evolution towards expected outcomes.
- ***Quality Function Deployment (QFD)*** – typical methodology used in product design to define successful and non-successful characteristics of specific products within the market. Through a matrix of evaluation and a scoring assignation between functions and characteristics, best solutions are identified to be used for definition of a new successful product for the market.

DST is implemented joining this methodology and testing with stakeholders' results achieved and verify the accuracy and usefulness of DST for users. Tool should be finally uploaded as open source to diffuse SBG contents and to allow further implementation with other specific stakeholders' competences. Figure 9-1 reports the methodology adopted to create the thinking tool.

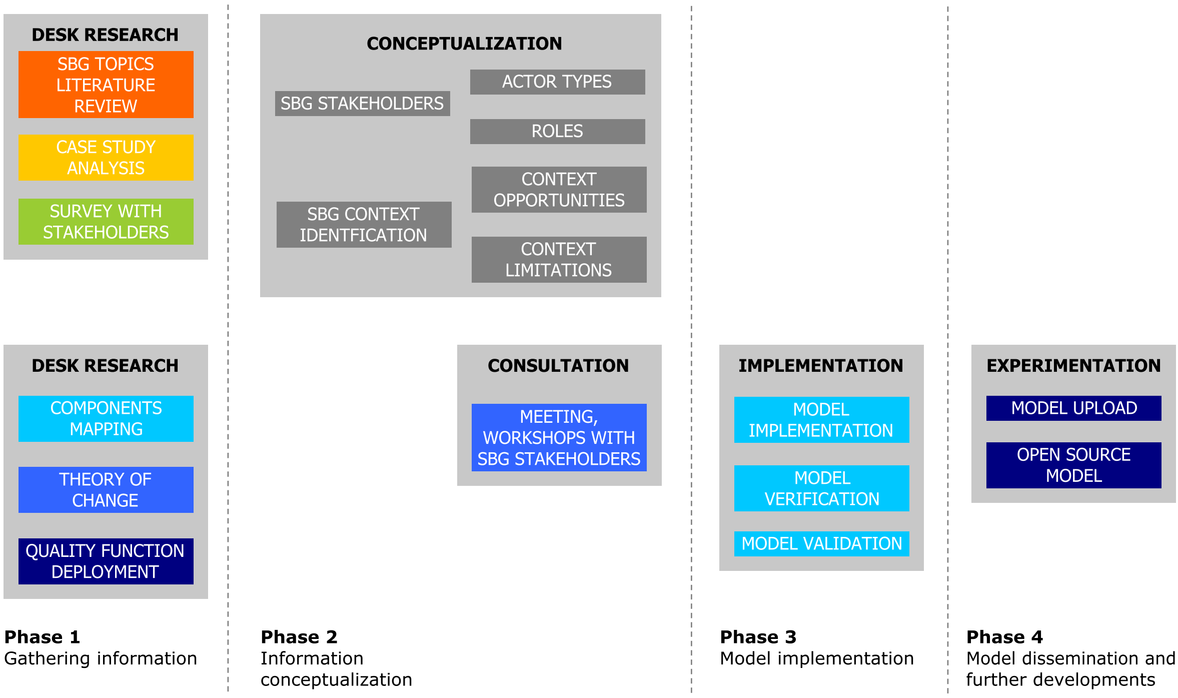

Figure 9-1: methodology adopted to assess DST for SBG

9.3. The decision support tool

The role of DST can be relevant to promote TIS inside an existing regime, especially as in the case of SBG project that faces multiples aspects in different scientific fields; indeed explicit and detailed conceptual tools can be useful to analytically frame the complexities (Smith, Stirling, & Berkhout, 2005). This original DST is a self-evaluation instrument that enables stakeholders to assess the degree on which critical success factors are in place to support urban biogas strategies implementation in their districts. DST user enters input data and receives, thanks to specific calculation processes, outputs that fulfill its possible role and its expectations within the project. The outputs are a set of strategies that contain actions, insights and advice to achieve success factors in the realization of close loop system in city areas.

9.3.1. Modelling DST

Focusing on the aim of DST is crucial to understand which is the modelling strategy to adopt: the aim of this DST is showing opportunities to actors in the development of integrated approach in energy supply, with a focus on SBG. Nevertheless, the same approach as well as many insights, are common of good energy practices and RES in general. Therefore the DST should address this process investigating a set of possible actions not only on energy efficiency and biogas supply, but based on local expectations, energy efficiency practices, waste and transportation sectors, planning and policy measures, analysis of the energy, environmental and social benefits. Through DST, district's actors evaluate which solutions better fulfill their district characteristics and player expectations, anticipating and working in parallel during project definition with other actors, in particular public authorities, energy and waste companies and businesses-SMEs.

Many modelling approaches exist and are further investigated to frame transition processes ("EU FP7 project PATHWAYS," 2015; Turnheim et al., 2015):

- ***Integrated Assessment Model (IAM)*** – macro-level and quantitative system model that combines information on global environmental problems, their main causes and possible response options and their costs and benefits, to provide a forward-looking of transition pathways towards sustainability targets to achieve under specific set of goals and technological assumptions. IAMs have typically little to say about the interests or motivations of actors and social groups involved in these transitions.
- ***Socio-technical transition analysis*** –meso-level level that focuses on different social actors and the degree of alignment or tension in their problems, expectations and strategies. Transition studies introduce more complexity in the description of social systems than techno-economic models, sacrificing the macro-level and future-oriented analysis of IAM.
- ***Initiative-based learning (IBL)*** – micro-level qualitative approach that uses case study analysis to examine the mechanisms and dynamics in concrete projects and local initiatives involving a wide range of social actors. In the IBL approach, the focus is on social learning defined above as the processes and interaction among actors that determine the success or the failure of a given initiative and it includes technical, organizational and cultural aspects.

Within different possibilities, models that better fit SBG's scale of interest are IBL and socio-technical transition analysis, and the choice is to create a thinking tool that could pair methods from each approach, in order to create an integrated, multi-scale and interdisciplinary chain of analysis (Forrest & Wiek, 2014). Agent based modeling (ABM) would have represented a more precise solution to target urban scenario, social, environmental and energy fields (Chen, 2012; Gilbert, 2008; Gilbert & Bankes, 2002; Gilbert & Terna, 2000; Süsser, 2016; Verhoog, 2013), but for the purpose of this research, the aim is not the creation of a model to assess possible scenarios to be evaluated by specialists, but it is also a thinking tool for not-trained actors that could approach SBG topics and would like to provide a vision of existing opportunities. The decision is to assess a model that uses principles of models over mentioned, but can be used by a large public, thanks to its availability in common calculator machines and easy to be used; the choice is to model a DST on Excel-Office. Excel-office software is a spreadsheet with calculation, graphing tools, pivot tables, and a macro programming language features, produced by Microsoft and available on many operative systems – macOS, Windows, Android and iOS – in order to be accessible for a large group of potential users.

9.3.2. Stakeholders of DST

The DST is intended for all possible actors of SBG. As mentioned in the social innovation chapter, actors are several – community member, community group, business-SME, educational institution, government, non-government organization, other. Each one with its background, know-how and expectations on SBG is a potential stakeholder of SBG and, consequently, a user of DST. This is particularly interesting in DST modelling because different actors have different possibilities to operate and work within SBG, affecting their participation in different phases of the project. DST considers these different possibilities of involvement and direct outputs using this preliminary information. In such way, DST is tailored on actor categories, providing specific outputs and solutions dependent on stakeholder roles in society and, consequently, within the project.

9.3.3. Functioning and utilization of DST

This section takes into consideration the aspects about the functioning of the DST based on MCDM. Some characteristics are common in these matrixes (Yoon and Hwang, 1995):

- ***Alternatives*** – finite number of alternatives collected during the research are screened, prioritized, selected and/or ranked, constituting the whole set of possibilities within SBG.
- ***Multiple attributes*** – project has multiple attributes and a decision-maker must consider the most relevant. The number of attributes depends on complexity of the project, and higher this complexity is, higher is the amount of attributes to consider. SBG's attributes are the ones studied in previous chapters in different scientific fields – energy field, environmental, normative, technological and social. Theory of change is used to organize these attributes.
- ***Incommensurable units*** – in relation to specific field of interest, attributes have different units of measurement and are assessed differently within DST.
- ***Criteria weight*** – MCDM methods require information regarding the relative importance of each criterion and for this reason quality function deployment is used to weight the importance of different criteria to evaluate outputs goodness.

All the factors assessed in MCDM have been identified within the research and the analysis conducted within SBG. The process embodied by the DST and schematized in Figure 9-2 allows to the '*user*' to have access to DST through three phases parts:

- ***Input data phase*** – aspects the user must enter in the DST forms;
- ***Evaluation phase*** – input data are analyzed by evaluation processes assessed in DST;
- ***Output data phase*** – results obtained by DST calculation.

9.3.3.1. Input data

First phase of DST is the input of data requested. In this phase users define who they are, which are the context's characteristics on which they would like to assess the SBG project, which are the requirements searched in the project implementation. This phase collects all those aspects reviewed in specific scientific researches and casa studies considered pertinent for the definition of strategies for SBG promotion and diffusion. Figure 9-3 shows the user interface of DST.

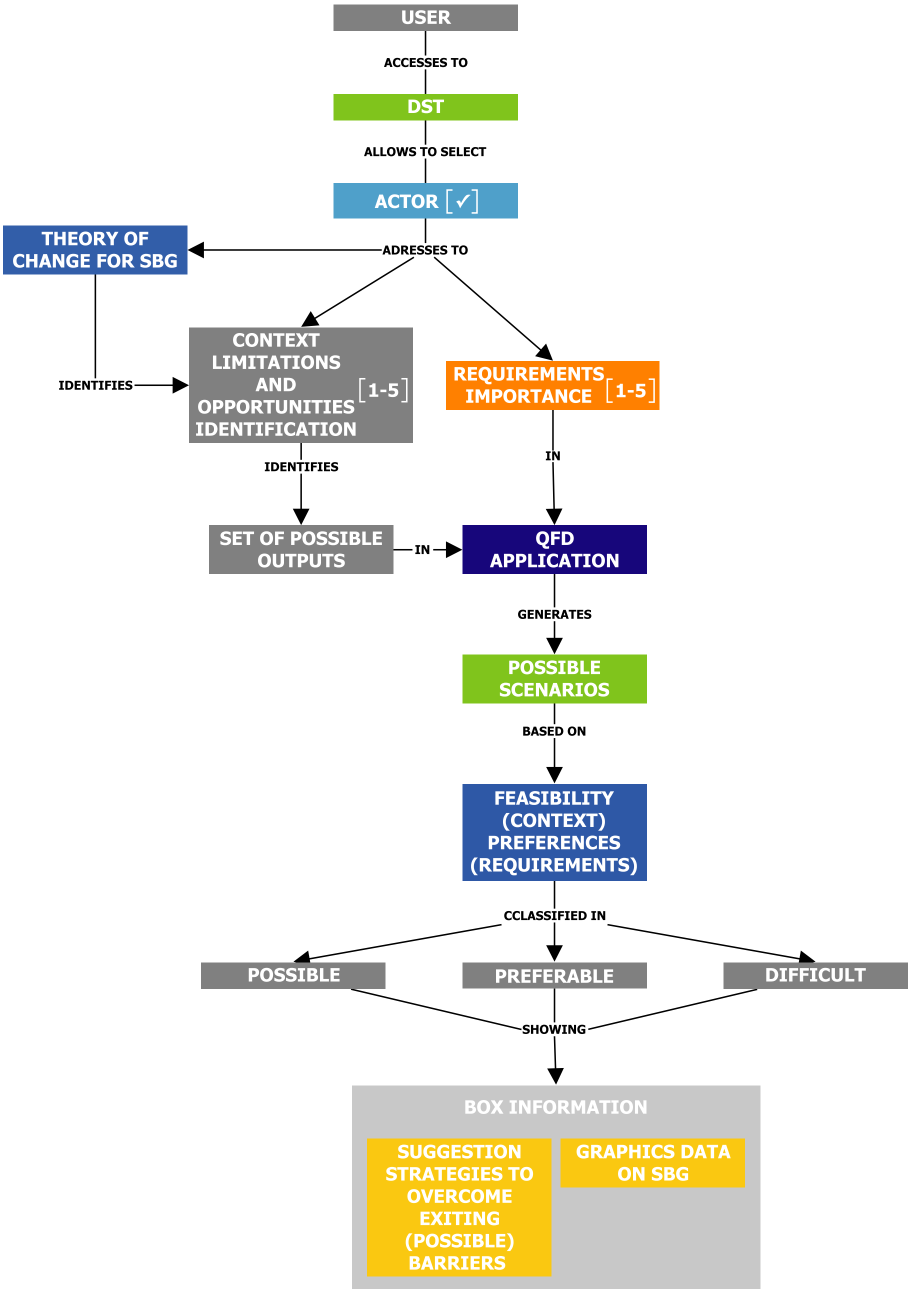

Figure 9-2: functioning of DST

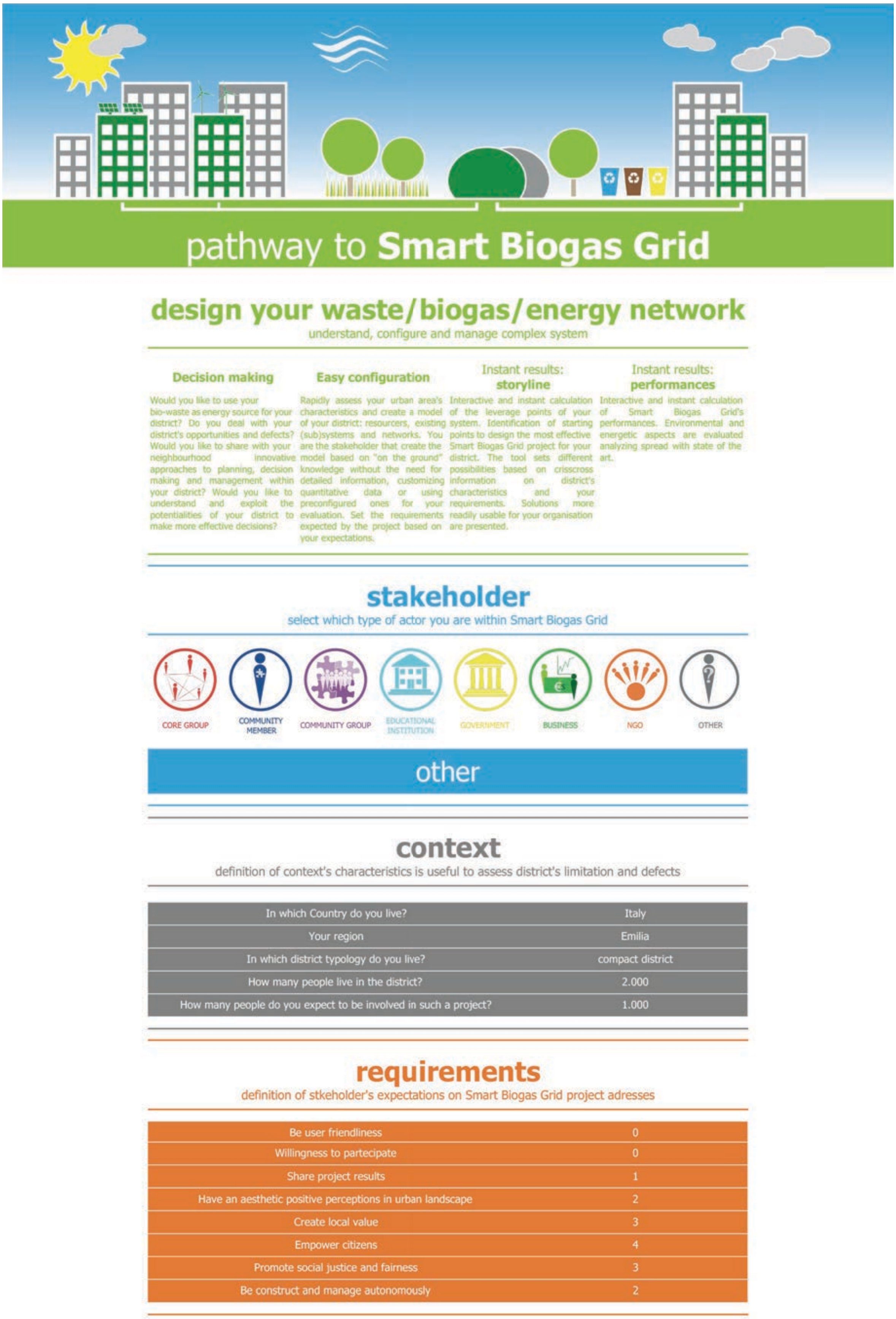

Figure 9-3: DST user interface with fields to enter input data

9.3.3.1.1. Actors and core group

ACTOR

First input to enter identifies '*actor*' category. Actors classified previously in the research – community member, community group, business-SME, educational institution, government, NGO, other – instigate and develop projects for their own institutional forms and capabilities, reasons that effect their decision making. DST user is a specific actor who addresses aspects of SBG and it can provide a certain quantity and quality of information on the context on which he intends to operate SBG project. Not all actors can have all the information needed by context identification and, for this reason, it is important to assess a network among actors interested in the project to develop consciousness on aspects that are included in decision making process and provide information requested. DST user becomes for DST the '*core group*' of SBG, introducing his potentialities in the project.

9.3.3.1.2. Context identification

CONTEXT

Context is central for success of SBG. Case studies analyzed demonstrate the importance of the local context, showing a diversity between initiatives in different domains that can end up differently because of the different contexts in which they are carried out. Context is the resemble of set of elements that describe opportunities and boundaries of SBG application in a specific area. Within this classification, there are questions on technological and infrastructural context – spatial limitations that can limit or support SBG application are studied – as well as social scenario, are elements that address possible strategy to work on. Context identification is important because it provides the foundation for the application of a novel technology overall if it is completely different from existing ones (Markard, Wirth, & Truffer, 2016) and within DST components qualification and quantification are parameters to assess SBG feasibility. Defining technological, energy, environmental, social and networking aspects, DST collects data that frame context's opportunities. The role of '*actor*' selection is an opening screening of context's answerable questions; '*actor*' activates specific questions of DST based on the capacity of the user to answer requests. Users customize the context with their information, giving insights about strengths and weaknesses on theri districts. Also context's answers allow a constant customization: specific answers activate or not other connected requests.

Aspects related to resources are of particular concern, because they are necessary as input to all the activities within SBG. Understanding possibilities for SBG to mobilize material sources – bio-waste from households and green area, existing systems useful for the project, network infrastructures –, human capital – education in specific scientific and technological fields, entrepreneurship, management and finance –, financial capital is crucial to assess the best strategies to develop. Each question related to context is an attribute, with or without a unit of measure, that direct consequences on SBG. Quantity and quality of answers direct specific change in outputs achievable and in case no answers are provided, benchmark values for the context are used, based on research conducted.

REQUIREMENTS

9.3.3.1.3. Requirements

Selected '*actor*', provided context information, there are other elements to take into consideration and that are crucial to work on community's expectations and desires in project as SBG: actor's requirements. Assessing '*requirements*' includes in decision making personal and social aspects of the project that are considered fundamental in SBG promotion. Input data are not secondary. Individual believes typical of '*expectancy theory*' – valence, expectancy and instrumentality ("Vroom's expectancy theory," n.d.) – interact psychologically to generate in the system's user a motivational force within decision making process and, consequently harness SBG's actors to be active part of the project. Requirements, deduced on research conducted, allow to personalize SBG's outputs on actors' desires strengthening results achievable.

9.3.3.2. Evaluation phase

Next to '*input data phase*' is displayed the '*evaluation phase*'. A clarification is mandatory: the '*evaluation phase*' is not consequential to '*input data phase*', but work in parallel. As underlined in the previous sections, already selection of '*actor*' assesses context's queries, allowing a customization of DST on specific actor competences and role, as well as some context's questions make. This is of particular interest because there is a constant interaction and interactivity between '*input phase*' and '*evaluation phase*' that allow to DST user to develop the tool in line with his personal decision-making process. Emerges with this approach the importance of multi criteria decision analysis evaluation that affect further steps of DST and its outputs; theory of change and QFD are used to define this process.

9.3.3.2.1. Theory of change

All stakeholders have varying levels of interest, competence and influencing capacity in the SBG based on their core business (QUEST – Quality Urban Energy Systems of Tomorrow, 2016) and for this reason framing their potentiality within SBG is a way to focus on what they can and they cannot do. A cascade dynamics is generated and his understanding is important, because the change in one element triggers changes in others. A multi-level perspective is developed as an analytical and heuristic framework to understand SBG in the district, in line with the complexity of real-world developments (Geels, 2002). At this aim, the development of a theory of change is useful to assess connections between inputs, possibilities and achievable outputs of DST. *"Theory of change is a (simplified) description of the pathway that connects the actions carried out with the outputs and finally with the desired change (described by outcomes and overall aim)"* ("ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation," n.d.) and allows to connect elements on the base of analysis conducted and assumptions made on how actions/outputs/outcomes are logically connected. Theory of change is here considered as the map of SBG, a cognitive diagram made by '*actions*' that describe how the system works and how these '*actions*' are related one with the other, through multiple contacts and relations. In this DST, theory of change is not properly created by usual standard procedure – focus group, two workshops with two different groups of players, assessment of probability of estimation and final validation process with players –, but it is based on the information collected during the research and mapped in each chapter. In such a way, theory of change assessed by SBG map, setting '*actions*' that influence each other interfering or working together to achieve the desired outcomes. Theory of change operates in DST creating and/or excluding pathways made by '*actions*' that actors and context activate assessing different possibilities for SBG development and implementation that are weighted with requirements through the utilization of QFD. '*Actions*' are subdivided for stages of SBG.

9.3.3.2.2. *Quality function deployment – QFD*

Utilization of QFD, out of its traditional use in '*product design*', is here performed as a method for '*SBG project design*'. Quality function deployment in DST is developed on an evaluation matrix that crosses '*actions*' offered by context possibilities and defined thanks to the theory of change, with '*requirements*' evaluated by DST user who assigns a value in a range between 0 (not desired) to 5 (very important) – for the '*requirements*'. '*Actions*' can be aligned with the '*requirements*' and these correspondences between '*actions*' and '*requirements*' have been estimated in a matrix that set values of 0 (not correspondence), 1 (weak correspondence), 3 (moderate correspondence) or 9 (strong correspondence). Multiplication between '*requirement*' value (0-5) and '*action*' correspondence (0, 1, 3 or 9) adds a value that is weighted with other actions/requirement' values and allow to assess the best solution for actor for specific SBG stage.

9.3.3.3. *Output data*

Evaluation phase sets outputs of DST helpful for decision-making of tool's user that identify the best opportunities for the conditions entered by the stakeholder. Two outputs are provided: '*SBG's actions*' and '*SBG's performances*'. Figure 9-4 shows a screenshot of output data in DST.

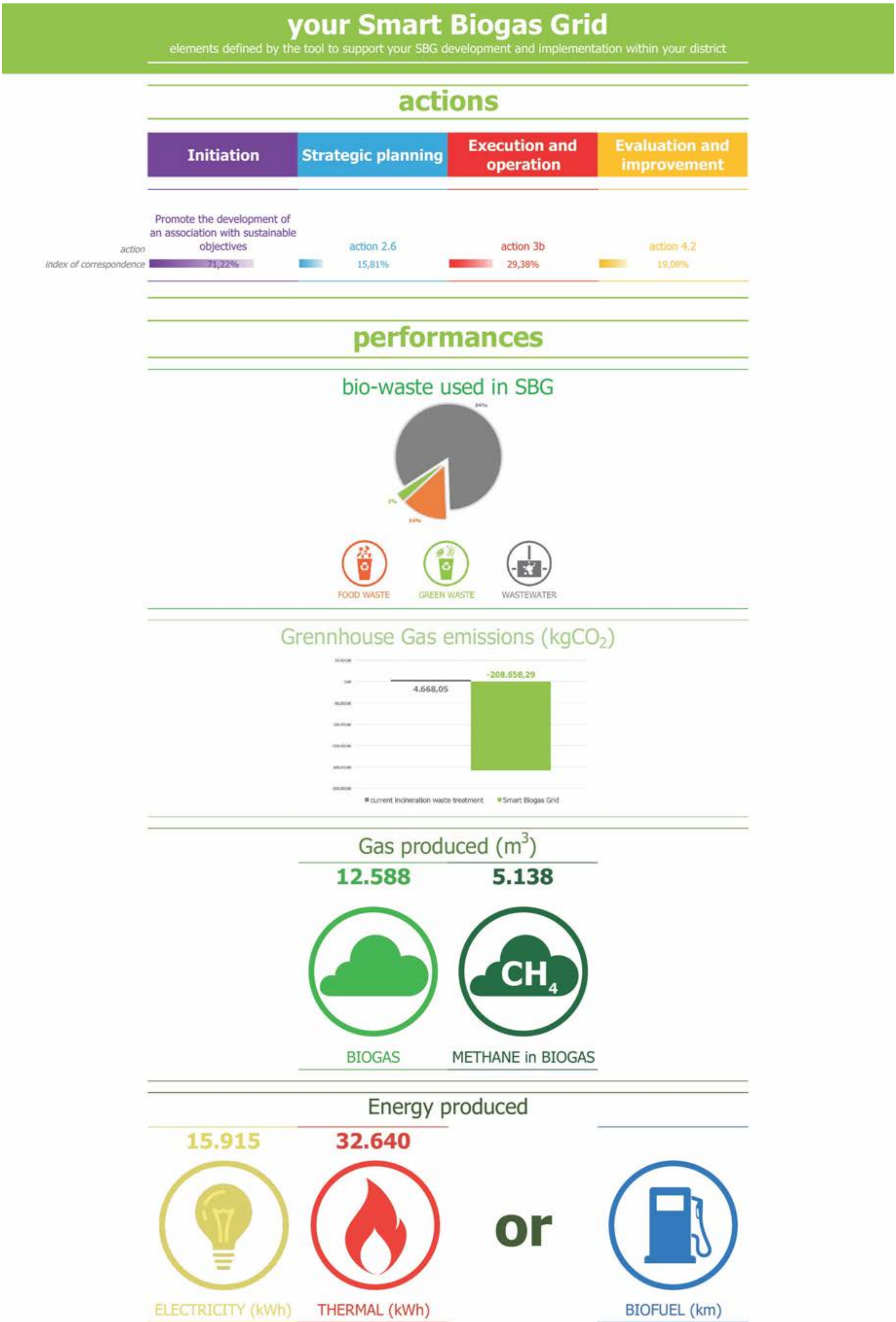

Figure 9-4: DST user interface with a screenshot that shows output data

9.3.3.3.1. SBG actions

First outputs consist of actions that through QFD fulfill not only context's limitations and opportunities, but also actors' expectation on SBG. Actions divided for SBG stages, provide a sort of storyline that can fit different members' ideas, codifying expectations in SBG into realistic solution. As typical of socio-technical transition (Forrest & Wiek, 2014), SBG projects may vary from single action, single intervention with easily identifiable outputs to complex, multi-stranded baskets of interventions and actions and through the evaluation process, actions are evaluated to design scenarios more or less complex, offering possibilities for short, medium and long term implementation plans that have impact thanks to set of practical actions.

9.3.3.3.2. SBG energy and environmental performances

Second, but not for importance, is output that set *'SBG performances'*. Through calculation presented in previously chapters, analysis of context resources connected to energy utilization provided by '*actions*' show the performance of SBG project.

9.4. DST importance within TIS

DST responds to TIS's needs. Understanding of complex system as SBG in all its aspects provided by DST, can support potential actors in decision-making, reinforcing their perspective, funded new visions and facing exiting regime. Raise of awareness and know-how that DST offers, represents a good encouragement for actors engagement. In this context, also implementation of DST should be run to fit better TIS transition. A solution could be to provide the opportunity for DST to work on the same SBG project assessed by DST with other actors to coordinate their resources to achieve greater results and expand opportunities. In such a way, an empirical overlapping of the functions fulfilled by different actors – thanks to interactions through networks or coalitions – would emerge, contributing into the search of adaptive capacity, serving to open up new and expected collaborations in SBG project (Smith et al., 2005). At this aim, the prevision of a new platform for DST, preserving targets achieved by this version DST, can be assumed using a web domain guaranteeing access and project implementation. This solution is resumed in Figure 9-5.

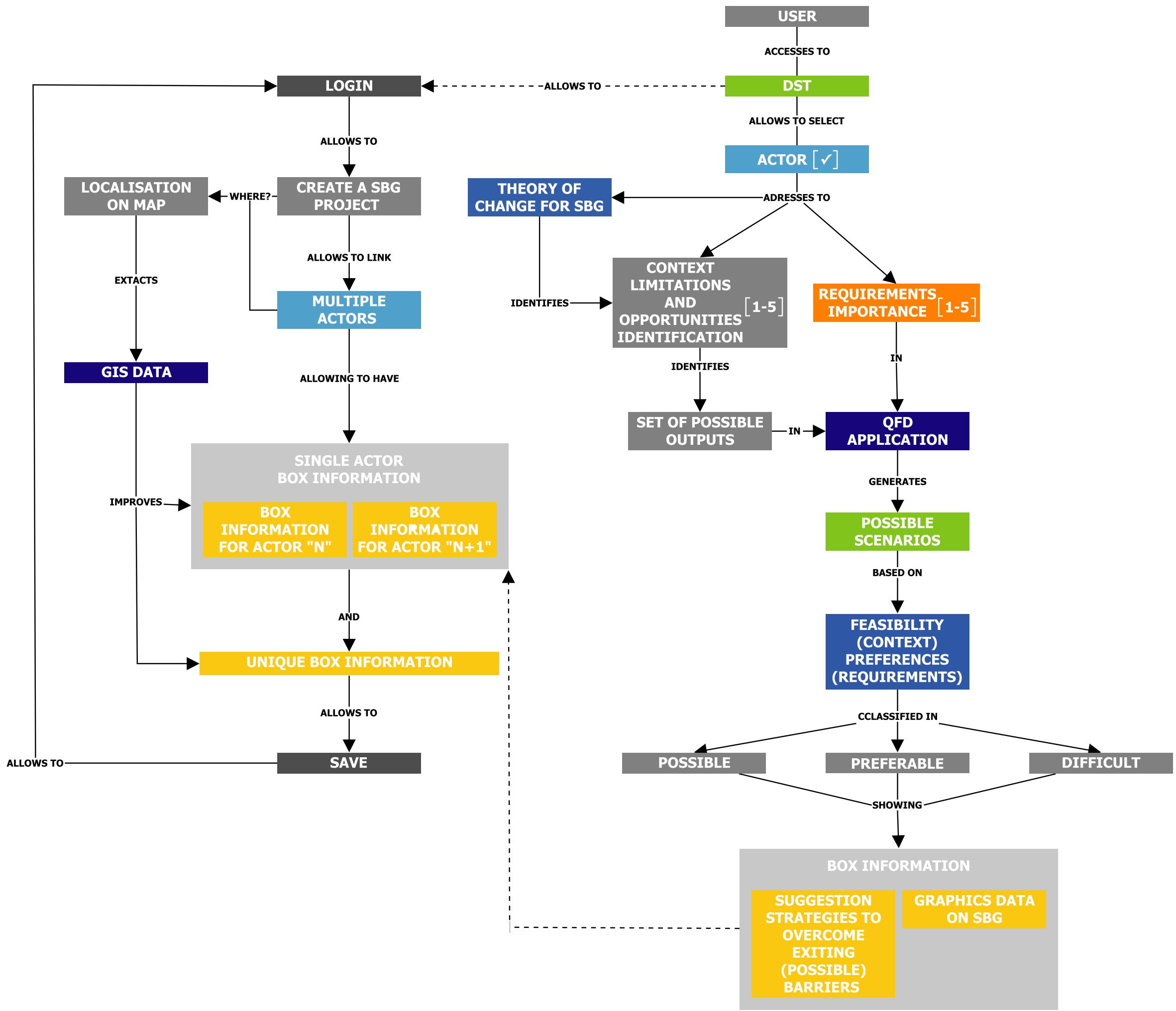

Figure 9-5: DST implementation with multi-actors access to allow project implementation by different players

9.5. Conclusion

This original tool developed within SBG research and presented in this chapter aims to be useful to suggest possible solutions for smart biogas grid creation. DST faces the current lack of biogas urban energy community projects through a novel innovative approach, based on a raise awareness of biogas and public participation, creation of new affiliations and partnerships between stakeholders, exchange and dissemination of ideas, promotion a social behavioral change, understanding the potential of biogas and describing the stages for its development and implementation. The different results of the thinking process guided by the DST depend on several factors, ranging from the context, the resources, the exiting expertizes, the community engagement, the possible stakeholders to be involved; the results differ actor to actor and project to project, offering scenario targeted with the peculiarity of a precise space, moment and need. In such a way, '*action*' is combined with context's parameters and requirements to identify the strongest link between different factors and support decision-making of the DST users; the realization of a predictive model provides an explanatory guidance to direct SBG actions and create a more supportive environment for its development within actors.

DST improves TIS consciousness as a policy tool that guides analysis in the search of central interactions between a SBG and its context. Thanks to DST, TIS finds a support to raise awareness of actors in general, and decision-makers in particular, understanding potential of SBG development in different contexts. Indeed, explicit considerations of context increase the understanding of SBG's components and its stages providing support for the project. In the perspective of future integration provided by stakeholders and by other projects, DST could also be a tool to evaluate context structure during time of project implementation allowing to identify particularly favorable opportunities for development of the project itself, facilitating evaluations on TIS impacts.

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10. Conclusions and Further Developments

Organization of chapter

This chapter draws the final conclusions of "*Smart Biogas Grid: biogas utilization to operate diffused micro-generation solutions in urban areas through the bio-waste exploitation*". The aim is to present the outputs achieved by the research work, focusing on the different disciplinary aspects and the benefits emerged during the research. Some further developments of the research are suggested to keep contributing in SBG's aspects promotion and development.

10.1. Introduction

SBG research has provided a study of the various aspects that contribute in the creation of smart biogas grid project within a district inside urban area; a synthesis and a summary of the elements investigated that characterize SBG is important to set conclusions of the research, helpful for stakeholders to identify the most valuable and affordable options for their district. Despite each chapter presents its own conclusions, this final chapter tries to merge different investigated aspects, in a joined vision and, consequently, regain the systemic view of the whole work. In such a way, it is possible to understand if SBG project allows to achieve the aim of integration of different features involved, incorporating plural perspectives in the evaluation of this project within TIS. This chapter described outputs achieved by the research starting from research questions initially assessed, synthetizing benefits achievable by SBG project thanks to the disciplinary aspects overlapping, understanding the outputs reached by the research itself, to finally presenting possible further development to keep working and researching on SBG solutions and similar.

10.2. SBG research's outputs

Focus on outputs of SBG, research involves a set of considerations that include the whole work carried on during its phases and its aspects developed. Complexity of the system demands to evaluate outputs from different points of view and in a gradual way to understand the correspondence between initial expectations and final results achieved in research. For this reason, different output typologies are here presented to focus on different features of the research. Outputs are organized as following:

- ***Answers to SBG's research questions*** – starting from the research questions presented in Chapter 1, this section draws conclusions on the basis of queries initially assessed to focus on elements that were considered as keys into SBG research study and definition. Answering to these questions is priority to understand the results achieved by the research and, consequently, assess further steps of analysis.

- ***Outputs of Smart Biogas Grid research*** – presentation of specific outputs achieved by SBG research, emerged in the studied relations between aspects that are referable to multi and inter-disciplinary solutions investigated.
- ***Promotion of mix actions within community*** – analysis of SBG in the frame Technological Innovation System, evaluating the rightness of its choice and the merged pitfalls.
- ***Creation of a thinking tool for decision making*** – definition of future possible steps to improve know-how on SBG and implement its solutions.

10.2.1. Answers to SBG's research questions

Which is biogas potential (energy field) at district scale?

Within SBG, biogas emerges for its significant energy potential at district scale. Different features seem relevant for this evaluation:

- ***Biogas and population density*** – biogas is produced by bio-waste and a huge part of this waste is collectable by human activities and, consequently, population density is a key element to take into consideration. Indeed, household food remains and wastewater are precious sources to produce biogas at district scale and higher is population who live within district boundaries and attend SBG project, higher is the amount of biogas produced and therefore its energy potential.
- ***Biogas and district energy needs*** – districts have different energy profiles, depending on their daily activities – residential or offices –, sustainable practices and project assessed that direct different preferences on biogas utilization – thermal, electric, co-generative, biofuel. Biogas has the potential to answer specific needs of district energy demand depending on district's peculiar characteristics.
- ***Biogas and RES*** – biogas is, for definition a gaseous energy source. Once produced biogas in anaerobic digestion, its energy potential can be used independently of daily time, but answering specific users' energy needs. Biogas has the possibility to overcome the fluctuation of other most diffused RES as

photovoltaic and wind energy, allowing its utilization on-demand, fostering peak load use more than base load.

It is possible to identify connections between biomass and biogas production and urban morphology?

Biogas production depends on bio-waste produced within the district that is affected by population density and green area; however, the role of urban morphology can be relevant. '*Compact district*' and '*suburban district with multifamily buildings*' seem to be the most valuable biomass/biogas/methane producers among district typologies, because they merge density with green area. In term of energy potential density is the parameter to consider, but the evaluation of urban morphology helps to identify parameters that can be useful to issue guidelines to connect and balance urban planning indexes – built and green areas, infrastructures, volumetric index – for a better optimization between population density and green area presence within the district, in particular for new project district.

Which are the district parameters which can affect biogas systems application and energy utilization?

A balance between built area, volumetric indexes and green area standard, infrastructural spaces are not only useful to address bio-waste evaluation, but also to assess the applicability of technological components of SBG. This is particularly relevant for biogas production components that need preferably (semi)public spaces for installation because evaluated as preferable in a perspective to engage local actors within the project without having necessity to use private lands and consequently negotiation processes. These spaces can integrate also energy generators for biogas utilization as well as columns for biomethane supply.

Which are pitfalls of biogas in urban area?

Good balance between urban parameters and public property of land used for components installation, are only some of necessity of biogas within district that are basilar pitfalls if not considered. In addition to the verification of energy potential and technological components' applicability, the other item to consider is the social component. SBG is a project that work with and for local actors and, consequently a large share of biogas potentialities and complex SBG's perspectives are fundamental for the success of the project. For this reason, only if there is the presence or, at least, the base to fund a community of interests, SBG can be promoted, developed and realized.

Which is people acceptance of biogas and community system in their district?

Therefore, the role of population is relevant to share project and, overall, to accept biogas utilization. Despite there is a general predisposition to work in community, biogas faces prejudices to be hazardous for risks of nuisances – odors and emissions –, gas and liquid dispersion and explosion; these preconceptions need to be faced with information, participative development of the project and a realization that respect the normal good practice of construction. These elements allow for biogas to be accepted and, consequently, used by a larger part of community within the district. If this is an option, but the acceptance of population depends on presentation of this possibility; at this aim companies of waste and energy sectors – multi-utility companies – that operate within the district and pursue a profit in existing waste treatment are usually an obstacle because this new waste treatment will decrease their incomes and change their business assets.

Which is regulatory framework of reference for urban biogas application?

Two components appear to be important for biogas application within district: population that accept biogas and the project, and local government, that issue urban plans parameters within the district. The importance of local governments is not only limited to the definition of a supportive urban plans, but because it is the first institutional interlocutor for community interested in the development of the project. The supportive national and regional regulatory framework finds in local governments the opportunity to be applied concretely and declined through urban plans, availability of resources and offices know-how.

How can the city council foster and develop SBG?

This fact is not obvious, but depend on local government political choice that depend also on city council decisions and acts, often appeared to be more favorable to multi-utility logic being investee companies. Therefore, identifying political representatives within city council can support the adoption of measures in SBG direction and, consequently foster the development of the project. For this reason, if there is not a local institution supportive, local community should find political representatives, traversal to political front, to find support in the promotion of acts towards SBG. In this way, the current regulatory framework interested in the diffusion of practices of sustainability and energy efficiency, can structurally modify the organization process that projects as SBG within institutions.

Which are the incentive policies to promote biogas among RES?

This is especially relevant because of presumable future ending of incentives policies. Today biogas is not profitable as energy source without incentives – feed in tariff and premium tariff the most relevant – but economic logic depends on political choices and incentive provision is expected to decrease in the future years for RES. Biogas is currently supported more or less in line as other RES – expect for countries that have high solar radiation that make photovoltaic more profitable – but in a near future, the perspective is to have reduce biogas production costs and, consequently, the need to have support incentivizing schemes for its promotion.

How can incentives, policy frameworks and tariff structures better serve SBG?

An opening direction for SBG is the creation of new support schemes that could support waste diversion from landfill – carbon tax introduction – and that financially support the promotion of multiple aspects embodied in the project – energy, environmental, social. In such a way, it is not only the energy industrial sector that has economic return by the application of a RES, but it is all the society that can benefit from policy framework, building the foundation for the success of innovative sustainable projects.

Which are the common positive/features of success/failure of sustainable project in different domains and in different countries?

Indeed, only in the presence of a wide engagement of local actors and of the community they constitute, the projects find the key for their success. For this reason, appraisal and constant participation of stakeholders are crucial actions to carry on, preserving during the time people interest and awareness in the projects. At this aim, the role of a core actor with capacity to implement engagement after the kick-off moment is fundamental, to guarantee project stability and pursuing of its expected results.

Which is biogas potential (environmental) at district scale?

Only if there is with a continuous operative status of the project, environmental potential of SBG can be appreciated because SBG's perspectives are not in the short period. Practices SBG implements and actors it aims at engaging need time to be taken root and producing results that can widely spread over district boundaries. Waste separated collection practices are the first element in this chain.

How organic waste can be collected?

It is no imaginable that environmental results in waste collection are satisfactory in a short period. Long time program and constant actions of communication of performances achieved are the only way to improve quality of bio-waste collected, especially through door-to-door collection, and consequently, achieved good performances of waste diverted from landfill with connected reduction of GHG emissions. In this way, there is an increase of bio-waste collected that allows to improve biogas amount and its replacement to traditional fossil fuel. The environmental impact of SBG starts with waste and ends with energy produced. Biogas emerges to be a justification to introduce a set of actions that change stakeholders' behavior and decrease their ecological footprint.

How can digestate contribute at closing the urban metabolism of city?

In environmental consideration, not only waste and biogas/energy should be considered, but also the contribute provided by digestate utilization. Digestate produced in anaerobic digestion has a good environmental impact because it improves green growing, reduce the utilization of artificial fertilizer and contribute in closing the urban metabolism, because it is used locally in the district. At this aim, an improvement of green solutions – horizontal and vertical – should be provided in the refurbish of buildings and brown fields.

What is the cost of biogas system in comparison with other renewable energy technology?

All these considerations on SBG should be supported by the creation of proper business plan and governance solution. For what concerns the business plan, SBG is difficult to be compared with other RESs. The reason is that SBG is complex system of components and actions that does not provide only the installation of biogas technological components. Differently from other RES' systems that are installed and connected on-grid as well sued off-grid, SBG has a level of interactions of components and actors that is more complex with a cost of maintenance and operation that is higher.

Which is the role of biogas in share of renewable energy technologies?

However, business plan should include also those savings derived by environmental and social aspects that are usually costs for society and that mark the positive upgrade of biogas in relation to other RESs.

How new initiatives are challenging the existing regime and how the regime can respond?

Indeed, SBG includes all a set of possible initiatives more than biogas, that represent the real value of this solution in urban areas. Waste use locally, energy prosumers, educational activities, communitarian programs, food growing and other opportunities, face existing regime in its energy and economic dominant position, with a new concept of shared environmental, energy, social and economic responsibilities that are the elements that characterize the emerging regime of SBG.

Which are multi-level and multi-actor interactions?

The interaction between actors, as well as the organization of different level of expertizes and willingness to participate, engage stakeholders in a community of practice that share interests and benefits of the project; the combination of support from a large variety of stakeholders is the most successful factor.

Which is biogas potential (social) at district scale?

In such a way, the social potential of biogas emerges, offering the opportunity to improve solutions that raise awareness on environmental and energy topic, and restoring a sense of social cohesion that was typical of traditional historical urban aggregation. This potential is unevaluable without specific studies, but it can improve sense of belonging to a community and consequently decrease costs paid by society for welfare and security.

What are the main challenges for the governance of SBG?

The definition of a governance model that support this social vision is crucial. If local actors and community are main player of SBG, their role should be recognized also with the possibility to share property of SBG's assesses, as well as participate in decision making process for project implementation.

There are innovative models to go beyond the as usual business scenario to be translated into a range of options and priority setting to support decision-making?

In this way, models of governance based on community driven or cooperation or SME-driven a community of interests should be promoted to meet individual expectations of governance of SBG of the actors. These governance solutions share outputs of the project among shareholders increasing the consciousness to be part of a community that run into the same directions.

How is it possible to promote SBG model widespread?

This is the added value of SBG that marks a point to widespread positive results – beyond energy and environmental calculations – of Smart Biogas Grid. People should not considered technologies only as prostheses of the spaces or as a system driven by a specific logic (Torricelli, 2011); SBG promotes a vision of biogas technological components as opportunity to generate districts where skills, expectations and knowledge interact, driving a new system of spatial, temporal, material and immaterial relations typical anthropic environment where people should live.

In this way biogas is an environmental and energy instrument, useful as model for new district and neighborhood foundation, helpful to direct change in existing social fabric, restoring or creating ex-novo those characteristics that make people feel good in urban and architectural context where they live. SBG has not anymore an only center in biogas and energy as outputs, but insert the variable of people in the SBG project.

When SBG should be developed and what are the catalysts that take SBG from vision to reality?

Participation of people is the starting step of SBG to achieve results in social innovation and therefore increase the performance of the whole system. Without local actors constant involvement, SBG loses its potential and decrease its possibility to use technological components to serve anthropic environment.

What steps need to be taken to begin development of a SBG project in urban district?

10.2.2. Outputs of Smart Biogas Grid research

Answering the research questions is preliminary to underline outputs achieved by the SBG research.

10.2.2.1. Study of urban biogas aspects

First output provided is a study on urban biogas aspects – environmental, energy, normative, technological, social, economic and governance – and their relations. In the scenario of biogas application, urban plants at district scale are not common and complete studies do not include all aspects, but focus on precise components and particular experiences. This research offers a contribute within this panorama including aspects that affect urban biogas application in cities. The literature on biogas usually provides chemical, energy and environmental considerations that are valuable independently of local context where biogas system is applied; this research introduces elements typical of the context of realization in particular technological application within urban district, normative that can direct urban biogas and role of local population. Inter-disciplinary and multidisciplinary aspects underlined help to frame biogas topic in a precise context of application and can be supportive for specific disciplinary analysis and demonstrate the necessity to think inside a systemic view over the specialist sectorial discipline.

10.2.2.2. Definition of guidelines

SBG research assesses guidelines that help project designers and managers to evaluate the best solutions for the specific district. District predisposition to admit technological components, regulatory guidelines, energy solutions are provided and are useful for decision making process SBG's stakeholders. Private and public authorities are involved in the definition of new strategies for promotion of these systems and solutions suggested by the research can direct specific scenario.

10.2.2.3. Promotion of mix actions within community

Community is one of the stakeholders of the project and the most important final user. SBG includes a set of actions that show how aspects considered independent one with the other can be related to reach better and optimized results. There can be a wide variety of reasons that lead a community to be part of a project of this type – environmental, energy, social and economic – but actions are often seen unconnected one with the other; SBG provides the demonstration of how different actions are strongly related. In particular the following outputs are achieved by the research:

- ***Promotion of bio-waste practices*** – separated collection provided by SBG is a strategy to teach separation collection and advantages of this waste scheme. The result is to diffuse recycling and reuse practices, eliminating costs of transportation, reduce emissions, reuse locally organic fraction of municipal solid waste, raising awareness on waste potential and footprint impact. waste diversion from landfill help to meet European target to reduce landfilling.
- ***Promotion of energy awareness*** – bio-waste producers are biogas makers and energy users, promoting the vision of '*prosumer*s' that empowers population in a responsible use of energy, reducing of electric and heat district energy costs,

towards the independence from fossil fuel thanks to integration with other RESs.

- ***Promotion of renewable energy practices*** – SBG is centered on biogas utilization as energy vector. Its use allow integration with other renewable energy systems, reducing electricity demand on the grid during peak load periods and consequently, reducing stress on national or regional power grids and energy losses because biogas is use locally where it is produced. All these aspects contribute to meet national and European targets for carbon emissions and renewable energy shares.
- ***Promotion of social innovative solutions*** – energy community and community of practice embodied in SBG promote a sense of belonging in community that is helpful to preserve and improve the attendance at the district and social cohesion. Dimension of neighborhood is fortified through activities of participation in different stages of the project development and implementation.

10.2.2.4. Creation of a thinking tool for decision making

Decision support tool has the aims to synthetize the contributions and considerations made and to promote the visions and contents of SBG research. The DST is a support for decision making process for stakeholders of the project.

10.2.3. Outputs achieved by the research methodology

The present section considers SBG as TIS (Bergek, Hekkert, & Jacobsson, 2008) and expected outputs of this methodology (Turnheim et al., 2015). Development of a multi-dimensional assessments have demonstrated to be interesting in the understanding of to deliver an effective support, providing the basis for the development of a significant body of empirical evidences having an impact on policy and real-world for decision-making useful to decision-makers and practitioners. SBG can be considered demonstrates to be a technological innovation system because it contributes in knowledge development and diffusion, forming a market that mobilizes local resources and legitimate technological application in the context of application and within population, funding the basis to support entrepreneurial experimentation and developing products as energy and digestate but also utilities for different range of stakeholders. SBG fits perfectly TIS logic and represent a good framework to maintain systemic view researcher in the project.

10.2.4. Further developments

The considerations above done open further perspectives to deepen research topics and better understand SBG full potential.

- ***Development of SBG case studies within urban area*** – despite it funds its reflections on real experiences derived by existing projects' results, this research does not realize a SBG project; to exam properly the valuations made, it is considered important the realization of case studies to test, integrate and implement SBG' considerations. At this aim, the following steps should be pursued, in line with elements emerged in this research:
    - ***Creation of networks of actors*** – expertizes, universities, public institutions – interested in development of complex, multi and inter-disciplinary systems based on biogas in urban area.
    - ***Identification of funding resources*** – private and public, national or European economic resources can be used. In particular, considering the aspects treated in the research, many European programs can be embodied in the research aim with many opportunities.
    - ***Identification of case studies and communities*** – targeting multiple groups that get the opportunity through the project to learn more in a series of hands-on activities. Innovative or modern community concepts will enable new stakeholder groups to participate in community of practice frame. Engagement of local actors since the very beginning phase should be provided.
    - ***Realization of SBG*** – utilization of network's expertizes and fundings collected to realize SBG.

- *Monitoring of SBG* – since the very early phase of project development and during its implementation, a monitoring should be assessed to collect data on the project, its actors and fix eventually problems emerged.

The realization of case studies as above presented is helpful to verify the considerations and implement SBG to enlarge the experience to unique cases to a shared standard to diffuse widely its positive benefits and contribute in the creation of future net zero energy city.

- ***Decision support tool implementation*** – the tool assessed to support SBG decision making is a good instrument that can achieve widely results with a further implementation. These phases should be assessed:
  - ***Validation with all range of stakeholders*** – the current validation made with '*community member*', should be enlarged with other stakeholders, in particular with those actors – public authorities, biogas technologies producers, energy supply, education institutions – that can be partner of the project for specific aspects. In this way, the usefulness of the tool is tested among specialists, receiving their feedbacks to be integrated in the DST.
  - ***New platform for DST*** – as mentioned in chapter 9, a new platform to diffuse larger the tool and provide the opportunity to create more detailed project should be designed.
  - ***Integration in early district design tool*** – according to property of simulation of future energy performances, the DST can provide a set of operative data to be integrated in early district design tools, useful to assess strategies and solutions.

These two actions can allow to have a DST that could be helpful to promote SBG and, contemporary, support the diffusion of complex system that integrate energy performances with innovative solution typical of other scientific fields, as social and economic.

10.3. Conclusions

The results achieved by this research are considered valuable and, even if not exhaustive, a first step towards the system realization. SBG is a complex system that lead to much more than energy considerations on creation of micro- co-generation system within district. Biogas is a vector that assesses more complex and multi aspects strategies with the potential to lead to widespread environmental, social and economic, in addition to energy, benefits. The role of stakeholders is central. Indeed, the most critical success factor for SBG implementation is enabling the actors engaged, in particular local community, to meet their expectations and objectives in the project development and use biogas exploiting its full potential.

The methodology adopted is evaluated as a positive model to approach these complex systems including multiple aspects that assess a dialogue between disciplines and experts for the development of mutually reinforcing policies, actions and technologies.

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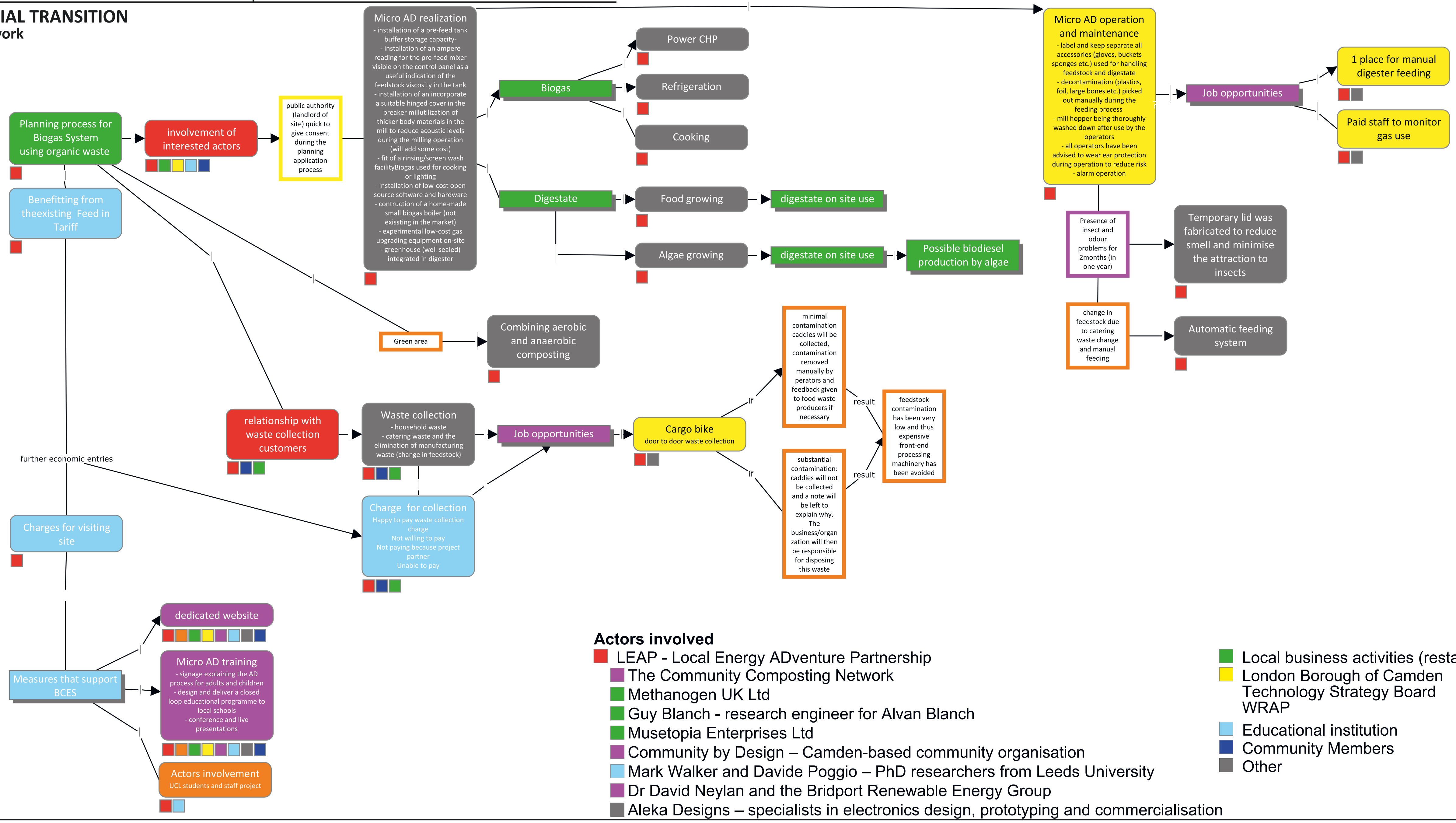
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Camley Street Natural Park, 12 Camley Street, London, UK | 1

TOPICS
biogas, micro AD, waste collection

REFERENCES
http://communitybydesign.co.uk/
WRAP. (2013). Optimising Urban Micro AD Networks.

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved

- LEAP - Local Energy ADventure Partnership
- The Community Composting Network
- Methanogen UK Ltd
- Guy Blanch - research engineer for Alvan Blanch
- Musetopia Enterprises Ltd
- Community by Design – Camden-based community organisation
- Mark Walker and Davide Poggio – PhD researchers from Leeds University
- Dr David Neylan and the Bridport Renewable Energy Group
- Aleka Designs – specialists in electronics design, prototyping and commercialisation
- Local business activities (restaurants, cafè)
- London Borough of Camden
Technology Strategy Board
WRAP
- Educational institution
- Community Members
- Other

NOTES

1-1

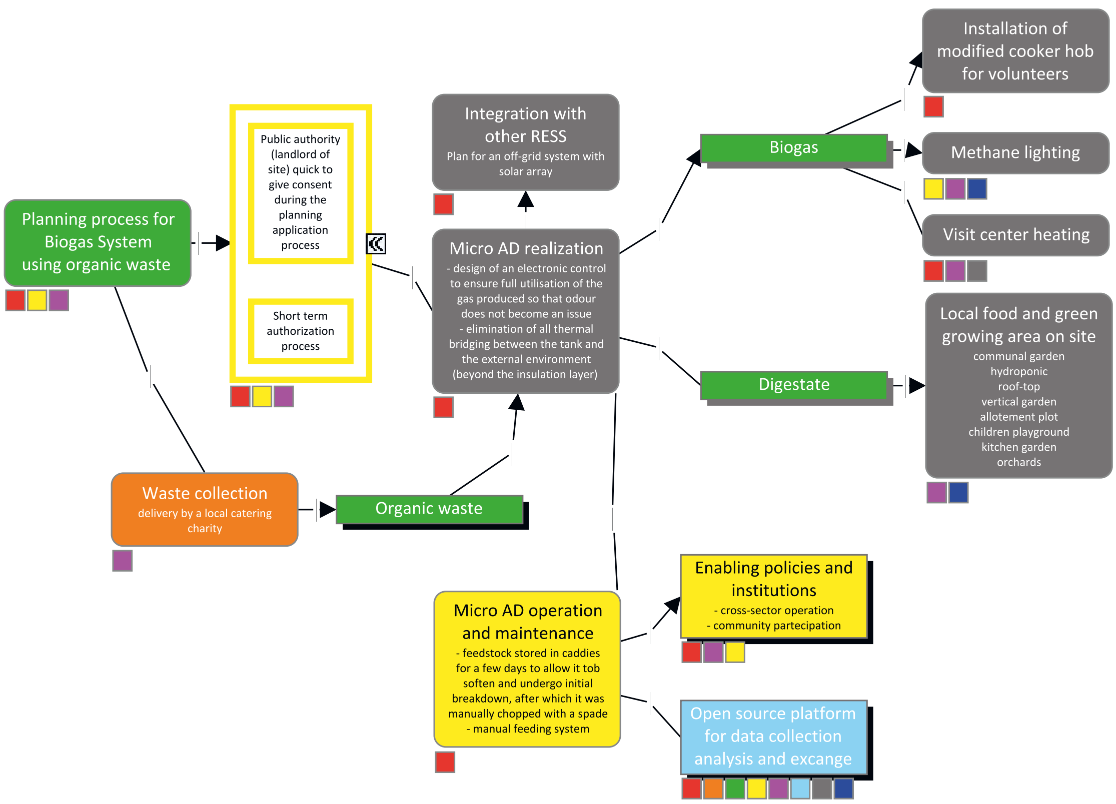
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

The Calthorpe project, 258-274 Gray's Inn Road, London, UK | 2

TOPICS
biogas, micro AD, community

REFERENCES
http://calthorpeproject.org.uk/
http://communitybydesign.co.uk/
WRAP. (2013). Optimising Urban Micro AD Networks.

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved

- LEAP - Local Energy ADventure Partnership
  - The Community Composting Network
  - Methanogen UK Ltd
  - Guy Blanch - research engineer for Alvan Blanch
  - Musetopia Enterprises Ltd
  - Community by Design – Camden-based community organisation
  - Mark Walker and Davide Poggio – PhD researchers from Leeds University
  - Dr David Neylan and the Bridport Renewable Energy Group
  - Aleka Designs – specialists in electronics design, prototyping and commercialisation
- Calthorpe Project community
- Camden Council

NOTES
notes

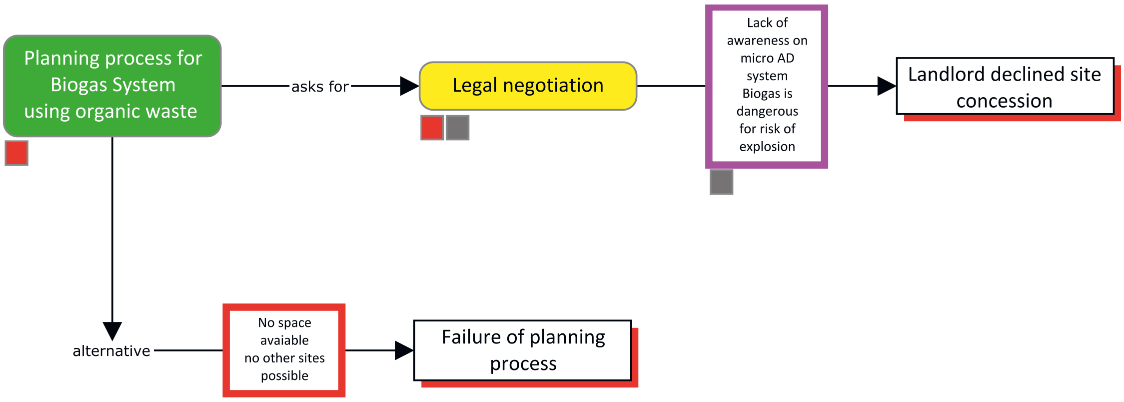
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Alara wholefoods, 110-112 Camley Street, London, UK | 3

TOPICS
biogas, micro AD, landlord

REFERENCES
http://communitybydesign.co.uk/
WRAP. (2013). Optimising Urban Micro AD Networks.

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved

- LEAP - Local Energy ADventure Partnership
  - The Community Composting Network
  - Methanogen UK Ltd
  - Guy Blanch - research engineer for Alvan Blanch
  - Musetopia Enterprises Ltd
  - Community by Design – Camden-based community organisation
  - Mark Walker and Davide Poggio – PhD researchers from Leeds University
  - Dr David Neylan and the Bridport Renewable Energy Group
  - Aleka Designs – specialists in electronics design, prototyping and commercialisation
- Site landlord

NOTES

The project, despite was developed by the same instigator than case study #1 and #2, failed bacause of a different landlord awareness on proposed project

3-1

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

BioNet, Germany | 4

TOPICS

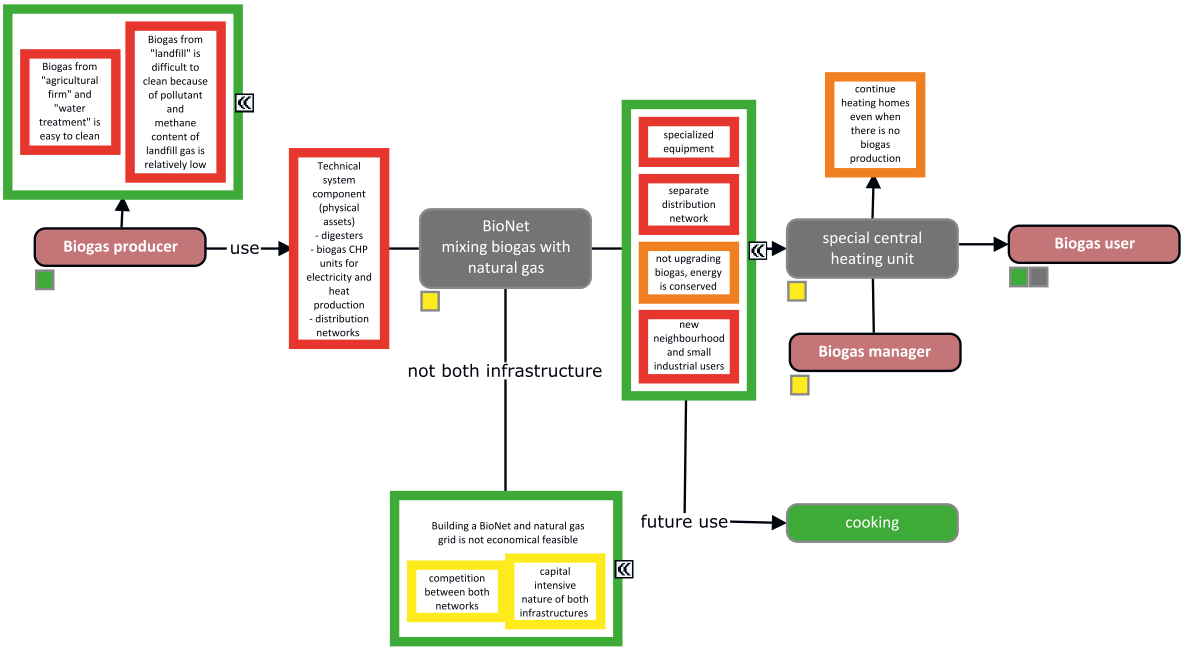
biogas, greengas, new neighbourhood

REFERENCES

Verhoog, R. (2013). Exploring biogas stakeholder interaction in the Netherlands. An Agent Based Modeling approach to explore location specific biogas system performance under different scenarios. Delft University of Technology. Retrieved from http://repository.tudelft.nl/islandora/object/uuid:7eb84849-69fa-4708-b092-26718ae29b73?collection=education

SOCIO-TECHNICAL TRANSITION

Synoptic framework



Actors involved

- Agricultural firms
- Water treatment
- Distribution System Operators
- Factories (small/large consumer)
- Public building (small/large consumer)
- Office (small/large consumer)
- Household (small consumer)

NOTES

notes

4-1

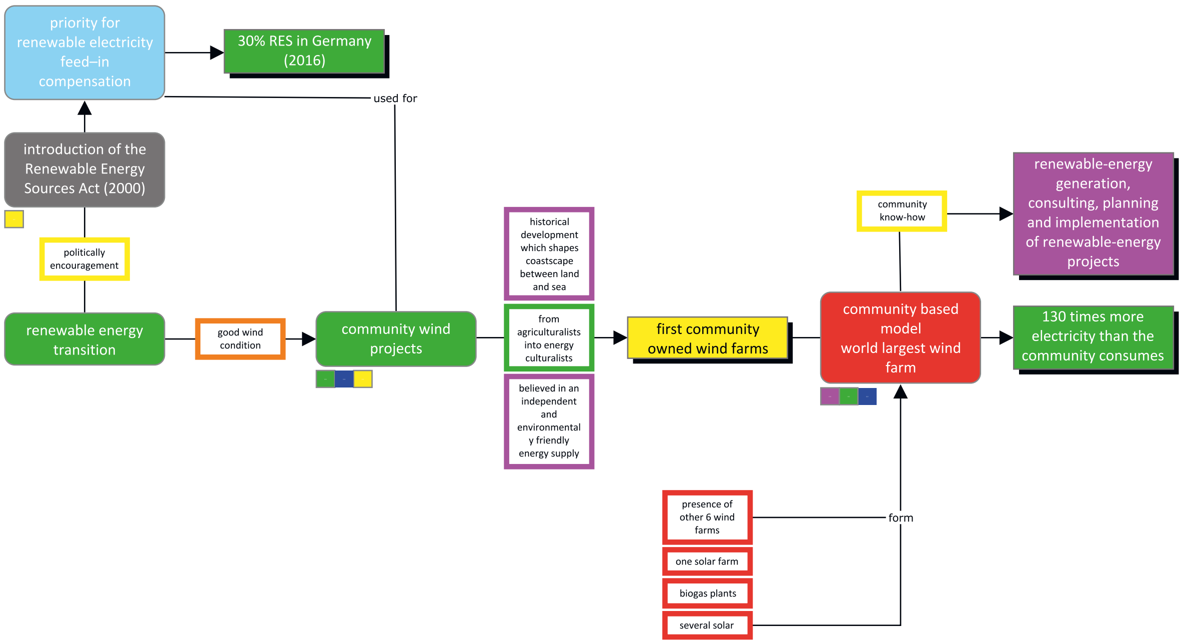
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Reußenköge, Frisia, Germany | 5

TOPICS
energy community

REFERENCES
Süsser, D. (2016). People-Powered Local Energy Transition Mitigating Climate Change with Community-Based Renewable Energy in North Frisia.

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- National Governement
- Private limited companies
- Cooperatives
- Households
- Municipality
- 6 Wind farms
- 1 solar farm
- Several solar and biogas plants

NOTES
notes

5-1

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Ashton Hayes, Cheshire, UK | 6

TOPICS

carbon neutral village, sustainabile community

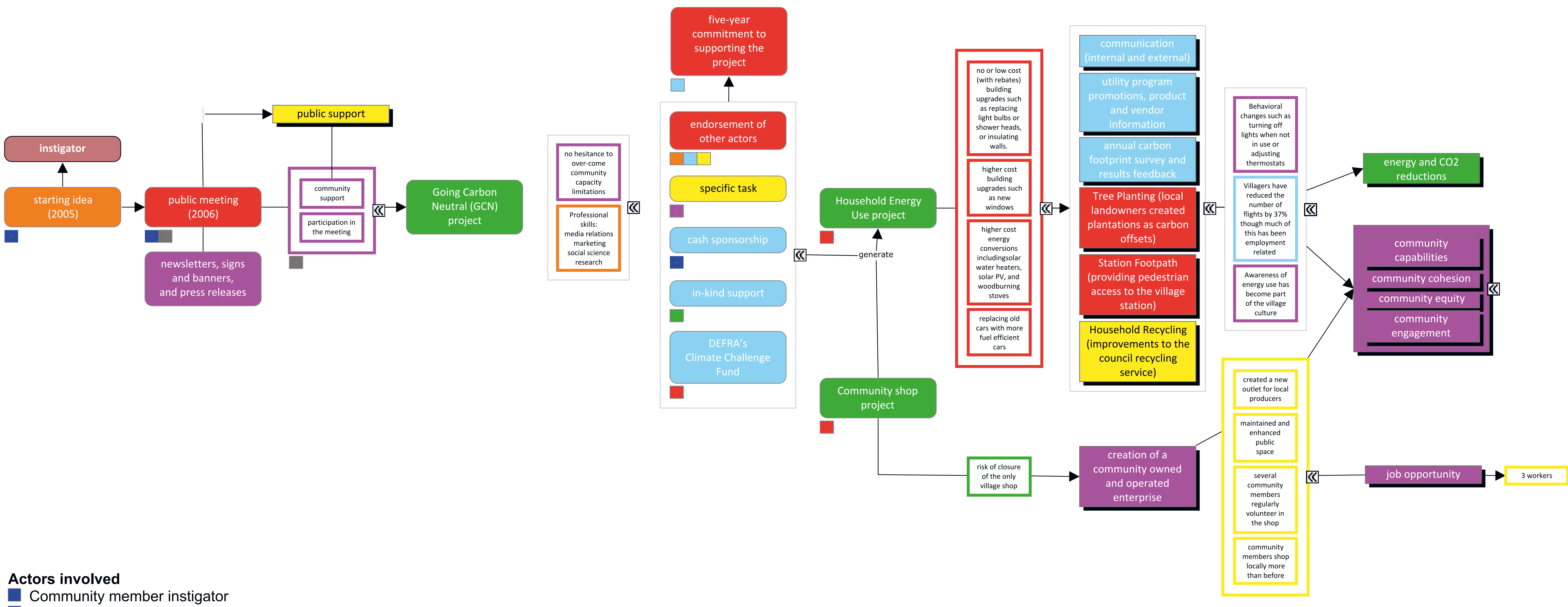
REFERENCES

Forrest, N., & Wiek, A. (2015). Success factors and strategies for sustainability transitions of small-scale communities – Evidence from a cross-case analysis. Environmental Innovation and Societal Transitions, 17, 22–40. https://doi.org/10.1016/j.eist.2015.05.005

Alexander, R., Hope, M., & Degg, M. (2007). Mainstreaming Sustainable Development–A Case Study: Ashton Hayes is going Carbon Neutral. Local Economy, 22(1), 62–74. https://doi.org/10.1080/02690940701195123

SOCIO-TECHNIAL TRANSITION

Synoptic framework



Actors involved

- Community member instigator
- Community member
- Local parish
- An official appendage of the parish council
- Volunteer workgroups
- Local businesses (SolarTwin, RSK ENSR, etc)
- University of Chester
- Energy conservation non-profit
- Local county council

NOTES

notes

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

BedZED, London, UK | 7

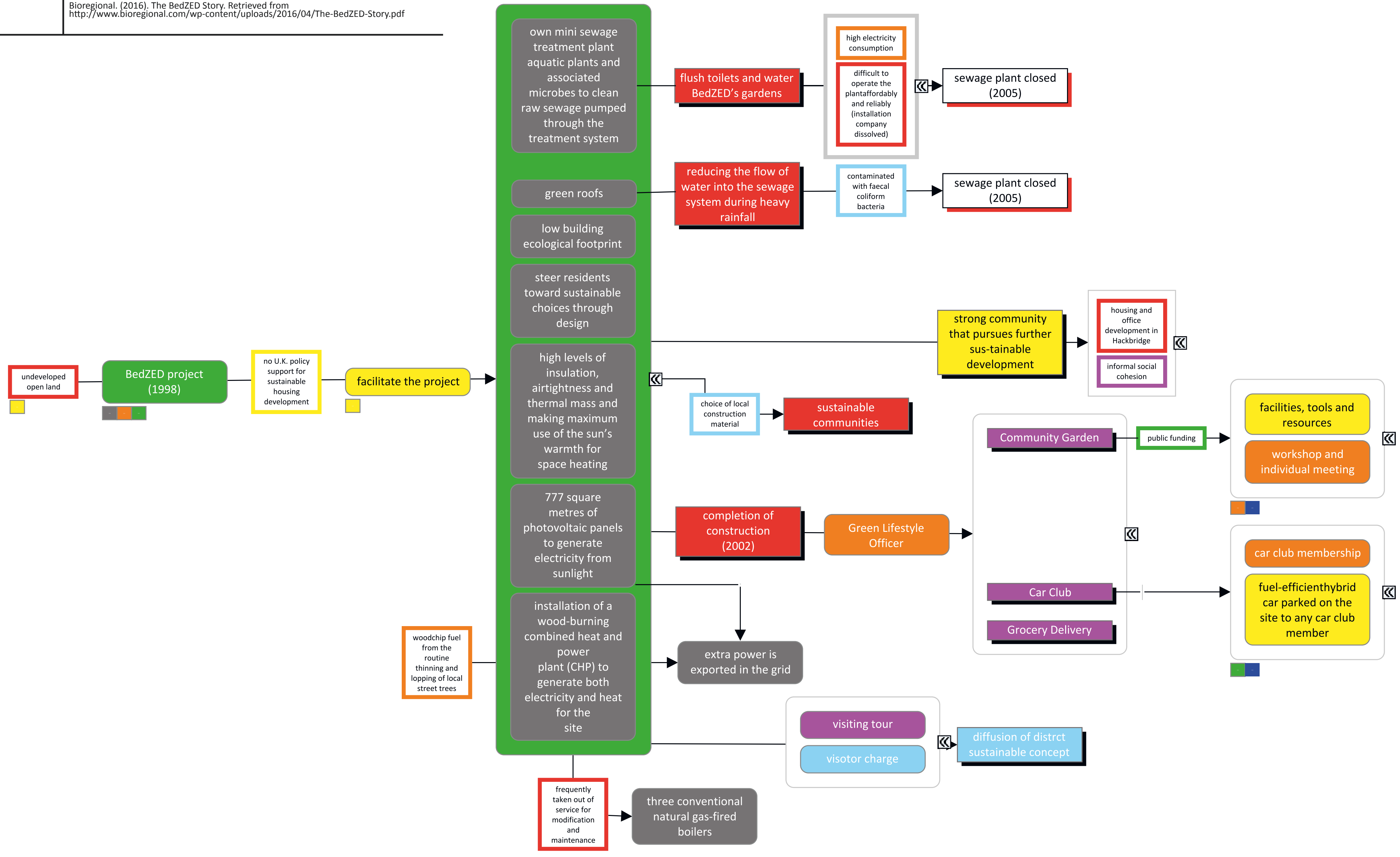
TOPICS
sustainable house and office, urban community

REFERENCES

Forrest, N., & Wiek, A. (2015). Success factors and strategies for sustainability transitions of small-scale communities – Evidence from a cross-case analysis. Environmental Innovation and Societal Transitions, 17, 22–40. https://doi.org/10.1016/j.eist.2015.05.005

Bioregional. (2016). The BedZED Story. Retrieved from http://www.bioregional.com/wp-content/uploads/2016/04/The-BedZED-Story.pdf

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Peaboy (social housing association)
- Resident association
- Bill Dunster Architects
- BioRegional
- Sutton Council
- Green Lifestyle Officer
- City Car Club

NOTES
notes

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

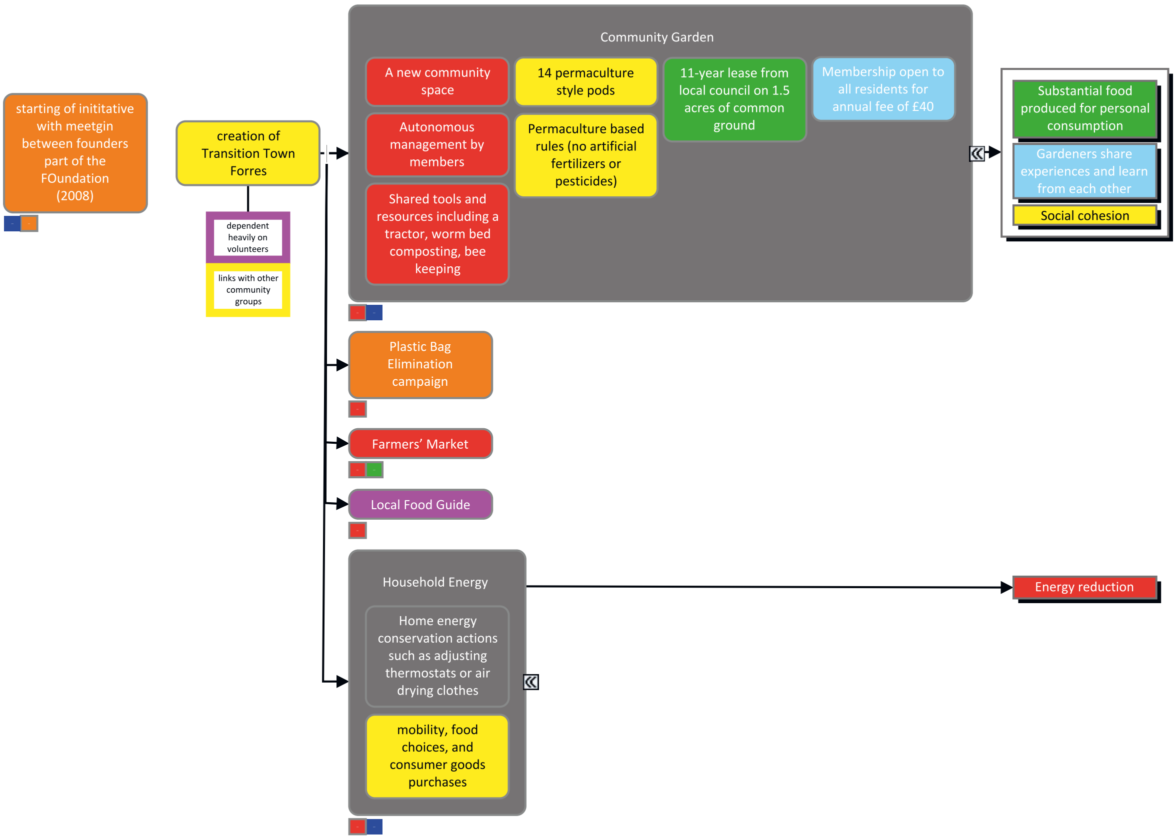
Forres, Highland, UK — 8

TOPICS
transition town, community garden

REFERENCES
Forrest, N., & Wiek, A. (2015). Success factors and strategies for sustainability transitions of small-scale communities – Evidence from a cross-case analysis. Environmental Innovation and Societal Transitions, 17, 22–40. https://doi.org/10.1016/j.eist.2015.05.005

https://ttforres.scot/

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Three community members (founders)
- Findhorn Foundation
- Transition Town Forres (charitable company)
- Local Council
- Local farmers
- Community members

NOTES
notes

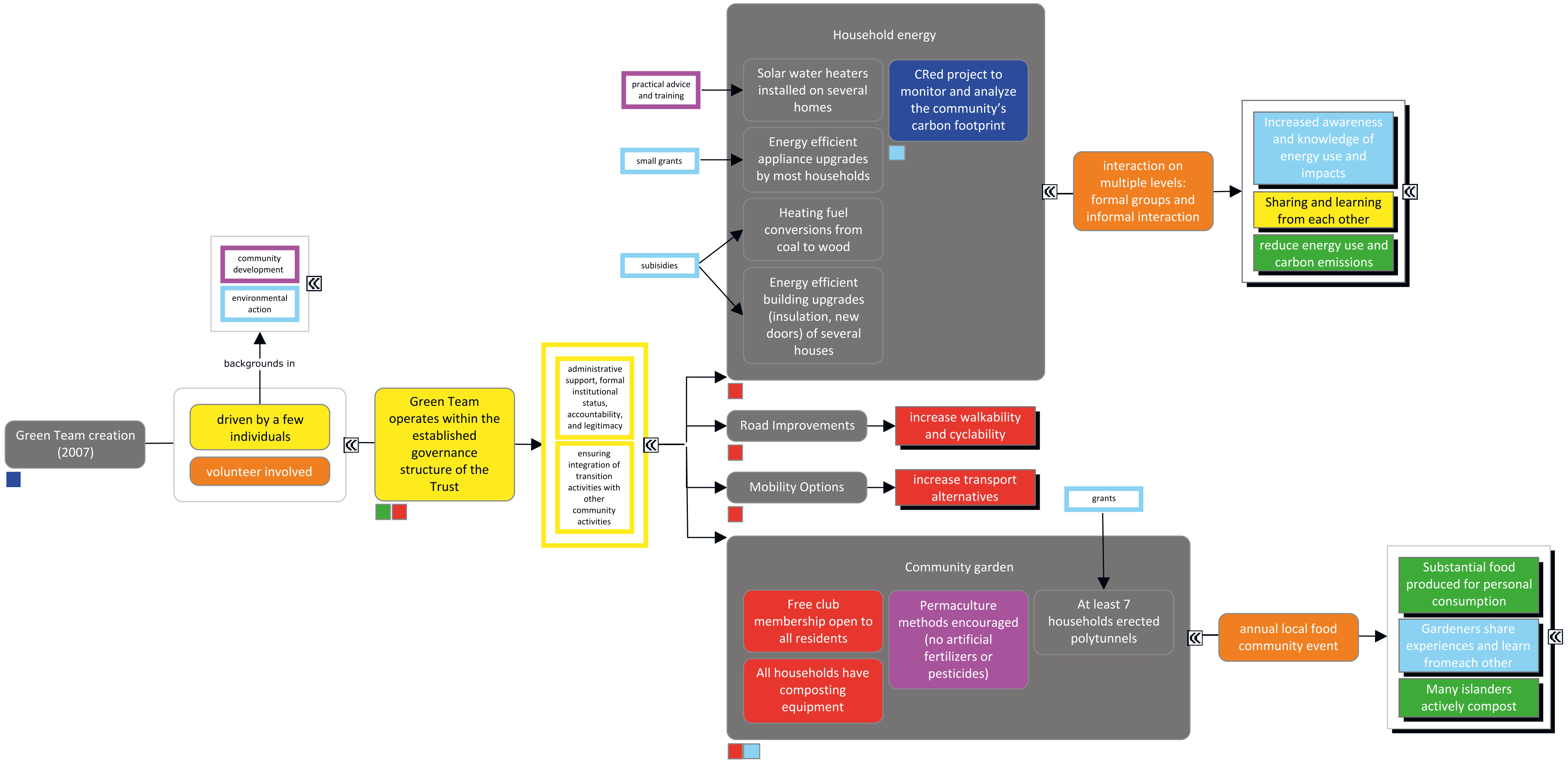
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Isle of Eigg, UK | 9

TOPICS
community-driven development, community garden, household energy

REFERENCES
Forrest, N., & Wiek, A. (2015). Success factors and strategies for sustainability transitions of small-scale communities – Evidence from a cross-case analysis. Environmental Innovation and Societal Transitions, 17, 22–40. https://doi.org/10.1016/j.eist.2015.05.005
https://islandsgoinggreen.org/about/

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Community land trust (50% community - 50% external representation)
- Residents' Association
- Green Team (core group of voluntary)
- Community member
- University ofEast Anglia

NOTES
notes

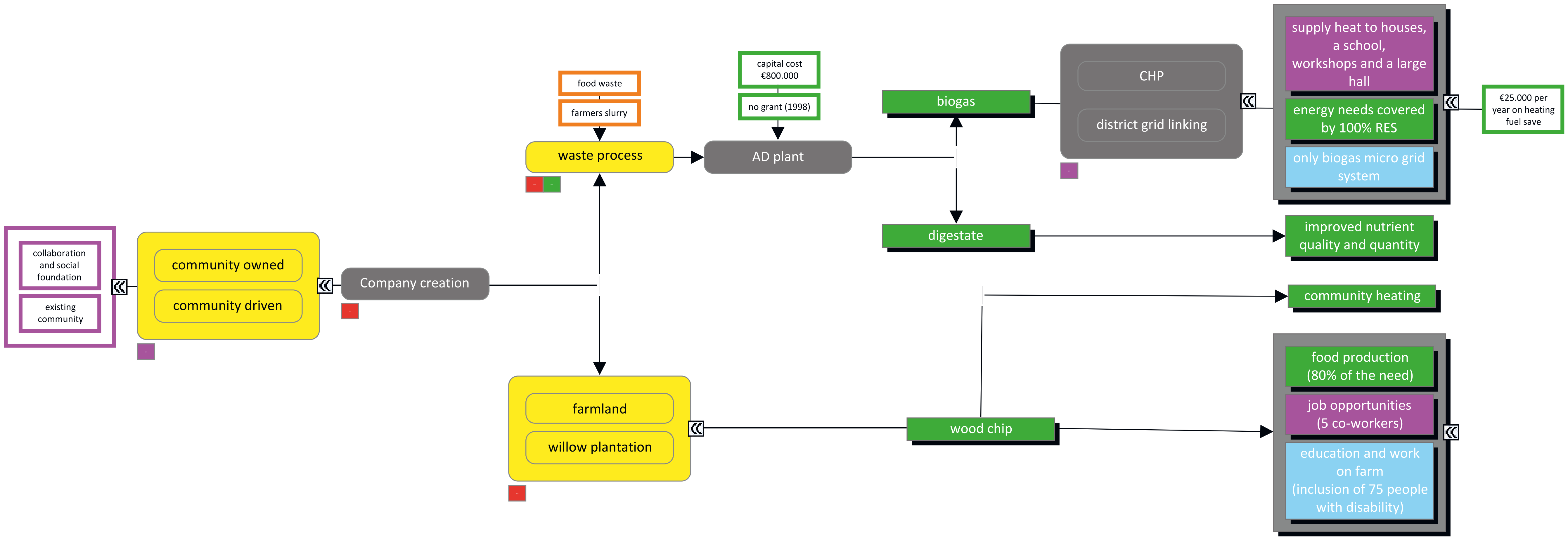
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Ballytobin, Kilkenny, IE | 10

TOPICS
biogas, social innovation, disabled people

REFERENCES
ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.)
IEA Bioenergy. (2005). Case Study. February 2005. Camphill Community Ballytobin, Co. Kilkenny, Ireland. Retrieved from http://www.sei.ie/uploadedfiles/RenewableEnergy/Task29CamphilCommunityBallytobin.pdf

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Camphill Community Ballytobin (75 disable people, co-workers)
- BEOFS (Bio-energy and Organic Fertiliser Services)
- Neighbouring farmers

NOTES
notes

10-1

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Gussing, Burgenland, A | 11

TOPICS

biomass, community energy, jo opportunity

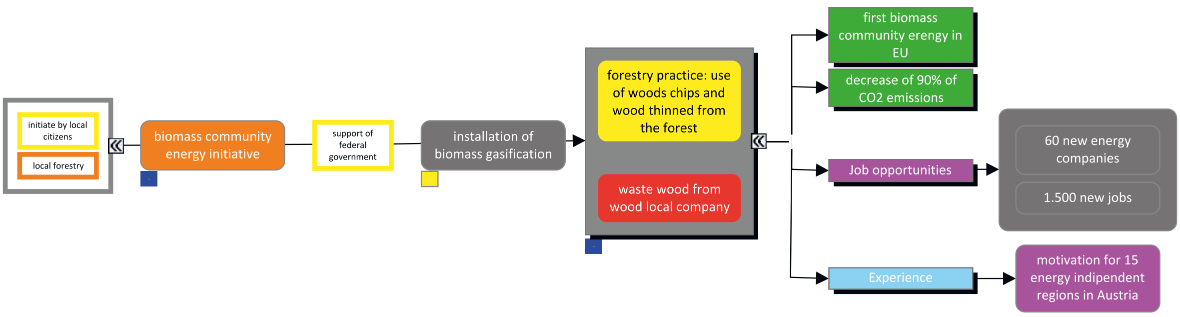
REFERENCES

ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.).

Tirone, J. (2007, August 28). “Dead-end” Austrian town blossoms with green energy. The New York Times. Retrieved from http://www.nytimes.com/2007/08/28/business/worldbusiness/28iht-carbon.4.7290268.html

SOCIO-TECHNIAL TRANSITION

Synoptic framework



Actors involved

- Citizens
- Federal Government

NOTES

notes

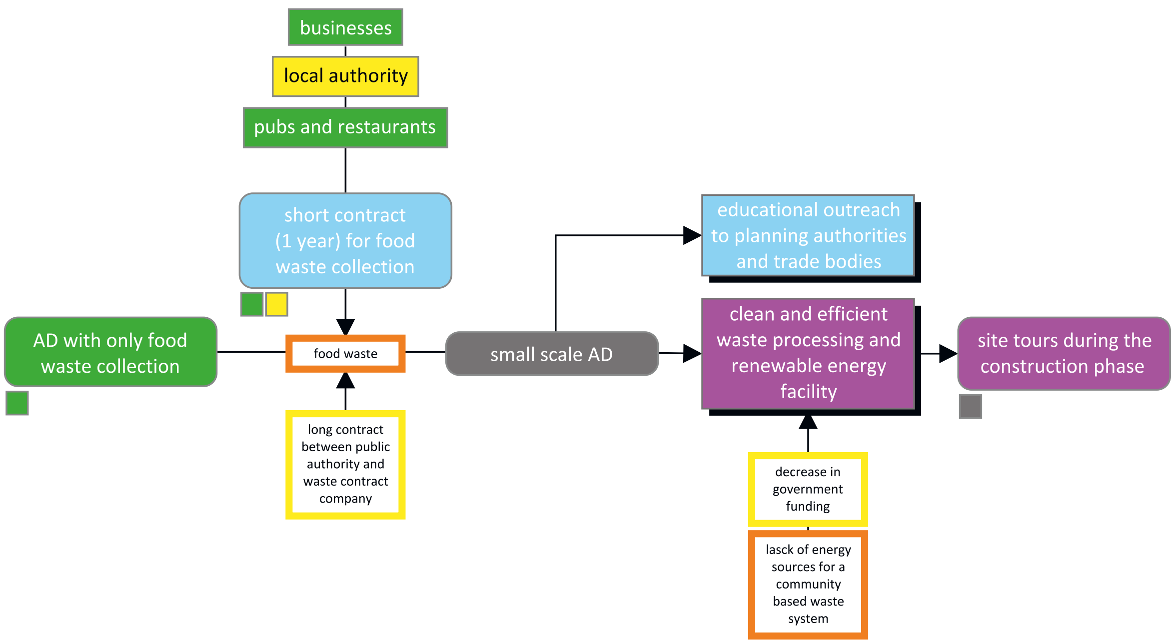
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Warminster Farm, Wiltshire, UK — 12

TOPICS
biogas, food waste

REFERENCES
ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.)
Working to Achieve Genuinely Sustainable Energy | Malaby Biogas. (n.d.). Retrieved May 15, 2017, from http://www.malabybiogas.com/

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Malaby Biogas company
- Businesses
- Local authority
- Restaurants and pubs
- Interest groups, sustainability groups, schools and industry professionals

NOTES
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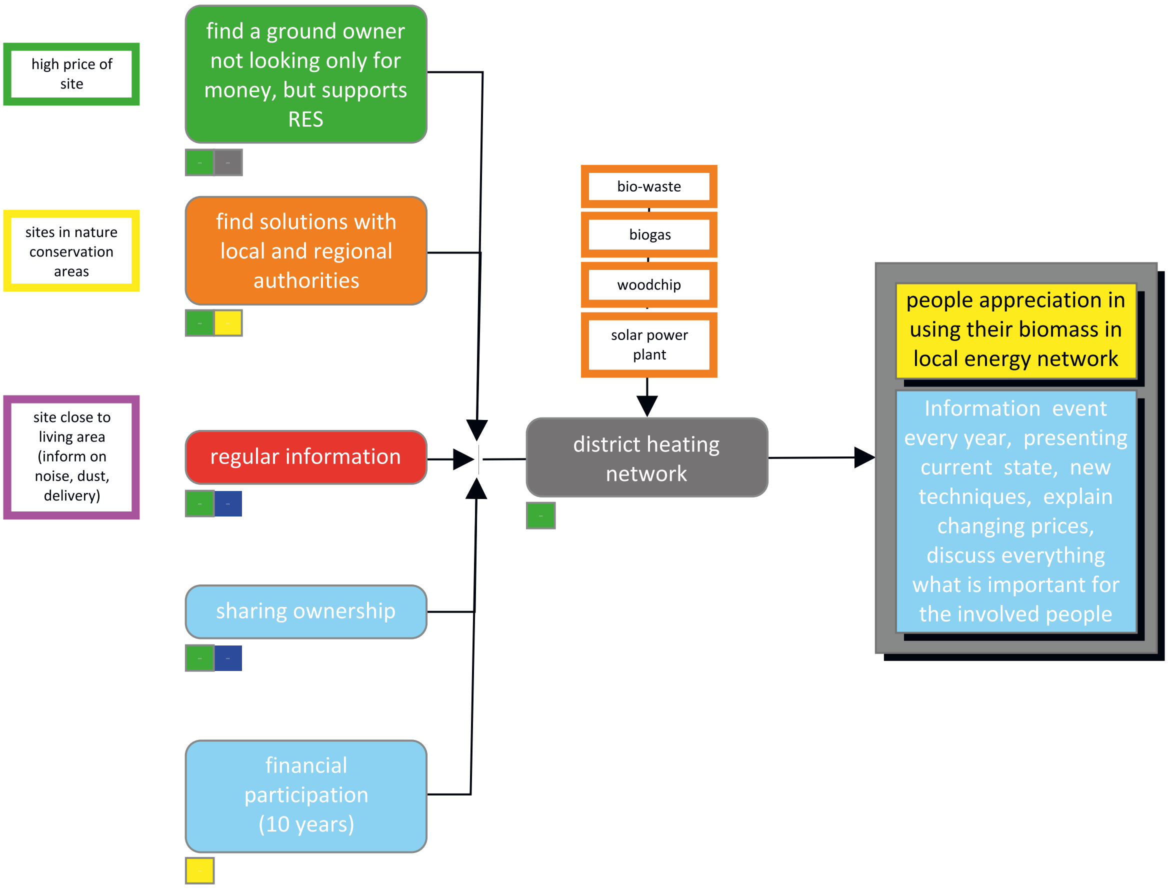
CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Radolfzell district heating, Konstanz, De | 13

TOPICS
biogas, integration other RES, district heating

REFERENCES
ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.)

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Energy company
- Landlord
- Public authority
- Community member

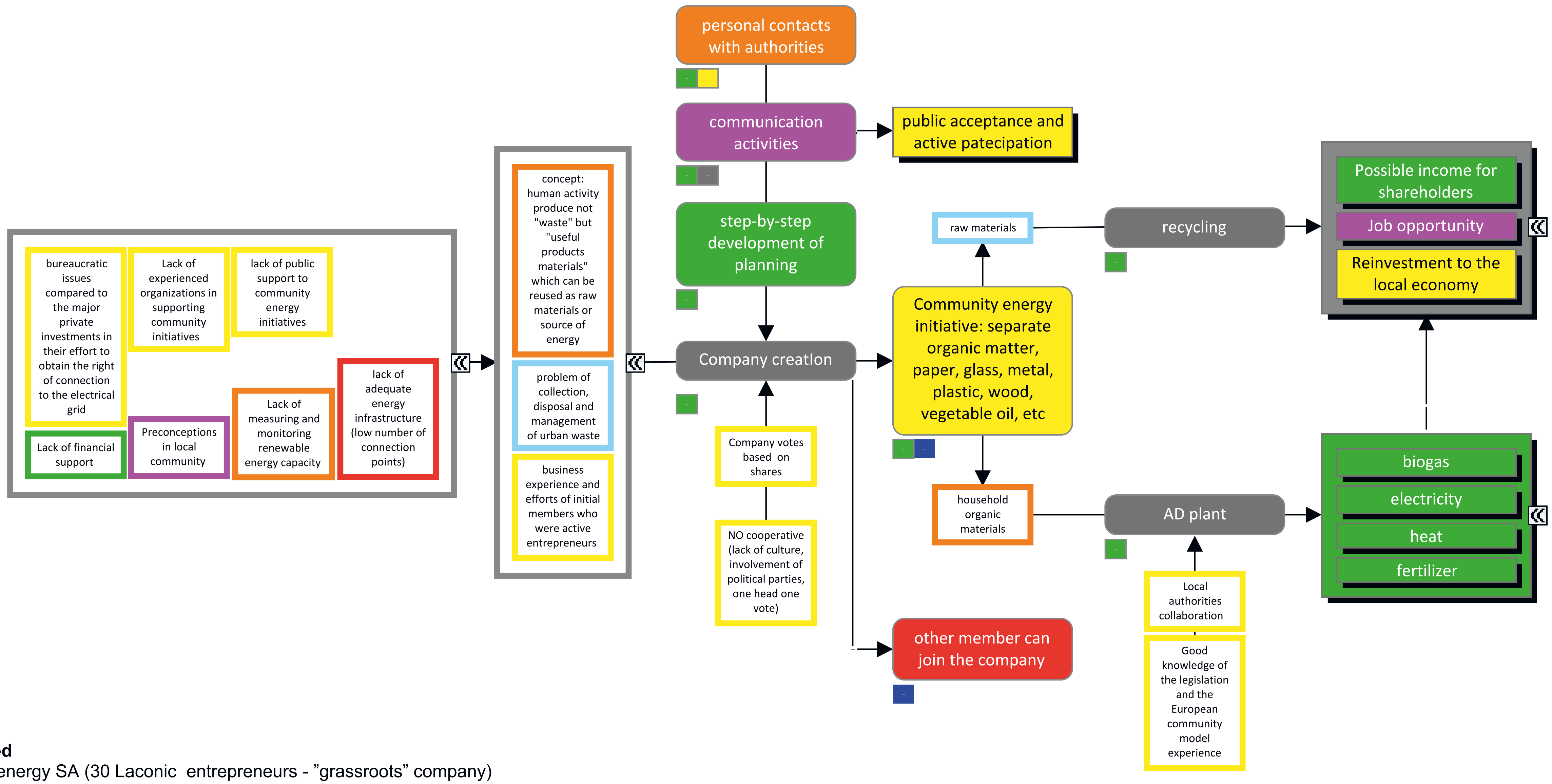
NOTES
notes

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Sparta, Laconic, GR	14

TOPICS	**REFERENCES**
biogas micro size, co-generation, community, etc	ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.)

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Laconic Bioenergy SA (30 Laconic entrepreneurs - ”grassroots” company)
- Public authority
- Community members

NOTES
notes

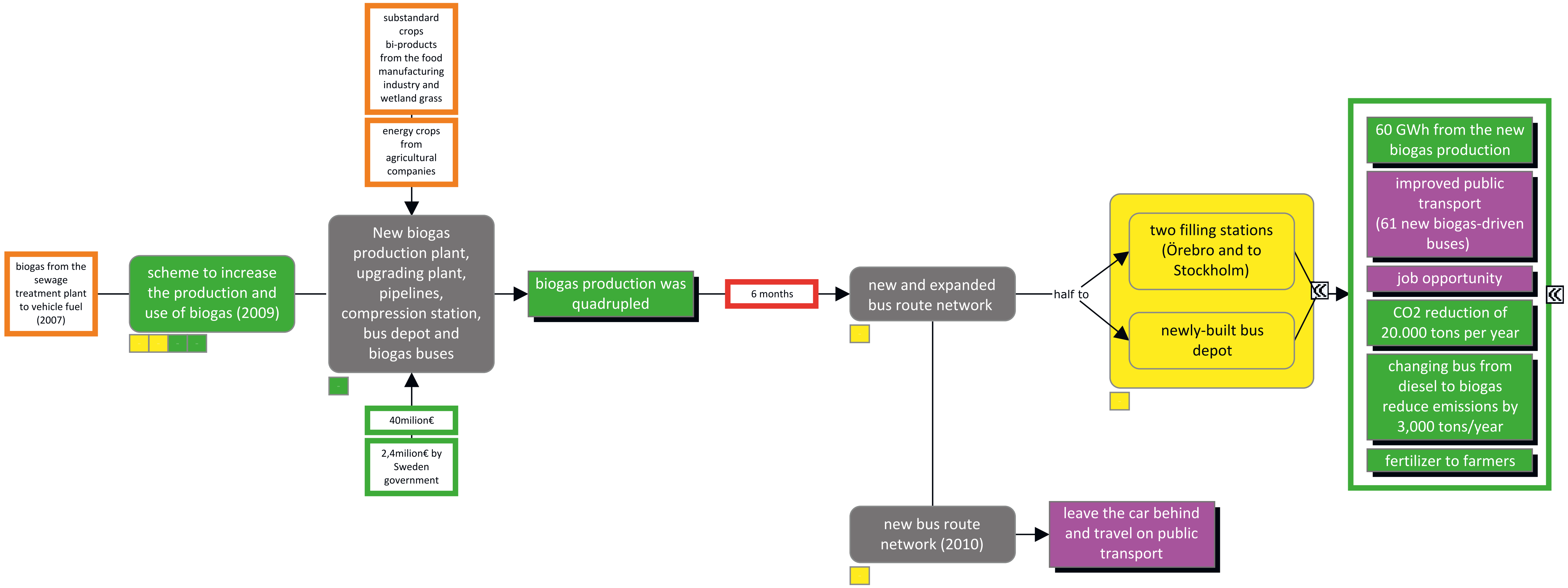
14-1

CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Örebro, Närke, SE	15

TOPICS	**REFERENCES**
biogas, biofuel transport	Biogas production and new city buses in Örebro (Sweden) | Eltis. (n.d.). Retrieved May 15, 2017, from http://www.eltis.org/discover/case-studies/biogas-production-and-new-city-buses-orebro-sweden

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved
- Municipality of Örebro
- Other public sector organisations
- Local trade and industry
- Local farmers
- Private company

NOTES
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CASE STUDY ANALYSIS and FEATURES CLASSIFICATION

Spirit of Lanarkshire Cooperative, Lanarkshire, UK | 16

TOPICS

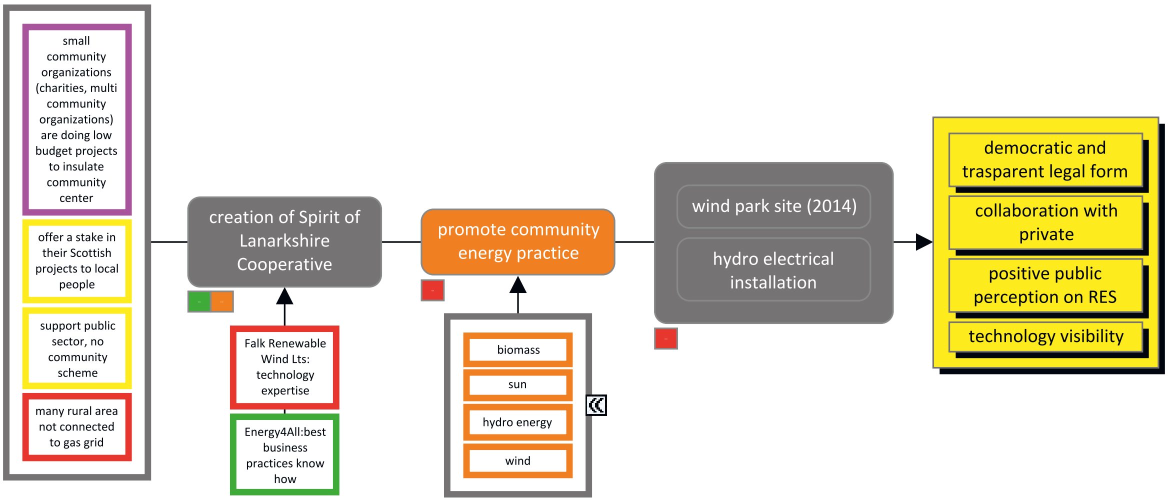
RES, cooperative

REFERENCES

ISABEL | Triggering Sustainable Biogas Energy Communities through Social Innovation. (n.d.).

Lanarkshire Wind Energy. (n.d.). Retrieved May 16, 2017, from http://www.spiritoflanarkshire.coop/

SOCIO-TECHNIAL TRANSITION
Synoptic framework



Actors involved

- Spirit of Lanarkshire Cooperative Ltd (607 members)
- Energy4All (non-profit social enterprise (co-operative)
- Falk Renewables Wind Ltd

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ANNEX 2 – SCIENTIFIC PUBLISHED CONTRIBUTIONS (2014-2018) BY THE AUTHOR

- **Published contributions referred to SBG research**

Pracucci, A. (2018). La gestione del rifiuto organico urbano attraverso l'utilizzo di micro digestori anerobici: il caso studio di Camley Street Park, Londra, UK. L'Ufficio Tecnico (ISSN: 0394-8293), 03/2018. (in press)

Pracucci, A. (2018). The restoration of water quality in the Seman basin through sustainable practices. Convert settlements activities waste into energy supply source. In When a river flows. Strategies for environmental, touristic and infrastructural development of Albanian rivers (pp. 166-172) Tirana. (in press)

Pracucci, A. (2018). Nuove strategie di valorizzazione del potenziale energetico della città. Lo sfruttamento del rifiuto organico nei quartieri attraverso lo studio di Biogas Community Energy Systems. In Proc. of La Ricerca che cambia. Venezia, Italy. (in press)

Pracucci, A. (2017). Smart biogas grid: biogas utilization to operate diffused micro-generation solutions in urban areas through the bio-waste exploitation. How to Face the Scientific Communication Today. International Challenge and Digital Technology Impact on Research Outputs Dissemination, 42, 193, ISBN: 978-88-6453-497-8.

Pracucci, A., Zaffagnini,T. (2016), Synthetic parameters to promote energy sharing system in urban areas: Biomass Energy Ratio for organic fraction evaluation in relation to urban district typology. pp.99. In Proc. of 12th Miklós Iványi international PhD I DLA symposium, (p. 99) (ISBN: 978-963-429-094-0). Pécs, Hungary.

Pracucci, A. (2016). L'Energia "per" il Cittadino: accezioni, utilità e potenziale produttivo. Dalla percezione d'utenza delle Fonti Energetiche Rinnovabili alla definizione di nuove strategie a livello di quartiere mediate dal ruolo pro-attivo dei cittadini. L'Ufficio Tecnico (ISSN: 0394-8293), 11–12/2016.

Pracucci, A., Bizzarri, G., & Zaffagnini, T. (2016). The Regulatory Framework in urban biogas plants realization to define new steps for a common development of regulatory guidelines in EU Member States. In Proc. of SBE16 – Malta, Europe & the Mediterranean towards a sustainable built environment (ISBN: 978-99957-0-935-8). La Valletta, Malta.

Pracucci, A., & Theo Zaffagnini. (2016). Urban morphology and energy efficiency practice: the urban pattern analysis as framework for impact evaluation of biomass production towards energy efficient districts. id 120. In Proc. of 41st IAHS World Congress on Housing. Sustainability and Innovation for the Future (ISBN: 978-989-98949-4-5). Albufeira, Algarve, Portugal.

Pracucci, A., & Zaffagnini, T. (2015). La micro-cogenerazione a biogas: se partecipare vuol dire risparmiare [con consapevolezza]. L'Ufficio Tecnico (ISSN: 0394-8293), 11/2015.

Pracucci, A., & Zaffagnini, T. (2015). Microgenerazione ed efficientamento energetico. Dal rifiuto al biogas, come uno scarto può diventare risorsa energetica. L'Ufficio Tecnico (ISSN: 0394-8293), 01–02/2015.

- **Published contributions not referred to SBG research**

Medici, M., Modugno, V., & Pracucci, A. (2017). How to face the scientific communication today. International challenge and digital technology impact on research outputs dissemination. Firenze: Firenze University Press – FUP, ISBN: 978-88-6453-497-8.

Medici, M.; Modugno, V.; Pracucci, A. (2017), Preface. How to face the scientific communication today. International challenge and digital technology impact on research outputs dissemination. Firenze: Firenze University Press - FUP, ISBN: 978-88-6453-497-8.

Pracucci, A. (2017), Part III – Conclusions. How to face the scientific communication today. International challenge and digital technology impact on research outputs dissemination. Firenze: Firenze University Press - FUP, ISBN: 978-88-6453-497-8.

Pracucci, A. (2016). L'unitarietà tra spazio inclusivo e tecnologie [immateriali] sostenibili Modelli innovativi per la progettazione di ambienti didattici inclusivi adatti anche a studenti con Disturbi Specifici dell'Apprendimento – DSA. L'Ufficio Tecnico (ISSN: 0394-8293), 05/2016.