INFLUENCERS OF ENVIRONMENTAL TECHNOLOGY DIFFUSION: A CASE STUDY ON DIFFUSION OF LANDFILL GAS TO ENERGY TECHNOLOGY IN TURKEY

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Approval of the Graduate School of Social Sciences

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ABSTRACT

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The aim of this study is to describe influencers of Landfill Gas to Energy technology diffusion in Turkey and explore influencing mechanisms in order to shed some light on environmental technology diffusion. The grounded theory was adopted as the research methodology. 8 semi-structured interviews were carried out with actors from private sector who are engaged in Landfill Gas to Energy investments in Turkey.

The results of the data analysis suggest that, the feed-in-tariff mechanism has fulfilled the duty of supporting Landfill Gas to Energy technology diffusion in 2015 and after that it has begun to act as a compensator for the shortcomings of the municipal solid waste management system in Turkey. Our hypothesis is that; the feed-in-tariff instrument which have been introduced without considering its environmental impacts, has resulted in a lock-in to the marginal environmental innovation and has been a barrier in front of radical changes. Finally, we have proposed technology policies in micro, meso and macro scale to solve the technological lock-in problem.

Keywords: Eco-innovation, Renewable Energy, Feed-in Tariff, Waste Management

ÖZ

ÇEVRE TEKNOLOJİLERİNİN YAYILIMINA ETKİ EDEN ETMENLER: TÜRKİYE'DE ÇÖP GAZINDAN ENERJİ ELDESİ TEKNOLOJİSİNİN YAYILIMI ÜZERİNE VAKA ÇALIŞMASI

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Yüksek Lisans, Bilim ve Teknoloji Politikaları Çalışmaları Bölümü

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Bu çalışmada Türkiye'de Çöp Gazından Enerji eldesi teknolojisinin yayılımında etkili olan etmenlerin tanımlayıp, etki mekanizmalarının incelemesi ile çevre teknolojilerinin yayılımı araştırmalarına katkıda bulunulması amaçlanmıştır. Bu teknolojinin yayılımında etkili olan etmenlerin belirlenebilmesi için, bu sektörde yatırımları bulunan özel şirketleri temsil eden 8 katılımcı ile yarı yapılandırılmış mülakatlar gerçekleştirilmiş; elde edilen verilerin nitel analizi tamamlanmıştır.

Çalışmanın sonuçları, yenilenebilir enerji destek mekanizmasının, 2015 yılına kadar çöp gazından enerji eldesi teknolojisinin yayılımında etkili olduğu ve sonrasında Türkiye'de belediye atıklarının yönetimi alanındaki eksiklikleri kapatıcı görev üstlendiğini göstermektedir. Bulgular ışığında; çevresel etkileri göz ardı edilerek geliştirilen destekleme mekanizmasının marjinal çevresel teknolojiye kilitlenmeye neden olduğu ve radikal çevresel değişimin önünde engel oluşturduğu hipotezi geliştirilmiştir. Sonuç olarak, teknolojik kilitlenme sorununa işaret edilerek mikro, meso ve makro ölçekte politika önerileri sunulmuştur.

Anahtar Kelimeler: Eko-yenilik, Yenilenebilir Enerji, Sabit Fiyatlı Alım Garantisi, Atık Yönetimi

I would like to dedicate my work to;

My mom,

my dad and

my grandparents;

Nail, Melek, Alaattin and Fevziye

And to those that make a living from wastes, true alchemists

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LIST OF ABBREVIATIONS

AERC	Applied Ethics Research Center
BoO	Build Own Operate
BoT	Build Operate Transfer
CH4	Methane
CO2	Carbondioxide
EcoAP	European Union Eco-Innovation Action Plan
EMRA	Energy Market Regulation Authority
EMT	Ecological Modernization Theory
EPA	Environmental Protection Agency
EU	European Union
Ex.	Example
FiT	Feed-in Tariff
GHG	Green House Gas
Gt	Gigatons
IEA	International Energy Agency
ISWM	Integrated Solid Waste Management
kW	Kilowatt
kWh	Kilowatt hour
LFG	Landfill Gas
LFGTE	Landfill Gas to Energy
LMOP	Landfill Methane Outreach Program
NWMAP	National Waste Management Action Plan
MBT	Mechanical-Biological Treatment
MEI	Measuring Eco-Innovation
METU	Middle East Technical University
MM	Metropolitan Municipality
MoENR	Ministry of Energy and National Resources
MoEU	Ministry of Environment and Urbanization

MoSIT	Ministry of Science, Industry and Trade
MSW	Municipal Solid Waste
MWe	Megawatt Electric
MWh	Megawatt hour
NGO	Non-Governmental Organization
OECD	Organization for Economic Co-operation and Development
O and M	Operation and Maintenance
PPP	Public-Private-Partnership
R and D	Research and Development
RDF	Refuse-Derived Fuel
RER	Renewable Energy Regulation
RET	Renewable Energy Technology
SW-EG	Solar-Wind Energy Generation
SWM	Solid Waste Management
USA	United States of America
USD	United State Dollars
US. EPA.	United States Environment Protection Agency
YEKDEM	Renewable Energy Support Mechanism

CHAPTER 1

INTRODUCTION

Tackling global environmental problems is a great challange in the world of 2000s. Associated problems are partly due to incremental population growth and industrial development in the late century but most of the quilt is upon the shoulders of "fossil fuel" based back bone of economic activities. In 2018, global energy related carbondioxide (CO2) emissions hit the record of 33.1 gigatonnes (Gt), the highest amount in the world history due to colossal rate of global energy consumption (IEA, 2019). The discourse for eco-innovation stimulating policies has grown with the hope to that diffusion of eco-innovations will reduce anthropogenic impacts on the climate change. In the published set of policies in 2001 "Technology Policies and Environment Report" OECD countries have encouraged elaboration of strategies in the areas of technological development and climate change as well as the environmental impact of subsidies (OECD, 2002). In this sense, diffusion of renewable energy technologies have received particular attention in recent years.

Landfill Gas to Electricity (LFGTE) is a biomass type of renewable energy technology that converts the waste gas from disposal sites (LFG) to electrical energy. LFG is half-methane and half-carbondioxide with some amount of other chemicals inside. Both methane and carbondioxide are acknowledged green-house-gases (GHG). They act like a blanket for the atmosphere and prevent cooling mechanisms of the planet earth. This interference causes the fact known as the global climate change. Because of that reason; municipal solid waste landfilling is one of the most important anthropogenic sources of global climate change (Salihoglu, 2018). Indeed in 2014, municipal solid waste (MSW) landfills were the third largest anthropogenic source of methane emissions in the United States, accounting for approximately eighteen percent (18%) of total methane emissions. If not managed properly, toxic chemical content of LFG may cause harm to its near environment and it causes disastrous explosion events due

to gas pressure[1]. Implementation of LFGTE projects on MSW disposal sites reduces environmental side effects and renewable energy is produced as an additional value.

Utilization of renewable energy resources is of strategic importance to Turkey to intensify its domestic energy supply and to meet its intended targets for the global climate change contribution. Turkey is a member of the OECD since 1961 and the country has been harmonizing its legislative structure to European Union (EU) norms since 2005. Turkey has contributed to 440 million tons of carbondioxide equivalent GHG emissions to the global emission inventory[2] . The country has committed to decrease its GHG emissions by 21% between 2021-2030 in the intended nationally determined contribution as a part of national commitment to the United National Framework Convention on Climate Change (UNFCCC)[3]. Turkish Government has set the target to have an electricity generation mix in which the share of renewable energy accounts for 30% of overall need by 2023 (MoENR, 2014). In this context Turkey has initiated its first Renewable Energy Law in 2005 followed by series of supporting legislations. The major renewable energy support in Turkey is the feed-in tariff mechanism[4] (MoENR, 2014). The feed-in-tariff rate of biomass power is among the

[1] In 28 April 1993; the largest dumpsite of Turkey, Hekimbaşı has "exploded" due to gas compression. 39 People have lost their lives in the incident. That has been the first incident on dumpsite explosion in Turkey and it has left a remark on memories of İstanbul citizens including myself. This incident was a milestone for beginning of construction of sanitary landfills in Turkey.

[2] 70% of this contribution was due to energy sector (fossil fuel fired power plants) and 8% was due to the waste management sector (landfills/disposal sites) and 7% is owed to agricultural activities (animal husbandry).

[3] In accordance with decisions 1/CP.19 and 1/CP.20, the Republic of Turkey presented its Intended Nationally Determined Contribution (INDC) towards achieving the ultimate objective of the United Nations Framework Convention on Climate Change which is set out in its Article 2 and clarifying information (UNFCCC, n.d.).

[4] The first FiT was declared in 2005 with the Renewable Energy Law. The Renewable Energy Law was amended in December 2010 with higher feed-in tariff rates, and other incentives for domestic equipment use.

highest[5] together with the solar power. Altough all biomass power plants benefits from the same renewable energy support only LFGTE facility capacities have extensively developed and diffused almost all over the country since 2006. As of 2019, LFGTE facilities have contributed to 50% of the total installed biomass power in Turkey (see **Figure 1**).

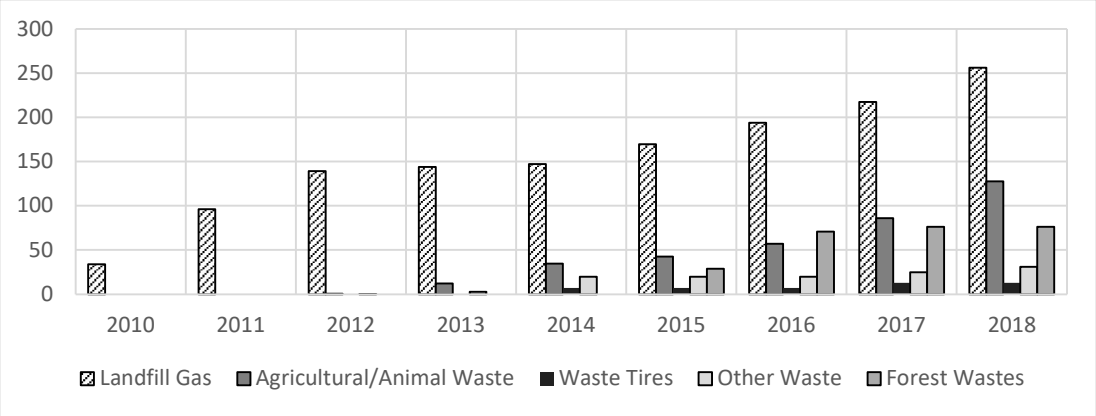

Figure 1 Installed Power Capacity of Biomass to Electricity Plants in Turkey
Source: YEKDEM Licensed Facility List for 2020; EMRA, 2018

The LFGTE technology is first adopted in 2005 in the capital city of Ankara (Çelebi, 2017; MoEU, 2016; MoENR, 2019). Based on the available data of licenced facilities from Energy Market Regulatory Authority (EMRA); one may conclude that the number and capacity of licenced LFGTE plants have increased swiftly since 2010, with the amendment of the renewable energy feed-in tariff support. But what are other influencers of LFGTE investments, than the feed-in-tariff, so that there has been a distinctive capacity increase among other biomass technologies? That was the main question which initiated our curiosity to begin this research.

We have designed our research around the specific curiosity for diffusion of LFGTE technology in Turkey. We have looked for answers to questions of; What are the

[5] The state feed-in-tariff support for wind and hydropower is 73 USD/MWh, for geothermal power the feed-in-tariff support if 105 USD/MWh. For solar and biomass power the feed-in-tariff rate is 133 USD/MWh.

influencers (drivers and barriers) for diffusion of LFGTE technology? How do they influence the diffusion process?

The aim of this thesis is to analyse influencers of LFGTE sector. Our objectives to meet this aim are; defining the sectoral status quo (actors involved, relevant legislative structure, economic actions and motives), define influencers (drivers and barriers) of LFGTE technology diffusion and explore influence mechanisms. In the beginning of the research; the publicly available data was limited to the licensed facilities list by the EMRA. There was lack of information about the unlicensed LFGTE facilities. In order to learn more about the sector and identify the gaps we have carried out a preliminary study of document review and expert interviews. Further, we have found out that the contracting agreement for each LFGTE plant may be different from one another depending on the specific demands of the implementing municipality. As a result of the preliminary study we have determined the focus of analysis as "investor perspectives" on influencers that effect adoption of LFGTE at a municipal disposal site[6].

This is an empirical research with an aim to provide information that can be used to influence environmental technology diffusion policies in the future. In the beginning of the research process, we have benefitted from survey of literature studies of Karakaya and Hidalgo (2014), Hojnik and Ruzzier (2016) and Kemp and Pontoglio (2011) in order to address gaps in the litareture and to frame our focus of interest. Whether eco-innovation research should be distinguished from the general innovation theory is often questioned in the literature. The common consensus about environmental innovations is that; general diffusion innovation theory (Rogers, 1962) applies for diffusion of eco-innovations as well to some extent. Most recent literature reviews related to diffusion of eco-innovations emphasize that there is a need for case-specific qualitative data to complement quantitative models of eco-innovation studies (Hojnik and Ruzzier, 2016; Kemp and Volpi, 2008). Regulatory effects and market-based instruments are found to be influential especially in marginal eco-innovations

[6] In order to prevent the ambiguity for the selected technical terminology for environmental technology diffusion and waste management practices, a glossary of terms is presented in appendices. Please refer to Appendix A: Glossary for detailed description of preferred terminology.

(Kemp and Pontoglio, 2011; Demirel and Kesidou, 2011). An interdisciplinary theoretical framework and a different policy outlook is suggested to explore and further investigate eco-innovations due to social and environmental externalities of different types of eco-innovations (Rennings, 2000; Hojnik and Ruzzier, 2016).

For the purpose of this research, we have followed the grounded theory methodology and carried out multiple-case studies to collect empirical data from investors of LFGTE technology in Turkey. We have designed this research study in three dimensions based on our objectives; the literature review, the preliminary study and the field work. First; we have identified theoretical basis of diffusion of eco-innovations and provided an empirical framework for drivers of environmental technologies based on the literature. This allowed us to identify gaps and open fields for research in our field of interest. Accordingly, we have formulated our research questions as; *What are the influencers (drivers and barriers) of LFGTE diffusion?* and *How do these influencers influence the diffusion process?* Secondly, as a part of the preliminary study, we have searched through websites of municipalities, project specific news/announcements and available documents relevant to the sector status quo in Turkey. By this way we have been able to retrieve detailed information about the actors in the sector, their affiliations, way of doing business etc. In addition to this, we have completed in-depth interviews with four sector experts (2 freelance private experts, 2 municipality officers) in order to determine the focus of interest. Interviewees were purposefully selected by the researcher based on their background and experience in projects in the sector. The peculiarities of the sector, actors involved, and responsibilities of actors were received as the expert opinion within the context of the preliminary research. The focus of analysis was determined as "investor perspectives" as a result of the preliminary study. We have structured the interviewee profile and prepared the interview guide for the field work within the scope of the preliminary study. As the third pillar, we have designed a multiple-case study to collect empirical data from the field. In the LFGTE sector, each projects business agreement is uniquely determined by a contract between the municipality and the investing company. Therefore, each case is specific to the business strategy of the private investor and demands of the municipality. We have completed eight semi-structured

interviews with eight private LFGTE firm representatives within the scope of the multiple-case study. We have carried out snowball sampling strategy to reach participants for the multiple-case study. Each of the interview participants represent a different LFGTE investor company. Total number of LFGTE investments of these 8 companies sum up to 50 projects with a total installed capacity of 347 MWe[7]. The multiple case study approach has allowed us to explore variety of cases and acquire empirical information from a diverse set of firm perspectives.

This study contributes to the technology diffusion literature with a special focus on diffusion of eco-innovative technologies. Mainly, it provides a comprehensive analysis of the status quo of LFGTE technology in Turkey and influencers (drivers and barriers) of LFGTE diffusion. To our knowledge, this study is the first empirical analysis of the LFGTE investments in Turkey from investor perspectives. As a result of this study we were able to complete the gap of quantitative information in literature and identify the role of the feed-in-tariff mechanism in diffusion of LFGTE technology. In addition to this we have been able to address the role of policy and institutional dimensions in LFGTE technology diffusion.

The thesis proceeds as follows; the second chapter includes the literature framework for diffusion of LFGTE technologies, including theoretical, empirical and conceptual dimensions with a conclusion of research gaps and delineation of our research questions. In the third chapter we have elaborated our research methodology and data collection process in detail. Findings of the field research, discussions of results and associated problems are presented in chapter four. Finally, in chapter five we have summarized our conclusion, claimed our grounded theory (the hypothesis of this research), addressed problems with diffusion of this technology and proposed technology policies together with our humble opinion about future research in this field.

[7] As a result of this study we have found that there are 83 LFGTE facilities in Turkey. The total installed capacity of LFGTE facilities is approximately 435 MWe. Our set of analysis represents a diversity of firms with different properties. Their total number of investments and total installed capacity represents a majority of the LFGTE investments in Turkey.

CHAPTER 2

LITERATURE REVIEW

The subject of this thesis is influencers for diffusion of the LFGTE technology, a marginal eco-innovation. Based on the peculiarity of the subject, we have studied the literature in four dimensions; definition and typology of eco-innovations, theoretical literature, empirical literature and conceptual background. In the first section of this chapter we have summarized mostly attributed definitions and types of eco-innovations in literature. In the second section we have explained our findings on theoretical and empirical literature on diffusion of eco-innovation research. In the third section we have summarized the "conceptual background" of LFGTE diffusion. The final section includes research gaps that we identified as a result of the literature review. We have explained points which have raised our curiosity and put forward our research questions at the end of the chapter.

2.1. Definition and Types of Eco-innovation

Sustainable innovation, green innovation, environmental innovation (Yiğit, 2014) are often used synonyms of ecological innovation (eco-innovation). Definition of eco-innovation sets the benchmark for assessment and measurement of its diffusion. Innovation is defined by the OECD in the recent version of the Oslo Manual (2018) as: "*a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)"* (OECD/Eurostat, 2018).

Depiction of eco-innovation in literature stems from the basis of OECD definition of innovation yet branches towards environmental performance and environmental aim-

oriented definitions.[8]. In the innovation strategy document eco-innovation is defined as; "*Innovation which, intentionally or not,* ***results in a reduction of environmental impact*** *compared to relevant alternatives.*" (OECD, 2009) with a reference to its "green" aspects and contribution to sustainability to address "long-term societal challenges[9]. Diminishing the environmental burden may not be always the primary reason (Hojnik and Ruzzier, 2016) for deployment of eco-innovations. The European Union (EU) has structured the "Eco-Innovation Action Plan (EcoAP,2011)" on an environmental aim-based definition of eco-innovations including the consequences (i.e. performance) as well[10].

Turkey, a candidate country to EU, accepts an aim (i.e. environmental aim) oriented definition (OECD, 2009) "*Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, by reducing impacts on the environment or achieving a more efficient and responsible use of natural resources including energy.*" The official attribute to eco-innovation is made in 2010 in Turkey in the 16th World Efficiency Congress[11] (Engin and Dincbas, 2012) by the General Directorate of Efficiency of Turkish Ministry of Science, Industry and Technology (MoSIT).

[8] Kemp and Pearson (2007) has defined eco-innovation in the Measuring Eco-Innovation (MEI) Project as "*Production, assimilation or exploitation of a product, production process, service or management or business method that is* ***novel to the organization*** *(developing or adopting it) and which* ***results****, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use)* ***compared to relevant alternatives*****"** (Kemp and Pearson, 2007)

[9] Both Kemp (2007) and OECD (2009) are benchmarks for eco-innovation research. OECD (2009) offers indicators for measurement of macro level eco-innovation and survey results from example countries as a general framework. The MEI Project offers macro-meso level indicators for measurement of eco-innovation.

[10] Eco-innovation is defined in the EcoAP as; "*any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources*". (Communication "COM2011,899)

[11] 16th World Efficiency Congress (16. Dünya Verimlilik Kongresi) was held in Antalya, Turkey in 2010, Nov.2th-5th

There is not a common consensus on definition of eco-innovation (Karakaya et.al., 2014) in the literature, but all depictions of eco-innovations (and related synonyms) refer to "fewer adverse effects on the environment" and "more efficient use of resources" (Hojnik and Ruzzier, 2016) as a consequence of implementation of eco-innovation.

Until the recent update of the Oslo Manual in 2018, the OECD definition of innovation included four different types such as; Product, process, organizational and marketing innovations (OECD and Eurostat, 2005). Like the ambiguity in definition of eco-innovation there is not a common consensus (Hojnik and Ruzzier, 2016) on types of environmental innovations. Yet the OECD innovations clusters has been a basis for definition of eco-innovation types (Kemp, 1997; Horbach et.al., 2012; Akçomak et.al., 2016: 441) in economics and business management literature.

Ecological innovation can be in forms of technological and organizational innovation, social innovation and institutional innovation (Rennings, 1998). Technological eco-innovations can be categorized based on their rank in technological development (Akçomak et.al., 2016: 440) as "environmental technologies" or "clean technologies" (Kemp and Pontoglio, 2011; Horbach, 2008). Degree of innovation becomes more important while studying determinants of eco-innovation diffusion. Curative technology type of eco-innovations may just remedy the problem in hand whereas preventive technological solutions create changes within the process. In either case, these environmental innovations aim are restricted to envisaged incremental changes. On the other hand; social and institutional innovations lead to radical environmental changes (i.e. systemic changes) (Rennings, 1998; Kemp and Pontoglio, 2011).

Environmental technologies are curative technologies (Rennings, 1998) which are applied as an "end-of-pipe" solution to remediate/treat the pollution in hand. Such technological solutions can be applied to facilities without making a change in the usual production process i.e. typically curative technologies do not interfere with the core business of a facility. Preventive technologies (clean technologies) on the other hand, try to avoid (Rennings, 1998) environmental damage by integrating changes into

the core production processes of a facility (Kemp,1997; Horbach and Rennings, 2007) (**Figure 2**). The most developed level of eco-innovation (Demirel and Kesidou, 2011) is "ecological research and development" that result in development of environmental products and processes. Such innovations are referred as patented innovation (i.e. environmental patent applications) by Hojnik and Ruzzier (2016).

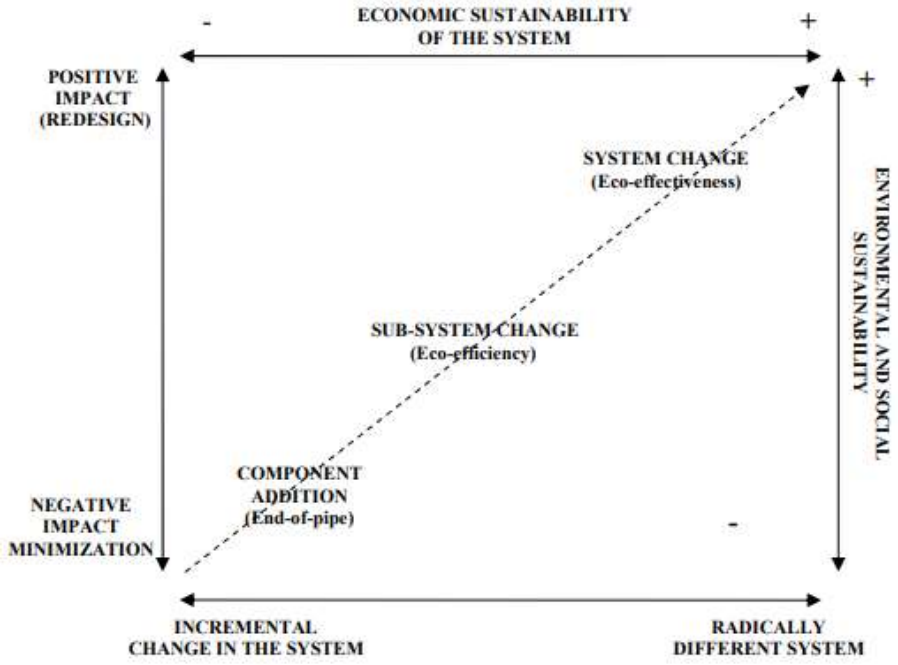

Figure 2 Dimensions and Degree of Eco-Innovations

Source: Könnöla et.al. (2008)

Our scope of interest within the framework of this thesis (i.e. the LFGTE) is an energy recovery[12] technology which fits in to the typical "end-of pipe" cluster. For the purpose of this study, we have accepted the Turkish definition of eco-innovation definition[13] (OECD, 2009) to be in consistency and harmony with the national political jargon.

[12] A detailed technical description of the LFGTE is explained under Section 2.3 of this thesis.

[13] "*Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, by reducing impacts on the environment or achieving a more efficient and responsible use of natural resources including energy.*" (OECD,2009)

2.2. Theoretical and Empirical Literature

Eco-innovation is a interdisciplinary area of research (Karakaya et.al., 2014) owing to to its social, technological, institutional and environmental (Rennings, 1998) dimensions. Diffusion of eco-innovations has been studied under disciplines of economics, management (Akçomak et.al., 2016: 441), marketing and sociology. Diffusion of eco-innovations has been interest of environmental economics, innovation economics and ecological economics (Karakaya et.al., 2014).

The mostly referred theoretical background in eco-innovation research is the "*diffusion of innovation theory*" (Hojnik and Ruzzier, 2016). The diffusion of innovation theory (Rogers, 1962) aims to explain "*how, over time, an idea or product gains momentum and diffuses (or spreads) through a specific population or social system.*" (OECD/Eurostat, 2018). At the beginning of the diffusion process alternative technologies are in competition with one another and the technology diffuses with a slow rate. As diffusion of the new technology proceeds nature of costs and benefits associated with diffusion process (Hall and Khan, 2003) influence the speed and consequences of diffusion. Scholars of neo-classical and evolutionary schools of thought contribute to phenomenon of innovation diffusion from different perspectives. Where deductive approach is used for policy making either one of the two views are chosen by policy makers (Lipsey and Carlaw, 1998). As a part of the grounded theory approach we especially kept our distance to both theoretical views before the finalization of the analysis. In this section we will elaborate fundamentals of both approaches and their contributions to policy making. Information digested from the theoretical foundations has been used while articulating our findings in terms of judging the validity of outcomes, relating to similarities and differences with existing theory and to construct new theori/es about new concepts.

Neo-classical Theories

Innovation economics as an extention of the neo-classical economics guides innovation policies whereas the neo-classical environmental economics guides environmental policies. The neoclassical view depicts the economic activity as a

production function of inputs and suggests that there is an equilibrium (Rennings, 1998) state to reach optimum performance outputs for the defined function. The main assumption of neo-classical theory is that individuals are perfectly rational beings and the markets will function as expected unless there is a disturbance from outside. According to neo-classical economists; anything that deteriorates the equilibrium state is a market-failure (i.e. market power, imperfect information and externalities,). Neo-classical policy approach aims at eliminating reasons (asymmetric information and externalities) which may lead to market failure (i.e. distorted or missing markets) (Lipsey and Carlaw, 1998). Such as funding R and D activities and inducing market-based economic incentives (such as feed in tariffs in energy sectors) (Hall and Khan, 2003, Stoneman and Ireland, 1983). Market structure of the supplying and demanding industries may generate a market failure. Stoneman and Diederen (1994) give the "common pool" problem as a prime example for market failures due to the market structure of the potential buyers. The common pool problem arises when the supply industry is a perfectly competitive environment as assumed by the neo-classical model but there are limited number of potential buyers. Under such an environment; diffusion paths are too fast from the "welfare" point of view because sellers would be in rival with one another to reach as much clients before reaching the finite limit. Another cause for market failure is deficiencies and asymmetries in information. Potential adopters of technology may acquire knowledge through passive spillovers (observation of experience from other actors or learn from information spreading activities) or through active search for information. In neo-classical world potential adopters make comparison of potential benefits of acquiring the technology with the costs of adoption to make investment decision. An actor may decide on delaying the technology adoption in favor of future benefits from not adopting that technology (there might be opportunity costs of waiting, i.e. adoption costs may decrease, a better technology may come in future etc.). In addition to this, promotion of the specific product by suppliers before the technology in general (Stoneman and Diederen, 1994) may cause a shift in supply of that specific technology. Therefore; information provision as a policy tool for innovation diffusion may not necessarily speed up diffusion in fact, it may cause delays. Other policy interventions to deal with market failures due to imperfect information can be; shifting the risks of imperfect information

to the public sector and reducing uncertainty through creating information (i.e. impose a standard on the market) (Lipsey and Carlow, 1998).

The position of neo-classical innovation economics is to address influence of supply and demand factors for technological innovations. Supply factors (i.e. technological push) depend on developments in technology (costs of producing a technology) and demand factors (i.e. market pull) depend on costs of acquiring the technology by customers. Policy (i.e. technology policy, innovation policy and adoption policy) in neo-classical innovation economics is therefore a function of markets for new technologies and changes in their patterns (Stoneman and Diederen, 1994).

From the viewpoint of neo-classical environmental economics; an economic party internalizes the costs of resources for the sake of ongoing economic activity, but it does not have an economic motivation to decrease its damage to the environment. As a matter of fact; negative impact of economic activities to the environment imposes a cost on the society (i.e. negative environmental externality) (Jaffe et.al., 2005). A peculiarity of eco-innovations is that there are also environmental externalities embedded within application of an eco-innovation. While knowledge externalities occur due to adoption/diffusion of innovations, environmental externalities are also produced as a result of eco-innovations which leads to a social desirability. Briefly, companies comply with the costs of eco-innovation while society benefits from it. Rennings (1998) describes that as the "double externality problem". Due to double externalities of eco-innovations; balancing role of regulations become an important factor for eco-innovations (especially for environmental technologies) (Hojnik and Ruzzier, 2016; Rennings, 2000). Simply, there is a need for "punishment" of pollution a support for adoption of "non-polluting" technologies. Typically, diffusion of a new technology will be the result of the interaction of supply (technological development or technology push) and demand (market pull) factors from the perspective of innovation economics (Stoneman and Diederen, 1994). However, influencers are not limited to technology-push and market-pull factors for the case of environmental innovations. Due to the double externality problem there is an additional factor of "regulatory-push/pull" that distinguishes eco-innovations among others (Rennings,

2000). Jaffe (2005) argues that market failures associated with environmental pollution rationalizes public policies for environmental protection and development/adoption of environmental technologies. A similar statement is made by Stoneman and Diederen (1994) that environmental protection policies are externalities which cause market failure and therefore have a major impact on innovation diffusion. According to this theory market-based instruments (i.e. taxes and marketable licenses; carbon taxes, carbon cap and trade systems for example) are the most important element of a cost-effective environmental policy strategy. Indeed, polluter pays principle is widely accepted environmental policy measure within the OECD countries and the EU. Despite its success in pollution reduction, neo-classical environmental policies have proven to be effective for a limited time only for marginal improvements. Typically, the motive for technological advancement is lost once the standards set by the environmental policy are met (Rennings, 1998; Jaffe et.al., 2005; Çoban et.al., 2012). In addition to negative externalities that comes with environmental problems there are positive externalities due to nature of technological innovation. The innovating firm creates benefits for other competing firms when it internalizes costs of innovation and adoption of innovation as a result of technological improvement. Rennings (1998) explains this phenomenon as the "double externality problem" of eco-innovations and emphasizes the importance of "regulatory influence" on diffusion of eco-innovations. "For theoretical and practical reasons" as Rennings (1998) explains referring to the imperfections of the real world, "the double externality problem can and should not be solved by environmental policy alone". Jaffe et.al. (2005) proposes a portfolio of policies which include elements of technology policies to complement environmental rules and regulations to make technological advance attractive against interacting cases of energy and environment (such as the climate change). It is important to note that; "Technology policy can be costly; if it is used as a substitute for, rather than complement, to environmental policy." (Jaffe et.al. 2005). From the perspective of neo-classical innovation economy taxing the origin of externality and changing the ownership rights to internalize the externality are policy tools to support diffusion of a new technology. In case of supporting adopters of a technology with subsidies or government procurement supply side factors (i.e. initial and expected costs of technology) will play an important role (Stoneman and Diederen, 1994).

From a neo-classical perspective, Jaffe et. al. (2005) argues that continuous, systematic, quantitative assessment is the only way that the relative effectiveness of alternative policy approaches can be compared over time. Market success, market failures and rationale for government policy intervention is analyzed by neo-classical equilibrium models. Lipsey and Carlaw (1998) define five characteristics of neo-classical models as; "*maximising behaviour*", "*unique equilibrium*", "*secrecy of technology*", "*technological change is seen only by its results*", "*no explicit economic structure*". According to the neo-classical perspective, all agents calculate benefits of their actions and show a rational maximizing behaviour under a perfectly foreseeable environment. Two individual with a same set of given inputs will always make same choice between two alternative courses of action. Therefore, there is a singular welfare-maximizing equilibrium in neo-classical models. Details of a technology are no explicitly modelled and the process of technological change is observable only by its results i.e. "outputs". The neo-classical macro models tend assume policies do apply to the whole economy. In the micro models inputs and outputs are assumed to be homogenous and certain; circumstances which create an "uncertainity" are classified as risks. The neo-classical view is often found to be valid for explaining short term dynamics (Stoneman and Diederen, 1994) within the defined set of environment but its contribution for the long term for an "unexpected" series of events is critisized to be rather weak. Rennings (1998) argues that neo-classical models have their merits in explaining dynamics of incremental innovations (i.e. environmental technology and clean production) however, technology push and market pull factors are relatively weak in explaining radical innovations. A radical innovation is when there is a discontinuous improvement in existing technological systems. Such discontinutiy may be due to consequence of series of unexpected events.

Ecological modernization theory (EMT), sustainability transition and lead market hypothesis are other approaches that is remarked by Karakaya et.al. (2014). The feature of the EMT (Toke, 2011) is its focus on the influence of technological development in socio-ecological transformations. Ecological modernization focuses on the supply sided driving forces of eco-innovations and innovation oriented environmental policy (Karakaya et.al. 2014) to link modernization movement in the

developed market economies to a long-term environmentally friendly development. The EMT is often referred to in research of social movements in eco-technological development and implementation (Toke, 2011; Breukers and Wolsink, 2007; Karakaya et.al., 2014). The concept of ecological modernization has been widely diffused in EU in 1990s. Eventually it has evolved to the concept of "Eco-efficient innovation" to form the basis of the EU Lisbon[14] strategy for growth and employment. The pro-regulation approach of ecological modernization depicts that developed economies should foster eco-efficient innovations in major investment decision and to support diffusion of these innovations. Although the EMT is generally accepted by the contemporary industrialized societies; there are critiques that the EMT falls short of demonstrating validity of its arguments, measuring outcomes (i.e. whether reducing the negative impact of some industries contribute to expansion of negative impacts by other industries etc.) and proving that the overall production increases due to increase in resource efficiency (York and Rosa, 2003). The criticisms to EMT are mainly because the EMT falls short of addressing the linkage between micro and meso scale economic activities to macro scale environmental problems. Despite the critiques; it is worthy to note that the pro-regulatory, multi-level and multi-actor nature of ecological modernization brings challenges the traditional neo-classical arguments by highlighting a positive relationship between environmental regulation and a country's competitiveness (Janicke, 2008). Even more importantly; EMT has embraced the argument that if competition for innovation and environmental protection are at stake it is a "functional necessity" to reinvented and strengthen the role of the government (York and Rosa, 2003) within the context of multi-level governance. Briefly, the theory is that; "*an environmental problem proves politically less difficult to resolve if a marketable solution exists. In contrast, if a solution to an environmental problem requires an intervention in the established patterns of production, consumption, or transport, it is likely to meet resistance*." (Janicke, 2008) In the case of Turkey, which has been dedicated to adopting most of its environmental legislation to the EU acquis,

[14] Based on the Lisbon Strategy on partnership for growth and job creation. This strategy relies on a mix of the commitment of member states to act at the national level with making best use of community instruments at the EU level.

we have been careful about regarding the EMT, while discussing issues of institutional capacity building and technology policy making.

Evolutionary Theories

The major critique of evolutionary economists to neo-classical theory is that the real world is far from being perfectly rational and there is a factor of "chance" and "unexpected events" in dynamics of technological change. Evolutionary environmental economics, evolutionary policy and sectoral systems are three key approaches (Karakaya et.al., 2014) to eco-innovation research. Characteristics of evolutionary innovation models constrast sharply with the neo-classical models.

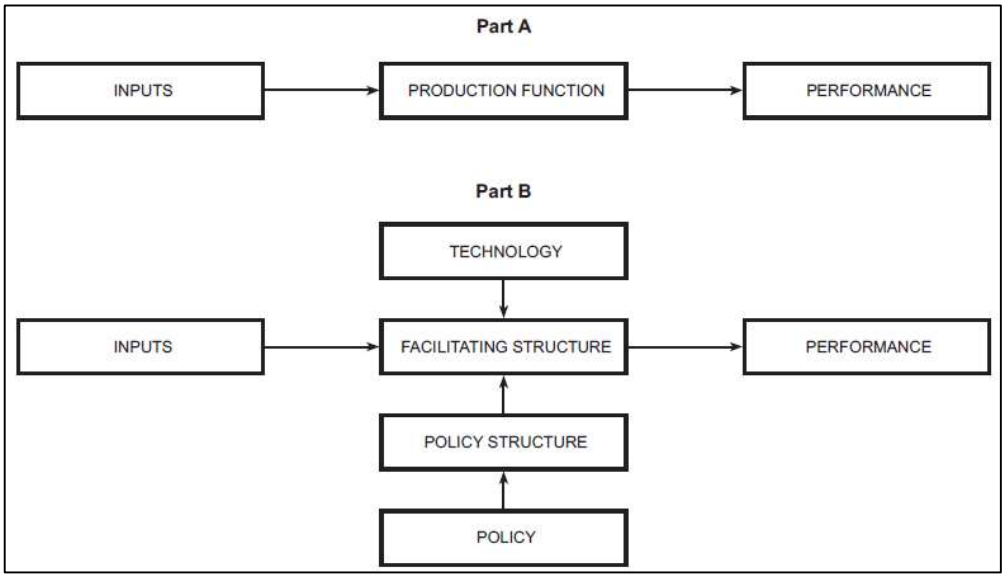

Figure 3 Neo-classical and Evolutionary Approaches

Source: Lipsey and Carlaw (1998)

In the neo-classical approach (**Figure 3**; Part A) inputs (i.e. human and materials capital etc.) flow through the aggregate economy production function to produce economic performance (i.e. total national income). The model can describe only the expected amount of outputs from a given amount of inputs but relevance to structure of the economy and technology within remains in a black box. On the other hand, in evolutionary approach (**Figure 3**; Part B), technology is embodied in the facilitating structure. The policy structure includes public institutions of all types that embody and

influence the policies. Inputs are transformed by elements of the facilitating structure to produce economic performance. Therefore, all elements of a system are connected to one another. Changes in technology require changes in the facilitating policy structure before they can have their full effect on the economic performance. Changes in policy through changes in the policy structure can cause changes in the facilitating structure. Changes in policy can also influence technological changes and changes in the facilitating structure can cause changes in the rate of technological progress. Ultimately the performance of the economy is determined by the compatibility of technology, policy and facilitating structure. The evolutionary economic framework states that, the aim of technology policy is to identify and solve system failures (Metcalfe and Georghiou, 1997). Because there is no unique equilibrium state when technology is changing endogenously under uncertainty conditions, there is not an optimum policy set with respect to innovation in particular and adoption/diffusion of technologies in general.

The evolutionary view accepts the technological systems approach where exogenous factors (i.e. policies, network affiliates, developments in technology etc.) may impact the performance of the system. The systems approach is especially found appropriate to analyze eco-innovations (Jacobsson and Bergek, 2011) due to impact of social and institutional changes to radical technological change (Rennings, 1998). Evolutionary theory also embraces the specific characters for different adopters, different suppliers in different sectors (Geroski, 2000, Hanel and Nosi, 2007). Evolutionary models empraces the explicity of technologies which implies interaction of technologies within, interactions with sub-technologies, cooperative technologies and development of differentiating parts create horizontal and vertical interactions among the technological systems. The technological convergence (Lipsey and Carlaw, 1998) may cause discontinuous jumps in product technologies to produce a radical change in technology development. From an evolutionary perspective technology diffusion may depend on a variety of micro-level factors. These factors may be and not limited to; network externalities, sunk costs, response of older and/or competing technologies, availability of information related to the costs and benefits of adoption, the importance of complementary inputs, and the market structures of both the adopters and the

suppliers of technological innovation, type and number of users etc. (Hanel and Nosi, 2007). The economic structure is explicit in evolutionary models and the performance of the economy is not independent of the compatibility of technology, policy and the facilitating structure (Lipsey and Carlow, 1998). A major theme in the evolutionary literature on adoption concerns the role of increasing returns and the frequency of "lock-in" situations (Akçomak et.al., 2016). Kemp and Volpi (2008) states that the lock-in effect in diffusion of eco-innovations is often overlooked but it is important to note that diffusion of some eco-innovations may results in lock-in effect which means it will prevent diffusion of other eco-innovations which would have been more environment friendly. Stoneman and Diederen (1994) also acknowledges that the technological way dependency of evolutionary approaches makes very useful predictions in terms of analyzing the bifurcation and long termed effects of technological trajectories.

The evolutionary school of thought supports the idea that rational maximizing behavior is not possible in the world of "uncertainty of the future" and there is a factor of chance or "accident" within the decision of technology adoption (Akçomak et.al., 2016; 246-250). In evolutionary models where firms seek technological advances under circumstances of uncertainty. As a matter of fact, agents are often unable to assign probabilities to alternative future states to act towards a rational maximizing behavior. Therefore, there is no unique welfare maximizing equilibrium in *evolutionary models of innovation diffusion.* There may be perpetual change, punctuated equilibrium for stable periods which are open to alteration by unpredictable events and multiple equilibria where historical accidents may determine which will be approach at any time (Lipsey and Carlaw, 1998).

The evolutionary framework is more appropriate to analyse eco-innovations because it acknowledges all sub-systems (social, ecological, institutional etc.) in the systems framework analyses (Rennings, 1998) where complex feedback mechanisms are present in equal evolution of eco systems and social systems (Stoneman and Diederen, 1994). Evolutionary approaches are more interested in the analysis of transition and learning processes. Evolutionary disequilibrium models are developed to built an

understanding of radical changes" associated with unpredictable events (i.e. societal changes, interactions of sub-systems, irreversibility, path-dependency, lock-in effects etc.) (Rennings, 2000). Evolutionary approaches have enriched empirical studies with case studies and successive analysis on adoption of new technologies (Geroski, 2000). On the other hand, testability of evolutionary methods is often critisized due to difficulties of measuring technological trajectories, uncertanity and micro-economic learning (Hanel and Nosi, 2007).

Both neoclassical equibrium approach and evolutionary non-equilibrium approach have their limitations and merits. Neoclassical approaches offer quantitative tools and they contribute to analysing mostly predictable events such as incremental innovations. The common ground of both neoclassical equilibrium approach and the evolutionary theory is that; they agree that the role of the government is to ensure a healthy and open economic environment for investment and adoption of new technologies to boost technology diffusion. Klaus Rennings (2000) suggests adoption of an integrative theoretical framework (integrating elements from neoclassical and evolutionary perspectives) to consider complexity of factors in diffusion of environmental innovations (especially the specific role of environmental instruments) where ecological, social and economic aspects of sustainable development could be integrated for opening up innovation research to social and institutional changes (Rennings, 2000). The OECD seems to view the neo-classical and the evolutionary policy advice sets as complementary. Lipsey and Carlow (1998) on the other hand argue that; there are strong differences in neo-classical and evolutionary policy making approaches. In sum, both approaches offer useful frameworks for policy recommendations. In our opinion, assumptions of the neo-classical theory have its merits with framework policies (i.e. macro policy) where country wide plans and programs are introduced. Neo-classical theory also has its merits in focused policy making (i.e. micro policy) where agent-based strategies are assessed to sketch out optimal pathways for a technology. On the other hand, assumptions of evolutionary theory promise much of a richer environment for blanket policies (i.e. meso policy) where technological spill overs in complex environments is addressed.

Theories mostly referred to in eco-innovation diffusion literature include the *resource-based theory, institutional theory, stakeholder theory and environmental innovation theory* (Hojnik and Ruzzier, 2016). Environmental innovation theory is a version of the general diffusion of innovations theory specific for investigation of eco-innovative activities. Environmental innovation theory encompasses demand side (market pull) and supply side (technology push) like the general innovation theory and involves institutional, and political influence drivers of eco-innovation as an improvement (Horbach, 2008).

While designing our research we have deliberately kept our distance from the literature in order to avoid prejudical effects to the grounded theory methodology. Neo-classical school of thought could provide valuable tools to analyse LFGTE technology diffusion because it is a marginal environmental technology with low complexity. On the other hand; the evolutionary approach could be useful in analysing institutional dimensions of LFGTE technology diffusion. Before initiating the study we have kept our distance from one or the other end of the spectrum in order to have an open mind to information from either school of thought. As our literature review has grown we have seen that an evolutionary view point is especially useful in addressing non-financial influencers of eco-innovation. In the beginning of this chapter, we have emphasized peculiarities of eco-innovations as; double externality problem associated with their adoption, their relationship with social and institutional innovations and their response to regulatory changes. Rennings (1998) suggests use of evolutionary approaches to identify complex network relationships and interactions between societal and institutional systems to elaborate eco-innovation research. Evolutionary approaches in innovation economics include unpredictable set of events and radical changes which are embedded within the structure of some eco-innovations. Adopting an evolutionary perspective for research and policy making for environmental technology diffusion will contribute to our work in three ways. First, it helps us include all sub-systems (i.e. co-evolving social, ecological and institutional systems) (Stoneman and Diederen, 1998) without ranking of their importance. Second, it helps us to address and develop an understanding of interactions of all sub-systems. Finally, this perspective allows us to design policies that would address path dependencies and spillovers for the specific

case of technology diffusion. In Turkey, initial policies for LFGTE diffusion are aligned with a neo-classical perspective. In our policy design approach, we have decided to adopt an evolutionary perspective as a complementary set of policies to initial status but also, we have linked our approach to the neo-classical perspective while proposing improvements in initial policy set.

Empirical Literature on Diffusion of LFGTE

Almost all theories related to diffusion of eco-innovations address same topics as influencers of environmental innovations (i.e. compliance with regulations, market conditions, network linkages, endogenous resources etc.). Hojnik and Ruzzier (2016) has found that the regulatory pull/push hypothesis by Rennings (1998) is also supported by several empirical studies in the literature. Stoneman and Diederen (1998) emphasized influence of public policies on general innovation diffusion, like R and D policies, industrial policies, policies on education, on infrastructure and public transport, on employment and industrial relations, on tariffs, on accounting rules (depreciation) and on environmental protection. Other influencers for eco-innovations may include institutional factors (corporate image, customer pressure etc.), domestic and foreign demand-pull policies and cost savings. Company size has also found to be encouraging for cleaner technology type of eco-innovations (Demirel and Kesidou, 2011; Kemp and Volpi, 2008).

There are not many empirical studies on diffusion of LFGTE technology in literature. However, there are abundant sources of information regarding diffusion of renewable energy technology, including biomass sources. We have completed the empirical literature review in an expanding concept from the most specific keywords to the most general scope. In the first place; we have searched for empirical research related to "diffusion of LFGTE" and then we looked for "diffusion of waste to energy technologies", "diffusion of biomass", "diffusion of renewable energy" and "diffusion of environmental technologies". It is crucial to note that; each empirical study is uniqe within the preferred methodology, used tools for research, sampling set, place and time of research. We have aimed to have a glimpse of similar yet varying studies to enlarge our vision in the field of environmental technology diffusion. There were two main

reasons to do so; first, we wanted to see if there was a convergence in literature towards a common theory and second, we wanted to check if our findings are really unique as we have expected them to be.

In USA, the main driver of LFGTE projects has been federal tax credits and regulatory requirements for LFG control in larger landfills. Other factors such as increased concerns contribution to global climate change and market demands for renewable energy options are stated to be less influential than regulatory and market-based instruments (US.EPA, 2017). The quantitative research by Li et.al. (2015) shows the positive influence of renewable portfolio standarts and investment tax credits on adoption of LFGTE technologies in the USA. Similarly, Thorneloe (1996) has shown the influence of state and local environmental regulations on gas collection in diffusion of LFGTE projects. Thorneloe (1996) states that "*California has the largest number of landfill gas projects partially because state and local requirements in the collection and control of gas*". On the other hand, market conditions prevail other influences. Many landfill gas energy projects have been initiated because of attractive economics, particularly in the early 1980s when the price of energy helped make this more economical (Thorneloe, 1996).

Negro et.al. (2012) suggests that systemic problems should be addressed through different types of actors in order to analyses the complexity of the situation and understand systemic problems which trigger and reinforce each other. A prime example of analyzing systemic problems of renewable energy technology (RET) diffusion is Erden-Topal's (2016) dissertation on policy design model for market formation of solar and wind electricity in Turkey. This study is a thorough research which involves perspectives of all energy sector stakeholders on sectoral problem analysis and investigation of influencers of wind and solar power (SW-EG) in Turkey for further policy model formation. As a result of this study Erden-Topal (2016) addresses administrative, economic, political, physical, technological, psychological and institutional drivers and barriers to SW-EG. Erden-Topal's (2016) findings suggest that *government subsidies* play an important role as drivers of the SW-EG in Turkey. Masini and Menichetti (2013) suggest that investor believe that market

inefficiencies can be corrected through the adoption of appropriate policy instruments. Erden-Topal (2016) argues investment uncertainties are main obstacles to SW-EG investments in Turkey both from the profit and non-profit agents' perspectives. Her findings are line with the research of Foxon et.al. (2005) where reason of RET systems failure were analyzed for the case of the United Kingdom (UK). Foxon et.al. (2005) argued that; *a stable and consistent policy framework* is required to help create conditions for a healthy innovation diffusion environment. Foxon et.al. argued that such a framework should be determined especially for technology specific context including risk/reward ratios for demonstration-precommercial projects (Foxon, et.al., 2005). Engelken et.al. (2016) have studied RET diffusion from a broader perspective by reviewing the RET business model literature and found that; RET are mostly driven by *microfinancing opportunities* and the major barrier for RET business development is the *inadequacy of the infrastructure*. On the other hand, for developed countries, opportunities are driven primarily by *climate change mitigation motives* and businesses are discouraged mainly by the *high cost of energy storage and complexity of institutional factors* (cooperation) (Engelken et.al, 2016).

Current and anticipated *regulations and policy measures* are the most effective driver (Hojnik and Ruzzier,2016) of environmental technologies. Horbach et.al. (2008) has aimed to test if different types of eco-innovations are steered by different factors and found that expected government regulation is a major influence for adoption of environmental technologies (air pollution, noise emissions, hazardous substances etc.). Similarly, Kemp and Pearson (2007) state that regulations are influential especially in stimulating radical innovation than market-based instruments (Kemp and Pearson, 2007). Masini and Menichetti's (2013)[15] qualitative assessment on *non-financial influencers* (i.e. a priori beliefs, institutional pressure, propensity for radical innovations and investor's knowledge of the RE operations) of RETs suggests that;

[15] Masini and Menichetti have followed a qualitative approach to assess non-financial drivers of renewable energy investments. This perspective suggests that the actual development of an emerging technology is influenced not only by the technology's performance, but also by its perceived potential influence. This framework also suggests that reaction of local stakeholders to renewable energy projects should also be considered while assessing technology diffusion as well as the design of environmental policies.

proven performance of a technology is a major driver for investments whereas investors have little faith in policy measures (i.e. short-lived subsidies) which directly support RE technologies. The literature review by Negro et.al. (2012) shows that; lack of stable institutions and poor alignment of the available institutional with other actors (regional/local institutions, other sectors etc.) has been a major reason for slow diffusion of RET within Europe. Masini and Menichetti (2013) suggest that *decentralized influences* (institutional pressures such as consultants etc.) were stronger influencers of renewable energy investments than the governmental interference. Non-financial drivers for RET investments are presented in **Figure 4**.

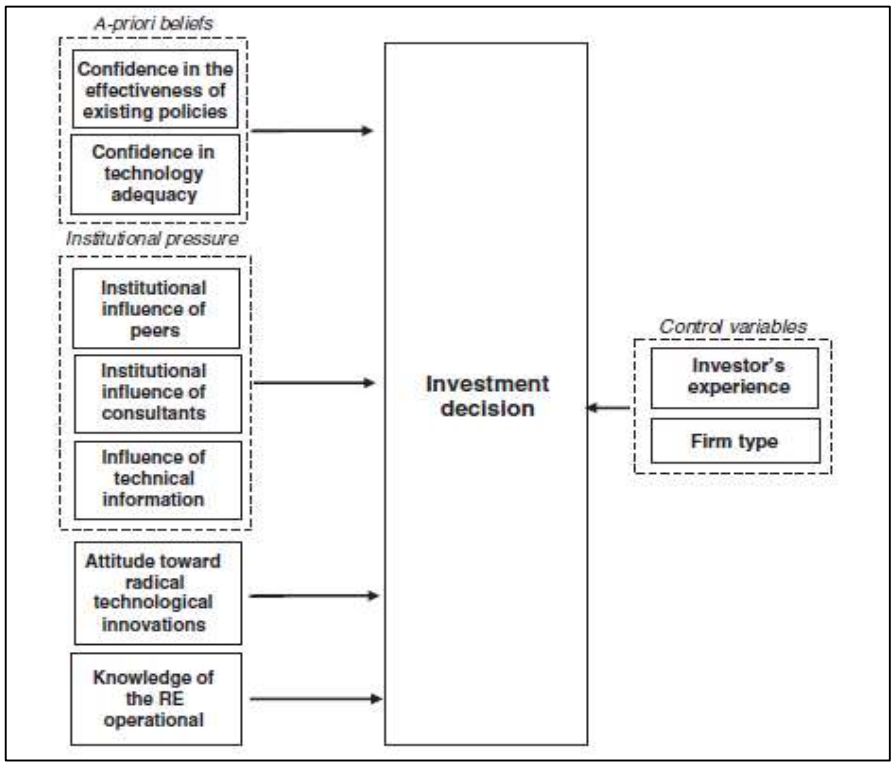

Figure 4 Conceptual Model for Non-financial drivers of RE Investments

Source: Masini and Menichetti (2013)

Mignon and Bergek (2001) underscore differentiating institutional demands and responses of different investors. Their case study has shown influencers for biogas facility investments included social benefits, institutional pressures (from municipality and from the client) and regulatory influences. Negro et.al. (2012) states that; lack of capabilities of actors, lack of technological knowledge of policy makers, lack of

capabilities of entrepreneurs form a uniform message about the kind of support they need from the government. A lack or misalignment of regulations might block the development and diffusion of RETs or it might strengthen "lock-in" into the fossil fuel-based system.

Empirical results and sectoral guidance documents shows that efficiency of landfill gas capturing is a crucial determinant that facilitates the feasibility of the LFGTE project (Ireland EPA, 2011; US.EPA, 2017). Therefore, physical limitations and infrastructure of the landfill comes forward as major determinants of LFGTE implementation. LFGTE research studies in Turkey are limited to environmental engineering discipline. The infrastructure material, covering techniques, operational parameters are important factors for the gas collection rates (Salihoğlu, 2018; Kiriş and Saltabaş, 2011). Kiriş and Saltabaş (2011) has listed critical determinants of amount and quality of LFG as;

- Waste amount and composition of wastes
- Degree of pre-processing (waste minimization, recycling, composting etc.)
- Degree of compressing
- Hydrogeological properties of the landfill site
- Local Climate (humidity, temperature etc.)
- Management of the landfill site operations

Salihoğlu (2018) argues that the local climate is not directly an influential factor on performance of the LFGTE facility but the waste amount and composition tends to change with season which is the indirect impact of local climate. Kiriş and Saltabaş's (2011) research is based on empirical data from two LFGTE facilities located in Istanbul Metropolitan Municipality landfill. They state that technical management of the landfill site operations is an important factor of LFG quantity/quality. Salihoğlu's (2018) findings also show that the share of responsibility among contractors (i.e. landfill operator and the LFGTE facility operator) is an important factor for the collection efficiency of LFG from the site. Technically, if different contractors are responsible for management of the landfill operations (i.e. compressing, covering, stacking etc.) and the LFGTE power plant, priorities of both actors may be conflicting

(Kiriş and Saltabaş, 2011; Salihoğlu, 2018). Kiriş and Saltabaş (2001) refers to carbon emission reduction by the LFGTE projects and suggests that "carbon credit" sales in voluntary carbon markets could be a motive for LFGTE investors. However, influence of the carbon market has not been mentioned in the study of Lantz et.al. (2007) which involves more recent empirical data. Instead, other market-based instruments and regulations seems to prevail the biomass energy sector. Lantz et. al. (2007) has studied incentives, drivers and barriers of biogas technology in Sweden. They found that biogas systems are affected by series of policies including energy, waste treatment and agriculture which influence either production of the biogas or use of the biogas. Their findings for influencers of biogas and waste to biogas technologies are summarized in **Table 1** below.

Table 1 Incentives and Barriers for Biogas Production (Example of Sweden)

	MUNICIPAL/ INDUSTRIAL WASTE TO BIOGAS	**OTHER BIOGAS PLANTS**
INCENTIVES		
Policy Objectives	National environmental quality objectives	Security of energy supply in EU
Legislation	Ban on landfilling	-
Taxation	Tax on waste incineration (suggested)	-
Financial Subsidies	-	Investment subsidies for climate mitigation projects and agricultural development
BARRIERS		
Economy	Competing treatment technologies	Partly immature market, leading to high investment costs
Others	-	Public acceptance

Source: Lantz et. al.(2007)

Altan (2015) has studied inpact of the landfill regulation to LFGTE plants operation in Turkey. Altan (2015) argues that full compliance to the landfill regulation will result in a dramatic decrease in organic fraction of landfilled wastes. It will also lead to development of other biomass technologies (co-digesters, anaerobic digestors, incinerators etc.).

In summary; findings of the empirical literature review suggest that initial political environment, environmental policies, institutions, market-based instruments, competing technologies could be influential in diffusion of LFGTE technologies.

2.3. Conceptual Background

2.3.1. Technology Description

Landfill Gas to Electricity (LFGTE) is a modular technology used in the waste management sector. LFGTE technology is based on the principle of capturing/harvesting gaseous emissions from landfills, refining captured gas into a valuable quality and then converting it to electrical energy through controlled burning processes. Chemical composition of Landfill Gas (LFG) is mainly carbon dioxide and methane with varying amounts of trace contaminants (different types of hydrocarbons and toxic chemicals) and moisture (Thorneloe, 1996). Raw LFG has approximately half the average heat content of pipeline natural gas. It is possible to produce a variety of products (i.e. pipeline quality natural gas, electricity, supplementary fuel for industry/facilities, alternative fuels for vehicles) by processing LFG (**Figure 5**).

Figure 5 Treatment Steps of LFG

A low-grade LFG can be directly sold to nearby facilities (if it constitutes a suitable market[16]) as a supplementary fuel. (US.EPA, 2017; Williams, 2008; World Bank, 2016; Thorneloe, 1996). Advanced treatment of the LFG for removal of the trace

[16] When the price of LFG is cost-effective compared to natural gas some manufacturing plants may choose to locate near a landfill site (usually 3-4 km range is considered feasible and a maximum range of 10 km is mentioned in the literature)

contaminants and the carbon dioxide gives out a pipeline quality high grade fuel which is equivalent to the heating value of natural gas. This is not a widely preferred option currently due to expense of gas treatment, but it has a potential when the price of natural gas is comparatively expensive. High grade fuel can also be used for electricity production through fuel cells. Varying composition of the LFG over time makes it difficult to design a treatment process with a constant output of a pipeline quality gas. Also for other applications such as creating auto fuel additives (biodiesel or ethanol) or industrial chemicals (such as methanol) an extensive level of treatment is required (Thorneloe, 1996; World Bank, 2016; US.EPA, 2017). Only a handful of such projects are currently operational, but several more are in the construction or planning stages in the US owing to scale of economics (US.EPA, 2017). Gas capture and flaring, direct use of gas, and electric power or co-generation of heat and power are the most prevalent uses in developing countries. Upgrading LFG as a pipeline quality gas on the other hand is very rare even in developed countries (World Bank, 2016).

The medium grade fuel is produced after removal of heavy end hydrocarbons and particulate matter in addition to the moisture within the LFG. Medium grade fuel utilization is a widely preferred option for its moderate treatment costs and high energy value. Such a fuel can be directly sold as a supplementary fuel for the industry[17] but its most preeminent use in the industry is for electricity production. Currently, four technologies are available for conversion of LFG to electricity; internal combustion engines (reciprocating engines), gas turbines, steam turbines and a combination of steam and gas turbines (combined cycle) (US.EPA, 2017). Selection of either of the four technologies depends on the technical constraints (availability and quality of LFG, availability of equipment and skills), financial constraints (availability of financial instruments, market situation etc.) and other factors such as environmental requirements (such as air pollution requirements of the area) and local government policies in project location.

[17] For heating applications in cement industry, potteries or brick industry, sludge dryers, infrared heaters, paint shop oven burners, tunnel furnaces, process heaters, blacksmith forges, lumber industry and greenhouses

Reciprocating engines are amongst the most polluting technology in comparison to other electricity production options. However, they require less capital investment cost (McBean, Rovers and Farquhar, 1995) and they offer commercial availability for different project sizes which made them the globally mostly preferred technology. Gas turbines are comparatively more environment friendy (World Bank, 2016) but they are less efficient and theremore mostly preferred for larger scale combined cycle projects in order to utilize the waste heat from gas turbines (McBean, Rovers and Farquhar, 1995). In combined cycle applications, LFG is combusted in a gas turbine to generate electricity and the heat generated by the gas turbine is used for conversion to electricity in the steam turbine. By this method the energy efficiency of gas turbine systems is improved (Thorneloe, 1996). Another option is to in-situ direct use of LFG for leachate (the liquid that percolates through a landfill) evaporation. Leachate evaporation can reduce the cost of treating and disposing of leachate on site (US.EPA, 2017).

2.3.2. Economic and Environmental Benefits

LFGTE projects are complex in structure with involvement of consumer behavior, public and private involvement in land acquisition and financing options, local/national environmental regulations.

Typical lifetime of an LFGTE investment is 10-20 years. In regions of drier climate and uniform temperatures, the design life may reach 25 to 40 years. Pay-back periods on the other hand may range between 1-15 years. There is not a direct correlation of the payback period to the size of the landfill, or the amount of energy recovered but the capital costs versus payback period chart shows that large scale projects typically have a shorter return period (Thorneloe, 1996).

Direct sales and other means of revenues are important determinants to secure the project design and financial sustainability of an LFGTE project. Influencers of expenses and revenues of LFGTE projects are determinants for financing LFGTE projects. (US.EPA, 2017). Revenues for energy sales are usually based on prices of the “competition” of equivalent energy sources (i.e. petroleum products). As the value

of the energy base commodity can fluctuate, this can impact on profit. Local conditions are dramatically influential on the income from sale of gas and/or energy (Thorneloe, 1996). World Bank (2016) notes that carbon markets act as a financial option for generating revenue where carbon credits could be sold to wealthy countries through the Kyoto Protocol's "*Clean Development Mechanism*"[18]. But they have proven less profitable than expected. (World Bank, 2016). Important parameters in LFGTE project design are summarized in **Table 2**.

Table 2 Important Parameters/Constraints in LFGTE investments

THEMES	IMPORTANT PARAMETERS
Waste Management Practices	- High organic waste composition. - About 200 tons of waste input per day. - Layering, capping and covering of landfill
Availability of material and labor	- Experienced workers - Availability of technology - Accumulation of knowledge - Knowledge transfer through partnerships
Political/Regulatory Environment	- Predictable legal and regulatory framework around landfill operations, contracts, and other ancillary activities or industries (e.g., energy markets)
Saleable environmental attributes	- Availability of an efficient carbon market - In-situ utilization of LFG energy - Government incentives for LFG energy
Energy infrastructure	- Availability of pipeline network/grid connection
Community Engagement	- Demography, level of income, education, cultural factors

Source: World bank (2016)

Economics benefits of LFGTE systems can be to landfill owners, end-users and local community. Direct sales of LFGTE products and other means of revenues such as

[18] The Kyoto Protocol is an output of the United Nations Climate Change Framework Agreement Numbered 5386. Turkish Great National Assembly has accepted to be a part of the Kyoto Protocol in 2009. However, the country did not have a commitment to decrease its emissions. The Paris Agreement is accepted in November 2016 as an amended continuum to the Kyoto Protocol. Turkey has signed the Paris Agreement, but it has not been a party to the agreement yet; meaning that it does not commit to an emission reduction.

renewable energy incentives, carbon credits and indirect benefits such as off-setting in-situ energy use by utilization of energy from the LFG are benefits to the LFGTE system owners. End-users can benefit from the LFGTE systems by saving on energy costs depending on the local/national fuel/electricity pricing policy. Indirect economic benefits to the end-user (for instance for a cement kiln) can cause increase in reputation as a renewable energy user. Local community can greatly benefit from the LFGTE systems as well through creation of short-term and long-term job opportunities throughout the installation and operation of the system. In addition to direct job creation, LFGTE system requires hiring logistic and consultancy services and works from local vendors.

In addition to their economic benefits there are direct and indirect environmental benefits associated with LFGTE projects. Developing LFG energy projects is an effective way to reduce GHG emissions, improve local air quality and control odors. LFGTE projects offer better management of landfills which results in better management of impacts on local soil and groundwater quality as well as the local flora and fauna (**Figure 6**).

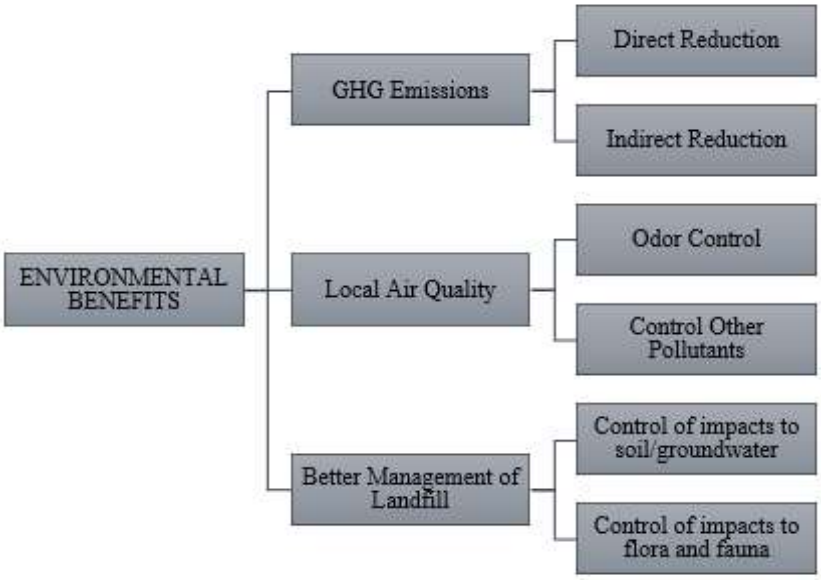

Figure 6 Environmental Benefits of LFGTE Projects

An LFGTE plant will capture 60 to 90 percent of the methane generated by a landfill over its lifetime, depending on system design and effectiveness. Producing energy from LFG displaces the use of fossil fuels (coal, oil or natural gas) that would be needed to produce the same amount of energy (US.EPA, 2017; Thorneloe, 1996). Collecting the LFG improves also helps mitigating explosion hazards due to trapped gas within the landfill (US.EPA, 2017). As a matter of fact, LFGTE technology may not produce a great amount of energy in comparison to a conventional fossil-fuel based power plant but it mitigates a reasonable amount of greenhouse gas which otherwise would be emitted to the atmosphere.

2.3.3. Examples to LFGTE Diffusion in Developed Countries

The first LFGTE plant was established in the USA (Palos Verdes) in 1975 for direct use of LFG as a blending supplement with pipeline gas and in manufacturing plants[19] (McBean et.al., 1995) but most of the existing plants were established in 1985 or later. Upgrading landfill gas to pipeline quality was considered more attractive in the early 1980s when the price of oil and natural gas helped make it more economical. Low natural gas prices in the late 1980s forced several previous projects to shut down and continues to inhibit the development of new high value LFG projects in the USA (Thorneloe, 1996). In 1990s one third of LFGTE plants in Germany were used for heating hospitals, residential units, factories or green houses, some sites supply brickworks and two thirds is used to generate electricity which is sold to the public grid (Coombs, 1991). For example, in Husum, Germany, electricity is generated directly from combustion of the landfill gas. In addition, the energy recovered from the engine coolant radiator system is utilized to heat green houses. generate electricity use internal combustion engines (McBean et.al. 1995). In the UK the largest use of the gas was for local industry for industrial heating (i.e. brick making kilns and horticultural use) (Coombs, 1991). Dramatic rise in energy savings were recorded in the UK over the period 1986 – 1989 due to landfill gas use in a variety of ways, including in kilns, in boilers, and for power generation (McBean et.al. 1995). Also, in

[19] This project was followed by the Mountain View in 1978, Monterey Park and Cinnaminson in 1979, Fresh Kilns in 1982 and C.I.D. Chicago in 1980, Fresh Kilns in 1982. For detailed information on these sites please refer to McBean, Rovers and Farquhar, 1995.

UK where there are no industries nearby, there was an interest in producing electricity from LFG (Coombs, 1991). In the UK until the energy act of 1983 there was no obligation on the part of the area electricity boards to purchase the energy. After 1983, in two landfill sites in Bedfordshire, UK, the LFG was first used as commercial supply of gas to the first phase of the electricity generation program (Moss, 1996). Thorneloe (1996) reports more favorable economics for pipeline quality gas production in Netherlands and diesel production from landfill gas as vehicle fuel in Pueblo Colorado, USA, in 1990s. Different utilization of LFG has been present in developed countries. Accurate statistics on LFGTE are difficult to compile from the literature for several reasons; plant information is not always complete in the literature and actual site information may not be in accordance with literature information. Willumsen (1996) has reported 246 plants from 18 countries based on available information as of 1990. **Figure 7** illustrates numbers of first LFG utilization projects in different countries in the early phases of diffusion.

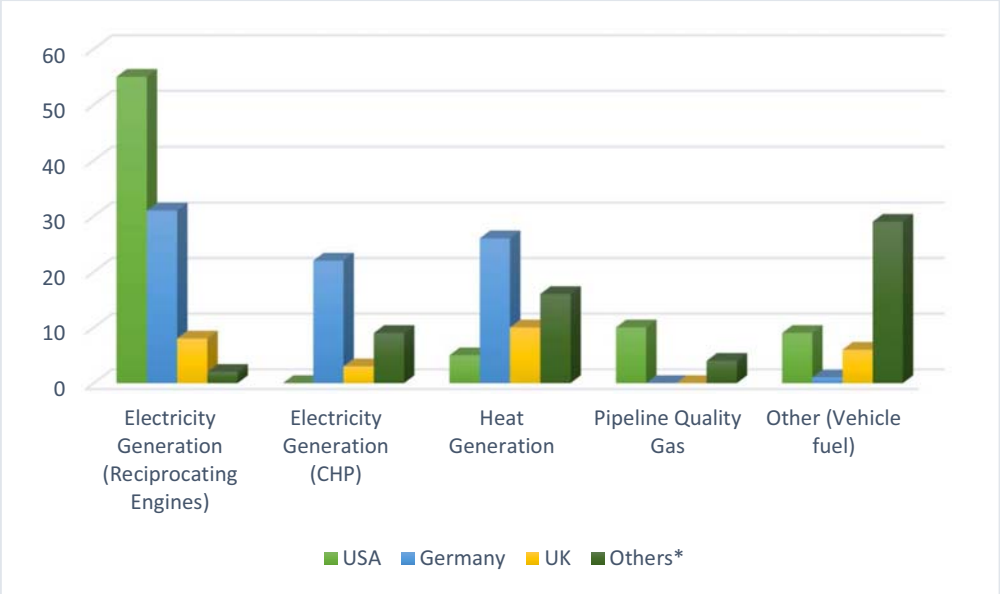

Figure 7 Number of different LFG utilization projects in 1990s

Source: Willumsen (1996)

A major influencer of LFGTE technology diffusion in the USA was the "Public Utility Regulatory Policy Act" which required that utilities purchase LFGTE power at an

affordable price. In addition, tax credits have been available that also help to encourage LFGTE projects (Thorneloe, 1996).

Number of LFGTE plants have increased from 79 to 634 in the United States between years 1990-2017. MSW landfills are the third-largest human-caused source of methane emissions in the United States. Because of the health and environmental concerns, United States Environmental Protection Agency (USEPA) has designated "landfill air emissions" as a pollutant. As of June 2017, 634 LFG energy projects are operating in 48 states in U.S. territory. Roughly three-quarters of these projects generate electricity, while the remainder are either direct-use projects where the LFG is used for its thermal capacity or upgraded LFG projects where the LFG is cleaned to a level like natural gas. The 634 projects are estimated to generate 17 billion kilowatt-hours (kWh) of electricity and deliver 96 billion cubic feet of LFG to direct end users and natural gas pipelines annually. Approximately 258 million tons of MSW were generated in the United States in 2014, with less than 53 percent of that deposited in landfills which continue to produce LFG for as many as 20 to 30 years after it has been landfilled. Many landfills collect and use LFG voluntarily to take advantage of this renewable energy resource while also reducing GHG emissions (US.EPA, 2017).

The European Union (EU) adopted a progressive transition strategy from landfill based MSW management to integrated waste management techniques, such as recycling, mechanical biological treatment (MBT), incineration with energy recovery (The modern waste hierarchy). The modern waste management hierarchy aims to reduce final disposal (landfilling) of waste and encourage minimization of waste generation. Landfilling is strongly discouraged in developed countries (Edwards et.al.,2015). Advanced organic waste management technologies are proliferated by means of regulatory (complete ban) and market-based (trading or taxing landfilled wastes) instruments instead of direct disposal methods. The recent trend in the EU is to promote anaerobic digestion technologies (including electricity, heating, gas and transportation sectors.). In a similar vein, no organic wastes are sent to landfills in Germany as of 2006. Instead, the country encourages anaerobic digestion technology.

Edwards et.al. (2015) and Lantz et.al. (2007) argue that the policy backbone of promoting better waste management technologies stems from climate change and energy security policies above all. The strictness of market based, and regulatory instruments are adjusted according to regional development and waste management policies. Performance based financial incentives are introduced for renewable energy in forms of feed-in tariffs and/or renewable energy certificates in Germany and the UK. In addition to this, government support to small scale investments (150 kW-500 kW) have found to be especially effective in gradual increase of number of anaerobic digestion plants (Edwards et.al., 2015). In addition to this, negative externalities due to landfilling are being balanced by market-based instruments such as gate-fee. Such instruments also aim to improve the waste management up the hierarchy. Landfill levies are issued by some countries (**Figure 8**).

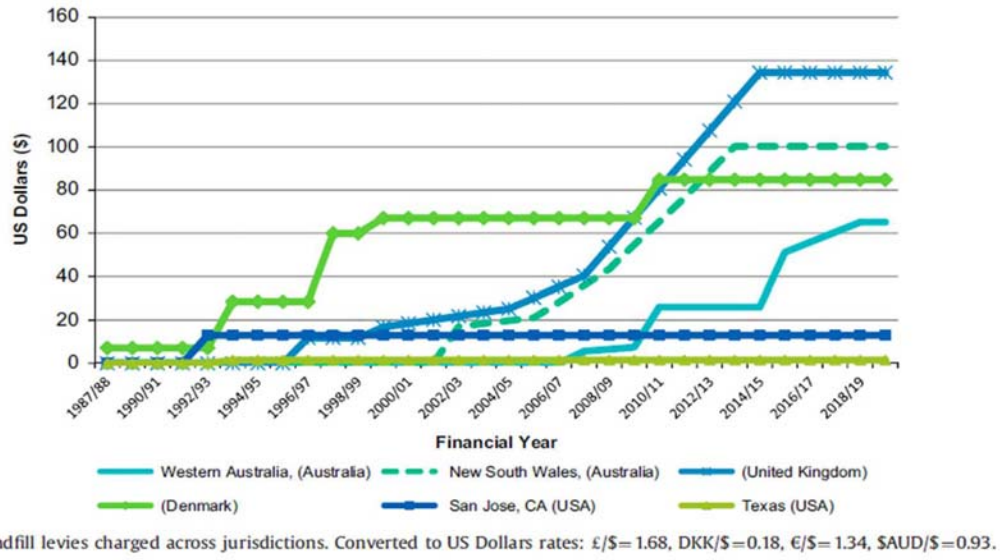

Figure 8 Landfill levies charges across jurisdictions

Source: Edwards et.al. (2015)

The aim of landfill levies is to support reduction and recycling of wastes (i.e. carrying the waste management up the waste management hierarchy), funding "closure operations" after the lifetime of landfill is over, generate revenue for alternative sustainable MSW strategies and infrastructure.

Briefly; the raising trend in developed countries is use market-based instruments in favor of upgrading waste management applications towards recovery of economic value of wastes and supporting radical changes in production and consumption patterns. This phenomenon is usually referred as the modern waste management hierarchy (**Figure 9**).

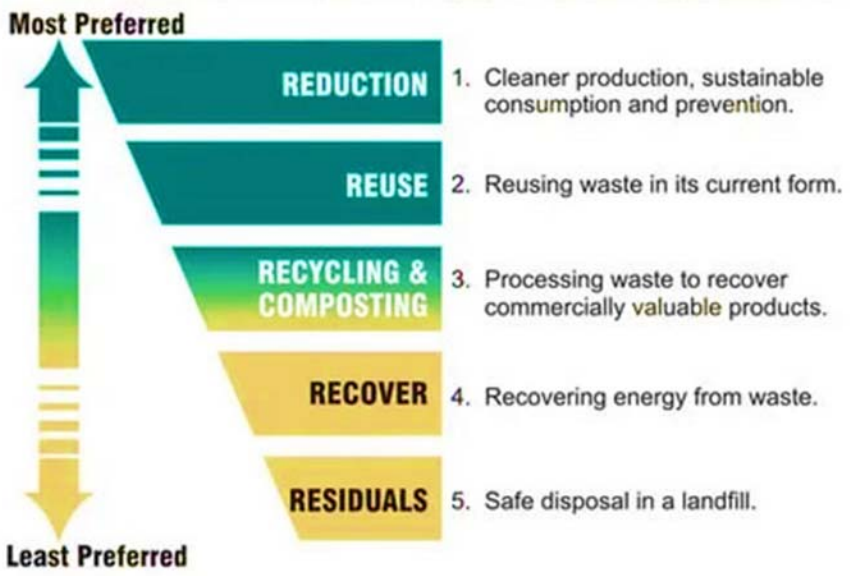

Figure 9 The Modern Waste Management Hierarchy

The most favorable option in waste management is "avoidance" of waste production. This requires an active participation of the society with the aim of producing less waste. Reduction, reuse and recycling of wastes include societal changes with radical eco-innovative decisions. In addition to this, eco-innovative design of products to prevent waste production (such as biodegradable packages etc.) If waste generation cannot be avoided, the next favorable option could be processing waste to produce commercially valuable products; such as compost from organic wastes and/or recycled materials from the original input. This step is usually discussed under the phenomenon of circular economy. Finally, if the waste neither can be avoided nor it can be recycled into a valuable product, the least preferred option is to dispose of the material in hand. In modern waste hierarchy, only the materials which cannot be revalorized anymore (residues) are send to disposal plants. In conclusion, landfilling and incineration for disposal are marginal solutions to waste management problem. A marginal

improvement is producing energy from waste at these disposal plants. A radical improvement would be to encourage a societal change towards less consumption and less waste generation.

2.4.Research Gaps and Delineation of Research Questions

LFGTE technology is both a renewable energy and an environmental management technology. This peculiarity of the LFGTE technology makes it distinctive from other renewable energy technologies. When we have first began searching for information on diffusion of LFGTE technologies, we recognized that there were not many case studies specific to this subject. The most relevant study to our curiosity was the case study of Li et. al. (2015) where market-based instruments were found to be the major influence in LFGTE investments. On the other hand, Thorneloe (1996) has shown that impact of environmental regulations was especially stronger as the LFGTE projects diffused in USA in 1990s.

In Turkey, as of December 2019, 57 LFGTE facilities have a renewable energy production license and can be tracked via the YEKDEM list of facilities. LFGTE facilities constitute half of the total biomass power investments in Turkey. The first LFGTE power plant was adopted in 2005 and the sector has almost reached its full potential by the end of 2019. We have acknowledged from the conceptual literature that; there is lack of publicly available quantitative data (i.e. project capacities, type of contract, terms of agreement, total number of unlicensed projects etc.) on LFGTE projects in Turkey. The socioeconomic context of LFGTE diffusion has not been investigated. A study on of diffusion of LFGTE technologies in Turkey has the potential to uncover different fields of research in fields of environmental economics, public policy, urban planning and environmental engineering.

Understanding diffusion of environmental technologies/renewable energy technologies requires deep down investigation of institutional aspects and different actors' opinions (Brown, 2001; Foxon et.al., 2005; Mignon and Bergek, 2016). Case studies are found useful (Erden-Topal, 2016) to understand the complexity of factors (local regulations, public opinion, project-based business agreements etc.) in

renewable energy diffusion studies in Turkey. We acknowledged from the empirical literature review that; influencers of renewable energy diffusion are very much dependent on the type of technology. We have therefore, decided to generate case-specific empirical information to complement quantitative studies (Hojnik and Ruzzier, 2016; Kemp and Volpi, 2008) for diffusion research in similar field.

As a result of the literature review, the research gaps in this field were identified as;

- There is lack of empirical data related to influencing mechanisms of LFGTE diffusion.
- There is a FiT mechanism to support renewable energy diffusion in Turkey but its influence on the LFGTE sector has not been researched at all.
- Relationship of environmental policy with LFGTE diffusion in Turkey is not addressed in literature.
- There are no empirical findings in the literature that show diffusion of environmental technologies within partnership/cooperation of public and private bodies (municipality-private investor relationship)

After having reviewed the available literature related to diffusion of LFGTE technologies we have concluded that; there is hardly available information related to status quo of the LFGTE technology investments in Turkey. Therefore, we have designed an inductive research to explore the initial situation and influencing mechanisms of LFGTE diffusion so that; further studies for sector-specific policy making could be initiated. Accordingly, we have formulated our research questions as;

- What are the influencers (drivers and barriers) of LFGTE diffusion?
- How do these influencers influence the diffusion process?

As the research proceeded, we have developed the main hypothesis as; the feed-in tariff policy has resulted in a lock-in to LFGTE technology and prevented radical innovations in the waste management sector.

CHAPTER 3

METHODOLOGY

In this chapter, the research process and followed methodology is described under four sections. We have first presented our research methodology in the first section. Later, we have elaborated the research design; explained the multiple-case study method that we have followed to collect empirical data from the field and summarized the methods followed for the analysis of data. In the final section, we have explained our limitations and ethical considerations during the research.

3.1. Research Methodology

Diffusion of biomass energy is a recently emerging topic in the literature. There are hardly available empirical data on the field of environmental technology diffusion regarding public private partnership investments. Although general innovation theory and several others (institutional theory, the stakeholder theory etc.) are benefitted to explain the eco-innovation diffusion phenomenon; scholars have disserted that each theory has its shortcomings in explaining eco-innovation diffusion behavior (Horbach et.al., 2012; Hojnik and Ruzzier, 2016; Rennings, 1998). The aim of this research is towards describing and explaining conclusions for LFGTE diffusion in Turkey from studied example cases. Our objectives are;

- To describe the influencers of the LFGTE technology diffusion in Turkey
- To explore influencing mechanisms of LFGTE technology diffusion

We were convinced that an inductive research would allow us to discover unexplored fields of research regarding environmental technology diffusion and discover beyond the available theoretical framework. Our research strategy is built around the context of LFGTE technology diffusion in Turkey. Main goals of the research are to describe the influencers of LFGTE diffusion in Turkey to explore the influencing mechanisms.

In order to achieve our research goals, we have followed an inductive approach and used qualitative techniques for data collection and analysis. Our research structure is summarized in **Table 3**.

Table 3 The research structure

	ADOPTED CHOICE
Epistemology	Interpretivism
Research Methodology	Grounded Theory
Research Methods	Secondary data investigation Expert opinion Participant observation Multiple case study
Research Tools	Document review In-depth interview Semi-structured interview

After having reviewed the literature dedicated to diffusion of eco-innovation, we have understood that; multiple-case study approach would allow us to address influencers and assess weight of each influencer for different cases of LFGTE diffusion.

Grounded theory is an often-preferred inductive research methodology in social sciences. The term "Grounded Theory" is both the name of the research methodology and the underpinning theory. It is a "constant comparative method" that aims to theorize based on the results of the research. This methodology was first proposed in 1967 by Glaser, B. and Strauss, A. in the field of health science research. The main philosophy of the grounded theory is "*discovery of theory from data*". This innovative methodology for theory building research has its mere distinctions from deductive research especially in the form of literature review (Birks and Mills, 2015). Grounded theory is explicitly against engaging with existing literature *prior to* primary data collection (Dunne, 2011). Dunne (2011) emphasizes the strong consensus in the field of grounded theory that; the literature review must not be done in the substantive areas of research before collecting the primary data. The researcher must enter the research field with no preconceived problem statement, research tools or extensive review of the literature.

In this sense, we were very careful about carrying out a "phased" form of literature research. Before narrowing down our focus to "LFGTE diffusion in Turkey", we had to identify theoretical basis of diffusion of eco-innovations and provided an empirical framework for drivers of environmental technologies. Initially we have benefitted from the literature to familiarize with the main streams of research and the concepts in eco-innovation studies. Later, as we have recognized that there was "lack of research" in the field of biomass energy diffusion in Turkey, we have decided to focus our attention to this field. Our search for the conceptual background has guided us to perform a field research in the scope of diffusion of LFGTE after recognizing the weight of LFGTE technology among other biomass power plants in Turkey.

We have continued the literature review as we have proceeded through data collection, conceptualizing and coding. The grounded theory methodology has allowed us to have a perspective free of embedded knowledge in the eco-innovation literature. On the other hand, we had to maintain the pace of field research and theoretical research in a constant comparative and iterative manner in order to (re)formulate our research questions. We have first completed our review of the conceptual background literature in order to have a better understanding of the technology and to complement our lack of knowledge about the current status of the sector in Turkey. As a second step, we have reviewed the empirical literature in eco-innovation studies. We have kept our distance to the theoretical literature until the emergence of first results of the data analysis in order to avoid a preconvinced status for the field research period. The field of eco-innovation research is quite rich and it has been approached from different disciplines of social research through a variety of theories. Since it was not possible to elaborate each and every theoretical concept in detail we have seeked benefit in referring to two recent literature research studies; "*Diffusion of eco-innovations: A review*" by Karakaya, E., Hidalgo, A. and Nuur, C. (2014) and "*What drives eco-innovation? A review of an emerging literature*" by Hojnik, J. and Ruzzier, M. (2016). Karakaya et.al. (2014) has made a quantitative research about diffusion of eco-innovations with the aim of identifying different research streams working in this field. They have searched the *Google Scholar* database and by using keywords of eco-innovation and its synonyms they were able to identify 1024 scientific publications

between 1990-2012 directly on the topic of diffusion of eco-innovations. We have benefitted from this study in having an overview of eco-innovation publications in different streams of social sciences and we have learned about mostly attributed theories within the limitations of the study. The latter study by Hojnik and Ruzzier (2016) is a review of 155 articles about drivers of eco-innovation published between 2000-2015. Despite its limitations (i.e. that only Science Direct, Wiley and Blackwell databases were used for research and the study was carried out for a limited time period), this document analysis has helped us to understand the general framework of theories and research tendencies in the field of eco-innovation drivers. The study of Hojnik and Ruzzier (2016) complements the quantitative analyis of Karakaya et.al. (2014) with qualitative analysis of all documents in hand. By reviewing these two sources, we have acquired a list of literature of eco-innovations between 1990-2015. After that; we have carried out our own literature research specifically on the concepts of "peculiarities of eco-innovations", "influences of regulations on eco-innovation diffusion", "diffusion of environmental technologies". After we have completed the field research; we have polished our discussion in the theoretical framework and empirical literature background sections in order to establish a stronger link to our findings.

Our literature review has revealed that there is a single major study on diffusion of LFGTE technologies. Li et.al. (2015) has performed a quantitative analysis while assessing the role of renewable energy policies in LFGTE projects. This study benefits from a data of 277 projects from USA ranging between years 1991 to 2010. Erden-Topal (2016) has carried out an extensive research on market formation dynamics of renewable energy technologies in Turkey. She has performed a qualitative analysis in her research due to context dependency of the research problem. Although her study was limited to diffusion of solar and wind power technologies, her findings reveal future research prospects in different fields of renewable energy market research. In a similar vein, Lantz et.al. (2007) has investigated incentives, barriers and potentials of biogas diffusion in Sweden with a qualitative methodology. The reason behind selection of a qualitative approach was basically due to context dependency of research and the need for analyzing a complex set of actors from different experience within

the biogas sector. Qualitative analyses are generally considered to be less objective then quantitative analyses, but qualitative analyses offer comprehensive approaches to local institutional and socioeconomic research problems (Hojnik and Ruzzier, 2016).

We have carried out a three-pillar research design for the purpose of this research. The first stage was simultaneous review of literature while proceeding with the data collection and analysis as it has just been explained in detail in the previous pages. The second pillar was a preliminary study which includes document review and in-depth interviews with sector experts. The preliminary analysis has helped us to understand peculiarities of the LFGTE sector. As a result, we were able to determine the interviewee profile and prepare the interview guide for the semi-structured interviews. The third pillar was the field work where we have collected field data on influencers and influencing mechanisms of LFGTE diffusion through semi-structured interviews with firm representatives. The research design can be summarized in three pillars as shown in **Figure 10** below.

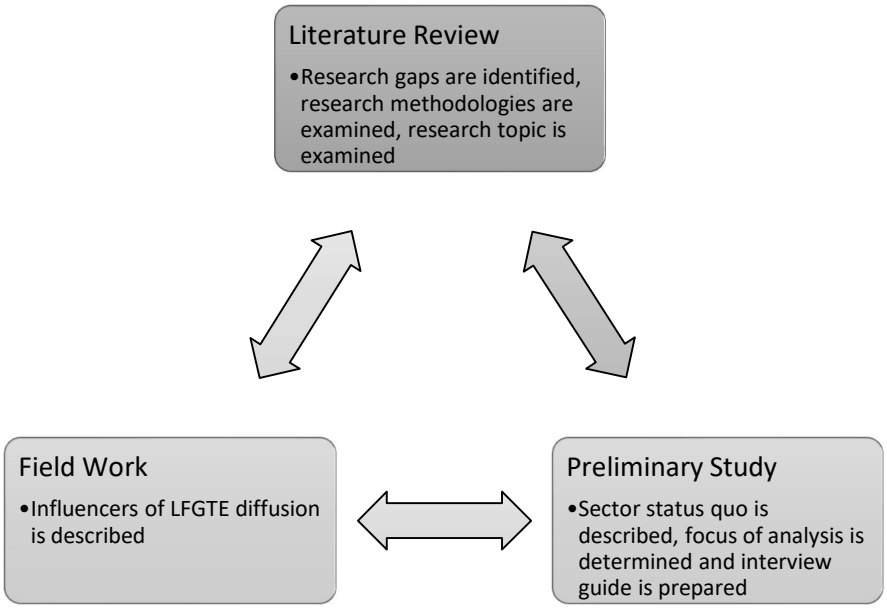

Figure 10 Pillars of the research

In the following passages we have elaborated details of the preliminary study. We have described the field research methodology in Section 3.2 and our methodology for data analysis in Section 3.3.

Document Review as a Part of the Preliminary Study

In order to retrieve detailed information about the actors in the sector, their affiliations, way of doing business etc. we have completed a document review. We searched through websites of municipalities, project specific news/announcements and available literature relevant to sector status quo. Analysis of secondary data before getting into field work is valuable in qualitative research because documents contain text and images that have been recorded without a researcher's intervention. Document analysis involves a purposeful selection of the source documents, a careful read through and interpretation to develop empirical knowledge in line with the goals of the research (Bowen, 2009). We have benefitted from national policy documents related to energy and environment policy in Turkey[20] and technical and non-technical documents related to LFGTE technology adoption/diffusion in Turkey (i.e. complementary information to the status quo) to scope out the national energy and environment policy and to understand the perception of government for diffusion of LFGTE phenomenon.

Each year in November, the Ministry of Energy and National Resources (MoENR) EMRA issues the list of licensed plants that benefit from the feed-in tariff mechanism. We have benefitted from the list of facilities issued in November 2018 and updated our work with data of November 2019[21] as the research proceeded. There are 57 LFGTE facilities in the given YEK-2020 list. However, we have learned from our first expert interview that there are over 80 LFGTE facilities in Turkey already, including

[20] National Policy documents that we have reviewed through this process include; Turkish Republic 11th Development Plan (2019-2023); National Waste Management Action Plan (2016-2023); National Renewable Action Plan for Turkey (2014); Turkey's National Climate Change Strategy and Adaptation Plan (2011-2023)

[21] This list is referred as YEK 2020 list in EMRA web site.

the non-licensed ones and the ones under construction. We have also learned that 200 thousand population is the threshold limit for implementation of a feasible LFGTE project. We have confirmed this information with information from our second expert interview within the preliminary study. We have defined our initial aim to identify and fill in information gaps about the licensed and non-licensed LFGTE facilities in Turkey. We have identified the gaps in the database table and performed another search with a purposeful sampling approach aiming for case-specific key words. Selection of key words are very much dependent on the expertise of the researcher. Relevant keywords for documentary search in this field were determined as; "*çöp gazı*" (landfill gas), "*çöp gazından elektrik*" (electricity from landfill gas), "*belediye, çöp, elektrik*" (municipality, waste, electricity). Case-specific key words for each project included the "name of the investor company" and "name of the adopter municipality". We have listed the provinces of Turkey according to their population and identified the provinces where we have no information about presence of LFGTE facilities from the YEK list. We have marked the provinces with population over 190000. We have run another web-based search by using key words "province name", "*çöp*" (i.e. waste) and "*elektrik*" (i.e. electricity). We have considered webpages of municipalities and webpages of firms as reliable information source. Local news was not accepted as reliable information source because these webpages can include misleading information to promote municipal services. We have also accepted news which include specific information to LFGTE "tenders" and "project financing" through EU or private banks as reliable information source. As a result of the document analysis we were able to identify 57 licensed LFGTE power plants and 26 non-licensed LFGTE power plants in Turkey. We have updated our database table with the following information for each case;

- Province of investment
- Is the facility already implemented or under planning stage?
- The capacity and date of investment
- The plant operator firm
- The business model (BoO, BoT or Concession Agreement etc.)

Document review has allowed us to learn about the contextual properties of the LFGTE diffusion in Turkey. We were able to identify the main actors and the political framework before stepping forward to the field work.

Expert Opinion as a Part of the Preliminary Study

Our aim in the preliminary study was to understand perceptions of different actors experienced in the LFGTE sector, discover peculiarities of LFGTE adoption. Since the main context for LFGTE diffusion is missing from the Turkish literature and our aim was to reach detailed case-specific information; we have decided to follow the contextual approach and perform in-depth interviews with actors who has sector experience. We have applied purposive-expert sampling based on the personal knowledge of the researcher on the background of experts from the sector. We have decided to interview at least two experts from the private sector and two experts from the municipal authorities who are experienced in cases of LFGTE adoption. The researcher used to have worked with both private sector experts in different LFGTE project cases. Both experts have more than 10 years of experience in LFGTE project implementation. Both were actively involved in business at the early periods of LFGTE diffusion and they still provide consultancy to LFGTE investor firms in the sector. Expert from municipalities were purposively selected based on relevance of their region and their experience in the municipal authority.

The first expert interview was completed face-to-face in İzmir Province. The first interview has last for about 40 minutes. Meeting notes were taken during the conversation upon consent of the participant. The participant was in İzmir for implementation of İzmir Dumpsite LFGTE project. The interview has begun with a general introduction of the research topic after the warmup speech. The participant was kindly requested to share his experience on; the history of the LFGTE diffusion in Turkey, his personal experience in the sector, his perceptions/opinions of the sector, his knowledge on roles of actors in the sector and his recommendations. After 30 minutes of interviewing, the participant was accompanied by a foreign waste management expert in the meeting table and his concentration was divided in between

translations. However, we concluded the interview with his recommendations for future interviews.

The second private sector expert was purposively selected based on his field experience with more than a dozen LFGTE facility implementations. He is an engineer who is experienced in installation of LFGTE infrastructure. He also has a business network with LFGTE investor firms which contributed to our snowball sampling for the semi-structured interviews in the third pillar. The participant has requested to perform the interview on the phone. Meeting notes were taken with the consent of the participant. The interview has last for 60 minutes. The participant was interrupted twice during the interview with other phone calls which took about a total of 15 minutes break from the interview session. The participant was kindly requested to share his experience on; the history of the LFGTE diffusion in Turkey, his personal experience in the sector, his perceptions/opinions of the sector, his knowledge on roles of actors in the sector and his recommendations. He contributed to the study with technical information on the types of engines used, suppliers in the market, relationship of key actors and the competition environment.

The interview with the first municipality expert has been initiated in the province of İzmir with an officer working for the İzmir Municipality, responsible from management of LFGTE project implementation at Harmandalı Dumpsite. The city of İzmir is purposively selected because it is one of the late adopters of the LFGTE technology in Turkey. We were looking for recent information related to adoption decision. From the literature information we would expect that; amount of waste input is a major determinant of LFGTE project feasibility. Ankara and Istanbul province are two greatest cities of Turkey and Izmir is the third biggest city in comparison of municipal populations. Ankara has adopted LFGTE in 2005 and Istanbul has adopted in 2006 but İzmir has not adopted the LFGTE technology until 2019. That was an interesting case to identify. Therefore, we selected to interview with an officer from the İzmir Municipality. Apart from the LFGTE experience we looked for a medium-term affiliation with the municipality and a knowledge of public policy as an asset for the in-depth interview participant. The interview was carried out in an official building

of the municipality solid waste management division. There was another municipality officer in the room during the interview, but he was not involved in the interview session. He has not been in contact with the researcher or the participant during the interview. The interview session took 80 minutes without interruption. The participant did not permit taking voice records during the interview, but meeting notes were kept with the participant's consent. The in-depth interview included open-ended questions related to; participant's experience, opinion and perceptions of the LFGTE sector, her knowledge about the LFGTE adoption case in İzmir, her perceptions about role of actors in the sector and recommendations. The participant was very much interested in the research topic and she paid attention to the background of the researcher. The first 10 minutes of the interview was the warming up period and the expectation of the participant was very low on the content of the interview. Meaning that; she was aiming for sharing very basic information with the researcher because she thought that a social scientist would not be familiar with the engineering concepts and basic definition of the LFGTE would be beneficial for the purpose of the study. After 10 minutes of warming up and giving a short introduction on the experience of the researcher in waste management field and her interest about the research topic the interview has turned into a fruitful flow of information. The results of the municipality expert interview have especially been useful to understand role of municipal authorities in LFGTE cases. The reason behind "late adoption" for the specific case of İzmir was learned from the expert. This information has then been compared to field results.

We have carried out our second municipality expert interview with an officer working for a municipalities' union. The participant did not agree to disclose the name of the union. The interview was realized on the phone upon the request of the participant. We have purposively selected to interview an expert from a municipal union in order to have a different municipal authority than a metropolitan municipality. The interview has lasted for 20 minutes without an interruption. The researcher could take notes during the interview session. The participant has been in administration of the LFGTE project since the beginning of the adoption decision. She was knowledgeable about decision making processes of municipalities, bureaucratic procedures, interaction between contractors and public authorities. This union has 7 municipalities and 1

province administration as its members. We were able to retrieve perspective of district municipalities towards LFGTE projects with this interview.

Carrying out in-depth interviews with experts with field experience has helped us to understand peculiarities of this sector, identify roles of key actors and their case-based relationships. Expert opinion was a crucial part of our preliminary study to complement the secondary information that we gathered from document review. We have also prepared the interview guide for the semi-structured interviews of the field work. We have followed a descriptive approach through the preliminary study. The descriptive approach has allowed us to develop the contextual framework of LFGTE diffusion in Turkey. Findings of the descriptive research has provided a basis for further exploring "*how*" is the influence mechanism of LFGTE diffusion processes and "*how*" do regulations impact the diffusion process. With the help of in-depth interviews, we were able to formulate our interview questions for the field work. In conclusion of preliminary study; we have concluded that private investor firm perspectives should be the unit of analysis for the exploratory research and we will follow a multiple-case study to collect field data.

3.2. Data Collection

After developing an understanding of the main phenomenon, we have begun our field research with the aim of describing influencers of LFGTE technology diffusion and exploring the influencing mechanisms. From the preliminary study we understood that each LFGTE project is uniquely determined by a contract between the municipality and the investing company. Therefore, each case is specific to the business strategy of the private investor and demands of the municipality. Therefore, we have decided to follow a multiple case study approach in order to identify the complex relationship for LFGTE projects from the perspective of variety of cases.

Before setting up the semi-structured interviews we have carried out one pilot interview with an environmental engineer who is not professionally involved in the LFGTE sector but knowledgeable about municipal environmental technology implementation (SWM and wastewater treatment) in Turkey and has over 10 years of

experience in environmental consultancy. The aim of the pilot interview was to understand if interview guide fulfills its design purpose. After the pilot interview we have reviewed our interview questions. We have not distributed our interview questions to the participants but instead each question was presented to the participant within the flow of conversation. The open-ended question in the interview included.

- Basic information about the participant and the firm
- Information about the status quo
- Information about influencers of LFGTE adoption decision
- Information about relevant legislations and their impacts on LFGTE adoption
- Problems and recommendations

The original interview guide (prepared in Turkish) can be found in the annex under the heading of "Appendix B: Interview Guide in Turkish/Mülakat Rehberi".

We have followed the snowball sampling strategy for the field analysis. We have completed a set of semi-structured interviews with 8 sector representatives. Each participant works for a different LFGTE investor firm. These 8 firms have a total number of 50 LFGTE investments in Turkey. The total installed capacity of LFGTE plants owned by these firms is approximately 347 MWe, which is about 80% of total installed LFGTE plant capacity of the country. **Table 4** shows number and capacity of plants that our interviewed firms have in sum.

Table 4 Number and installed capacity of LFGTE plants owned by selected cases

	Coverage
Number of interviewed firms	8 firms
Licensed LFGTE Plants owned by interviewed firms	38 licensed plants
Non-Licensed LFGTE Plants owned by interviewed firms	12 non-licensed plants
Installed Licensed Plant Capacity owned by interviewed firms	266,18 MWe
Installed Non-Licensed Plant Capacity owned by interviewed firms	81,23 MWe

Case studies provide comprehensive, specific and realistic information to complement complements quantitative research studies (Kemp and Pontoglio, 2011). The case study approach has allowed us to acquire project specific data on each case. By this approach we were able to retrieve information related to business agreements,

strategies, project specific influencers and relationship with regulations. By the help of information retrieved from the field interviews; we were able to complete status quo information, acquire data related to influencers of the LFGTE adoption for each case with a special focus on impacts of the environmental policy for recent and future decisions.

Selection of Cases and Firm Profiles

Our main aim was to cover as diversity cases of LFGTE plants as possible with the minimum set of interviews. As the research proceeded, we have continuously checked our sample set with the licensed LFGTE plants from EMRA YEK list. As the primary condition to be an eligible case for research; all firms represented in this study are active in field of LFGTE business in Turkey. We have learned with the preliminary study that, LFGTE facilities in Turkey are classified as; facilities with an electricity market license and facilities without an electricity market license. Moreover, firms in the market can be distinguished as; firms which have a singular investment and firms which have more than one investment. As we have proceeded with our research, we also found out that the terms of contract and terms of public-private-partnership (Build-Operate, Build-Operate-Transfer, Concession agreement etc.) is another determinant that distinguishes cases from one another. We have also distinguished between firms which identify themselves as an "energy company" and the ones which identify themselves as an "environmental technology company".

We were able to reach a total number of eight cases as a result of the snowball sampling. All cases in our study have more than 5 years of experience in the sector. Two of the selected cases are foreign environmental technology companies[22] with domestic business partners. These companies have more than 20 years of experience in engineering and they have been active in Turkey more than 15 years already. All the energy firms that we have interviewed are firms of Turkish origin which were

[22] To our knowledge there are three companies with foreign origin/partners, involved in the LFGTE business in Turkey; ITC (Swiss), CEV Energy (Korean), and SİTA Cevre (French). Since participants did not prefer to disclose firm names in the study; we did not include specific information on origin of the firms that we have interviewed.

private-partnership (PPP) with the municipal authority. Two firms have LFGTE investments with only Built-Operate-Transfer (BoT) type of business models where all machinery and equipment of the plant will be transferred to the municipal authorities after the contract of the firm is over.

In order to keep a distance from firm individualities we have coded each case with a code name. We have chosen names of goddesses from the Roman Mythology as codes for cases. Each participant that responded to our semi-structured interview represents a case which envisages a singular LFGTE firm perspective. The cases (i.e. firms) are referred by the assigned code names throughout the thesis. Names of participants and firms are kept confidential upon request of the respondents. Codes names assigned to selected cases are tabulated below (**Table 5**).

Table 5 Code Names Assigned to Selected Cases

CASES	ASSIGNED CODE NAMES
CASE 1	*TERRA*
CASE 2	*CERES*
CASE 3	*AURORA*
CASE 4	*LUNA*
CASE 5	*DIANA*
CASE 6	*FLORA*
CASE 7	*MINERVA*
CASE 8	*SALUS*

The first case (*TERRA*) was introduced to the researcher through a professional contact from the sector. TERRA is an environmental technology company established after 2010, as a branch of a construction firm active in landfill construction since 1994. This firm has three investments in LFGTE sector all of which are implemented under the area of coverage by municipal unions. The scope of their projects is limited to; management of disposal sites, separation of recyclable materials, extraction of the LFG and electricity production (i.e. LFGTE). The semi-structured interview with TERRA was completed through a video-call right after the approval of the Human Subjects

Ethical Committee[23]. The conversation was recorded with a tape recorder and meeting notes were taken with the consent of the participant.

The researcher has exchanged contact information with the participant of CERES during the "Zero Waste Symposium" held by the Chamber of Environmental Engineers within the premises of the Kadıköy Municipality in April 30th, 2019. The interview was carried out online by a video-call after a month of the symposium. CERES is a company established in 2018, for the purpose of integrated solid waste management (ISWM) within the premises of a municipal union. This is their first project in the market, and they combine other environmental technologies for waste management with the LFGTE as well. The main shareholder of the company is a foreign construction firm which has more than a few decades of experience in municipal wastewater treatment business in Turkey. The firm has made signed a concession agreement with the municipal union for a long term ISWM. CERES is convinced that; concession agreement type of PPP is the most appropriate way to exchange long-term responsibility between public and private parties.

The third and fourth cases (AURORA and LUNA) were advised by both participants of TERRA and CERES as remarkable cases. The researcher had former business connections to project engineers working for AURORA and LUNA, she has reached those affiliations through the phone and took their consent to participate in the research study. AURORA is a Turkish energy company which has four LFGTE investments in two provinces of Turkey. All investments of this company are under premises of metropolitan municipalities. The company owns two facilities under the name of the mother company, and they have formed a daughter company in order to invest in another city. AURORA invests in LFGTE and other means of waste to energy technology, they operate reciprocating engines as well as combined cycle power plants but they do not operate other waste management technologies (mechanical separation, recycling etc.). These services are contracted to other firms by the municipal authorities.

[23] The approval document of the Middle East Technical University (METU) Applied Ethics Research Center (AERC) can be found in Appendix C: Approval of the Human Subject Ethical Committee.

The researcher was able to reach three potential participants of LUNA through LinkedIn business networking platform. The participant with a technical background in LFGTE sector who has the longest experience with the firm was selected purposively by the researcher as the firm representative. The researcher and the participant from the case LUNA has a former connection from the environmental engineering program of METU. LUNA is an environmental technology company which has global experience in waste management technologies. The firm had a foreign shareholder at the establishment stage when it entered the Turkish market in 2000s. LUNA has about a dozen of LFGTE investments in Turkey in metropolitan municipalities (MM) and/or municipal unions. They prefer to invest in ISWM projects, but they also have project where only LFGTE technology is applied solely based on the request of the municipal authority. LUNA is convinced that privatization of MSW activities would be the best solution for SWM problems. They invest in Build-own-Operate (BoO) and/or Built-own-Transfer (BoT) type of PPPs.

The fifth case interviewed was DIANA, contact information for an officer of DIANA was shared with the researcher during the second private sector expert interview in the preliminary study. The contact person from DIANA was not willing to participate in the research but instead he provided contact information of an administrative officer working for DIANA. A face-to-face interview session has taken place at DIANA headquarters, it took about an hour to complete the interview session and an extra hour was spent on discussions for technical specifications of LFGTE projects, problems associated with their implementation and regulatory burdens. DIANA is a Turkish energy firm, which is established in 2005, right before the Renewable Energy Law (2005) The main business target of the firm was to enter “privatization tenders” for Hydroelectrical-Power-Plants. They could not succeed in the hydroelectric business but instead they have entered the LFGTE sector due to affiliation of one of the shareholders of the company to the MSW collection sector. One of the founders of the company owns another firm that collects/transports MSW. He knew about the potential of the LFG and informed his business partners about this sector. The firm has completed three LFGTE investments in Turkey. Today they operate two LFGTE power plants; one under the premises of a MM and the other one under the premises

of a municipal union. Both of their projects are Built-own-Operate (BoO) model where the firm collects all the machinery and equipment from the site after the project contract is over. DIANA only applies LFGTE, which means; its operational responsibility is limited to harvesting the landfill gas and producing electricity out of it. During the interview session with DIANA, the participant of DIANA has recommended that including FLORA in the research could be an asset to the study because they have lately emerged in the market and they have about a dozen of investments.

The researcher has contacted the representative of FLORA through the LinkedIn business networking platform. A face-to-face interview was completed at the FLORA headquarters in September 2019, when a few weeks were left for the last application date to the final YEK support period. The complete interview session has taken about an hour and a half, but it was often interrupted by phone calls and requests of the staff mainly because of "recent load of administrative burden" due to the "YEK applications". A field engineer of the firm and an administrative officer with a long-term affiliation in the company were also present at the interview session and made contributions to the interview. FLORA is a Turkish origin energy company. The firm was established in 2012. Its first investment was in wind power sector. The firm has decided that wind power plant operations were not feasible therefore, they changed their focus the field of LFGTE. One of the business partners of FLORA had business affiliations in the machinery sector within the premises of the MM. The local network of the business partner has been effective in involving in the LFGTE sector in the province of investment. The first project of FLORA was under the premises of a metropolitan municipality. FLORA has about a dozen LFGTE projects in Turkey, half of which are licensed after 2018. FLORA opts for implementing basic LFGTE projects (only harvesting the gas and producing electricity) but it also has installed biomethanisation units based on the request of municipal authorities. They also operate mechanical separation facilities, but this operation is basically due to request of the municipalities because of the regulatory pressures. Like LUNA, FLORA also opts for managing other types of urban waste streams such as municipal wastewater treatment sludges as an additional source of income. The interviewee from FLORA had former

business affiliations to MINERVA; he has provided the contact information for the seventh case.

MINERVA is a Turkish energy company established in 2010. The firm is involved only in LFGTE projects with basic LFG harvesting and electricity production. Their scope of work also includes operation/management of disposal sites, but they do not install other environmental management technologies. A face-to-face interview with MINERVA was initiated at the firm headquarters with the founder of the company. A field engineer of the firm was also present at the interview session and made contributions to the interview. MINERVA has around a dozen LFGTE investments in Turkey both under premises of municipal unions and metropolitan municipalities with either BoO or BoT models of PPP. The participant of MINERVA has claimed that SALUS would be an asset for the research study, he praised the quality of their operations and their initiatives in research and development activities. The participant has provided contact information of the next case study (*SALUS*).

SALUS is a domestic energy firm established in 2010. The core business of the firm is defined as energy production from waste disposal sites. SALUS has two LFGTE investments in Turkey both of which are under the premises of MMs. An online interview session was arranged with SALUS owing to the busy schedule of the participant in site operations. The interview session has taken around 70 minutes and the conversation was recorded with consent of the participant. The firm opts for ISWM projects and they support the MMs in recycling campaigns. Although SALUS is an energy company the firm claims it's sector as environmental management and it opts for carrying out social responsibility projects for the environment.

In summary, we have interviewed eight cases in our research. Three of them (TERRA, CERES and LUNA) are environmental technology firms, five cases are (AURORA, DIANA, MINERVA, FLORA and SALUS) energy firms active in the LFGTE business. Two firms, with the highest years of experience (LUNA and CERES) are environmental technology companies which has foreign founders. Both firms are technically capable of ISWM investments including refuse-derived fuel (RDF)

production, mechanical-biological treatment (MBT), compost and treatment of leachate. Four firms (DIANA, TERRA, CERES, FLORA) have partners which have other business affiliations in the premises of LFGTE project implementation (i.e. local business network). SALUS and LUNA carry out research and development activities in development of machinery, equipment and improvement of operational efficiency. All firms have more than one LFGTE in different cities except for CERES. Only CERES does not have a plant with an electricity market license, all other cases have plants with a license and/or have plants without a license as well. Four of the interviewed firms (AURORA, DIANA, LUNA and SALUS) are involved in the voluntary carbon market with a "*Gold Standard*"[24] certificate. Other firms are not involved in the voluntary carbon market[25]

As the research proceeded, our knowledge of the sector is increased as well. We have acknowledged that LFGTE investor firms are only involved in LFGTE business but not in other renewable energy activities. Therefore, we did not include, other business types as a distinguishing criterion. On the other hand, investment in other environmental technologies is commonly applied by environmental technology firms and is also applied by some of the energy firms. Therefore, we have included investment in other environmental technologies (landfill construction, construction/operation of waste processing plants (RDF, MBT etc.) as a distinguishing factor. Neither LFGTE investor firms of domestic origin nor firms with a foreign shareholder have investments in another country than Turkey. However, foreign

[24] The Gold Standard was founded in 2003 by the World Wild Fund (WWF) and other Non-Governmental Organizations (NGOs) and is acknowledged by more than 80 NGOs as most important best practice standard to ensure projects that reduce carbon emissions or reduce greenhouse gases in the atmosphere. For more information on "Gold Standard" certification one may visit www.goldstandard.org

[25] Turkey cannot benefit from the carbon market mechanism for emission trade because of the fact that it is not a party to the Kyoto Protocol/Paris Agreement. However, a voluntary carbon market is established in Turkey for the sake of environmental and social responsibility, independent from the global carbon market. Voluntary carbon market in Turkey is active since 2005. For the time being there are 27 waste-to-energy (including LFGTE and/or other biogas plants) projects involved in the voluntary carbon market in Turkey. These projects provide 3 mio tons of CO2 reduction per year. One may visit https://iklim.csb.gov.tr/gonullu-karbon-piyasalari-i-4391 for more information on voluntary carbon market in Turkey.

partners of LFGTE firms have investments in the environmental technology, renewable energy and construction sectors in the global market independent from their Turkish affiliations. We have also recognized that, presence of a local business partner within the premises of the municipal authority is a common factor for LFGTE investors.

As the research proceeded, we have updated our sampling criteria according to the mentioned criteria. Endogenous firm characteristics and investment characteristics of the firm establish the firm profiles. We have finished the sampling when we have decided that we have been able to sample from a representative case for each different firm profile for the case of Turkish LFGTE sector. Variables in firm characteristics and variables for types of different LFGTE investments are summarized in **Table 6** below.

Table 6 Criteria for Case Distinction

FIRM CHARACTERISTICS	INVESTMENT CHARACTERISTICS
Year of establishment	Number of LFGTE investments in Turkey
Firm Identity (how the firm defines itself)	Ownership of licensed/not licensed plants
Origin of shareholders	Capacity of owned LFGTE plants
Core business	Business model of PPP
Local business affiliations	Type of municipal authority for the PPP
Voluntary carbon market involvement	Other environmental technology investments
Research and Development Activities	

The firm profiles are summarized **Table 7** in the next page.

Table 7 Firm Profiles

FIRM CHARACTERISTICS								
	AURORA	**CERES**	**DIANA**	**FLORA**	**LUNA**	**MINERVA**	**SALUS**	**TERRA**
Year of Establishment	2007	2017	2005	2012	2002	2011	2010	1994
Firm identity	Energy	Environment Technologies	Energy	Energy	Environment Technologies	Energy	Energy	Environment Technologies
Foreign Shareholder	No	Yes	No	Yes	Yes	No	No	No
Core Business	Power Generation	Waste Management	Power Generation	Landfill Gas to Electricity	Waste Management	Landfill Gas to Electricity	Landfill Gas to Electricity	Waste Management
Local Business Partner	No	Yes	Yes	Yes	Yes	No	No	No
Voluntary Carbon Market Involvement	Yes	No	Yes	No	Yes	No	Yes	No
Research and Development Activities	No	No	No	No	Yes	No	Yes	No
INVESTMENT CHARACTERISTICS								
CASES	**AURORA**	**CERES**	**DIANA**	**FLORA**	**LUNA**	**MINERVA**	**SALUS**	**TERRA**
Number of LFGTE Investments in Operation	4	1	2	> 10	> 10	> 10	2	3
Ownership of licensed/not licensed plants	Licensed only	Not licensed	Both	Both	Both	Both	Licensed only	Licensed only
Capacity of owned LFGTE Plants (MWe)	> 10	< 2	2-10	> 10	> 10	> 10	2-10	2-10

Participant Profiles and Collection of Data through Semi-Structured Interviews

The source of data in the field research was series of semi-structured interviews conducted with experts working for LFGTE contractor firms. A total number of 8 interviews were realized between the beginning of May 2019 and end of September 2019. The interviews were realized by the researcher; in a random order depending on the availability of participants.

Interviewees are selected according to their expertise in the sector being involved in at least one business agreement of investment decision.

Participants to interviews are selected according to these criteria;

1. *Experts who has been involved as a decision maker in at least one LFGTE project implementation period:* The interviewed experts should actively take role in the firm operations together either as a decision maker or together with the decision makers. He/she should be knowledgeable about the decision-making procedures, history and ways of thinking in LFGTE adoption decisions.

2. *At least 5 years of experience in LFGTE sector:* First LFGTE investments has begun in 2005 in Turkey. The participant should be at least knowledgeable about the recent developments in the sector, but preferably should be involved in the sector since 2010. This option is limited to 5 years because, smaller firms have been entering the market and new jobs are being created since the last few years. We did not wish to limit the number of experts to a smaller pool.

3. *Willingness to cooperate:* Participants are selected based on their willingness to cooperate. We have reached the participants through personal connections and/or through business network platforms (i.e. LinkedIn). Their willingness and availability were assessed before arrangement of an interview.

4. *Specific knowledge about waste management regulations;* The participants should at least know about environmental regulations which are directly relevant to LFGTE operations within the project planning, implementation and closure stages.

5. *General knowledge about the sector*: Having worked for more than one LFGTE project is an asset.

6. *Knowledge about municipal waste management*: Specific knowledge about municipal waste management in Turkey is an asset.

All participants were actively involved in business and was responsible for more than one project. It was difficult to address the participants on their office. Instead during most of the time experts claims to be on field duty. Therefore, setting a date for face-to-face interviews in an office has become challenging for the timeline of the research. Finally, we have decided to realize interviews on digital platforms either on skype or by telephone conversation depending on the availability of the participant. Interviewees were reached through either by phone or by their LinkedIn accounts. Information about the scope of research was provided to each participant and their willingness to participate was received. Four of the interviewees wanted to learn more about the scope and privacy considerations of the research. For these participants, the general topics of discussion were shared and the methodology securing participant privacy was briefly explained. Ethical rules of METU and the approval document of the Applied Ethics Research Centre was shared by participants through email before the interview set up has been arranged.

All interviewed participants were male. The oldest participant was in his mid-50s. He is the founder of the company. Other participants' ages change between 35-45. Six participants have a background of engineering, two of them have a Master of Science degree in environmental engineering and one participant has a Master of Business Administration degree. Participants from TERRA, LUNA, CERES and AURORA are technical project managers in the firm. Participants from DIANA and FLORA were administrative managers. Technical managers were able to give engineering suggestions to plant operations and advice for system operations. Administrators on

the other hand, are responsible for assigning consultants and technical managers to site operations. Their scope of business is limited to business arrangements, operation of sites, business development and management of contracts. Each participant has more than 5 years of experience in the sector. Participant of AURORA has been working for the company since a year. However, he has been working for sub-contractors of this company and in affiliated LFGTE projects since almost 10 years. Participant from CERES has an academic background in ISWM, he also has experience in engineering consultancy before his job in CERES. Interviewee from DIANA used to work for an entirely different sector before his job in DIANA. He has begun working for DIANA because of his local knowledge in the project implementation area. After his success in the company as an administrator, he was promoted to all projects' management in the company. The participant from FLORA also as only one-year experience in the firm however, he has been working in the energy sector more than ten years. He was working for a different firm in the LFGTE business, but he has changed his job recently and has begun working for FLORA in 2018. The participant from LUNA has more than ten years of experience in the firm. He has worked most of his professional career in the company. He was hired as an engineer and worked in different positions in the company. Participants from MINERVA and SALUS are founders of companies. Both are entrepreneurs from backgrounds in different sectors. The participant from TERRA, is an environmental engineer who has previously worked in an environmental consultancy company. He has more than five years of experience in TERRA as a technical projects' manager.

Each interview session has begun with a warm-up speech and introduction of the research goals, background and the methodology. Participants introduced themselves and gave brief information about their professional experience. Participants were assured that their initials, private and business-related information are to be kept confidential. All the interview sessions were transcribed, and reflections notes were prepared at the end of each interview session. Names of participants are coded from P1 to P8; specific attributes of participants and given code named is summarized in **Table 8**.

Table 8 Interviewee Profiles

CASE	Interviewee	Age	Education	Position in Firm	Year of Experience in the Firm	Experience in Sector	Strengths
AURORA	**P1**	Mid 30s	Engineer (MSc.)	Project Manager	1	5 -10	Field experience
CERES	**P2**	Mid 40s	Engineer (MSc.)	Project Manager	5 -10	5 -10	Academic background
DIANA	**P3**	Mid 40s	Economist	Administrator	5 -10	5 -10	Local network
FLORA	**P4**	Mid 40s	Economist	Administrator	1	5 -10	Sector Experience
LUNA	**P5**	Mid 30s	Engineer	Project Manager	> 10	>10	Academic Background
MINERVA	**P6**	Mid 50s	Engineer	Founding Partner	5 -10	5 -10	Entrepreneur
SALUS	**P7**	Mid 40s	Engineer (MBa.)	Founding Partner	5 -10	5 -10	Entrepreneur
TERRA	**P8**	Mid 30s	Engineer	Project Manager	5 -10	5 -10	Field experience

In summary, with this set of case studies, we have interviewed 8 of the total set of 23 private LFGTE investor firms in Turkey. These 8 cases represent a diverse group of firms with; different number of investments, different scale of investments with different models, firms also represent different sets of business models (BoO, BoT or PPP) with different municipal authorities (metropolitan municipality or municipal union). Capabilities and identities of firms differ from one another. Therefore, with this approach we were able to cover a diverse set of examples which reflect the Turkish LFGTE market from different perspectives. Our set of case studies represent 60 % of total number of LFGTE plants in Turkey and they represent 80 % of the total installed plant capacity

3.3. Data Analysis Method

We have followed a multiple case study approach to explore variety of cases of LFGTE project investments within a single setting (Eisenhardt, 1989). The qualitative research is aimed for developing an understanding of perception of concepts and constructs by participants. The semi-structured interview guide has formed the basis for categorizing the results of field data. First, answers to the interview questions were grouped under the main categories of;

- Introduction
- Sector Status Quo
- Influencers of LFGTE adoption
- Regulatory influence
- Problems and policy proposals

In the introduction part, we have asked questions related to "*professional background of the participant*", "*business history of the firm*" and "*specific history of firm on LFGTE projects*". While this information helped to warm up the speech, we were able to extract contextual details on firm characteristics and relationship of strategic business decisions to milestones in LFGTE projects. With the help of this section we have been able to identify the "*milestones*" in the history of LFGTE diffusion in Turkey. We have reflected our findings from this section of the interview in the form

of a contextual analysis together with the results of the preliminary study in **Section 4.1.** of this thesis.

After the introduction part of the interview we have forwarded questions related to status quo of the waste management activities within the premises of municipal authority before and after the LFGTE implementation. We have asked four questions regarding; *"share of responsibilities in waste management within the premises of the municipal authority"*, *"basic factors for a municipality to adopt and/or change a waste management technology within its premises"*, *"pre-requisite conditions for LFGTE implementation at a disposal site"*, *"influence of LFGTE projects in sources of income and expenses in waste management business".* Receiving answers to the question on the share of responsibilities between actors has allowed us to understand the economic, legal, administrative, institutional and organizational burdens of key actors in the LFGTE implementation. The answers of firms to the first question in this category were mostly linked to the fourth question regarding the change in income and expenses. The second question on the other hand, has opened a wide window of discussion where firms were able to speculate about a diversity of factors including political concerns, technical needs, regulatory pressure as well as the economic factors to adopt and/or change waste management practice. Clearly, "*decision of municipal authority to adopt the LFGTE technology*" is the prerequisite for implementation of LFGTE technology by a private firm. We have elaborated our findings from this section of the interview in **Section 4.3.1.** of the thesis. The third question regarding the pre-requisite conditions for LFGTE implementation has also revealed information regarding physical, technical, administrative, organizational and institutional constraints for LFGTE project implementation from the perspective of the investor firm which is explained in detail in **Section 4.3.2.** and in **Section 4.3.3.**

We have forwarded questions regarding influencers of LFGTE implementation in the third part of the semi-structured interview. We have aimed to learn about *"the history of projects before the adoption decision"*, *"the decision-making procedure for an LFGTE project investment"* and *"the period after the adoption decision and the first operation of the LFGTE plant"* in this part of the interview. Our aim with the first

question was to learn about factors which have influenced both the municipality and the firm on the adoption decision. During the data analysis, we have also used answers of the participant at the second part of the interview as a cross check to this section. We were expecting to receive repetitive answers, and non-contradicting explanations to adoption history of same LFGTE projects. The interview responses to this section included project specific information which has enabled us to learn about the perspective of participants for each different project case. This section has helped us to understand "*milestones*" in diffusion of LFGTE. We were able to identify three different periods for diffusion process where influential weight of factors has changed based on the institutional and economic environment of the country. We have elaborated our findings in **Section 4.1.** of the thesis. We have assigned drivers and barriers which are explained by participants in the second and third part of the questionnaire under administrative, economic, institutional, physical, political, psychological and technical sub-categories.

The influence of regulations and public behavior to LFGTE projects is questioned with the fourth section. We have aimed to address the influence of regulation specifically because of the theoretical background knowledge of regulatory pull/push effects of eco-innovations. We have asked three questions in this section; "*which national/international legislations are influential in LFGTE technology adoption and how are they related"*, *"which regulations are directly influential in LFGTE technology projects"*, "*how would you define influence of public behavior to your project*". The first question was forwarded in order to understand weight of national and international legislations in LFGTE project investment decisions and the second question was forwarded to understand the general legislative framework, boundary legislations with direct impacts. The final question was asked in order to address the influence of society, if any, to LFGTE adoption. Questions in previous sections were open ended and did not directly address any influencers, this question is purposively asked so that, specific information related to public behavior is not missed as a subject.

Finally, responses to section five, "*problems and policy recommendations*" included questions which addresses the perspective of private firms. We have asked three

questions to participants; "*the greatest problem of the LFGTE sector, what would be the proposal of the participant to solve this problem*", "*room for improvement in the LFGTE sector and recommendations for development", "important factors for decision making, planning and installation periods of LFGTE projects and recommendations of the participant*". In this section we have aimed to understand the perspective of investors about the general bottlenecks of the sector, their vision for development and way of thinking for potential solutions to reach a more advanced stage or to solve initial problems. This section has helped us to see problems of the sector from the perspective of the investors. We have reflected results from this sector to **Chapter 5**.

After finishing the interview session all responses were compiled to the form of written transcriptions. We have classified the responses to semi-structured interview to five sections as defined in the preceding paragraphs. The responses of the "*introduction*" were used as complementary information to the responses from the preliminary study and depicted in **Section 4.1.** Responses to "*regulatory influence*" section were used to complement the regulatory framework in **Section 4.1.** and to complement findings related to influencers in **Section 4.3.**.The responses of section five were used to complement our discussion in chapter 5.

The responses to the "*status quo*" section, "*influencers*" section "*regulatory influence*" section was used as an input to the thematic analysis. Before beginning data analysis, we have stratified the data into two main higher-order categories namely "influencers for municipalities" and "influencers for private firms". Responses of cases are classified to these higher order categories. Later we have assigned sub-categories for each response as; administrative, economic, technical, institutional, political, psychological and physical drivers and/or barriers. After categorizing responses, we have begun the thematic analysis to understand the mostly addressed influencers and their influencing mechanisms.

The first step to data analysis is to design concepts and constructs from "codes" for cases for LFGTE diffusion. Concepts and constructs constitute the major variables in

the qualitative analysis. The "codes" are words and synonyms which are most frequently used and stressed by the interviewees. to define certain cases, situations, emotions etc. Despite the researcher may not be familiar with the terminology in the beginning of the interview process, after the first two interviews certain words appear to point towards certain concepts. Clearly, these words have embedded meanings to participants, and they converge to a certain meaningful context which form the basis of the "inputs" for the analysis. It was our job in the research to mark these words carefully, read through and try to identify "*what does the interviewee want to express*" by putting down these words. We have re-read through the same cluster of responses in order to compare and contrast the wordings preferred by the participants. We have extracted synonymous words and definitions which are used to explain the same concept as "codes". The interpretivist approach has enabled us to iterate through interview texts to discover contextual meanings behind codes. Mostly used keywords (codes), code clustering under sub-categories and the contextual meanings assigned to keywords are given in **Appendix D**.

We have used the thematic approach to explore settings to find out patterns that show differences and similarities among cases. In order to define themes, we firstly have defined main concepts and constructs of diffusion of LFGTE. Then we have followed an interpretivist approach to construct general themes from the constructs (Gioia et.al., 2012). Actual statements of the respondents, the constructs we have formed with the help of codes, themes and aggregate dimensions are tabulated in **Table 9** to **Table 14.**

Table 9 Construction of Aggregate Dimension A: Public Resources

THEME A.1: LACK OF MUNICIPAL RESOURCES	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
They are ready to give the project to the first firm that claims to manage the landfill for free [P2] They save the money by leaving all the operations burden to us [P3]. If we do not operate the site, they must pay for the operation costs [P4]. They would give the landfill operation in any circumstance that would save them from burden of costs and from operational difficulties [P5]. Waste management is such a burden on municipalities shoulders that, their priority is to get rid of this weight as a solution before earning money [P6]. Municipalities' motivation is to cut landfill operation expenses and make money from rental of landfill operation [P8].	The municipality wants to get over with the costs of disposal site management

Table 9. Construction of Aggregate Dimension A: Public Resources (continued)

THEME A.1: LACK OF MUNICIPAL RESOURCES	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
Our main reason to apply LFGTE in remaining organics is that; it will decrease the cost of whole ISWM, which will be to the benefit of the municipality [P2] Municipalities earn money from us. In addition to this they receive a gate fee per ton of waste from public [P3] By allocation of these projects, municipalities generate resources [P4]. Municipalities by right must collect some gate-fee per ton of waste from the residents. With YEKDEM they can do it with a small amount [P5]	The feed-in-tariff subsidy serves as a tool for municipalities for by-passing/decreasing the gate-fee charge on citizens
After 2012, the market got fierce, the municipalities aim for higher profits [P3]. Municipalities want to relive from site operation costs and profit on top of it [P4]. They look for profit from LFGTE plants [P8].	The municipality wants to make profit by privatizing disposal site management
If LFG is not managed with right techniques, it carries a big risk for environment and human safety. The municipality is aware of that [P1] Until 2012, the aim was to get rid of the landfill management problem [P3]. They get rid of the problem because they get into controller position [P4]. Municipalities wish to solve problems from dumpsites such as bad odors, risk of explosion, GHG emission etc. They would say, "save me from this waste problem no matter what [P5]. There is a pressure on the municipalities from Ankara (Central MoEU) and provincial MoEU directorates. They must dump their waste in a proper manner [P8].	The municipality wants to be free from the risks of disposal site management
THEME A.2: AVAILABILITY OF MUNICIPAL RESOURCES	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
They were already knowledgeable about alternative processes [P1] The union has a developed organizational model [P2] Greater cities can prepare the agreements [P3]. Preparation of strong ToRs, getting specification from related firms is extremely important [P5]. The municipality must know to guide the firm [P6]. Our contract with the head of environmental management directorate of the municipality determined the scope of the work [P7].	Technical background of the municipality determines the main framework
First, the amount of waste is important [P1]. The amount of organic wastes is important [P2]. I'd prefer more waste from west compared to less waste from east. The amount is important [P3]. We are not very tendent towards projects smaller than 200 tons [P4]. Population is a determinant of the amount of wastes which is the main determinant of LFGTE implementation [P5]. We just look at the waste amount [P6]. Amount of waste is important for our project implementation decision [P8]	Amount of available organic waste input is a prerequisite for investment in LFGTE
The height of waste, the history of disposal, if it is a new landfill or old landfill is important [P1]. We extract both from the old and new lots [P2]. It is crazy to invest in dumpsite also the transfer distance is important [P3]. If it is not an already established landfill the gas efficiency would be low [P5]. We implemented on landfills, on an already established system [P6]. The place of waste disposal, type, amount is important. Local utilities and infrastructure are important [P7]. It matters if the site is a landfill or a wild dumpsite. We do not apply for wild dumpsites for LFGTE projects. [P8]	The physical characteristics and quality of the disposal site is important for investment decision

Table 10 Construction of Aggregate Dimension B: Financial Resources

THEME B.1: AVAILABILITY OF ALTERNATIVE FINANCING OPTIONS	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
We take a fee from disposal of other wastes [P2]. We want to receive other organic streams, but it is not easy [P4]. We also giver services for medical waste [P5]. We have other services with sludge management [P7].	Accepting/processing different waste streams generates extra income for facilities
When we first begin there were not FiT, we were selling to the free market [P1] Regardless of FiT support, the system can be operated by rent payment to the municipality. Since we pay rent, the more waste means more profit [P3]. When the subsidy is over, probably firms will demand money from the municipalities [P5] If there is not Fit subsidy, then you can upgrade your operation according to the new system [P7].	There are alternative financing tools other than the feed-in tariff subsidy
If the YEK support is completely over, we would store the gas during the cheap price hours and produce electricity during peak price hours [P1]. In the city we don't have that much gas therefore we store the gas in balloons to produce later [P5].	It is an advantage that gas can be stored to produce electricity in peak hours
In Turkey carbon credits is not of a very much attention yet. We are selling carbon credits [P1]. In the past, voluntary markets also had a value. Now there is not an environment to expect a raise in carbon credit values [P3]. The prices are not preferable to sell. We are expecting that position of Turkey will change and prices will go up [P5]. We calculated the amount of carbon in the beginning, but it is too much effort to get this certificate. The prices are not worth it [P6]. It is not easy to register your firm to this international system; it is a prestige and its process and monitoring requires serious labor [P7]. It sure brings some prestige to the project but it has lost its popularity [P8].	Involvement in the voluntary carbon was profitable but now it is just a prestigious investment for future
THEME B.2: CHARACTERISTICS OF FIT	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
We established our firm for privatization projects, we were expecting YEKDEM in 2009 but it happened in 2010 [P3]. We would not think about investing in the waste gas if there was no government support [P4]. YEKDEM was a hot topic, the amount was obvious. The beginning and end of YEKDEM was present. We made our decision based on these inputs [P6] Therefore, we are sure that our project will pay itself off and we will finalize the project with profit before the YEKDEM is over [P8].	The definite time frame of FiT subsidy has compensated risks associated with adoption
First the FiT did not include incineration plants, but with the change in 2017; it covered waste incineration too, some firms try gasification based on that [P3] With this support the government tells us to design our system, innovate and operate sustainably. The FiT is a good amount to innovate and develop technologies [P5]. You need to understand the logic behind this support. The subsidy is a motivation tool for us to facilitate our plants faster, innovate and to relax future pay backs to increase the capacity swiftly [P7]	Diversity of the FiT increased the research and development efforts

Table 10. Construction of Aggregate Dimension B: Financial Resources (continued)

THEME B.2: CHARACTERISTICS OF FIT	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
These technologies are implemented with bank credits and with foreign currency. When your return is in TL and your dept is in EUR, nobody would consider investing in this business [P1]. Foreign currency rates are high; so, the YEKDEM support balances that all utilities are imported, and the waste is not homogenous [P3]. With the FiT support there is no risk of foreign currency [P6]. But for the case of LFGTE there are no domestic engine suppliers [P8]	Currency of the Fit compensated risks associated with dependence on The Foreign Currency
If there is a high waste amount even, you give a high share to the municipality the project will pay off shorter than a small waste facility [P1]. Facilities except for big cities do not profit from this job [P3]. The increase in the feed in tariff made it possible to implement LFGTE in smaller cities too[P5].	The amount of the Fit compensates costs of small-scale projects
THEME B.3: NATURE OF COSTS AND SUPPLIES (COST OF ACQUIRING THE TECHNOLOGY)	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
We have constant costs of engine, piping, rent and gasoline for vehicles on top of personnel and maintenance costs [P3]. Our input for energy comes from the waste site and it is very expensive to prepare the input [P4]. We pay to municipalities, personnel, material, equipment costs etc. The majority is engine maintenance costs. In some cases; leachate treatment and treatment costs are also our responsibility [P5]. We construct the LFGTE system, condition the landfill accordingly, cover operation costs and share a percentage of income with the municipality. With that model, LFGTE plants pay-off themselves within the first 7-8 years of the total 10 years of government support. [P8]	High Operation and Maintenance Costs
We receive ashes after autumn within the mixed waste because the municipality does not apply separate collection due to costs of transportation [P4]. As we cannot collect the wastes separately, we adopted our technology to mixed waste [P5].	Collection and transfer cost of wastes is a barrier to separate collection of different waste streams
Other means of production such as production of natural gas is not feasible. I don't believe that incineration will work in Turkey, it is so expensive now [P1]. It is not attractive to sell it as natural gas [P3]. We do not think that pyrolysis is applicable in Turkey because of the waste characteristics. Incineration is not feasible [P4]. I do not understand why Turkey wants to incinerate, everywhere is full of free space[P6].	Alternative processes are not feasible

Table 11 Construction of Aggregate Dimension C: Business Environment

THEME C.1: AVAILABILITY OF FIRM RESOURCES	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
Our partner was collecting that municipality's waste. [P2]. A brother company was doing the city's waste transportation [P3]. Originally our founders have the mother company in the project city [P4]. We had local affiliations in the very first projects but not after that [P5].	A business partner in the locality of the project area provides a network with the municipality

Table 11. Construction of Aggregate Dimension C: Business Environment (continued)

THEME C.1: AVAILABILITY OF FIRM RESOURCES	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
We invest our own money and we use credit from external sources [P3] We have a large margin of using our own equity and investment credits from development banks [P4] International banks and development organizations show our facility as an exemplary process this is a win win situation for both parties [P5]	Firms use private equity and long-term loans for upfront costs
We invite foreign experts to our facilities and pay them from our own equity to develop these technologies here [P5] We have initiated a TUBITAK project with the university and now we have a company in the techno park [P7]	Firms use private equity and national research funds for research and development
These firms are proposing too high offers to win the tender [P1]. Municipalities share is increased but the investment environment is bad [P3]. Such a ratio from sales does not promise profit [P6]. We have given more shares to the municipality then their original request to prevent other firms to cut out way in competition [P5].	Increased share of municipality profits
We aim for a model to save space and increase the lifetime of the landfill [P2] We opt for landfill operating and energy production [P4]. We apply biomethanisation in all our plants even if it is not requested by the municipality [P5]. Our model is very simple. There is mechanical treatment and electricity production from waste [P6]. Municipalities could tender different types of waste management model in each case. We look for which model is demanded for; we also consider the year of allocation [P8]	Firms prefer to attend specific business models due to associated costs and risks
THEME C.2: COMPETITION	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
The ones which already paid off will not be in a bad condition but most of facilities will lose money [P3] Our advantage was that we were in the first in the market. Municipalities did not know that they could make money from waste [P5]. In those years, municipality could not demand everything in the tender because there were not many firms [P6]. This is how they began; I have seen their contract. It is something like the first mover advantage [P7].	Early adopters have been advantageous in business deals

Table 12 Construction of Aggregate Dimension D: Accumulation of Knowledge

THEME D.1: MUNICIPALITY LEARNING	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
We inform the municipality if it is feasible to tender the facility on the estimated income and lump sum costs [P1]. We have studied Turkish regulations with municipality lawyers [P2]. Some municipalities reach us and ask about technologies to increase their knowledge for tenders [P5]. There were times that we explained the technology to municipalities. There were times that they reached and asked us. [P7].	Municipalities learn from firms to get prepared for tenders

Table 12 Construction of Aggregate Dimension D: Accumulation of Knowledge (continued)

THEME D.1: MUNICIPALITY LEARNING	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
Municipalities visit exemplary facilities [P1]. Experienced municipalities know what they do. Other ones learn from experienced municipalities. [P2]. Investors first would like to see successful operating plants [P3]. Municipalities are a closed circle. Therefore, our job does the marketing for us [P5]. Municipalities see example projects from each other [P6]. They hear mostly hear from each other. They have a sort of communication network among each other [P7]. Municipalities in Anatolia take İstanbul, Ankara and İzmir as an example [P8]	Municipal authorities learn from existing facilities
THEME D.2: FIRM LEARNING	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
This is a system which creates very high return of information. We research, develop technology and start operating within days. [P5] First we did not calculate our production in detail just put an engine with an estimated capacity but then we have seen that we can increase our production [P6]. We have begun with a pilot scale unit and then installed full operation [P7].	Firms Learn by doing
When we were getting prepared for the tender, another firm has helped us calculations. [P3]. We knew that they have a facility close-by and they wanted to get this municipality too, we supported them by not entering the tender as a competitor [P4]. They know that we do our homework before the tender. They look at our number and arrange their offers accordingly [P7].	Active and passive share of knowledge among firms reshape the investment environment

Table 13 Construction of Aggregate Dimension E: Formal Institutions

THEME E.1: CONFLICTS AND GAPS IN POLICY	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
I do not think that the sector will change because of organics limitation[P1]. That would mean that we must recover 65% or the organic waste. This is not likely in the current situation of the sector where energy from landfill is supported[P2] There is no way that it will operate. To store this amount of compost in the area for a week is not possible. We cannot even find a place to give it for free. It is not possible that organic waste will not come to the landfill[P3]. You are composting the organics; you convert organics to an invaluable state and bury it again. You are not able to do anything else [P4]. We can incinerate of wastes and biomethanes some. But with open compost it seems so hard. Then municipalities might have to give organic wastes to firms here and there. It happens now too [P5]. The ministry tells me to decrease the amount of waste in the disposal site. Why would I decrease that; you decrease it at home [P6].	Landfilling Regulation enforces decreasing landfilled biodegradable organics, but this enforcement is not applicable in practice

Table 13 Construction of Aggregate Dimension E: Formal Institutions (continued)

THEME E.1: CONFLICTS AND GAPS IN POLICY	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
The rules should not change after the game begins. I mean, long term policy before all [P4]. A support with a period of 10 years, having such a limitation creates problems [P5]. The issue is the country is not able to determine a long-term strategy since a long time. There are no long-term plans [P6].	There is lack of reliable long-term policies prevents prospects for further development of technology
We receive recycled materials, we make money, but we don't make profit [P3]. What comes to our plants is in poor quality. MBT plants lose money [P4].	Mechanical separation unit is established as an enforcement of the environmental regulation, but its operation is not feasible
There is a conflict of two ministries regulations. And there is conflict in regulations of the MoEU within [P4]	There are conflicts between regulations of MoEU and MoENR and within the MoEU regulations
THEME E.2: INTERFERENCE OF POLITICAL POWER WITH THE FREE MARKET	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
There are problems with priority of law, freedom of speech, democracy. In case of violation of right, we cannot search for our rights in the court [P3]. We expected that guardian ad litem would be assigned, such changes come from the center [P4]	Influence of country macro politics
There are inadequacies facility control due to lack of quality and quantity of staff in provincial directorates of environment.[P2] When I am passing by the MoEU, I feel nervous, their relationships and way of doing business of personnel is more corrupt then the system [P6]. What are the capacities of landfill in Turkey, this data is unknown?...Today, When I ask the MoEU that is the situation in Turkey, they could not give me an answer [P7].	Characteristics of the local and central environmental authority influence compliance to regulations
Political affiliations are required to invest in the sector. Otherwise it is very difficult [P1]. Municipalities do not wish to collect high gate fee from public due to political reasons [P2]. Monitoring and control of facilities are affected by political pressures [P3]. Political tendency of municipalities within the unions becomes important. There may be debates and conflicts among members [P4]. The relationship of the local administration with the government, if there is a conflict between the municipality and the government it effects the time negatively [P5]. We hear a lot of rumors about contractors close to government. But we as opposers must be extremely careful, open and transparent [P6]. Whoever has the political power, has a strong influence in changing the technology investment decisions and gets approval easier in their applications [P8].	Decision making, tendering, implementation and operation of these projects are highly dependent on political tendencies, affiliations, and acts between firm-municipality and local administration
It took 2-2,5 years for the whole approval period even though there were not any requests for revision. [P2] Projects are mostly for 10 years or 29 years due to necessary bureaucratic steps [P3]. Changes in personnel, circulation of personnel in the MoEU is very influential [P5]. First steps to implementation are bureaucratic works. All are simple permits, but the guy keeps the folder in the desk for 6 months just to delay on purpose [P6].	Bureaucratic processes cause time lags in project implementation

Table 14 Construction of Aggregate Dimension F: Informal Institutions

THEME F.1: SOCIAL LIMITATIONS AND REQUIREMENTS	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
Our investment region was a high acknowledged zone. Even if you do not do anything the public pushes you for better management [P2]. Separation at source is dependent on education level of the society [P4]. I don't expect that public will demand up on better waste management based on the level of development increases from east to west [P6].	Positive correlation between level of education and public demand for environmental development
Our country has a feudal village background. Here is Islamic culture, regional geographical conditions [P6]. While all legislations are towards leading to innovation, in our country unfortunately innovation happens in "innovative ways of by passing" the system [P5].	Social, Demographic and Cultural characteristics limits level of environmental development
THEME F.2: MUNICIPAL MOTIVATION	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
The municipal authority carriers out pioneer projects to support its reputation [P1] Municipalities want to keep the gate fee as low as possible because of their political benefits [P2]	Municipalities have political motivations to establish environmental technologies
THEME F.3:FIRM MOTIVATION	
ACTUAL PHRASES	**CONCEPTS/CONSTRUCTS**
Having an investment with positive input to the environment is a serious motivation. We feel happy while contributing to our neighborhood [P3]. We owe to this society. I could have done other business, but I wanted to make a production, something environmentalist [P6]. This is our responsibility to the society. When you are in a business related to environment you have a social responsibility to reflect this to your actions in my opinion [P7].	There are emotional motivations of investors in investment and development decisions
Our job is to produce electricity from wastes [P1]. We are a waste management company; energy production is a supporting role for us [P2] Ours is an energy company, we extract economic value from waste [P3]. Our job is integrated solid waste management. It is also not a big deal to extract the gas from waste. The important thing is to decrease the amount of dumped waste and to find technologies which will decrease amount of wastes [P5] We do not have an opinion about waste hierarchy. We are an energy company. We are recovering the economic value from organic wastes [P6]. Our firm is an active player in renewable energy sector. Our aim is to make projects that contribute to environment and economy and serve to its stakeholders through continuous improvement [P7].	Business identity of the firm determines the project design

CHAPTER 4

FINDINGS

In this chapter, we have described findings of our preliminary study and the field research in three sections. In the first section we have presented the development and current status of LFGTE diffusion in Turkey. In the second section we have presented results of the field research. As a result of iterations of the data; we have categorized and described influencing mechanisms of drivers and barriers to LFGTE diffusion in task environment and institutional environment. In the third section, we have discussed the results of data iterations and summarized our findings.

4.1. An outlook to the LFGTE Diffusion in Turkey

4.1.1. Quantifiable Facts from the Preliminary Study and the Field Research

There are 83 LFGTE plants in Turkey with a total installed capacity of 435 MWe[26]. The total number and installed capacity of LFGTE Plants as of December 2019 is summarized in **Table 15**.

Table 15 Summary of LFGTE Plants in Turkey

	Licensed LFGTE Plants	**Non-Licensed LFGTE Plants**	**TOTAL LFGTE Plants**
Number of Projects	57	26	83
Installed Plant Capacity	322,01 MWe	113,77 MWe	435,28 MWe

[26] 57 of these facilities are listed in the final YEK list of 2020 with a total installed capacity of 322 MWe. Information regarding other facilities (facilities that are not licensed and/or under construction) were retrieved through interviews, provincial environmental status reports, and new from official websites of municipalities and firms in the sector.

The first LFGTE power plant was adopted in Ankara Metropolitan Municipality in 2005. We have calculated the increase in number and increase in installed capacity of LFGTE plants in Turkey based on licensed plant information from the YEK 2020 list of EMRA and complemented this data with our findings from the document review in the preliminary study and responses to semi-structured interview sessions. **Figure 11** to shows the increase in number and capacity of LFGTE power plants in Turkey.

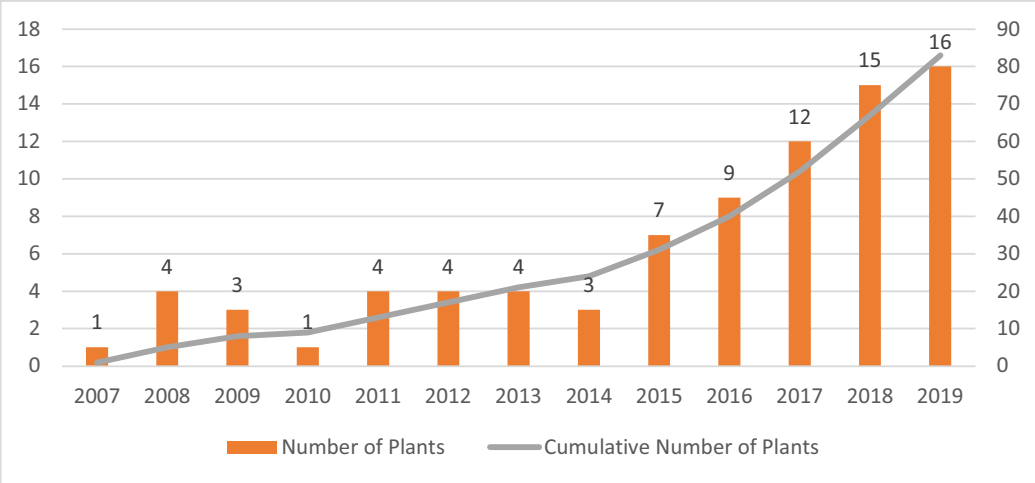

Figure 11 Installed number of LFGTE Plants per year (2007-2019)

Source: YEKDEM Licensed Facilities List 2020, EMRA (2019), Responses to Semi-Structured Interview Questions and the Document Review Study

All LFGTE facilities in Turkey are installed on disposal sites owned by municipal authorities. By the end of 2019 LFGTE technologies are adopted in 57 provinces[27] Installed capacities for LFGTE plants in different cities of Turkey is shown in **Figure 12** below.

[27] There are provinces which LFGTE is not applied but other means of organics to energy conversion is installed (pyrolysis, gasification, incineration etc.). In provinces in the Southeast Anatolia and East Anatolia regions there are either no disposal sites and/or LFGTE investors are not willing to operate there because of political conflicts between the government party and the local administrations.

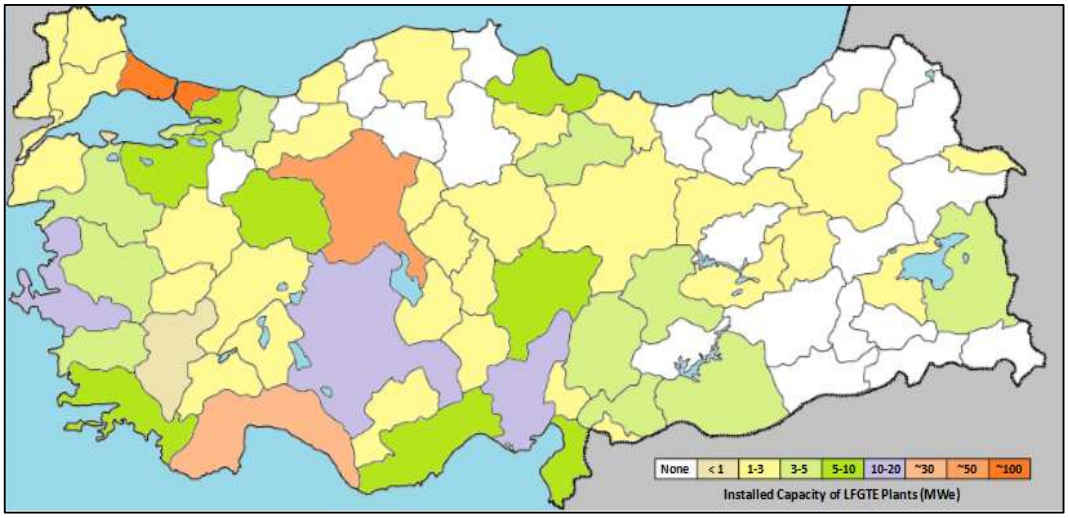

Figure 12 Installed Capacity of LFGTE Facilities in Provinces of Turkey (2019)

Source: Prepared by the author based on EMRA (2019)

4.1.2. The Organizational-Institutional Framework

Main actors in LFGTE sector are the municipal authorities (province municipality, metropolitan municipality and/or municipal union), investor firms, policy makers and local authority (provincial directorates of ministerial authorities). In metropolitan cities, the sole responsible authority for SWM is the metropolitan municipality (MM) and in other cities province municipalities and special provincial administration (city governance) share the SWM responsibility[28].

Municipalities are responsible for providing all services regarding collection, transportation, separation, recycling, disposal and storage of solid wastes, or to appoint other parties to provide these services. In Turkey there are 1397 municipalities[29].

[28] According to the Municipality Law (Law no: 5393, Official Gazette Date: 13.07.2005, 25874) in Turkey; municipalities are responsible for collection, transportation and management (disposal, recovery, recycling etc.) of municipal solid wastes (MSW) within municipality borders. For villages and suburban areas which are not under the borders of a municipality "Special Provincial Administration" (i.e. the local governance) is responsible for management of solid wastes. The Metropolitan Municipality Law (Law no: 5216, Official Gazette Date: 23.07.2004, 25531) states that metropolitan municipalities are responsible for transfer and disposal of MSW within the border of metropolitan cities and district municipalities are responsible only for collection of wastes.

[29] 30 Metropolitan City Municipalities and 519 Metropolitan City District Municipalities, 51 Province Center Municipalities and 400 Province District Municipalities and 397 District Municipalities.

Division of responsibilities between municipalities in metropolitan cities and provinces are summarized in **Table 16**.

Table 16 Division of SWM Responsibilities in cities

TYPE	DIVISION OF RESPONSIBILITY	
	WASTE COLLECTION	**TRANSFER AND DISPOSAL OF WASTES**
Metropolitan City	District Municipalities	Metropolitan Municipality
Provincial City	District and Province Municipalities	District and Province Municipalities (They can form a "Union" to assign this responsibility)

Once the landfill is constructed, municipalities and/or municipal unions are responsible for operating the disposal facilities. Collection, transportation and disposal services can be either carried out by the municipal authority itself or it can be contracted to private firms. The latter is the typical application in Turkey. An LFGTE project is basically about collecting the gas from the landfill site and producing electrical energy out of it. Municipal authorities (municipality/municipal union) may contract different stages of waste management separately or as whole depending on the preference of SWM model. The scope of the business model is framed by the "*Terms of Reference*" prepared by the municipal authority. Occasionally the contracting firm may extent the scope of the contract by means of adding a "bio-methanisation" unit to increase the efficiency of the system. In either case; there are costs (upfront costs and operation/maintenance costs), there are revenues (electricity sales, carbon credits, sales of other products, utilization of waste heat) and there are externalities (knowledge spillovers and social externalities) associated with adoption of LFGTE technology. All tenders must be prepared and processed by the municipal authority in line with the "Public Tender Law[30]". Therefore, tenders should be open to free entry by any eligible firm and it should not limit participation of potential eligible firms. Once the scope of the tender is outlined by the municipality and eligibility of

[30] Public Tender Law; Number 4734 (Official Gazette 22.01.2002, 24648)

the participants is specified, the tender is announced by the Public Tender Institution and any eligible firm (or a consortium of firms) can apply to tender.

As of 2019, there are 53 LFGTE facilities in metropolitan cities (**Figure 13**) in Turkey. The total capacity of LFGTE plants in metropolitan cities sums up to 383,06 MWe which is 88% of the total installed LFGTE capacity. There is at least one LFGTE facility in each Metropolitan city except for "*Diyarbakır*" and "*Mardin*".

Figure 13 Metropolitan Municipalities of Turkey

Every municipality deal with the SWM problem with different administrative models. Financial, technical and institutional capabilities of municipal authorities are important determinants for a sound design of a successful SWM system. Provincial municipalities with similar environmental problems, establish a "Union" in order to carry out SWM services in a more efficient and financially feasible manner. Unions are formed in line with the "Solid Waste Master Plan" of the MoEU. Today there are 59 SWM unions in Turkey (MoEU, 2016). We were able to reach LFGTE projects of 27 SWM unions. Number of LFGTE Plants under the ownership of Municipal Unions are listed in **Table 17**.

Table 17 Number and Capacity of LFGTE Plants under authority of SWM Unions

PROVINCE	UNION NAME	NUMBER OF PLANTS	INSTALLED CAPACITY
Afyon	AFCEBIR	1	2,40
Sivas	SİVCEKAB	1	2,82
Tokat	Tokat Union and Yesilırmak Un.	2	3,70
Zonguldak	**Unknown**	1	2,40
Elazig	Elazığ Municipality	1	2,80
Kütahya	KÜKAB	1	2,40
Canakkale	CAKAB	1	1,20
Osmaniye	Osmaniye SWD Union	1	3,10
Isparta	Göller Region Union	1	2,80
Yozgat	**Unknown**	1	1,40
Aksaray	**Unknown**	1	1,40
Edirne	EDİKAB	1	1,60
Kastamonu	KASMIB	1	1,60
Uşak	UCEB	1	1,20
Niğde	NIGKAD-BIR	1	2,40
Kırklareli	KIRKKAB	1	1,20
Bitlis	BİKA	1	1,40
Amasya	AKAB	1	1,80
Bolu	BEKAB	1	1,10
Nevşehir	Kapadokya Union	1	1,60
Kırıkkale	**Unknown**	1	1,00
Bingol	BİNCEVBİR	1	1,40
Burdur	Burdur Mun. Un.	1	1,50
Yalova	YAKAB	1	1,40
Karaman	Karaman Union	1	1,40
Kırsehir	**Unknown**	1	1,00
Erzincan	**Unknown**	1	1,60
Igdır	Igdır Env. Serv. Union	1	1,20
Kilis	Kilis Mun.Un.	1	1,40

The service agreement between a municipality and a firm is typically achieved through two different models in Turkey; Built-Own-Operate (BoO) and Built-Operate-Transfer (BoT). In such models; the municipality is the owner of the landfill/dumpsite area. It is responsible for all operations, processes, contracted services related to the site against the MoEU. Once the contract (i.e. service agreement) is signed, the contractor firm (i.e. the LFGTE investor) acquires responsibility of operations within the scope of the tender. Expense and income of operations are managed by the private

firm. The firm pays an agreed upon money to the municipality in return to rights of operating the system. The amount of paid share to municipality depends on the type of the projects i.e. costs and return. Once the firm owns the operational rights of the landfill, they build and operate the LFGTE plant and make profit from electricity sales and/or sales of other products (in other units, from other types of processes etc.). The contract time of an LFGTE investment change between 10-29 years. In a BoO model; the firm empties the site (all machinery and equipment) after the contract time is over. Different from the BoO, in a BoT business model, the firm leaves the site operation to ownership of the municipal authority after the service time is over. Therefore, municipality becomes the owner and operator of the plant. **Figure 14** is a schematic representation of landfill management model by the municipal authority.

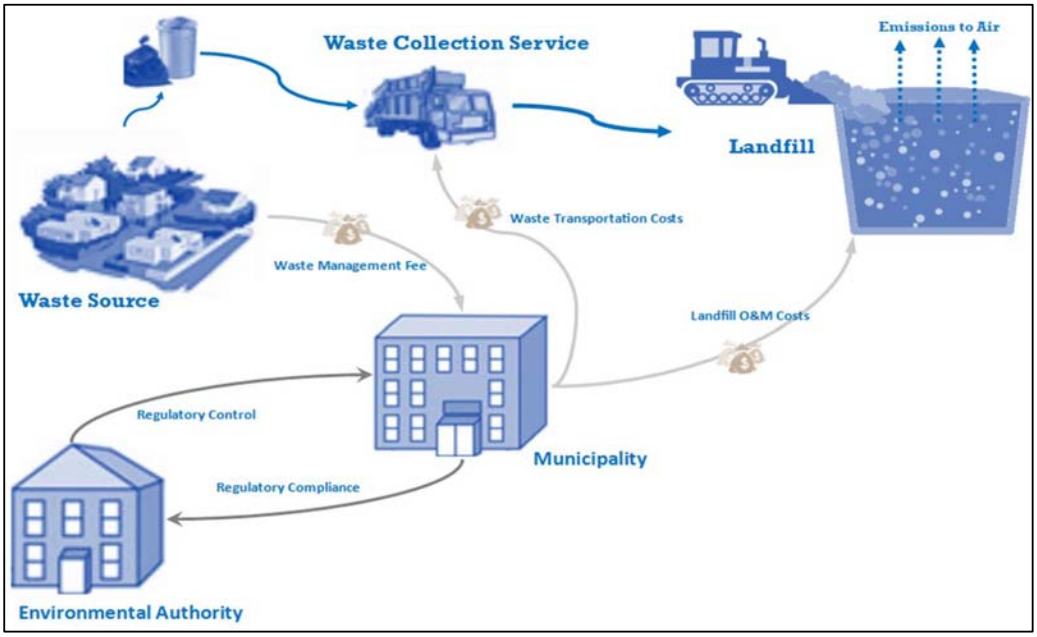

Figure 14 Generalized Model for MSW Landfilling in Turkey

The representation of a SWM model after BoO or BoT type LFGTE investment is presented in **Figure 15** in the next page.

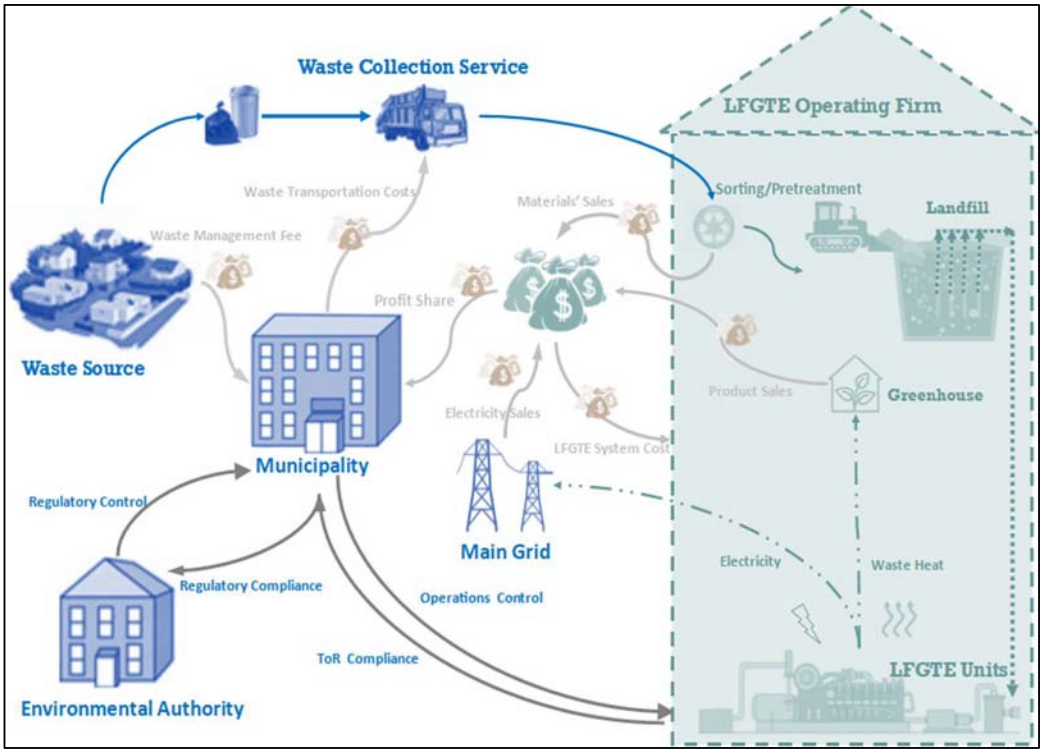

Figure 15 Generalized Model for BoO/BoT type LFGTE Investment model

Typically, operation of a disposal site is a costly process. In addition to this, municipalities must comply with environmental regulations and report to the environmental authority[31]. By contracting the operational rights of a disposal site municipalities seek for advantages of transferring operational responsibilities to private firms so that; they stay in "controller" position while the firm operated the facility in compliance with the environmental regulations and standards. The firm on the other hand, balances the "costs of the site management" with the income of electricity sales and/or other services (i.e. recycled products, greenhouse products, industrial waste disposal etc.).

Another model for LFGTE projects is the PPP between the municipal authority and the private company by a "concession agreement". In this model a cooperation is formed by the private and public entity in the form of a company. All income,

[31] Environmentally sound management of landfills are regulated by central environmental authority (i.e. MoEU) and controlled by the local environmental authority (provincial directorate of MoEU).

expenses, operation and maintenance costs, operational duties and regulatory responsibilities are covered by the PPP initiative. The electricity sales and other sources of income balance the costs of the model. Types of public private partnership business models are summarized in **Table 18**.

Table 18 Types of Public Private Partnership Models in LFGTE Projects

BUSINESS MODEL	SCOPE OF THE PPP	
Built-Own-Operate	i.	Public partner owns the landfill
	ii.	Private partner builds new facility and owns it
	iii.	Private partner operates the facility
Built-Operate-Transfer	i.	Public partner owns the landfill
	ii.	Private partner builds new facility and owns it
	iii.	Private partner operates the facility
	iv.	Ownership is eventually transferred to the public partner
Concession Agreement	i.	New or existing assets are owned by the private partner
	ii.	Private partner operates the facility
	iii.	Ownership is eventually transferred to the public partner

Some municipal authorities prefer tendering the basic LFGTE operation, some prefer contracting other processes to the LFGTE investor firm within a package of business agreement. Solid waste management (SWM) is a complex issue with modular technologies. The scope of a project can begin from just electricity production from the landfill gas, to acquiring additional responsibilities such as dumpsite management, leachate treatment, other operations for waste recycling/recovery and or to an integrated SWM which also includes collection and transfer of wastes. Mostly applied alternative business models in the sector are;

- Just only operation of the LFGTE Power plant
- LFGTE operation with responsibility of disposal site management
- LFGTE operation together with, disposal site management and leachate treatment
- Integrated Solid Waste Management where; waste collection is also included in addition to LFGTE operation, disposal site management, processing other waste streams, separation of recyclables etc.

In addition to these; one or couple of the modular technologies (mechanical separation, bio-methanisation, sterilization, bio-drying, cogeneration, green house) can be attached to any of the models.

As a general rule of thumb municipalities rent the management rights of the landfill for a certain period of time (10-49 years) to the private investor in return for an agreed payment. Terms of payment and terms of landfill operation or operation of the waste management system as a whole is determined by the specified tender and the contractor agreement. Expense and income sources of a project depends on the type of agreement. Typical expenses for an LFGTE project are; materials (piping, layering etc.), personnel, machinery and equipment. In addition to this, landfill operation is a major cost item for projects where disposal site management is the responsibility of the LFGTE firm by the contract. Main income for LFGTE projects is electricity sales and firms also make a little income by selling recyclable packaging wastes. Investment cost of a typical 1 MW LFGTE plant is 3-5 mio EUR. Machinery and equipment is 80% of the total investment cost. Generally, this machinery has a maximum lifetime of 10 years, but they are usually renewed in 6-7 years for the sake of efficiency. Agreement between the municipality and the firm may change based on the; scope of the contract, type of business model and properties of the site.

Municipal authorities charge a SWM fee from citizens per kg of waste disposed in return for waste management services (collection, transportation, recycle, recovery and disposal). The MoEU encourages issuing a gate fee per ton of generated waste. The gate fee should be calculated based on; costs of collection, transfer, transport, disposal and return of sales and it should be affordable. SWM is a costly process; it might not be affordable for the public if all costs are directly reflected to the polluter. The municipality may optimize waste collection frequency and increase fees of the private firms to decrease the burden on citizens. As a rule of thumb by the World Bank, the total cost of the SWM should not exceed 1% of average household income. Municipalities usually charge an environment fee for general environmental services (cleaning of roads, water utility services, wastewater treatment and solid waste management) from the citizens. The higher the cost of environmental services, the

higher the environmental contribution fee will be for the residents in the province/district. As a matter of fact; municipalities are always under the responsibility of meeting demands of the citizens (collection of wastes, cleaning the environment etc.) and keeping the environment fee at a reasonable price for the public. The economic concern of the municipality is also related to its political representation. In Turkey, municipal elections are carried out once in every five years. Candidates of political parties' campaign for the right of municipal governance. Therefore, keeping the balance of environmental services at an affordable price is important for each elected municipal governance.

The Ministry of Environment and Urbanization (MoEU) regulates and monitors design, construction, operation and closure of solid waste management activities in a municipality. The MoEU has initiated many actions related to waste management and regulatory policies. The first legal regulation in this field in Turkey was the Solid Waste Control Regulation (14.03.1991) which provided for and guided practices in the collection and removal of domestic and industrial waste. Revisions of the regulation to harmonize it with the EU Landfill policy were carried out in 2010 (26.03.2010). Solid Waste Management Action Plan covering 2008-2012 was prepared by the former Ministry of Environment and Forestry, using the outcomes of the EU funded Environmental Heavy Cost Investment Planning (EHCIP) Project, solid waste master plan projects and the EU Integrated Environmental Adaptation Strategy (NES) (2007-2023).

According to the Regulation on Landfilling of Wastes (Official Gazette Number 27533, date 26.03.2010): In all landfills that accept biodegradable wastes, landfill gas must be harvested and used for energy production directly or after processing. The gas may be flared if the energy production from LFG is not economic. This regulation also states that decreasing the amount of biodegradable wastes to landfill disposal is essential. Landfilling of municipal solid wastes is discouraged by the waste management action plan for 2016-2023 issued by the Turkish MoEU. The national waste management action plan of the MoEU involves; encouraging mechanical-biological treatment plants (MBT) (i.e. digestors), compost facilities and incineration

plants (in cities of İstanbul, Ankara and İzmir). This strategy also includes recovery of economic value from wastes by means of extracting available methane gas from existing landfills (i.e. the LFGTE) (MoEU, 2016). All these waste management policies and actions in Turkey are expected to reduce the share of GHG emissions from the waste management sector.

The MoEU also regulates environmental licenses and permits in SWM facilities. The landfill operator is responsible from monitoring and reporting landfill operations (wastes are excepted and processed, LFG and leachate are treated, and license conditions are met in line with documentations). The landfill operator also prepares a control and monitoring plan for landfill operations and the landfill operator covers the costs associated with all measures, analysis and remediation of pollution. The facility owner is responsible for monitoring of the site, its maintenance and control after the closure of the landfill facility.

The Ministry of Energy and Natural Resources (MoENR) is the governmental authority responsible from regulating power plants and renewable energy investments including the renewable energy support mechanism (YEKDEM). The main aim of the government is to decrease energy dependency problem and to mitigate the effects of climate change while introducing the feed-in tariff mechanism and associated revisions in the renewable energy policy. A revision on renewable energy policies has begun in 2005 by enactment of the Law on Utilization of Renewable Energy Resources for Generating Electricity (i.e. The Renewable Energy Law (REL), Law No: 5346).

Utilization of renewable energy resources for electricity generation is regulated and supported by the Renewable Energy Resources Law (RER Law, No. 6094) in Turkey which was enacted in 2010. The law includes electricity selling prices, terms, conditions, procedures, and principles concerning the payments to investor generating energy by using renewable energy resources and technologies. The amended REL in 2010 (Law No:6094) has announced that YEKDEM mechanism was going to be issued in 2011. YEKDEM the only support mechanism given by government and includes only direct incentives as monetary support of 13.3 USD cent/kWh for biomass

energy[32]. According to the RER Law the facilities are registered and licensed based on the annual electricity generation rates that they could produce with their installed capacity. The RER Law also requires the facilities to apply for the incentives annually; therefore, the facilities make commitments for the following year's energy generation every year. Renewable energy investors can sell the electricity they have generated to the electrical wiring interconnect systems with the permission of the Republic of Turkey Energy Market Regulatory Board (EMRA).

4.1.3. Findings Related to the Milestones in LFGTE diffusion

Based on our findings, we argue that diffusion of LFGTE technology in Turkey should be studied in three phases. The behavior of actors and influencers of diffusion show differences in each phase of diffusion. When the RER (Renewable Energy Regulation) was first issued in 2005; the amount of FiT (i.e. 5,5 Euro Cent/kWh) was not competitive with the free market prices of electricity. Later, the RER has been amended in 2011; the FiT has been restructured. The new RER includes two different support to the renewable energy investors; Important amendments in the "The Feed-in-Tariff" was the increase in the amount of FiT from 5,5 Euro Cent/kWh to 13,3 USD Cent/kWh and introduction of the "domestic equipment use support". The years of the introduction of the first FiT; 2005, amendment of the FiT; 2011 and up rise year of USD currency; 2015 are milestones in diffusion of LFGTE technology. Later, in Section 4.3.1. we have discussed influencers of LFGTE diffusion with respect to these three phases identified in the preliminary study. LFGTE technology diffusion in different phases is depicted in **Figure 16** below.

[32] For details of this mechanism: http://www.yegm.gov.tr/yenilenebilir/YEKDEM.aspx, Last access: 08.11.2019)

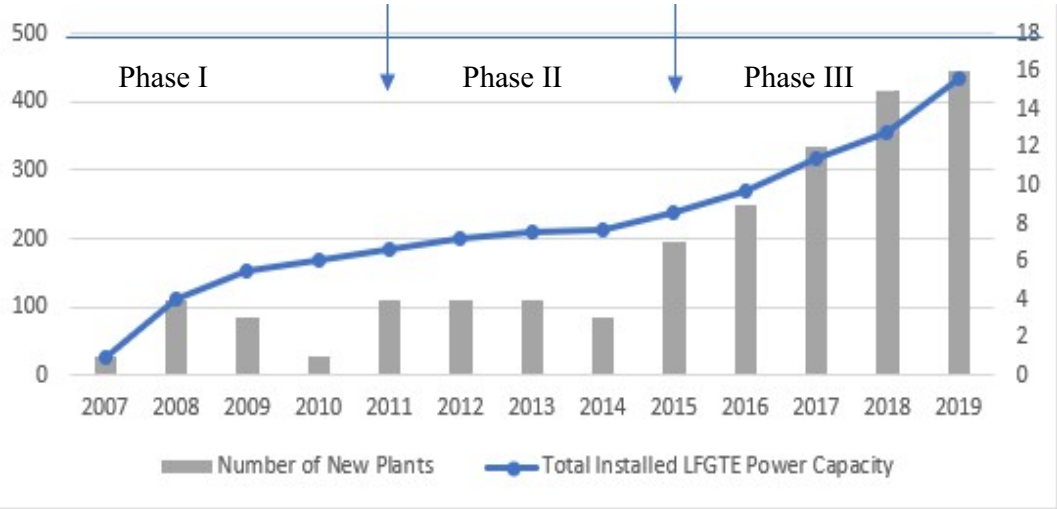

Figure 16 Installed LFGTE Plants and Cumulative Capacity Increase (2007-2019)

The milestones of LFGTE diffusion are influenced directly from the change in the feed-in-tariff policy and the public administration policy in Turkey as well as the macro-economic environment and macro politics. These factors are summarized under "economic", "political" and "institutional" dimensions in **Section 4.2.** Policies which have been a milestone for LFGTE diffusion in Turkey are summarized in **Figure 17.**

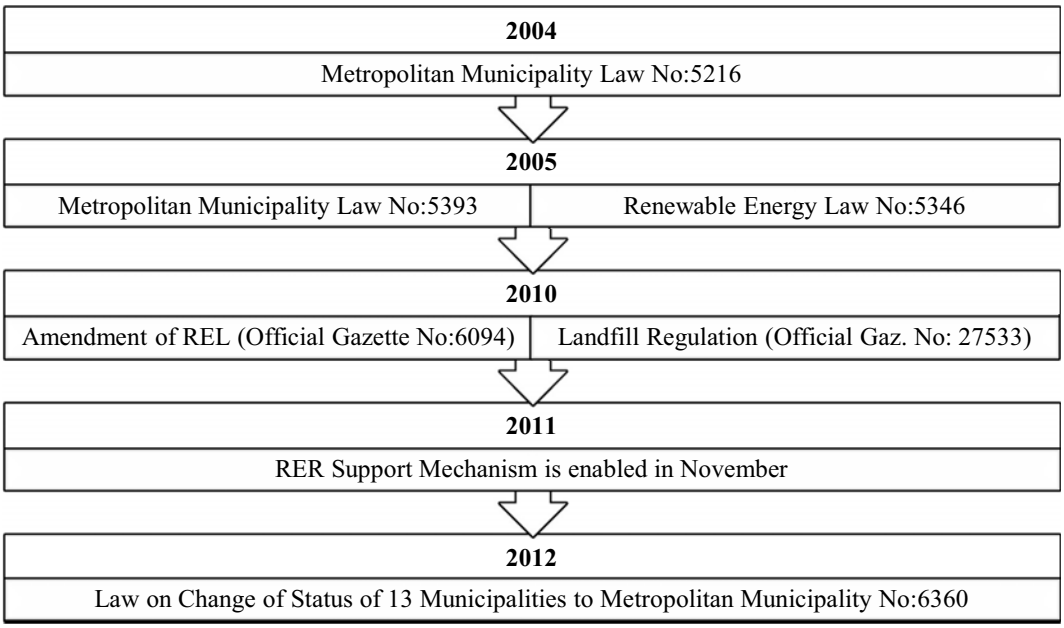

Figure 17 Milestones for the Landfill Gas to Electricity Diffusion Period

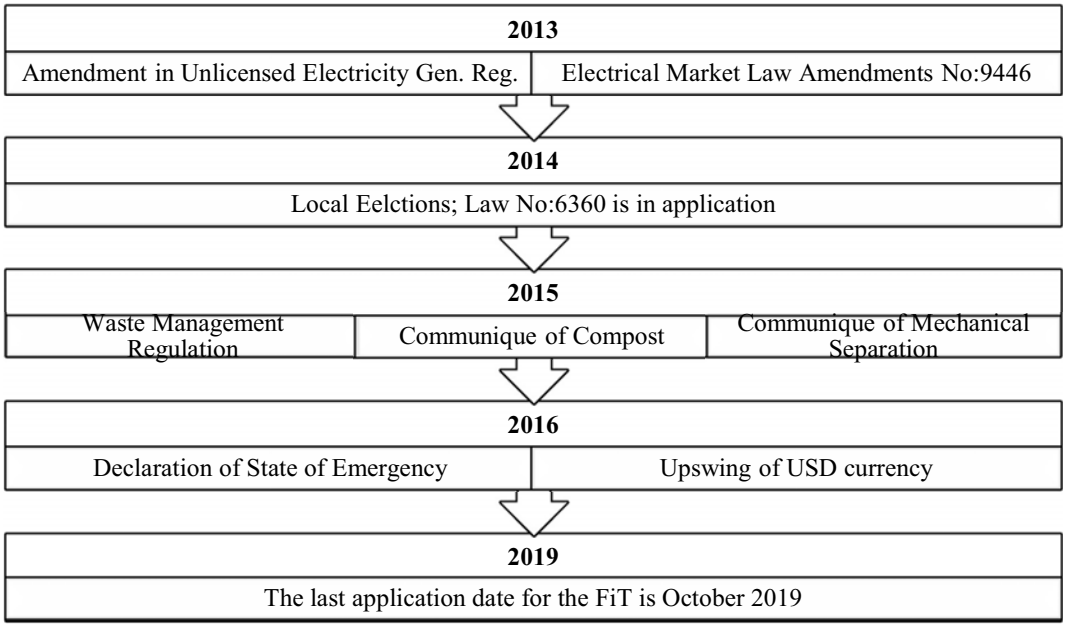

Figure 17 Milestones for the Landfill Gas to Electricity Diffusion Period (continued)

Phase I (2005-2011): The first amount of the FiT subsidy given with the RER of 2005 was not competitive with the market prices. Therefore, early adopters preferred storing the LFG in gas balloons to sell the gas in peak hours to the national grid. In that sense business model between the firm and the municipality was in the form of; firm may pay an annual rent and/or share from its sales to the municipality in return to rights of "utilizing" the resources in the site. By this way a win-win agreement is formed, saving the municipal authority from the burden of disposal site management and providing a guaranteed long-term, predictable investment for the private company. In this period, early adopters have constructed facilities in metropolitan cities with a population over 2 million. These cities have *previously established landfills and dumpsites*.

During the early phase of diffusion, the number of successfully operating LFGTE facilities were limited and municipalities were recently constructing sanitary landfills. Firms were trying to convince the municipalities about the success of the technology while trying to establish sustainable, long-term business contracts. The "distance" between actors due to the knowledge gap of municipalities were gained by organizing visits to exemplary facilities in Turkey and in Europe. In addition to this, partners in business were selected from local affiliates of the municipality to increase the trust in

business cooperation. Technical capabilities of firms were adjusted towards priorities of municipalities (i.e. decrease disposal site management costs and provide technically secure operations). The market was not saturated, and firms have aimed for the cities with high amount of organics.

There were only 3-4 players in the market and a maximum of 8 LFGTE plants but the installed capacity has increased to 200 MWe (i.e. half of the total installed capacity of the country in 2019) already in 2011. **Figure 18** shows the status of LFGTE plants in the first stage of technology diffusion.

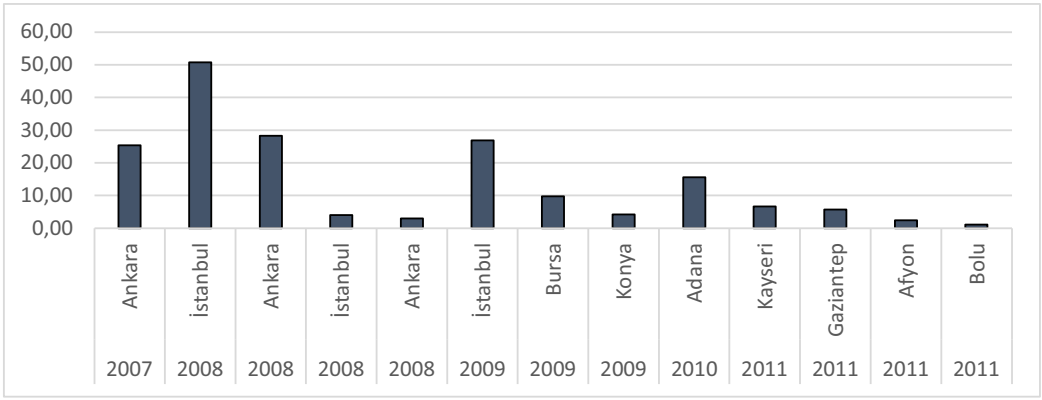

Figure 18 Diffusion of Technology in the First Phase

Phase II (2011-2015); After 2011, when the RER was changed, and the FiT was increased to 13,3 USD cent/kWh attention of more firms was driven to this sector. As there have been more applicants in tenders, the nature of biddings has changed, and the *desire of municipalities* have shifted from "getting rid of risks and costs of disposal site management" to "making money from waste". Therefore, the scope of tenders has shifted from "disposal site management" to "electricity production from waste".

After the increase in the FiT, the barrier of LFGTE implementation has dropped from population of millions to hundreds. Number of projects have doubled whereas the total installed capacity changed by only 20% meaning that; there has been several increases in *smaller scale projects* due to the impact of the *amended FiT mechanism*. The business agreements between the municipality and the firm included a share from the sales of electricity in return for disposal site operations. Municipalities have

included as much as allocation of "costly activities" to the firm while "demanding a reasonable amount of profit" from the company share. With increase of FiT from 5,5 Euro cent to 13,3 USD cent; project scale has dropped to a minimum of 200 tons/day. By the end of 2015 there were about 30 LFGTE projects in Turkey with a total capacity of 250 MWe.

It shall be kept in mind that, *presence of a landfill* is a prerequisite for LFGTE implementation. Turkey has issued its first "Landfill Regulation" in 2010. When it was the end of 2014; only a 64% of municipal wastes were disposed in landfills and 30% was disposed in dumpsites (MoEU, 2016) which might have been a limiting factor for the development of the LFGTE sector in this period.

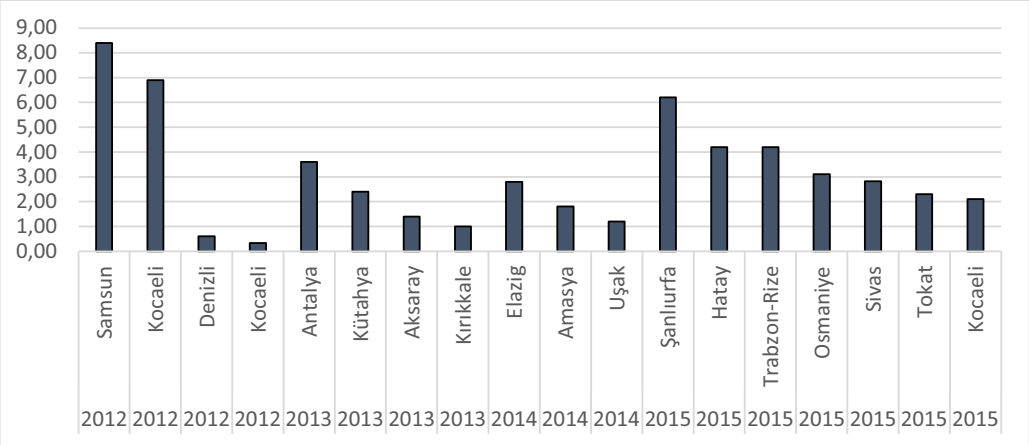

Figure 19 Diffusion of Technology in the Second Phase

As the market has grown and municipalities orientation have changed from disposal site management to making profit from the operations as well, influence of competition has become more effective in the market. The influence of the landfill regulation issued in 2010 was effective in this period in the form of "increased pressure on municipalities to better management of disposal sites" which have increased the demand of municipalities for disposal site management including the costly items such as leachate treatment. The increase in the FiT made it possible to invest in smaller scale projects. The physical limitation of waste amount was mostly removed at these stages with the help of increased FiT. In addition to this, municipal authorities have learned about successful examples of LFGTE facilities and their willingness to cooperate has

increased. On the other hand; there were only 16 metropolitan municipalities in Turkey until 2012. Nine of these municipalities[33] have adopted LFGTE technology within the first phase of diffusion. In Diyarbakır, from the remaining six, neither an LFGTE plant nor a landfill has been constructed due to conflicts of the local politics and the government policy. Municipalities of İzmir and Eskişehir have experienced delays in LFGTE adoption due to; indecision in the disposal technology (waiting for a better technology to emerge). Another reason for delaying of adoption was length of bureaucratic procedures due to conflicts between local administration with the central government politics. Erzurum has the physical limitation due to lack of a landfill site. Mersin has also suffered from political dispute between the local and central administrations. In addition to this, districts in Mersin are located far from each other which has made; planning, design and construction of landfills difficult.

Phase III (After 2015); It was already known to investors that the final date of licensing for the FiT subsidy was going to be in 2020. Therefore, there has been a rush to get approved for the FiT before the end of 2019. Stoneman and Diederen (1994) explain this phenomenon as the "common pool problem". The common pool problem arises when the supply industry is a perfectly competitive environment as assumed by the neo-classical model but there are limited number of potential buyers. Under such an environment; diffusion paths are too fast from the "welfare" point of view because sellers would be in rival with one another to reach as much clients before reaching the finite limit.

In 2014, the environmental permits and licenses regulation (Official Gazette Number 29115, date 10.09.2014) was issued in Turkey. According to this regulation, municipalities must install mechanical separation units at the landfill sites in order to get a landfill operation license. It has been also a common practice that municipal authorities included the mechanical treatment plant construction and operation in the ToR of the LFGTE tenders. Moreover, with the law numbered 6360; 14 Provinces[34]

[33] İstanbul, Ankara, Adana, Bursa, Konya, Samsun, Kocaeli, Kayseri, Gaziantep and Antalya

[34] Denizli, Urfa, Hatay, Trabzon, Aydın, Manisa, Muğla, Balıkesir, Tekirdağ, Ordu, Van, Kahramanmaraş, Malatya, Mardin.

in Turkey has “upgraded” to the status of Metropolitan Municipality in 2012; which have made it easier for these municipalities to arrange tendering procedures. The influence of the *municipal status change* has been effective after the enforcement date of the law, by the end of the local elections 2014. Indeed, 12 of these municipalities have established LFGTE plants after being a metropolitan municipality. In the beginning of 2015, there were barely 12-13 firms in the market and by the end of 2019, the total number of firms has increased to 23. Nevertheless, most of these firms have only 1 or a maximum of 2 plants in Turkey with the total capacity less than 2 MWe. The increase in the total installed power capacity is mainly due to 5 plants (İzmir, Eskişehir, İstanbul and Antalya) in major metropolitan cities of Turkey. İstanbul Municipality has decided to install another two plants. İzmir and Eskişehir were two major municipalities which have delayed LFGTE implementation due to institutional (lack of motivation and bureaucratic problems with the central authority) and task based (lack of knowledge) reasons. Antalya has accomplished tendering the LFGTE operations right after being a metropolitan municipality. It was delayed mainly due to political conflicts within unions for years. These five plants’ capacity sum up to 68 MWe. As of 2019, the amount of landfilled solid wastes has reached 24 million tons by increasing 35% compared to figures of 2014 (**Figure 20**). On the other hand, the total installed capacity of LFGTE plants have increased by 100%.

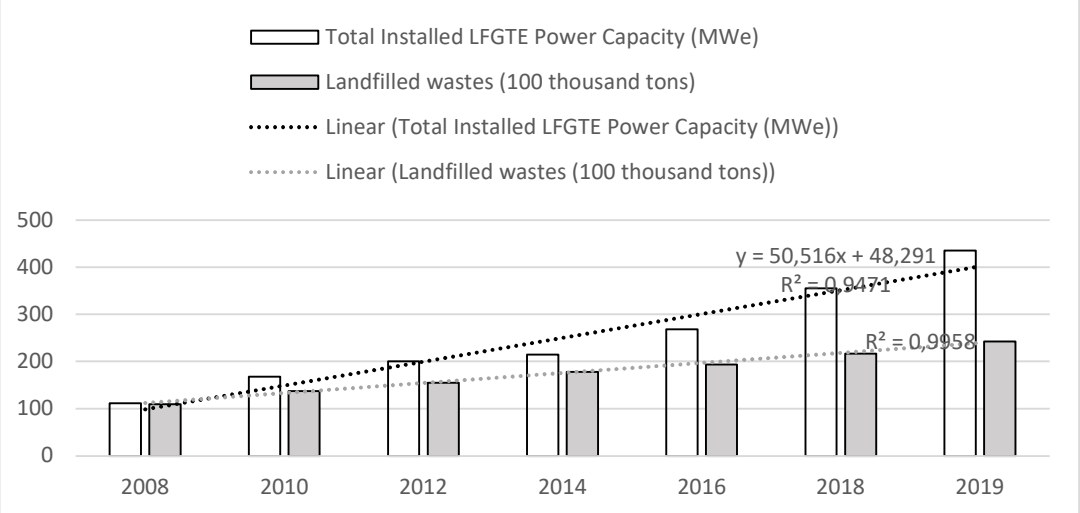

Figure 20 Landfilled amount of wastes vs Installed LFGTE Plant Capacity in Turkey (2008-2018) (TurkStat, 2019)

By the end of 2019; in every municipal authority which has a landfill and can provide at least 200 tons of MSW input/day to the facility a LFGTE power plant is implemented. The total number of plants have increased from 27 in 2014 to 83 in 2019. Likewise, the installed LFGTE capacity has increased from 200 MWe to 435 MWe in the last 5 years. In Phase III, barrier of bureaucratic delays has been mostly removed with the change of status of 14 provincial municipalities to "Metropolitan Municipalities". By this law, municipal unions have been closed and responsibility of disposal site operations are transferred to authority of Metropolitan Municipalities. Physical limitations are remarkable by the end of Phase III as; there are only 24 provinces in Turkey without an LFGTE plant. In six[35] of these plants there is no landfill. In ten[36] of them, the population is so low that there is not enough waste to construct a feasible LFGTE plant even is there would have been a landfill. In Bilecik an alternative disposal technology is applied and in Muş, implementation of an alternative technology is planned. Giresun, Çorum and Düzce are under planning stage for landfill site design including and LFGTE power plant installation. In Ağrı, Mardin and Diyarbakır on the other hand, political disputes between the central government and local authority have caused instabilities in tender and construction of solid waste management projects. The third stage of diffusion is more complicated from the first two stages in the sense that there are three types of investment behavior in this stage;

- First, there are early adopters whose initial investments have almost paid themselves off and these players do not prefer to get into aggressive competition with other firms, their aim is to continue a stable and sustainable operation with the technical experience they have in hand. Therefore, each firm has a characteristics business model and applies for tenders which suit their perspective. These firms have aimed to invest in metropolitan municipalities for large scale projects.
- Second, there are local players, which have only invested in one or a maximum two small scale projects within a certain project location based on their local business affiliations.

[35] Şırnak, Hakkâri, Adıyaman, Batman, Rize, Bartın.

[36] Artvin, Bayburt, Gümüşhane, Karabük, Tunceli, Sinop, Çankırı, Kars, Ardahan, Siirt.

- Third, there are firms in between, which have bloomed in the last years of the second phase and playing aggressively to get a large share of capacity in the market before the FiT ends.

4.2. Results of Field Research

During the field research we have completed eight semi-structured interviews with representatives of LFGTE firms in Turkey. We have performed a thematic analysis on transcripts of interview sessions. In our first iteration we were able to define keywords for general concepts. We were able to define 41 constructs as a result of our second iteration which have merged to 14 themes that point out influencers of LFGTE diffusion in Turkey. These themes have merged to six aggregate dimensions; "*public resources"*, "*financial resources*", "*business environment"*, "*accumulation of knowledge", "formal institutions"* and *"informal institutions"* as a result of our third iteration.

A classification of themes in interview results (**Figure 21**) shows that availability and lack of municipal resources is the mostly mentioned influencers of LFGTE diffusion. Participants usually refer to "availability of organic wastes" as the major determinant for their investment decision. Lack of municipal resources is on the other hand is often mentioned as a factor which influences the "aim" and/or "tendency" of the municipality for the project. It is often stated that; municipalities want to get rid of the waste management problem because it is a technically difficult (and/or risky) and costly activity. Firms state the lack of resources (i.e. financial resources, technical resources, personnel resources etc.) of municipality is a driver for municipality to tender the landfill operations for energy production. Of course, this answer cannot be thought entirely independent of financial influencers of diffusion such as; the FiT mechanism. Clearly, municipalities see the LFGTE projects as an income source so that they tender the operations with the hope of making money from the process. However, statements of participants converge to the fact that; the heaviest factor for the municipality is to get over with the costs of landfill operation.

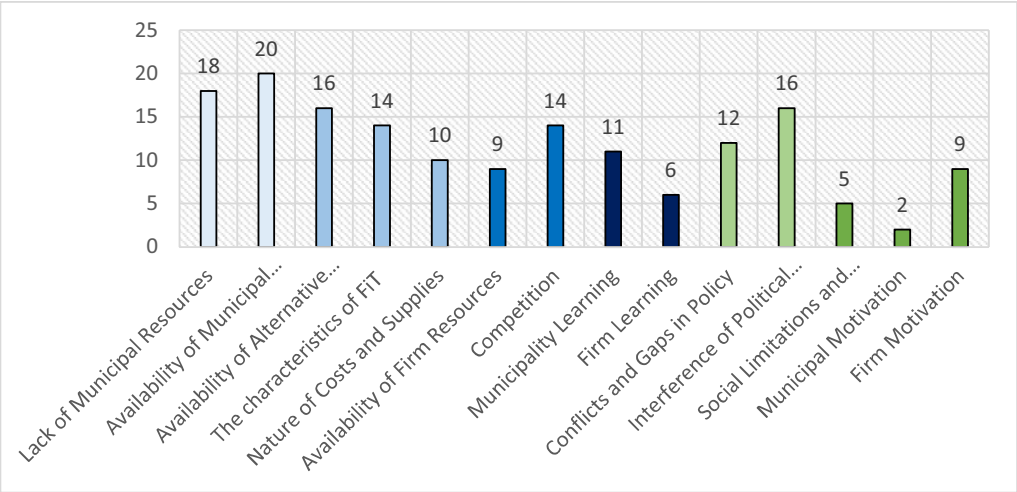

Figure 21 Distribution of Themes in Interview Results

Another distinctive theme is "interference of political power". Influence of political power in LFGTE diffusion is mostly relevant to political nature of municipal authorities. Municipalities act towards the political aim and benefits of the major. Moreover, political power of the major and/or power of the elected party is often expressed by the participants as "influence of political relationships". The most addressed influencer as policy gap is the "lack of long-term policies" in the sector. In addition to this, most participants have emphasized the fact that; requirements demanded by environment legislations are not possible in practice. Influence of political relationships is accepted as a rational fact. It is not referred to be a barrier or driver for diffusion but simply it is seen as a facilitator to enter the market. Lack on long term policies is on the other hand is a strong barrier for development of technologies and investment for long-term projects. Clearly, the FiT acts as a mediator for such long-term hesitations of investors. Most of the participants have expressed their preference to arrange the project return time in line with the end of the FiT support. The predominant market-based instrument for facilitating diffusion of LFGTE is the Feed-in-Tariff (FiT). Each participant has mentioned specific characteristics of FiT to balance disadvantages of barriers to technology diffusion. The renewable energy FiT in Turkey is 13,3 USD-cent/kwh electricity produced by the LFGTE plants. The FiT is based on foreign currency, it is a fixed price for a period of 10 years. This FiT covers not only LFGTE plants but also bio-methanisation facilities which also encourages firms to adopt bio-methanisation technology as an additional

utility to LFGTE facilities. **Figure 22** shows that; financial resources (i.e. market based instruments) are the most influential mechanism in diffusion of LFGTE technologies. Public resources (i.e. availability of feed-source, land, technical resources etc.) is the second most influencing mechanism. A vast majority of answers in semi-structured interviews converge to "task environment" (Mignon and Bergek, 2016) influencers (i.e. public resources, financial resources, business strategy and accumulation of knowledge). Only about a 27% of answers point out that institutional environment (i.e. formal institutions and informal institutions) is influential in diffusion of LFGTE technologies.

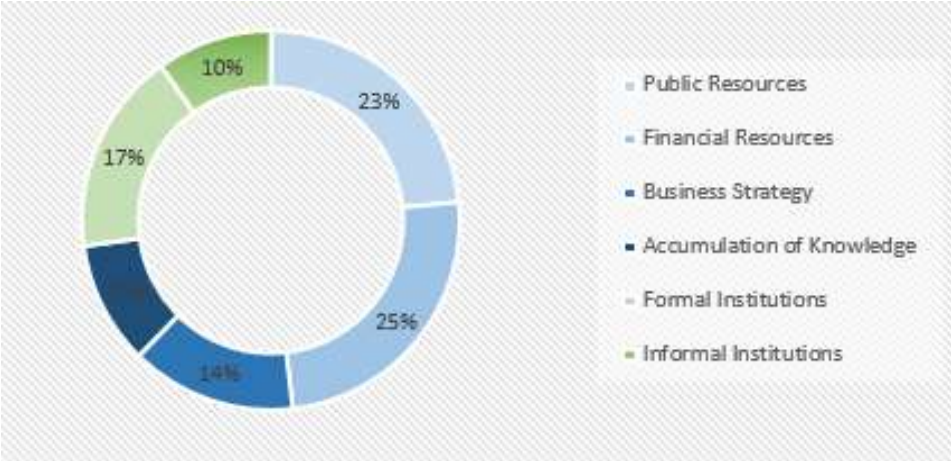

Figure 22 Distribution of Aggregate Dimensions

The number of responses from participants range between 12-29 constructs per participants. Percentage distribution of attributed concepts by participants and number of responses in each theme is shown in **Figure 23**. The results have shown that; the number of responses is directly affected by the length and quality of interviews. Our longest interviews were with P3, P4, P5 and P6. We were able to extract 28, 21, 29, 22 constructs respectively from these cases. On the other hand; we were able to derive only 12, 16 and 17 constructs from interview results of P8, P7 and P1. These three cases were especially difficult to get an appointment for interview session. Participants were busy and they all had another appointment after the interview session. Therefore, their concentration may have not been primarily on the scope of the interview. In our opinion, this may be a factor that caused a decrease in number of addressed constructs by these participants.

Case CERES; which has been represented by P2 is the only "concession agreement" type of business model. The difference in divergence of answers is naturally expected to be due to this variety in the type of business agreement between the municipality and the private firm. For instance, ratio of "formal institutional" and "informal institutional" influencers for diffusion is mostly mentioned by P2. The influence of "financial resources" is distinctively mentioned less than other cases. This can be explained by nature of the "concession agreement" business model. In the concession model, the major financing source of the ISWM system is the solid waste disposal fee paid by the citizens. The FiT is accepted as an additional source of income which increases the income of the system therefore, a decreasing factor for the solid waste management fee. As a matter of fact, financial sources (other services, FiT mechanism etc.) are mentioned less than other business models.

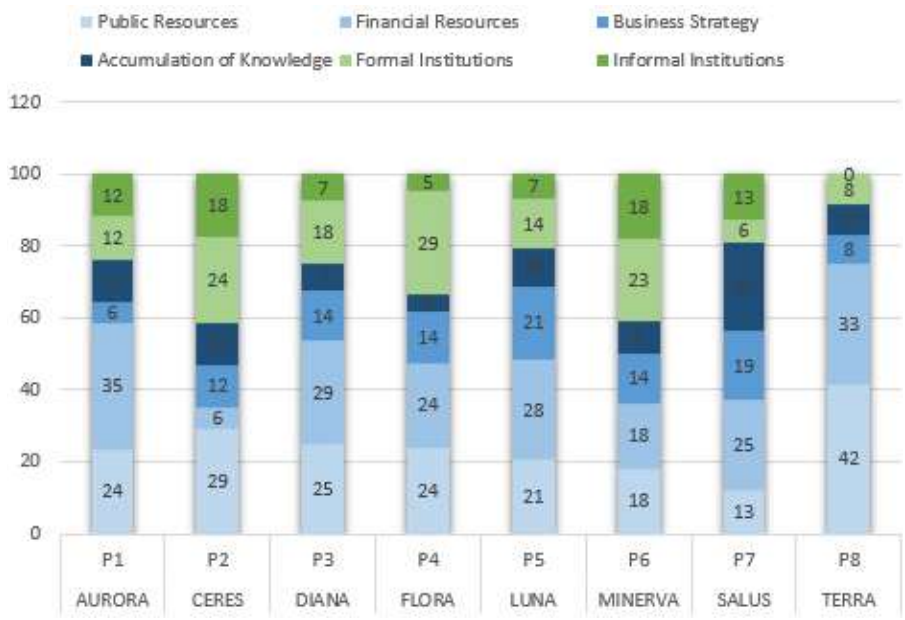

Figure 23 Percentile Distribution of Responses by Participants

Figure 23 shows that P8 has the least response to institutional environment as an influencer for LFGTE diffusion. The case TERRA which P8 has represented is an environmental technology company or Turkish origin. TERRA was the first case study of the thesis. Answers of the participant is rather short. The participant has not

provided a complex network of opinions and ideas observed in other cases. In this case a factor might be the role of P8 in the firm. P8 is a project manager in TERRA. Typically, in all interviews project managers (i.e. technical staff) have not directly addressed the role of institutional factors in technology diffusion. On the other hand, administrators and founding partners of companies such as in cases of DIANA, FLORA, MINERVA and SALUS have mentioned influence of politics, local relationships and regulatory aspects in their investment decisions. Project managers on the other hand, have shared their opinion on the subject while it is structured by the interview questions. Only P2, case CERES, have addressed more institutional factors than others but this is an expected case as the "concession agreement" requires a closer cooperation of the municipal authority and the firm. In addition to that, concession agreement also results in a closer cooperation where the share of responsibilities of the firm towards the MoEU increases with the ISWM model.

The aggregate dimension related to usual business aspects related to the development and production of products that actors exchange in the market (i.e. sources of input, markets for outputs and competitors) are classified as the "task environment". Regulations, social norms and social expectations that individuals and organizations must comply with in order to secure legitimacy, resources and power are classified as the "institutional environment" (Mignon and Bergek, 2016). In Section 4.2 we have discussed our findings related to task environment influencers and in Section 4.3 we have elaborated the findings of institutional environment influencers of LFGTE diffusion.

4.1.1. Task Environment

We were able to define four task environment influencers (i.e. aggregate dimensions) from responses of the interviewees. The task environment primarily exerts demands (or pressures) on actors in the form of requirements on efficiency and effectiveness (for example customers bargaining to get higher-quality products or lower prices) (Mignon and Bergek, 2016). The participants have addressed to nine themes which are; lack and availability of municipal resources, the characteristics of the FiT, availability of other financial resources, nature of supplies/costs, firm capabilities,

competition, municipality and firm learning. The aggregate dimensions which are formed as a result of iteration of themes were; "*Public Resources*", "*Financial Resources*", "*Business Strategy*" and "*Accumulation of Knowledge*". Distribution of number of responses for task environment influencers of LFGTE diffusion in Turkey for each case is shown in

Figure 24.

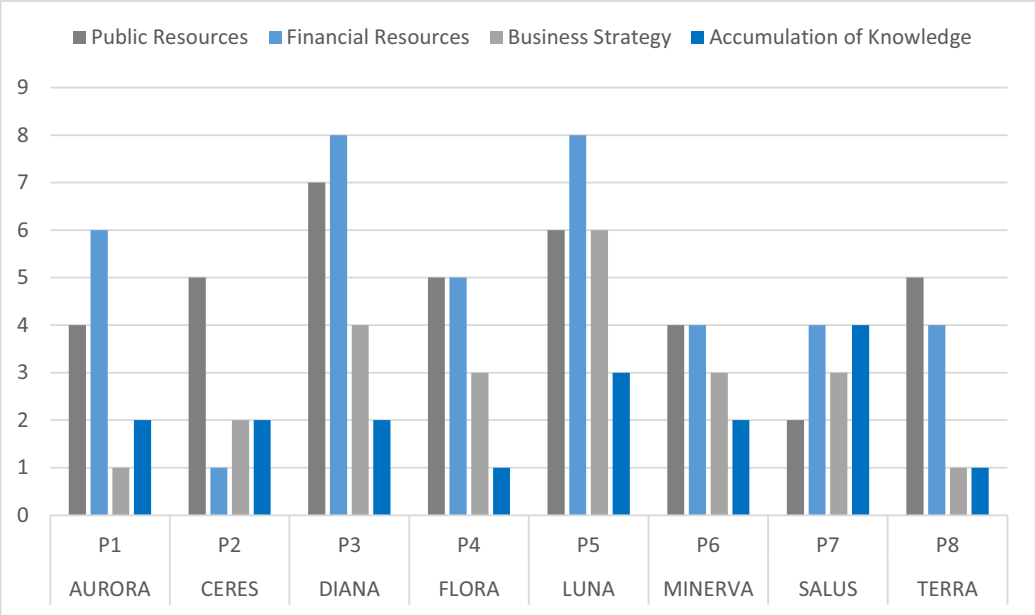

Figure 24 Number of Responses related to Task Environment Influencers

The highest addressed themes are public resources (i.e. lack and availability of municipal resources) and financial resources (i.e. the characteristics of the FiT, availability of other financial resources, nature of supplies/costs) in each case. Accumulation of knowledge (i.e. municipality learning and firm learning) is on the other hand is mostly emphasized by LUNA and SALUS which are the two cases with their own R and D efforts to increase the operational efficiency, plant performance and development of new product/processes. Business strategy (i.e. firm capabilities and nature of competition) was mostly mentioned by LUNA which is proud to be one of the early adopters of the technology in the market and values secrecy of information. Indeed, LUNA was mentioned to be one of the most ungenerous firms when it comes

to sharing information by quite a few participants during the interviews. The most emphasized fact related to business strategy theme was the increased competition. According to results of our case study, after 2012, competition in tenders have become more severe as the share of municipalities have increased above 40% in project sales. Capabilities of the firm is usually seen as, financial credibility, technical capacity (i.e. capability of design, construction etc.) and ability to form partnerships. In cases of CERES, DIANA, FLORA, LUNA and TERRA have partners in business which have other business in at least one of the project locations. Establishing a partnership with a local firm in the SWM business and/or establishing a partnership with a local firm with a strong business history with the municipal authority is a strategy of some firms to design "trustworthy" networks in the project area.

Despite fluctuations in number of responses of participants, public resources have a certain weight for diffusion of LFGTE technologies. All cases except for SALUS have responded that; financial problems and costs of SWM is an important determinant for municipalities to tender SWM operations to private firms. LFGTE has been a form of income to balance the deficiencies of municipal SWM system. The participant from SALUS has expressed their opinion otherwise. They believe that the technology would eventually diffuse because of nature of technological development. The needs of the municipality and the FiT has only influenced the "swiftness" of diffusion, but it is not a major factor for the "adoption" process. The characteristics of the FiT has often been addressed to during the interviews as a major motive for a firm to implement an LFGTE project. However, in cases which also implement other processes and services such as biomethanisation units and disposal of medical wastes, sludges, industrial wastes etc. such as cases of DIANA, FLORA and LUNA; influence of other financial resources were emphasized. Weight of each theme in different cases is discussed and responses of participants are elaborated in sections below.

Public Resources

The "Public Resources" aggregate dimension includes the themes; "lack of municipal resources" and "availability of municipal resources". Our findings suggest that lack of

financial resources in municipal authorities cause a tendency of municipalities to aim for LFGTE technology implementation. The participants have mentioned that;

- The municipality wants to get over with the costs of disposal site management.
- The municipality wants to be free from the risks of disposal site management.
- The municipality wants to make profit by privatizing disposal site management.
- The feed-in-tariff subsidy serves as a tool for municipalities for by-passing/decreasing the gate-fee charge on citizens.

The constructs addressed by the respondents on the availability of public resources are;

- Amount of available organic waste input is a prerequisite for investment in LFGTE (Critical keywords: amount, organic content, tons of waste).
- The physical characteristics and quality of the disposal site is important for investment decision.
- Technical background of the municipality determines the main framework of the project.

Number of responses to two different themes for each case is represented in

Figure 25.

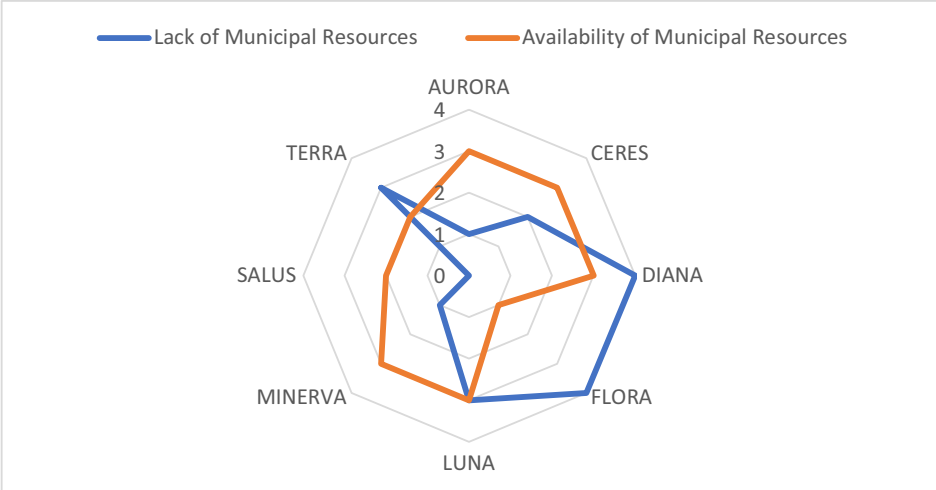

Figure 25 Number of Responses to Public Resources Aggregate Dimension

Both themes of lack of resources and availability of resources are exogenous factors that influence LFGTE diffusion. The influence of "lack of municipal resources" can show dramatic difference from the perspective of different cases however, availability of municipal resources (i.e. amount of organic wastes, availability of land and technical background of the municipality) is a major influencer from the perspective of all cases.

Lack of Municipal Resources

It is often stated by participants that the cost of disposal site management is a problem for municipalities, and they see LFGTE projects as an opportunity to get rid of the site management costs. In addition to this, there are risks associated with disposal site operations. Municipalities both get rid of the risks of operations, they relieve from the costs and make money on top of it by tendering the disposal site operations to private firms which are capable of operating LFGTE technologies. Actual statement of P3 gives a detailed idea of the construct;

> *Before the YEKDEM support, we agreed to pay a rent to the municipality. The municipality wanted to get rid of the landfill management problem. Therefore, they save the money by leaving all the operations burden to us and in addition to this they get an additional income from the rent.*

Representative of CERES, who has a concession agreement with a municipal union states that; lack of municipal resources have resulted in a decrease in the quality of projects in the market. P2 states that;

> *The municipalities lack finances. They are in dept. They are ready to give the project to the first firm that claims to manage the landfill for free.*

Financial problems of municipal SWM does not only decrease the quality of project specifications but also it impacts the framework of the project which results in a decrease in technological development activities of firms. Like P8 and P6 states;

> *Municipalities' motivation is to cut landfill operation expenses and make money from rental of landfill operation. Firms carry the economic burden of operation costs and share the profit of the system.*
>
> *Waste management is such a burden on municipalities shoulders that, their priority is to get rid of this weight as a solution before earning money. Being environment friendly, making an income, carbon saving is secondary on municipality agenda.*

Technical risks of disposal site management are acknowledged by the participants. LFGTE operations is a technically demanding job and firms think that municipalities tender the disposal site management to firms because they do not wish to deal with risky operations of landfill gas management. Almost all participants address this issue as "municipalities want to get rid of risks of site management".

> *Landfill gas is explosive… If LFG is not managed with right techniques, it carries a big risk for environment and human safety. The municipality is aware of that. They had problems of gas compression and landfill slides. They want to get rid of this problem as soon as possible.*
>
> *When these projects first began municipality motive was to be relieved from waste management problem. Municipalities wish to solve problems from dumpsites such as bad odors, risk of explosion, GHG emission etc. They would say, "save me from this waste problem no matter what.*

Our findings suggest that; the first motive of municipalities was to benefit from technical capabilities of private sector to manage a disastrous risk. The value of LFG as a "saleable" attribute has caused attention of private firms to disposal site operations. As a result, municipalities have also acquired a double benefit by allocating the costs of disposal site management to the firm as well. However, introduction of the Feed-in-Tariff and emergence of competition in the market has caused profit orientation of municipalities in the final phase of technology diffusion. The statements of P3, P4 and P8 are good examples to explain that situation.

> *After 2012, the market got fierce, the municipalities aim for higher profits. Share from sales is demanded in the tender terms of reference. The municipality says, I will get my share from the sales and I do not want to be involved in operations.*
>
> *Motivation of municipalities is money. Until 2012 it was to relieve from waste management problem, after 2012, it is to profit.*

Municipalities want to relive from site operation costs and profit on top of it. The cost rises as the dumpsite is more compliant with environmental regulations.

The municipalities cover costs of the SWM services by charging a SWM fee to the citizens and private entities. For the time being, the business agreements of LFGTE projects have arranged so that; firms pay a certain share to municipal authority from the electricity sales. Usually the highest bidder for the share wins the tender of LFGTE plant operation. As a matter of fact; the FiT serves as a tool for municipalities to finance their SWM services. By this way municipalities by-pass/decrease gate-fee charge on citizens. P2 describes that model as the major philosophy behind their business agreement.

Our main reason to apply LFGTE in remaining organics is that; the profit from electricity sales will be deducted from the whole system cost. Therefore, it will decrease the cost of whole ISWM, which will be to the benefit of the municipality. The aim is to keep the service cost at an affordable level.

As municipalities become profit oriented, they have cared less about quality of projects, but they have begun allocating the sites to the highest bidder. In addition to this, they also get a gate-fee from the public. Resultantly the municipalities have become profit oriented; technical scope of projects have decreased. The market is almost fully satisfied and there is a room for alternative business models after the FiT is over. According to P5, the sector will continue operating after the FiT is over but the ratio or model of payment to municipalities will change. Even municipalities might have to pay a fee to the private firm in return for their services if there is no FiT subsidy. P3 and P4 summarized their opinion on final situation of municipalities in the LFGTE business as follows;

Recently, greatest problem of municipalities is equity problem. They cannot find money. By allocation of these projects, municipalities generate resources.

The municipality charges a gate-fee from the public, they also take a share from us. I don't think that they calculate this amount based on our operations. In addition to this they receive a gate fee per ton of waste from public.

The case DIANA (respondent P3) has emphasized that calculating the gate-fee based on actual SWM activities is important in order to reflect consequences of polluting

activities on the public. There might be a possibility that the FiT has been a barrier in application of the "polluter pays" principle. By that way, social reaction for waste minimization, recycling and reuse could have been prevented.

Availability of Municipal Resources

Organic waste flow is the main input of the landfill which is the source of the LFG; fuel of the LFGTE facility. In some cases, biomethanisation facilities are established in order to process organics before the landfill to extract the gas quicker than a landfill operation. Such cases extract biogas from the methanisation unit, and they extract the LFG from the landfill to produce electricity together from both. In either case amount of organic waste input is the major prerequisite for LFGTE investments. In all cases either the "amount of waste" or the "availability of site" is mentioned within the same construct of availability of organic waste input. We have classified the amount of organics is an asset for the municipality because, municipality is the owner of the landfill site and it provides the input to the system. The influence of waste amount is mostly stated by the participants.

> *Amount of waste is important for our project implementation decision. There are several factors that changes the waste amount, for instance scavengers (street collectors), landfill fires, wild dumping are factors that influence the quality and quantity of waste input. We have to know the real amount of wastes before deciding to invest in a project.*

> *We look at scale of the project. We are not very tendent towards projects smaller than 200 tons… We check anything above that. This is our strategy. Greater cities with higher population are attractive to all companies.*

High organic content is also an important factor for efficiency of LFGTE systems, TERRA states that;

> *Another advantage for LFGTE investment in Turkey is that; the content of the waste is high in organics. In theory, it is expected to harvest good amount of LFG from a landfill within 2 years of time. But in Turkey, the organic content is over 50%, even if the 10% does not yield gas; we are able to harvest the remaining part within 6 months after the waste is dumped. We can continue the process for 1,5 years and the organic content is totally decomposed*

According to DIANA the amount of waste is much more important than the ratio of organics. Because the composition of MSW is almost above 50% everywhere. He states that; they would prefer greater amount of wastes with a lower organic content in comparison to low amount of waste with high organic content because yield of the greater amount will be much higher.

> *In my opinion organic amount will not decrease. Therefore, these facilities will not close when the YEKDEM is over. Facilities will go on. In east for example, there is high ratio of organics, but the waste amount is low. I'd prefer more waste from west compared to less waste from east. In Afyon the organic content is high for example, it will yield more gas, but it won't make a huge difference for a waste of 100 tons. The amount is important*.

The physical characteristics of a disposal site (age, type of disposal, operational conditions, distance from the city, lifetime etc.) is another factor which is important for investment decision of firms. There are both institutional and non-institutional reasons behind this factor. Firstly, feasibility of a project is directly related to physical condition of the site. Responses of AURORA, DIANA, and TERRA are examples;

> *The height of waste, if the waste has been dumped before the LFGTE implementation, if it is a new landfill or old landfill is important...*
>
> *The waste amount, location of the facility (it should not be far from energy transfer line), continuity of wastes are all factors for us.*
>
> *It matters if the site is a landfill or a wild dumpsite. We do not apply for wild dumpsites for LFGTE projects. …We do not apply for dumpsite LFGTE projects because plant operation will not be efficient. Dumpsites suffer from wildfires and their productivity decreases*.

It takes some time to for generation of LFG in a landfill. Because of that, availability of an already established site, with a certain amount of readily decomposed wastes (already produced LFG) is attractive for firms. For instance;

> *If it is not an already established landfill the gas efficiency would be low. Organic accumulation in old landfill increases our efficiency. We implemented on landfills, on an already established system*.
>
> *We have a lot of 10 years of age. We plan to install a 1 MWe LFGTE facility by utilizing the LFG from this lot and the new incoming wastes*.

However, legal status, availability of environmental licenses and permits of the site is a factor for the investment decision. According to DIANA;

> *Whether it is a landfill, or a dumpsite has a large impact. It is crazy to invest in dumpsite. If the MoEU shuts down the area, what will you do? It is not about the technical management… I am talking about the legal status on paper. The age of a dumpsite is important gas is present in a new facility. Firms which prefer old sites for gas production are in fault decision.*

In addition to the physical factors such as availability of organic waste stream and condition of disposal site, institutional capabilities of the municipality determine the main business framework; For instance SALUS has stated that;

> *We have our contract with the municipal environment protection department; with the scope of; control of leachate and its treatment, waste characterization, and decreasing biodegradable wastes in accordance with MoEU Landfilling Regulation and the Provincial Waste Management Plan.*

Technical capabilities of the municipal authority are both a guidance and quality control for operations of the firm. The capability of municipal authority becomes especially important when preparation of the Terms of Reference (ToR) of LFGTE projects. The scope and the quality of projects are determined by the technical capabilities of the municipality. Availability of qualified technical personnel becomes an advantage for the municipal authority to develop the system model on their own For example, AURORA states that;

> *The municipality has completed gas potential estimations and projections in 2005. They were already knowledgeable about alternative processes.*

CERES emphasized that;

> *The union has a developed organizational model. They have an example for leading an EU project. 13 People work for the union just only for SWM.*

DIANA brings attention to that fact that capabilities of metropolitan municipalities are more than other cities. Furthermore, MINERVA stated that interaction between the municipality and the firm feeds each other;

The municipality and the firm must have a two ways interaction. The municipality must know to guide the firm. The firm has to know to guide the municipality.

Financial Resources

Participants have mentioned three concepts within the scope of financial resources theme;

- Availability of alternative financing options
- Characteristics of the FiT subsidy
- Nature of costs and supplies

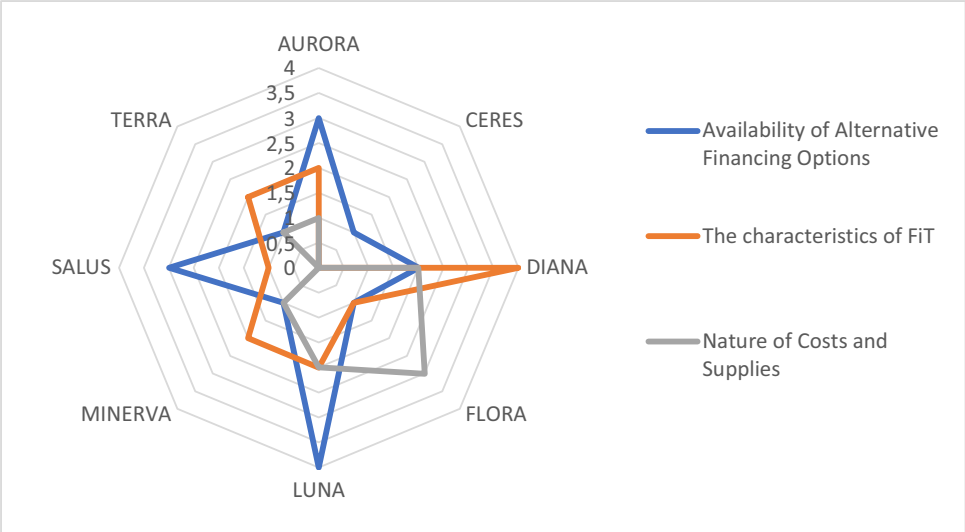

Figure 26 Number of Responses to Financial Resources Aggregate Dimension

Availability of alternative financing options such as; other operational services to industries, gate-fee payment by municipalities etc. is mentioned by AURORA, SALUS and LUNA as major influencers for diffusion. All three firms can provide biomethanisation services, they have developed engineering background with their own R and D efforts. According to DIANA, characteristics of the FiT is the most influential mechanism for diffusion of LFGTE in Turkey. The nature of costs and supplies (i.e. high operational costs) are mentioned mostly by FLORA, which is an energy company with only disposal site operation type of business and minor project with biomethanisation units.

Availability of Alternative Financial Sources

Business agreement and site properties of some LFGTE projects is suitable for accepting and/or processing different waste streams. Services to other waste streams generates an extra income for LFGTE firms. Such services are not necessarily directly related to electricity production. Firms, which allocated operational rights of the landfill may accept industrial wastes, municipal sludges etc. As a result of their service firms can charge a certain amount of fee from industrial facilities. DIANA states that non-hazardous industrial waste input is an extra income source for their facility. LUNA has claimed that services for medical waste disposal is also an income for their facilities. Likewise, SALUS states that; they process municipal WWTP sludges to further incineration in cement plants. This is the singular example in Turkey. This provides 3 million TL savings to the public.

There are also other financing tools than the FiT which is mentioned as a facilitator for LFGTE investments. The first LFGTE facilities were invested almost 5 years before the first FiT support. DIANA has stated that if the FiT was over and no FiT support was given to LFGTE firms, other means of financing would be generated and LFGTE operations would continue. The actual statement of P3 is;

> *Even if there is YEK or not, such system can be operated by rent payment to the municipality. It will not be in terms of share from sales Since we pay rent, the more waste means more profit.*

Similarly, SALUS has stated that; even if there is no FiT subsidy, income rates would decrease but still LFGTE investments would continue to operate.

> *If there is not YEKDEM subsidy, then you can upgrade your operation according to the new system. If you earn 3 million with the YEKDEM, you might earn 1 million without it. Is this money little? Briefly, we will evaluate the circumstances of the day and upgrade our productions accordingly.*

There is a physical advantage of the LFGTE systems. The LFG can be stored in gas balloons to produce electricity in hours where the electricity prices are a peak rate.

This is mentioned as an advantage of this technology just in case the FiT is over, and electricity is sold to the free market. As an example, AURORA has stated that;

> *If the YEK support is completely over, we would store the gas during the cheap price hours and produce electricity during peak price hours*.

LUNA has given an example of a previously experienced situation such as;

> *We operate 7/24 even though it is a free market for our sales. Also, in another site, there is not enough gas to operate the engine for 24 hours. Therefore, we operate fully capacity for 12 hours and rest for the next 12 hrs. We use gas balloons to store the gas*.

There is also the fact of voluntary carbon market involvement. AURORA, DIANA, LUNA, and SALUS have a gold standard accreditation for the voluntary carbon market. Firms which are a member of the voluntary carbon market and firms which are not involved agree on the fact that prices of the carbon market are not feasible to motivate investors to acquire gold standard certificate as "carbon providers". The voluntary carbon market is accepted as a "prestige" and investment for future from the perspective of companies. AURORA which has a gold standard states that;

> *Our job is directly related to climate change. We provide reduction of methane which is 20 times harmful than CO2 for climate change. We earn carbon credits with our facility. In Turkey carbon credits is not of a very much attention yet.*

DIANA who is not accredited by the gold standard has a likewise statement;

> *Climate change policies are directly related to our job. However, climate change is not hot topic in Turkey. If carbon market is active, it would be to the benefit of our sector. Mandatory carbon neutralization would be very effective. Now we have a voluntary market in Turkey. Under this economic circumstance, even in international market selling credits is not attractive. In the past, voluntary markets also had a value. Unless the USA is involved in the global carbon market, we do not expect a raise in carbon credits.*

The firms which do not have a gold standard validation for voluntary carbon market state that the bureaucratic procedures are long and costly. These firms support that the involvement in the carbon market is not feasible and being a gold standard firm is not feasible now. For instance, MINERVA states that;

> *Kyoto is meaningless. There is no such a market yet. If there is no global action on sources of climate change you cannot solve it by local solutions. In the current situations of the market there is no buy-sell circumstance. When we first begin, the ton of carbon was 4 EUR. But the prices have fallen now. If you find a client for 1 euro in the voluntary market, you can give it. But you must get accredited and the procedure is difficult, you would not want to deal with it.*

Or similarly, TERRA has said that;

> *We have studied the carbon credit option in the beginning. It is more like a commercial issue. It sure brings some prestige to the project but it has lost its popularity. I mean, it brings a value, but its expenses are much more than that.*

In summary; business agreements allow some firms to sell services other than LFGTE. Firms may accept non-hazardous industrial wastes, medical wastes, wastewater treatment plant sludges. Costs of these services are charged to the polluter by the firm. In addition to this, firms may charge a gate-fee per ton of wastes disposed by the municipality. Environmental technology firms, which acquire disposal site management and integrated waste management responsibilities of a municipality make use of such alternative waste stream inputs and management services as an extra source of income. Availability of alternative business models is an influencer to implementation of LFGTE projects by firms of environmental technology origin. In addition to this, firms which have adopted the LFGTE technology before initiation of the FiT mechanism and/or firms which has facilities already out of the scope of the FiT support are more aware of other models of business agreement with the municipality. Firms do not think that the FiT will be over soon but even if there is no FiT mechanism, the LFGTE technologies will continue to operate because of presence of landfilled organics. In this sense, new business agreements between the municipality and the firm may be designed. The advantage of the LFGTE system is emphasized to be "storability" of the gas. Therefore, LFGTE plants can operate during the peak hours of electricity. This is likely to be the case if the FiT is over. The plants would store the generated gas in gas balloons and produce electricity to the grid when the prices are at peak.

The factor of voluntary carbon involvement is often mentioned in cases. Firms have to be accredited by the "Gold Standard" to be carbon seller in the voluntary carbon market. Members of this market can sell carbon credits to firms which produce carbon emissions. At all cases, participants state that; accreditation for carbon market involvement is a long and difficult process. It is also often stated that; the carbon credit prices were around 4 EUR in the beginning (in 2005) but the prices have fallen almost to $1/10^{th}$ of initial rates. Therefore, firms cannot consider carbon credits as a reliable source of income. Firms which are a member of the voluntary carbon market consider this as a "prestige" and a measure of "quality" of operations. Carbon market involvement is also perceived as an investment for future (i.e. to establish an organization in case Turkey becomes a party to Kyoto and the carbon off-setting becomes obligatory and just in case the prices rise).

The characteristics of the FiT

The FiT subsidy 13.3 USD cent/kWh produced electricity, is valid for 10 years for LFGTE investments. The 10 years definite time frame for the FiT compensated the risks associated with adoption of the LFGTE technology. Firms calculate the feasibility of their investment plan in accordance with the 10 years FiT subsidy. The projects are aligned to pay-themselves of within the period of the FiT. For instance, MINERVA and TERRA state that;

> *YEKDEM was a hot topic, the amount was obvious. The beginning and end of YEKDEM was determined. We made our decision based on these inputs.*
>
> *Our plants have a lifetime of 10 years, we will collect our equipment of leave the site after the support is over.*
>
> *We have made our plan and calculations for the YEKDEM support period before getting into the tender. Therefore, we are sure that our project will pay itself off and we will finalize the project with profit before the YEKDEM is over. We do not have an action plan after the end of YEKDEM.*

FLORA states that they would not consider investing in the LFGTE business if there was no FiT subsidy;

> *We would not think about investing in the waste gas if there was no government support. No one would. Because it is not feasible. In that case, municipalities are left alone with the MoEU.*

DIANA has entered the energy business after the privatization of public power plants. However, they claim that they knew about the RER and the FiT subsidy before entering the business. The FiT was a factor for their business in the LFGTE sector. TERRA, which is an environmental technology company, has stated that; the FiT support was their initial motivation for investments. DIANA and TERRA stated that the time of the support is important for calculating the project pay-back times. Besides, a project agreement with a shorter period than the FiT is not found feasible by these firms.

The LFGTE sector is import dependent. Reciprocating engines which are the major equipment of electricity production are imported. Moreover, firms get long-term loans from banks based on foreign currency. Therefore, the foreign currency rate of the FiT has been a risk carrier for the foreign currency-based costs. For MINERVA with YEKDEM support there is not risk of currency rate swings.

DIANA has expressed its opinion that the import dependence of the sector is balanced by the rates of the FiT. AURORA, one of the biggest players of the market thinks that a change in the foreign currency-based nature of the FiT will be an obstacle for the sector.

Similarly, TERRA states that;

> *We work with sub-contractors to complete a project. We work with local companies for construction supplies. But for the case of LFGTE there are no domestic engine suppliers. There are small engines, micro engines but these are not suitable for LFGTE operations. The machinery easily rusts out. We have a serious expense in foreign based currency*

According to DIANA the FiT also balances the risks of non-homogenous nature of the municipal solid wastes. Typically, the greater the amount of wastes the shorter the payback time for LFGTE projects. Therefore, the FiT acts as a mediator for small scale

projects to compensate costs and risks associated with economy of scale. This phenomenon is simply expressed by AURORA as such;

> *If there is a high waste amount even you give a high share to the municipality the project will pay off shorter than a small waste facility. The smaller the facility the smaller the amount that will be given to the municipality*.

Smaller scale projects barely pay themselves of. For instance, DIANA has replied to a question about the inclusion of public interest in their projects as;

> *Facilities except for big cities like İzmir and Ankara do not profit from this job. For example, I really wanted to have budget in the project area to deliver souvenirs in schools, give trainings, to generate indirect positive image and to create culture of separation at source. But you cannot offer this to the investor before the plant pays the investment cost*.

LUNA has some of the major projects in the country. They say by the experience that;

> *Population is a determinant of the amount of wastes which is the main determinant of LFGTE implementation. Projects which serve to a higher population more easily pay off itself. For cities over 1 million population the first YEKDEM was enough to implement good quality ISWM projects. The increase in the FiT made it possible to implement LFGTE in smaller cities too*.

The scope of the FiT subsidy has led to development of other technologies that support and/or develop LFGTE. LUNA interprets the YEKDEM regulation as an opportunity to develop technologies;

> *The meaning of the YEK regulation is that; I set you a target of 10 Euros, you should innovate, develop your technology, and take this as high as you can. When there is a situation that you cannot go higher, than municipality should pay by distributing the costs to citizens with affordable prices. So, the system will be self-sustaining. This is very much doable. That means the municipalities burden will decrease a little. Because as a firm which will sell the product to 13,3 USD cent, we can offer our services to the municipality at a much lower price*.

For SALUS, which has a common ground of dedication to Research and Development with LUNA, the meaning of YEKDEM is also close;

> *You need to understand the logic behind this support. The subsidy is a motivation tool for us to facilitate our plants faster and to relax future pay backs to increase the capacity swiftly. It is nonsense to say, if there is no government subsidy these facilities will not be implemented, and they will be closed after the YEKDEM is over*.

He adds that the FiT is not a facilitator for adoption but; it has increased the swiftness of diffusion by allowing firms to develop their technologies and invest in smaller cities.

> *You may think that if there was not YEK support there would not have been this many plants. But I do not agree to that. Actually, I totally disagree. The ministry of environment is also with the same opinion. In last 3 years, firms in tender has given around 50% share of sales to the municipality. That means you can do your investment without half of the 13,3 USD cent support. That means you are OK with 7 cents. The electricity market is 4,5-5 USD. There is not much of a difference in between*.

Clearly characteristics of the FiT has played a role in development of the LFGTE market in Turkey. Our findings show that the FiT have balanced the risks of investment were there are small scale projects (smaller than 1 million population), it balanced the risks associated with the import-based supply market and investment loans in foreign currency. The 10-year period of the FiT support has made long term projects possible while creating a financial credibility of projects. In addition to this, the scope of the FiT includes technologies such as biomethanisation, pyrolysis etc, which are implemented by LFGTE firms as an auxiliary unit which increases the efficiency of disposal site management.

Nature of Costs and Supplies

Typically, LFGTE plants have high operation and maintenance costs. The rust out of equipment and the need for continuous renewal and upgrading is often mentioned by the interviewees. For instance, FLORA has said that;

> *You have to constantly upgrade facilities. You must leave these facilities in sound operation conditions to municipalities in BoT projects. You must change engine parts every 4 years.*

In addition to this, a landfill site is a live system where there is a continuous operation of waste layering, covering and gas extraction. Different from other renewable energy plants; LFGTE facilities do not have the luxury to "shut down" even though they do not produce electricity. That means, the disposal site operation runs 7/24 as long as the city services go on. FLORA states that the input of an LFGTE plant is expensive and it requires continuous attention of the operator which is technically risky and difficult. This is a basic barrier for investment of firms in the sector. According to FLORA;

> *For the moment market electricity sales prices about 4-5 cent /kWh. My production cost is around 4-5 cents… Our input for energy comes from the waste site and it is not cheap. There is the site operation cost, piping costs, and the investment. It is different from solar and wind power. It is also different on the fact that; we must operate 7/24. We must constantly maintain a good operation. Otherwise fixing the situation fixing it is even more costly. That means we really have very high operation and maintenance costs*.

DIANA also emphasizes the high operation costs of facilities;

> *Engine, piping, the biggest expense is the rent paid to the municipality. We also pay gasoline costs for site management vehicles (compactors, trucks etc.) Imagine buying 100 liters of diesel for 1 hour of work for each site. We also have personnel costs and maintenance costs*

For LUNA, maintenance cost is a major item but they also state that operational costs increase with the increasing scope of the SWM projects. For just only LFGTE projects, the costs are comparatively low.

> *Our major expense is the share given to the municipality. In addition to this, we have operational costs such as electricity, personnel, material etc. ISWM facilities require more personnel therefore have more operational expenses. Projects with only LFGTE systems have very little costs after construction in comparison to ISWM systems. The majority of expenses is engine maintenance costs. In some cases; leachate treatment and treatment costs are our responsibility too*.

Despite the obstacles of operational difficulties and high maintenance costs, alternative processes of LFGTE technology are not often found feasible in the market. The comparative advantage of feasibility among alternative technologies has become a facilitator for diffusion of LFGTE technologies in Turkish market. For instance, AURORA has searched for the option of producing "natural gas" from the LFG and

selling it to the national grid but they were discouraged by the prices of natural gas compared to treatment costs of LFG.

> *Then we look at the price that we can sell the gas. The selling price of the natural gas does not pay off the gas treatment cost of the gas. Other means of production such as production of natural gas is not feasible.*

DIANA has made a similar research a concluded that alternative utilization of LFG as natural gas is not feasible in Turkey;

> *In Turkey the gas ratios are 52-53 % methane and this number rises up to 54-55% after the sacrifice feast[37]. It is not attractive to sell it as natural gas. In the pipeline there is a pressure of 4 bar. You must raise the pressure above that to pump the gas in. It is not attractive to increase the pressure. Heating may be more attractive that electricity production; but we also harvest heat as a byproduct. If the natural gas prices increase heavily then it might be preferable. Now sulfate derivatives are not removed from the gas.*

FLORA has become critical about pyrolysis processes; and it has criticized the strategy of municipalities to "wait for the better technology".

> *Some municipalities delayed LFGTE projects because they opted for higher technology processes. Then they could not do higher technologies and they tendered initial system whatever they have available in hand.*

LUNA and MINERVA stated that landfilling is feasible because there is plenty of free space to dump wastes. They argue that incineration is not a feasible process due to long period of payback time. They have also criticized organic waste processing by bio-drying and biomethanisation due to additional need for energy input in the system.

An often-emphasized construct within the discussions was "costs of waste collection and transfer" … Collection/transfer costs are mentioned as factor which hardens separate collection of different waste streams. When firms were speaking about the content of wastes and upgrading the waste management system to Zero-Waste principle, FLORA and LUNA have stated that;

[37] An Islamic worshiping ceremony which is held for a week once a year in the country. In the sacrifice feast ceremony, a huge number of animals (i.e. cows, sheep etc.) is sacrificed to god by Muslim citizens.

In our plants we receive ashes in autumn period. For separate collection of organics, municipality has to issue a separate collection system, different vehicles for collection, Changing the system is not our responsibility, it is an extra cost for the municipality, they would not do it.

Two-way separate collection is not present in any of the municipalities. That would be very much to our advantage, but it is not present unfortunately. We cannot demand this from municipalities because that would require modification of all waste collection trucks in the municipality. We adopted our technology to mixed waste.

Business Strategy

So far, we have mentioned exogenous factors for diffusion of LFGTE based on themes of Public Resources (i.e. resources of the municipality) and Financial Resources (availability of initial and alternative financial options). Our findings have shown that endogenous firm capabilities and the nature of competition in the market are two factors that have influenced diffusion of technology. Responses to endogenous (firm based) and exogenous (competition based) factors of business strategy are schematically represented in **Figure 27**.

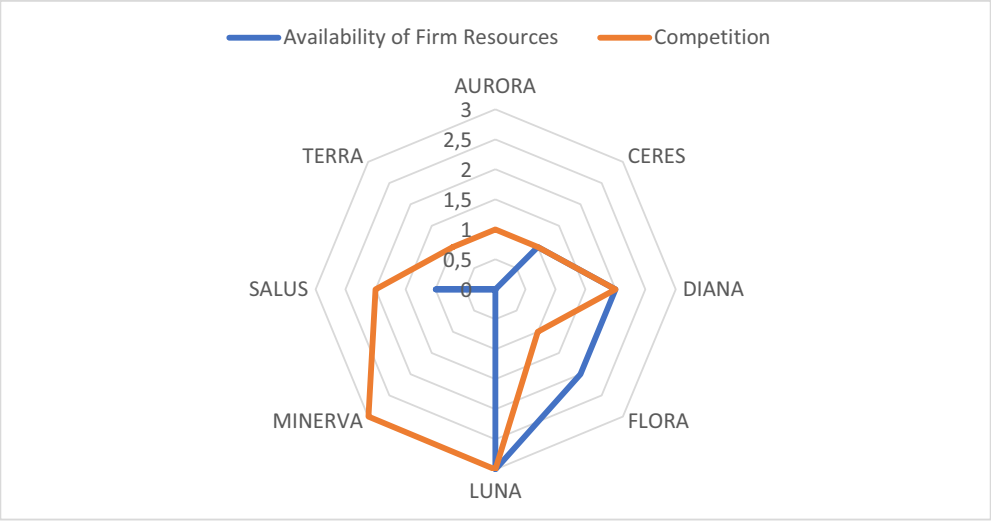

Figure 27 Number of Responses to Business Strategy Aggregate Dimension

All firms have mentioned the nature of competition and increased severeness of competition in recent years during the conversation. It is interesting to note that, more

aggressive firms of the market (i.e. firms with the highest number of facilities) mention the factor of competition more than the other participants. The capabilities of the firm (i.e. private equity, business partner) on the other hand, are mostly mentioned by firms which have affiliations to a local business partner in the project area.

Availability of Firm Resources

A business partner in the locality of the project area provides a network to the municipality. It is believed by the firms that a network with the municipality is a key to win a project in the sense of local politics. As a business strategy, LFGTE firms are not mentioned from company headquarters, instead new firms specific to project location is established by cooperation of a local partner. The local partner is often selected based on their network affiliations with the municipality. For instance; a firm which already collects the MSW of the area and/or collects the waste of one of the members of the union is often selected as a business partner. Firms do not cooperate with the local firm but instead they hold shares with the boss of the local affiliations. The local partner is usually the entrance ticket of the firm to the local market. They know the local relationships, local politics and the local business environment so that; they act as a mediator to success of managing the relationships before and after the tender process and during the operations of the LFGTE plant. For instance, CERES has stated that having a partner in the locality has helped them to know about the need of the municipal authority before other players in the market;

> *Our partner was collecting that municipalities waste. This is how we get to know about the project of the municipality.*

DIANA has mentioned that one of the founders of the firm is from the project locality;

> *The familiarity of our boss with the waste sector was our reason to decide in LFG sector investment. We learned about the project of the municipality because our boss was collecting the wastes of that region.*
>
> *They have first become partners with a local firm. They have a different partner in another project location. In a greater city municipality, they even have a partner involved in country politics..*

Local politics is an important dimension of this sector and firms strategically cooperate with local partners in order to have a strong hand within the project locality. An

additional endogenous resource for firms is the availability of private equity and long-term loans for investments. Firms cover a majority of the upfront costs of LFGTE projects through development bank credits. Ratio of private equity and loan share can vary between 30-70% depending on the firm strategy. During the interviews only administrative managers have mentioned weight of equity in their investments. Project managers have not addressed the construct of project investment costs. DIANA and FLORA have mentioned that they use bank loans to grow their place in the market.

> *We have invested 30% with equity capital. 70% from external source. We have benefitted from ERP program of European Investment Bank with help of Development Bank. We have used a long-term investment credit. By long term, they mean after 3 years the pay back begins. The total credit payback period may go up to 8 years*.

> *As an investment cost model; We are using long term loans. We are an aggressive firm; therefore, we pay 20-80 percent own equity, 30%-70 % investment credit*.

Competition

The competition has severely increased in recent years due to sharp increases in offers for municipality shares in tender. All participants have addressed the increasing share of municipalities as a problem for development of the sector (i.e. lower project qualities, lower profit etc.). According to DIANA;

> *Municipalities share from sales is increased but the investment environment is bad. In the project area there is not even 100 thousand population, but they have given 40% share from the sales. They should be in regret now*.

AURORA is one of the biggest players in the market, they state that;

> *The competition has severely increased. Firms are proposing too high offers to win the tender. We would like to invest in more affordable projects. I think some firms invest in this technology to promote their names in the market. They propose high prices in tenders. These numbers are so high that I do not think it is feasible, but firms still give these high offers*.

> *They compete very hard; they got this project with 60%. Such a ratio from sales does not promise profit. Now rates of share are about 30-40% ... when YEKDEM is over these idiot contractors still will give these shares. This amount is not related to the amount of income you see, after saying that this is the last period of YEKDEM rates will not go down. Other firms are*

not aggressive like that they make a reasonable decision to not to enter the tenders.

LUNA states that, they raise the bids in tenders to overcome the severe competition so that they can sustain their place in the market in future;

The greater city municipality asked for 10% of share and we proposed 41%. We did this in order to prevent municipality to make a wrong decision in the tender. They had a ToR that would prevent future development of the project. When we sense such situations that the municipality will face technical problems in the future, we try to prevent such occasions. We warn the municipalities about potential consequences. In some municipalities already completed tenders has been cancelled. We can make less money or one or two years this will not bother us. At least in such circumstances the municipality has the option that, when they are in a position of tendering for a fully integrated system, such a firm will not be preventing this option.

Early adopters have been advantageous in business deals. Firms with the first mover advantage had more profitable agreements with municipalities. Therefore, their earlier projects have already paid themselves off so that; they can invest in growth and technological development. A good example is the case of LUNA;

Our advantage was that we were in the first in the market. Municipalities did not know that they could make money from waste. We are one of the oldest in the sector, we have the know-how. Our waste acceptance capacity is high, we can process many different streams of wastes. We upgrade our operations in harmony with the place of investment.

MINERVA has stated that municipalities were inexperienced in the beginning and they kept the scope of the tender limited because there were not many firms in the market;

The municipality issues a tender and we participated. The municipality could not put everything in the tender, there were not many firms.

SALUS has mentioned the first mover advantage by giving an example from the history of the sector;

There was not the YEK law. They just convinced the municipality and started the business. It is something like the first mover advantage. They have benefitted a lot from this first mover situation. And they are successfully managing this work.

Types of business models, inclusive services and model of the PPP agreement is announced in the tender documents. Firms may get in contact with municipal authorities to share their experience and opinion about the advantages-disadvantages of different models but once the tender is issued, firms cannot be involved to change the framework set by the municipality. Therefore, the final framework of the terms of reference (ToR) is a major determinant for firms to decide whether to participate in a tender or not. For instance, MINERVA states that they participate in the basic technology requests of municipalities;

> *Our model is very simple. There is mechanical treatment. Just only electricity production from waste. Nothing else. We do not have such a motivation like methanisation or other technologies*.

FLORA has stated that the prerequisite for their investments is the amount of wastes and the investment model is the most important factor for their decision to participate to the tender or not. Interviewee from FLORA has stated that;

> *We look at the investment model. Our priority is the model of business. Municipalities demand different services in tenders. In Turkey there are problems that a private firm can solve or cannot solve. Leachate treatment is the problem of all landfills. For example, we do not prefer to participate in the tender if the leachate treatment responsibility is also requested from the firm. We are opting for landfill operating and only energy production from the harvested gas. We have some projects with only electricity production. Some projects are with LFGTE plant operation and site operation costs. We also have projects with mechanical plants. We also have biomass project, but they are not active, our works are under development. We also have sludge incineration*.

LUNA states that they prefer adding additional utilities for the sake of system development even though it is not requested by the municipality;

> *Wastes will be landfilled after processes in mechanical separation and biomethanisation. We apply biomethanisation in all of our plants even if it is not listed by the municipality*.

SALUS states that, the difference between the preference of a BoT model and a concession agreement is mainly due to tendered services. When transfer and collection is included in the system, concession agreement model is preferred by firms.

Participant of the case SALUS thinks that this diversity should be studied for its disadvantages and advantages, there may not be a single right for a project. Each project offers different set of solutions to the municipality;

> *In this sector there are; waste collectors, operators, energy producer, recyclers. System of Hexagon and Sita Environment are the same. Facilities in Pamukova and Bilecik are operated with this model. This is the commercial preference of a firm. I can collect and do the recycling as well I will prepare this project for the municipality and convince them… This is a style of business. That may be more profitable according to their opinion. There is no right or wrong in that. These should be analyzed with positive sides and negative sides*.

TERRA on the other hand has mentioned that, their priority is the FiT subsidy when making a decision on the feasibility of an investment model;

> *Municipalities could tender different types of waste management model in each case. We look for which model is demanded for; we also consider the year of allocation. If demanded year of allocation is more than 10 years; we have to keep in mind that we can only have a maximum support (i.e. YEKDEM) of 10 years and we have to consider if the project will be beneficial to us after the support period*.

Up-front costs of investments are neither a facilitator nor a barrier for LFGTE investments. Involvement of the public resources (waste input) in the project provides a constant assurance of plant operation and availability of a Feed-in-Tariff makes the feasibility calculations more solid. Therefore, firms have relatively easy access to long-term loans for regional development. Local and central political gaps and conflicts may have a role in affecting credibility of projects. We will be discussing this matter under "institutional environment" for diffusion. The FiT also has been the backbone of project feasibility calculations. Firms have a tendency for opting for only LFGTE technologies for a certain period of time to guarantee that their investment will pay off within the FiT support period. Only the early movers in the sector, can imagine investing in new technologies and sustaining the business after the FiT is over with different business models.

Accumulation of Knowledge

The results of our study have shown that both firms and municipalities increase their knowledge about LFGTE technology as the technology diffuses more. In

Figure 28 we have depicted the number of responses to accumulation of knowledge aggregate dimension.

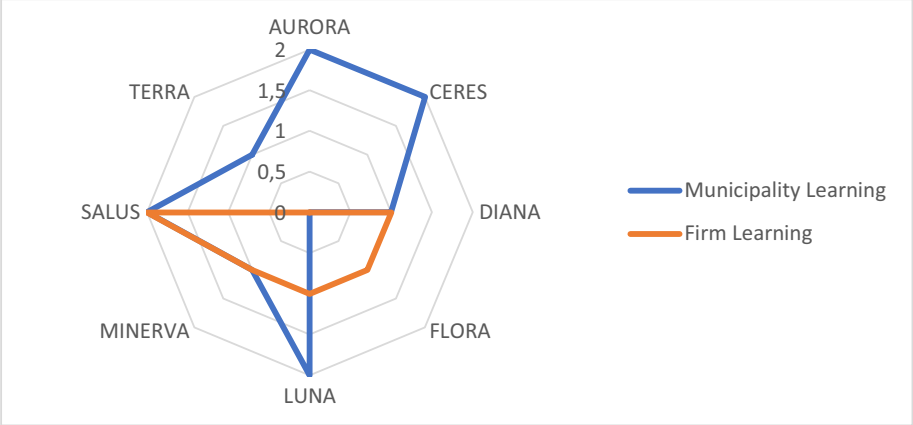

Figure 28 Number of Responses to Accumulation of Knowledge Aggregate Dimension

Increase in municipal knowledge and their influence on the LFGTE sector is mentioned more than firm learning. All participants to our study have a certain experience in the waste management and/or energy sector. They have certain opinions and beliefs about limitations of the municipal capacities. Therefore, only a few participants have shared with us that they increase their knowledge after project implementation. But almost all participants have stated that, municipalities lack technical knowledge and their personnel is of limited capacity and firms increase the technical knowledge of municipalities as a result of project implementation. Only SALUS, which has a great dedication for firm innovativeness and R and D; has emphasized on firm learning more than the other participants.

Municipality Learning

Needs and requests of the municipality is a key to framework contract of the LFGTE investment. Therefore, knowledge of the municipality before the tender process determines the backbone of the projects. There is a thin line between the firm-municipality interactions and involving in the tender process. Therefore, some firms strictly prefer not to get in contact with municipalities before the tender. They only

respond to municipalities if the municipal authority asks for their experience. On the other hand, some firms pro-actively promote their services to municipalities. They invite municipalities to their facilities, they get to the project site, visit the municipality and share their opinion on the site and share their technical experiences to acknowledge the municipality about the recent developments in the sector. For instance, AURORA is convinced that a site visit and exchange of information with the municipality is a prerequisite to carry out a feasibility of a project.

> *We go to the landfill site before making our decision to enter the tender. We see the site, make our project calculations and share our opinion with the municipality. We inform the municipality if it is feasible to tender the facility on the estimated income and lump sum costs*.

CERES has also stated that, they have completed a pre-feasibility study with the municipal authority. They have co-operated the union to prepare the model of investment after they had signed the concession agreement. Both MINERVA and SALUS state that there is a two-way interaction between the firms and the municipalities. As SALUS says;

> *There were times that we explained the technology to municipalities. There were times that they reached and asked us.*

MINERVA states that;

> *Municipalities reach us and ask questions about the technologies, implementation to increase their knowledge to prepare the tender. But if you get involved more than that, that would be considered a fraud in the tender process. Therefore, we should stay at a balanced position. Our position is that; we offer all available technologies in the market and inform the municipality about all possible solutions available. Therefore, I am not guiding the municipality to one single solution*.

Visiting the existing facilities and learning from site experience is often experiences by municipal authorities. As simply put by AURORA and CERES;

> *Municipalities take one another as example…. Experienced municipalities know what they do. Other ones learn from experienced municipalities, from example plants etc.*

For LUNA self-marketing is a strategy. LUNA makes use of its facilities as a showroom for promotion of its work. They have an open-door policy for some facilities just for the purpose of accepting visiting municipal authorities. According to LUNA;

> *Knowledge of the mayor is very important. He/she shall see the exemplary facilities in Turkey and abroad to gain knowledge. So, we recommend municipalities that, they should come, see our facilities. Ask us whatever they have in mind. Come and see our plants and then make their decision.*
>
> *We share our opinion with municipalities, they come and visit our plants and we explain them the business models as well. We try to get the job within our perspective but if the municipality insist on a different model, you can do nothing about it, we just hope that after some time they will also realize that ours is the better model.*

TERRA has emphasized the leading role of larger cities to smaller ones;

> *Municipalities in Anatolia take İstanbul, Ankara and İzmir as an example.*

The share of information may be among municipalities and/or with firm-municipality interaction as marked by SALUS and MINERVA;

> *There were times that we explained this technology to municipalities. There were times that they reached and asked us. They hear mostly hear from each other. They have a sort of communication network among each other*.
>
> *Municipalities see example projects from each other. They also call us and get information about our projects in order to prepare the tenders. LFGTE has begun from Ankara. When a new major is elected, they carry out meetings to solve initial problems. They want to do something different. Usually it is the person next to the president who introduces the idea of LFGTE by showing examples from other municipalities*.

LUNA agrees that municipalities learn from one another but, they also learn by visiting operational facilities. FLORA has expressed a similar opinion;

> *If you are in the sector, you have example projects in hand, this is very effective on municipalities. This is the most important thing I observe about this sector.*

DIANA agrees to the fact that having an example plant encourages municipalities to visit and learn by experiencing the operations on the site. According to DIANA, the reason for not having many other technologies is that there are not many successful examples of alternative technologies available to display.

> *Investors; first would like to see successful operating plants. Since there are not many examples of biomethanisation, this technology is not common.*

Firm Learning

Private firms tend to "praise" themselves while talking about their projects and investments. All participants were proud to be a part of the firm they are working for. They mainly claimed that municipalities lack technical knowledge and they are the information provider. Clearly there is an "active learning" in municipality side. Our findings suggest that there are also active and passive learning mechanisms for firms which have influenced diffusion of LFGTE technologies. We have learned about cases where firms share their experience with one another, and we have also observed cases where firm knowledge was increased through learning-by-doing (plant operations).

MINERVA for example states that they have bid in their first LFGTE tender experience based on calculations of the municipality. They have had a very rough estimation on the "potential" of the project and once they won the tender, they experienced that the project capacity was almost three-to-four times more than they have "thought". They increased the capacity accordingly and they have adjusted their estimations for other tenders based on this first example operation. On this issue MINERVA says that;

> *We estimated a rough capacity. After getting the projects we have seen that the engine works with full capacity. We put another engine, after 3 months, we put another one. We have completed full installation in 5 years.*

For a similar condition LUNA has explained their pathway to solution was by trial and error in their operational projects;

> *At first times we had a pump problem because waste in Turkey is collected separately. The liquid inside wears out the special pumps we bought from Germany in a very short time. We re-designed our facility to solve this problem.*

LUNA and SALUS are pioneering firms which integrate research and development in their activities. SALUS expresses their dedication to scientific thought and they also have great respect to approached of LUNA which has a similar innovative character. As a response to the interview question regarding influences of the FiT tariff the representative of SALUS has shared the information that they have learned a great deal from their projects and developed their processes by monitoring their operations, iteration of data and inclusion of universities and research instituted to integrate new technologies to their operations. SALUS has stated that;

> *It is utopic to say that biomethanisation will not work with municipal wastes. For instance, we wanted to integrate a biomethanisation plant to our site in 2014, we have received a support from TÜBİTAK TEYDEB to our R and D project. We have had a consultant from the Istanbul Technical University environmental engineering department. In the beginning, the general belief was that leachate and organic waste could not be bio-methanised together. However, our laboratory scale and pilot scale projects have yielded good results. We presented our findings in an international congress. Then we applied for Technological Investment support of Ministry of Science Industry Technology. We have installed a 23 times greater plant than our first one and it also worked.*

LUNA also have also used their plants in operation as an opportunity to develop their technology and operational capacities. They say;

> *Operation of biomethanisation of MSW is our trademark in this sector. Household wastes is not homogenous and changes daily. We have managed to operate biomethanisation plants in a similar efficiency to animal waste feed as a result of our R and D works. We have developed our bio-fermenter unit to be competent with Turkish waste. In this waste there is a lot of ash. We are doing dry fermenting. By that we increased gas efficiency and investment efficiency and minimized the risks associated with peaks in ash and sand content. This is our trademark in the sector*.

The interviewee from LUNA adds;

> *The BoT is a system which creates very high return of knowledge towards innovation. We do our research, develop technology and start operating*

within days in plants. We can this this owing to our cooperation with a Turkish Foundry firm. We have developed our capacity to produce and export machinery parts.

During the interviews we have observed that firms in the sector know about activities of one another. The plants are open for visitors. Of course, technical operational details are kept confidential within firms but more or less each company knows about investment characteristics of other players in the market. SALUS states that they searched for other firm activities to follow the recent developments in the sector and they try to stay as a pioneer for developments. In their own words;

We also know about applications of other firms. ITC for example prefers dry fermentation we prefer wet fermentation. Both systems are controlled digestions. Landfill is also a controlled digestion. Therefore, saying that it does not work is not logical. We follow developments of our competitors closely. One biogas plant was established in Malatya they want to receive external organic because they cannot receive organics to the landfill. Put aside the sector competition, the engineering behind such installations are correct jobs. Actually, in this sector we have begun working with the same engineers. All LFGTE plants are more or less the same. You can make a difference by taking some steps to difference like this.

Despite the fact that confidentiality is a priority for firms which dedicate themselves to be one of the pioneers of the sector. The LFGTE facilities have the same technology and it is not a secret for firms that which firm applies what sort of process on their site. The difference between projects is created through; type of business model, acceptance of different waste streams, agreement between the municipality, and other technologies/process developments by the firm. There is not a strong union between firms, but they have individual interactions. Almost all actors know each other in the sector, and they know about one another's type of doing business. Interestingly, one project may not be charming for a firm and they may not prefer to enter a tender for the benefit of another firm. Although such "courtesies" are not very common, firms may also support each other with information before preparing for a tender. For instance, DIANA has received a friendly support from AURORA to complete feasibility calculations because they were more experienced in the market.

4.2.2. Institutional Environment

Demands from the institutional environment come in the form of prescriptions regarding "the right thing to do" (in a legal, moral or cognitive sense) and the right way to do things (i.e. acceptable types of organizational forms for a particular task) (Mignon and Bergek, 2016). **Figure 29** shows the distribution of responses converging to the dimension of Institutional Environment. The influencers of institutional environment can be classified as formal institutions and informal institutions. Where formal institutions are; regulations, standards, rules set by the authority and informal institutions are; moral values, emotional motivations and barriers.

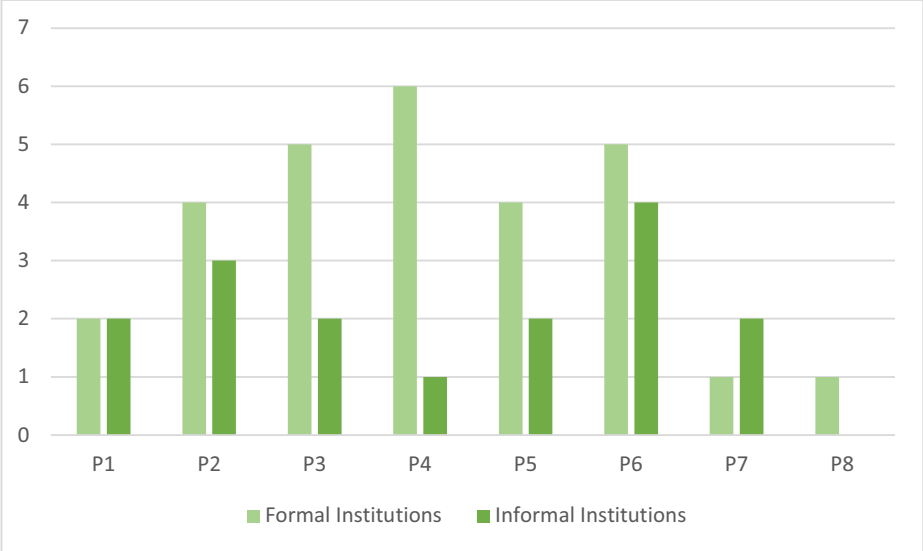

Figure 29 Number of Responses related to Institutional Environment

The results of our analysis have shown that for all firms, influence of formal institutional environment is mentioned much more than informal institutions. Indeed, participants have used very specific and direct words to define influence of regulations and they have addressed the problems they associate with the formal institutional environment very specifically. On the other hand, we had to iterate the results to identify informal institutional influencers of LFGTE diffusion. It was important to clarify conceptual identification of participants, understand the "meanings" they attribute to the concept. Moreover, we had to identify specific codes which addressed "emotions", "beliefs" and "thoughts" of the interviewee. Therefore, answers converge to constructs which aggregate to formal institutions are "indirect" expressions.

Formal Institutions

Participants summarize influencers of formal institutions by two major themes; "conflicts and/or gaps in policy" and "interference of politics" to the business. In **Figure 30** we have represented tendency of responses for each case for two different themes.

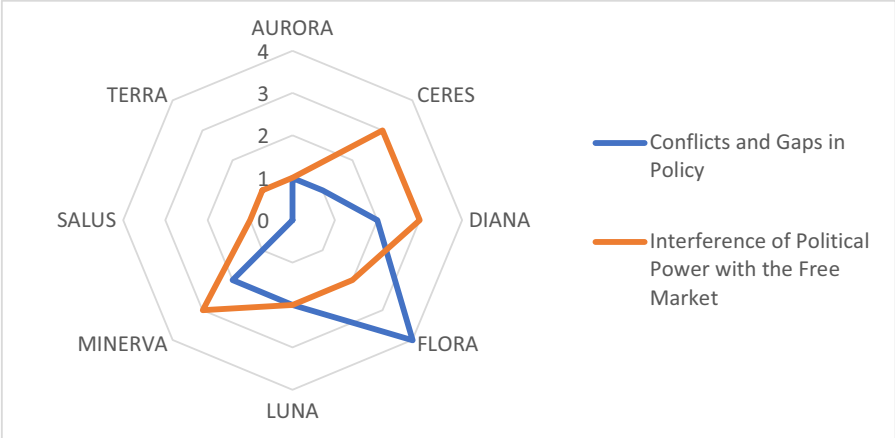

Figure 30 Number of Responses to Formal Institutions Aggregate Dimension

All firms have responded that there is politics interfere with the operations of the market. Cases except SALUS have also addressed that there are gaps and/of conflicts in environment policy which forms a barrier to their investment decisions for the future. FLORA, which defines itself as an "aggressive" player of the market has emphasized the policy conflictions more than any other case. This may be mainly because of the fact that; this firm gives high shares to municipalities due to their business strategy to have more facilities in the market. In return, they have spent serious amount of up-front investment costs many of which have included "obligatory" investment of sorting machinery and equipment due to environmental regulations. FLORA has a motivation to produce energy and they are not excited about materials recovery or other means of environmental technology services. DIANA and SALUS, which are also energy companies have not addressed the policy conflicts mainly because they have a smaller number of plants and they have different share of agreement in their business contract with municipalities. FLORA is a considerably new player in the market, and they kept their profit agreement lower than other

"established" firms to be able to compete with bigger players in the market. SALUS is a different profile than other firms because, they are specifically paying attention to their "endogenous" strengths instead of "exogenous" factors. The firm profile, perspective of the investor was a major determinant in their interpretation of exogenous factors.

Conflicts and Gaps in Policy

The lack of long-term policies is defined as a risk for long-term investment plants of firms. Firms identify a feeling of "undefined", "un-predictable" situation while talking about the future of the sector. FLORA, LUNA and MINERVA, the three players of the market which have the greatest number of plants in the country have expressed their concerns against uncertainty of the future.

> *Under uncertainty, you might expect anything. It is not the important point that the MoENR gives support to the sector and the MoEU regulates it… The issue is the country is not able to determine a long-term strategy for a long time.*

Similar to MINERVA, LUNA has also have a lack of faith in reliability of "policy making" in the country.

> *These problems can be solved by some sort of cooperative models between two ministries. But these solutions really have to be calculated in accordance with market conditions. Do you know how the rate of 13,3 USD cent was decided as YEKDEM support? The ministry has asked what the rate in Europe is… 26,6 cent. And they said OK just say 13,3 cent will be enough for Turkey. This is the case in policy making. A reliable policy with realistic models and may be involving opinions of sector firms is necessary.*

FLORA expresses their opinion on the role of a long-term policy as; "the rules must not change after the game begins". Conflicts of environmental regulations and conflict of regulations of MoENR and MoEU is often expressed by participants. A very distinctive example was given by the interview participant of FLORA;

> *Personally I think that the regulatory framework in Turkey is not right. There is a dichotomy between the MoEU regulations and MoENR regulations. MoEU regulations also have dichotomy within. MoEU says to municipal authorities to implement separation plants and separate recyclables from*

mixed wastes. On the other side, it also demands that source separation must be encouraged in line with the zero waste policy. On another side, it says municipality must dispose all organics by means of biological treatment such as compost, and bio-drying but it does not give a support to these technologies.

Operational applicability of regulations is often regarded by suspicion by the firms. For instance; DIANA, FLORA have expressed their opinion on operational difficulties by enforcement of mechanical separation units to their plants.

> S*eparation plants, as you know, are expensive investments. Especially, installing technologies to digest Turkish waste are so expensive. The waste management regulation says in order to have a licensed landfill you need to install mechanical treatment plant. The regulation obligates such facilities regardless of the plant capacity. A 5 ton/day facility has to make the same investment with 50 ton/day facility. I mean there is a serious need for adjustment here. Let's say you have installed this plant; the facility needs a sustainable financial model for operation. But then you are telling the district municipalities must separate their recyclables separately… to recover recyclables before going to the landfill. The MoEU legislations conflict with each other. This has to be studied carefully.*

Another frequently addressed environment policy is the "Landfilling Regulation". Municipalities are obliged to decrease landfilled biodegradable organics by 2025 according to the landfill regulation. This is the main reason that many municipalities request installation of bio-methanisation units at dumpsites in addition to the LFGTE facilities. LFGTE firms believe that operation of biomethanisation for the purpose of organics reduction is not applicable in practice. AURORA is responsible for only LFGTE production in the municipality. The interviewee from AURORA has expressed that;

> *The regulation to decrease organic matter content is in force for a long time but it is difficult to fully apply it. Landfilling is much cheaper than processing organics. I do not think that the sector will change because of organics limitation.*

Perspective of energy firms is different from perspective of environmental technology firms in this matter. Energy firms like MINERVA, support the idea that other technologies for organics management is not feasible and landfilling is unescapable in

Turkey. For instance, DIANA states that their technical opinion is to implement waste pyrolysis. However, large investments costs prevent installation of these facilities and the subsidy for LFGTE prevents thinking about other options. FLORA expresses their opinion in a similar vein;

> *Management of organic wastes is already a problem and municipalities solve this problem through energy production, if you take this source from them you will be destroying the organics management. By destroying I mean, destroying the financial source. Actually, there is a total unplanned situation. You are composting the organics; you convert organics to an out of use state and bury it again. You are not able to do anything else*.

Similarly, MINERVA states that;

> *The important thing in reality if that there is 50% organic wastes it means there is a serious "waste" of resources. The ministry tells me to decrease the amount of waste in the disposal site… why would I decrease that; you decrease it at home*.

CERES thinks that, the reason behind "inapplicability" of the regulation is because of the support given to LFGTE firms in form of the FiT subsidy.

> *According to the Landfill regulation; as of 2025 municipalities can landfill only 35% of the organic waste amount recorded in 2005. That would mean that we must recover 65% or the organic waste. This is not likely in the current situation of the sector where energy from landfill is supported, organics recycling ratio is not even 1% in Turkey now*.

LUNA has a strong confidence to their technical capabilities, and they implement several biomethanisation plants within the country, but they also think that composting is not practically applicable in Turkey. They have often expressed their opinion during the interview that making a change in the municipal waste management system is so difficult and effort taking that, instead they prefer upgrading their systems to the initial situation of Turkey. As LUNA expresses it;

> *We have a strong know how in operation of facilities. We can decrease the landfilled organics with biomethanisation plants. The landfill regulation states that the organics should decrease after 2020; we can incinerate of the wastes and bio-methanise some. But with open compost it seems so hard. Then municipalities might have to give organic wastes to firms here and there. Actually, it happens now too*.

In summary, technical difficulties for implementation of organic reduction processes and lack of environmental programs to reduce organics at source has caused a loose of trust to the environmental authority. Mainly energy companies tend to think that; they already contribute to an environmental benefit by conversion of energy value within the landfilled (i.e. disposed) wastes. Implementation of biomethanisation, compost and mechanical segregation units is often requested by the municipality based on regulatory pressures. However, these plants seem not to operate sustainably in practice. Only CERES, with the concession agreement; LUNA an early adopter with BoT model and "rent payment" and "gate-fee" type of business agreements in the market and SALUS which is dedicated to be a small but long-lived player in the market express their willingness to continue operating more advanced technologies. The FiT in that sense, seems to have prevented improvement of environmental technologies together with the lack in the environmental policy.

Interference of Political Power (Politics)

The institutional environment is directly related to macro-political environment of the country. By politics, firms usually refer to either local relationships with the political actors (major and elected members of the city council) and influences of central politics of the government and/or the president himself. Naturally, the conflicts between the parties in LFGTE business agreements are resolved through court cases. Firms lack trust in the legislative system, they do not strongly rely on the democratic judgement mechanism so that; firms basically trust on strength their local affiliations and good relationship with the municipality. A few instances that firms experienced have caused a lack of trust in the judicial system. DIANA has expressed that;

> *We do not invest more in this field because; firstly, the investment environment in Turkey has changed. It is not easy to invest any more. In Turkey, democratic rights, priority of law above all, freedom of speech is not present. Our plant was illegitimately taken from us, we are searching our right in the court, but it takes forever… our investment has just gone to trash on the mean time. The municipality has paid 5-6 billion, they shut the plant off and the total loss is 9 billion. Political issues are making the situation difficult.*

FLORA has explained that, they did not enter the tender for a municipality because they were expecting a change in the administration by the call from the presidency.

> *We knew that there was going to be guardian ad litem, we knew the major could change as a force from the center. Projects in certain areas, therefore, are a question mark for us.*

Meaning that, central political decisions which have an impact on local administrations directly influence their investment decisions.

> *Monitoring and control of facilities are effected by political pressures. The provincial directorate monitors some facilities more strictly if they have a negative relationship with the municipality.*
>
> *Municipality's decision for the solid waste management system, the way they want to acquire information, share of knowledge and management of bureaucratic procedures all have to do with political dimensions of the municipality. Whoever has the political power, has a strong influence in changing the technology investment decisions. Whoever has the political power gets approval easier in their applications.*

Local politics and political behavior of local actors is directly influential on LFGTE investments. Local provincial environmental directorates are often found to be inadequate to control the operational processes of facilities. In addition to this, some firms claim to have witnessed purposeful "retarding the approval of folders" and/or "inequal treatment of applications" by the controlling and/or regulatory authority personnel. This behavior is explained by incompetence of the personnel, lack of adequate number of personnel and/or frequent replacement of the competent personnel in public bodies. Moreover, non-professional behavior for favor of personal economic benefit (such as bribing, corruption etc.) might be encountered during the bureaucratic procedures.

As a matter of fact, decision making, tendering, implementation and operation of these projects are highly dependent on political tendencies, affiliations, and acts between firm-municipality and local administration. Responses of AURORA, CERES and MINERVA include statements supporting that the sector is totally politicized. An often-stated fact is that; the relationship of the local administration with the government is important. If there is a conflict

between the municipality and the government, it effects project approval time negatively. Political affiliations are required to invest in the sector. In a case, the participant stated he knows a company that won an LFGTE tender based solely on their political connections to the municipality. CERES makes a similar statement;

> *In the first years of these projects, there were only a few companies… In those years, big projects required very strong political affiliations. İstanbul and Ankara tenders were won due to firm connections to municipal administration. Of course, commercial and personal trust relationship was influential. But now small firms with no background experience win tenders based on their political affinations with the municipality.*

FLORA explains that there is a difference in projects with metropolitan municipalities and project of municipal unions due to political conflicts;

> *It is important where the union head is from. Majors exchange managerial positions in unions. Political tendency of municipalities within the unions becomes important. There may be debates and conflicts among members. We look at our harmony with the local administration. This is very important for me.*

When we have asked about the factors that influence the timing of investment; firms have responded that bureaucratic processes cause a delay in project implementation. Scope and period of allocation are important factors which determine the bureaucratic procedures. DIANA has informed us that project are mostly 10 and/or 29 years because of bureaucratic reasons[38]. Political power of local authority and relationship of the firm and/or municipality with the controlling authority can be another factor to influence bureaucratic procedures. CERES has stated that it took 2,5 years for until the implementation of the project due to bureaucratic procedures;

> *It took 2-2,5 years for the whole approval period even though there were not any requests for revision*.

[38] *For investments of over 10 years approval of "Council of State" is required. For investments over 29 years, approval of Central Budget is required. Therefore, the municipality either does not exceed 10 years of 29 years. Up to 10 years the administration can allow the investment. For more than 29 years, approval of central budget is required*. [DIANA]

> MINERVA; *First steps to implementation are bureaucratic works. Environment permit, EIA, permit from forests, if you are smaller than 20 MWe you are exempt from EIA. Such projects are much faster.*

LUNA explains that the delays in bureaucratic procedures can be due to frequent changes in the competent personnel of the environmental authority;

> *Changes in personnel, circulation of personnel in the MoEU is very influential. When we present a report, it takes 2 weeks- 1 month for a personnel to go over a report. When a personnel changes during the period, right before approval, the newcomer has to go over the report from the beginning. You must explain the project all from the beginning.*

Informal Institutions

Influence of informal institutions are expressed under three themes by the firms. Which are "s*ocial limitation and demands", "municipality motivation"* and *"firm motivation"*. **Figure 31** represents distribution of responses to aggregate dimension of informal institutions.

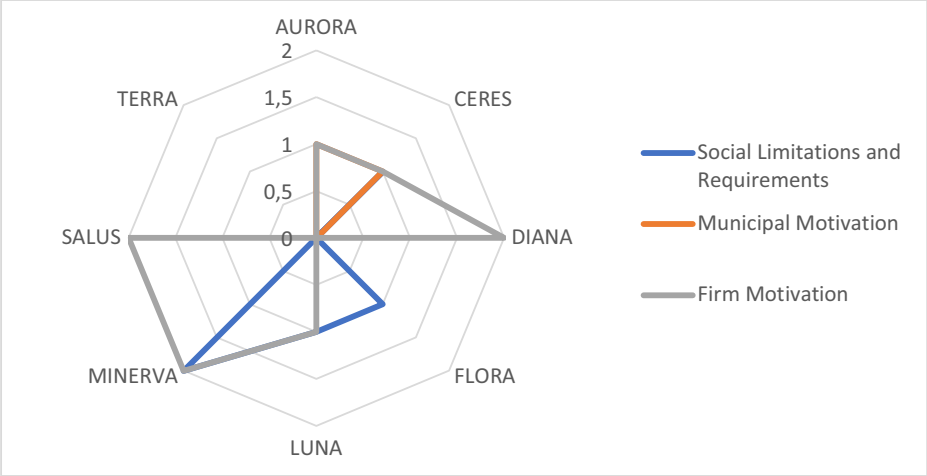

Figure 31 Number of Responses to Informal Institutions Aggregate Dimension

Informal institutions are the least mentioned influencer of LFGTE diffusion among all other responses. However, institutional factors for diffusion are very difficult to address and there is very rare information on institutional factors for diffusion. Therefore, addressing institutional factors from the perspective of investor firms has been a valuable output of our research study.

Firm Motivation

Motivation, beliefs and aims of firms are expressed to be the most influential informal institutional factors for LFGTE diffusion. Investors have emotional motivations while investing, upgrading and developing their technologies. We have observed that interviewees were much more excited when they spoke about their personal experience in the sector. When they tell their history and when they spoke about the firm history, a worthy note was that they built emotional attachments to projects when they have a personal connection such as; when the boss or a manager is from the project area, when they make a research on the subject of the project. For example, DIANA was enthusiastic to explain us his own motivation to serve to the city he was born in. He added that his boss is from the project city. Respondent from MINERVA who is also the founder of the company has stated that the motivation to contribute to the "production economy" was the reason to be involved in the LFGTE business. In his own words;

> *I could have begun any forms of trade. But in 2010s, I did not want to be one of the business mand with golden teeth. We owe to this society. I wanted to make production, something environmentalist, for human beings. My main aim to contribute to a production in the economy. And wisely use these production tools and share them correctly. I have entered energy sector to contribute to production.*

SALUS was enthusiastic to talk about creating jobs to project locality, giving trainings in schools, creating social responsibility projects.

> *Our workers all are from neighbor villages. We provide serious job opportunity to them. In both our facilities we have recycling museums. We are doing acknowledgement activities in schools. We participate in TV publications, project competitions etc. This is how we train and increase the capacity with public, starting from our neighbors; this is also our firm's reputation. This is not a request of the municipality. This is totally our social responsibility. Everyone has their own social responsibility and acts according to the perspective of the world in my opinion.*

In the LFGTE business there are firms named as "environmental technology" and/or environmental consultancy companies and firms named as "energy companies". Very

much expectedly so, the vision of the company grows towards in accordance with its firm identity. Business identity of the firm is an important determinant of it is way of constructing and projecting the future of LFGTE projects. Firms which identify themselves as an environmental technology company are more dedicated to developing their technologies for giving environmental services, extending the line of business towards different waste streams and developing the environmental technology for further applications of waste processing. Often mentioned concepts by the environmental technology firms are; the waste management hierarchy, cooperation with municipality, future of the waste management sector etc. CERES for instance has stated that electricity production is a supporting tool in their business activity. LUNA has an extensive scope of waste disposal and energy recovery technologies. Their perspective is that;

> *Our job is integrated solid waste management. We think that all projects must be fully privatized, and municipalities must be the controller. Our principle is to maintain sustainable systems. We cannot dictate a single technology. I think this is the most important point. Our technology is todays technology of course, but they are modular and can be implemented with yesterdays technology and tomorrow's so that municipalities should not concern waiting for the next generation technology to solve their waste problem.*

Similar to CERES, participant from LUNA also does not think that LFGTE production is the main line of business but it is complementary to other environmental technologies. Firms with an "energy technology" business identity on the other hand, more often express the concepts of "energy production", "extracting value from waste". FLORA for instance has stated that;

> *We are an energy firm. It is important how a firm defines itself. Our perspective is different from theirs. We look at our performance in electricity output*.

MINERVA has a similar perspective;

> *We do not have an opinion about waste hierarchy. We are an energy company. We are recovering the economic value from organic wastes.*

DIANA thinks that firms have entered the LFGTE sector without technical background in energy and/or environment have caused the technological development in this sector to cease. Firm motivation and development of capacities is an important factor to solve such problem. For instance, firm which define their core business as environmental management state long-term dedication to waste management sector even if the FiT will be over. They consider the FiT as an opportunity to extent their business to advanced technologies. On the other hand, firms which define their company aim as only LFGTE, plan ahead just for the period of the YEKDEM subsidy. These firms have not stated future plans in the waste management sector when there is no state guarantee.

Social Limitation and Demands

Our findings have shown that participants often express their observation for a correlation between level of education and demand for environmental development by citizens. According to LUNA, making a behavioral change in society is much more difficult than adjusting the processes to manage the problems of the on-going activities. FLORA has made a similar statement that separation at source is dependent on the education level of the society. He does not think that a price-based punishment will be effective unless the society is above a certain level of understanding. CERES considers themselves as "lucky" because their investment location can be classified as an educated society Meaning that, the public behavior can be guided for different waste generation, collection and recycling system etc. MINERVA states that they do not include public trainings in their projects because they think that their project locations suffer from poor public knowledge. MINERVA adds that, the society should not be thought separately from its cultural background, habits and religion. In a way; social, demographic and cultural characteristics limits level of environmental development. In own words of the founder of MINERVA

> *Our country background is feudal villages. Development is a natural process. It cannot be faster. Here is Islamic culture, regional geographical conditions. In Erzurum in Erzincan there is 6 months of hard winter, you will for sure close everything and control everything. Karadeniz suffer from heavy rain, human behavior is much different there.*

Likewise, LUNA is discouraged by cultural influence against development of a better environmental management demand by the society in Turkey. The societal behavior might be much more influential than the regulations of the ministry. MINERVA supports that; the MoEU should be focused more on making a change in the society to have better waste management instead of shaping the technologies with regulations.

Municipality Motivation

Solving waste management problems is a political issue for municipalities. Municipal authorities proudly announce the LFGTE projects as a salvation from the waste disposal problem and income generation from waste. Municipalities are trying to promote their activities with words such as "pioneer", "the first", "better", "the largest", the most profitable etc. as a factor for receiving public attention to increase their political position. Briefly, political motivations of municipalities are a driver to push LFGTE technology adoption. For CERES, political motivation of the municipality impacts the project because municipality wishes to collect less fee from the public as possible;

> *Municipalities want to keep the gate fee as low as possible because of their political benefits.*

AURORA on the other hand says that, there is a race between municipalities to be a pioneer to others (especially for greater city municipalities).

> *The municipal authority is doing initiatives to set an example to other municipalities. It carries out pioneer projects to support its reputation*.

In addition to the political motivation of municipal authorities, personal/professional characteristics of their personnel is an influence in designing and operation of LFGTE projects. The personnel of the municipal authority is responsible for preparing the tender documents, project implementation and to control the project operations after it is installed. While the availability of organic wastes is a prerequisite for investment of an LFGTE project, technical capabilities and willingness of the municipality personnel

is important in framing a contract and following up all bureaucratic procedures with the MoEU. FLORA explains the weight of municipal authority personnel from a different perspective. The interviewee from FLORA has stated that, the project may be interesting to the mayor but at the end of the day the technical personnel from the municipality will execute all administrative procedures of the project. Therefore, their capabilities and level of cooperation with the private firms will be important for completing the tender procedures.

4.3. Analysis of Field Results, Discussions and Summary of Findings

As a result of the field research, we were able to define influencers of LFGTE diffusion in task environment and in institutional environment. We have followed a three-step iteration process. In the first step we have identified the concepts and constructs identified by the participants. In the second iteration we have identified which themes are addressed to by these constructs. Finally, we were able to define six aggregate dimensions from the themes emphasized by the participants. Aggregate dimensions of LFGTE technology diffusion in Turkey are shown in **Figure 32**.

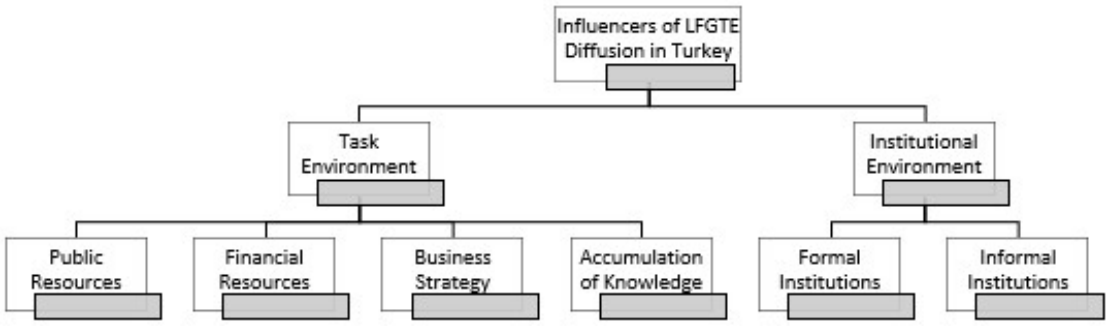

Figure 32 Aggregate Dimensions as a result of the Semi-Structured Interviews

Availability of financial resources and public resources are the most mentioned influencers of LFGTE diffusion. Then comes influence of formal institutions, business strategy, diffusion of knowledge and informal institutions respectively.

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4.3.1. Decision of the Municipal Authority as a Prerequisite

In Turkey all LFGTE facilities are installed on disposal sites owned by municipal authorities and operated by private companies. The prerequisite for an LFGTE facility implementation is the public tender issued by the municipal authority. According to firms; reasons for municipal authorities to issue a tender for LFGTE operations are;

- High operation costs of disposal site management
- Risks associated with improper management of disposal sites
- Political motivations of the municipal authority
- Knowledge about the technology

All respondents to our interviews have stated that; municipalities want to allocate responsibilities of disposal site management because of high operation costs and high technical requirements of operations. Environmental compliance requirements[39] for disposal site management brings in a series of bureaucratic procedures and costly investments to landfill operations. Day to day covering of wastes, treatment of leachate water, collection of gaseous emissions and their treatment in order to prevent risks of explosion and environmental harm are major costs items for disposal site operation. A successful management of such a project requires a dedicated organization with adequate institutional and financial capacity. For such complex, technical problems beyond the administrative capacity of a municipality; Turkish *local administration laws* (i.e. the Municipality Law and the Metropolitan Municipality Law) allow municipalities to tender operation of these facilities to private companies.

From the early examples of public private partnership of solid waste management in Metropolitan cities of İstanbul and Ankara we have learned that; the first amount of the FiT subsidy given with the RER of 2005 was not competitive with the market prices. In that sense business model between the firm and the municipality was in the form of; firm may pay an annual rent and/or share from its sales to the municipality in

[39] Requirements of "Law on Protection of Soils and Land Utilization", "Landfill Regulation", "Water Pollution Control Regulation", "Environmental Impact Assessment Regulation" etc.

return to rights of "utilizing" the resources in the site. By this way a win-win agreement is formed, saving the municipal authority from the burden of disposal site management and providing a guaranteed long-term, predictable investment for the private company. After 2011, when the RER was changed, and the FiT was increased to 13,3 USD cent/kWh. As the amount of feed -in tariff increased, attention of more firms was driven to this sector. As there have been more applicants in tenders, the nature of biddings has changed, and the *desire of municipalities* have shifted from "getting rid of risks and costs of disposal site management" to "making money from waste". Therefore, the scope of tenders has shifted from "disposal site management" to "electricity production from waste".

Technical capacities and motivation of the municipal authority personnel forms the basis of the Terms of Reference (ToR) of the tender. There is a two-way interaction between the firms and the municipal authorities where; municipalities reach private firms to ask about their technology, visit their facilities and firms may visit disposal site before the tender in order to prepare their bidding document. In addition to this, municipalities have a "closed network" among each other where they learn from one another's experience. As "good examples" get adopted by more and more municipalities, other municipalities also get interested in the subject and begin searching for similar solutions. In short, being accustomed to the technology, *observing successful operational examples* are important for judgement of the municipalities.

Another important factor is; *political motivations* of the municipal authority. After elected, mayors try to initiate distinctive projects. Constructing a modern waste management facility, "saving" the public from the waste problem and "making money from waste" on top of it, is often a good campaign for a mayor. Municipalities make use of LFGTE projects as an achievement for their political success. In addition to this, the profit gain from the LFGTE projects may be used to decrease the amount of "waste management-fee" collection from the citizens which might be another political gain for the party of the major elect. However, we have not observed such a relationship of fee paid by the citizens and the profit of the municipality from the LFGTE plant in our

study. Just only in the case of "concession agreement" as a public-private-partnership; the waste-management fees were calculated by the municipal union according to the actual costs of the SWM system and the return of LFGTE plant was deducted from the costs. Such a fee reduction is also possible with the BoT and BoO type of business agreements between the firm and the municipality based on the organizational and financial structure of the municipality. In that sense, we can say that; the municipal SWM has to be financed by the public who receives the SWM services but now the feed-in-tariff is financing some (or may be whole in some cases) of the municipal solid waste disposal in cities.

Clearly, the *physical prerequisite* for an LFGTE project is *presence of a landfill*. Apart from the physical barriers, some municipalities have initiated tenders later than others mainly because of institutional barriers. Results of our study suggest that;

- Lack of qualified personnel and lack of personnel motivation
- Institutional instabilities such as; frequent changes in municipality personnel, frequent changes in ministry of environment personnel
- Political conflicts and instabilities within municipal authority

Institutional capacity and political power of municipal authorities differ from one another. In our preliminary interview sessions with experts from municipalities we have learned that; the mayor was always enthusiastic about remediation of the disposal site and construction of an LFGTE plant as a part of the remediation plan. However, administrative progress was achieved within the municipality when the head of the technical department was replaced with other personnel who was experienced in waste management. The new technical manager has assigned staff who is trained in mechanical engineering, environmental law, public law and waste management so that the team of municipality engineers have studied on the terms of reference to issue the tender. The delay in tender procedures were mainly caused by the *"lack of motivation" and/or "lack of competence"* of the municipality personnel. In another case, the MoEU officer responsible for approval of the project implementation folder was replaced after three months of submission of the application document. We were informed during

our case studies that; frequent changes in ministry officers cause delays from months to years in project approvals.

Another incident is that, there may be *conflicts and political dispute* within the municipality management and/or between members of the municipal unions. In this case, decision making for a project may be delayed. Summary of influencers for adoption decision of municipalities are presented in **Table 19**.

Table 19 Most Distinctive Influencers for Municipal Authorities to Adopt LFGTE

CATEGORIES	DRIVERS TO ADOPT LFGTE	BARRIERS TO ADOPT LFGTE
Administrative	Dedicated qualified personnel	Lack of qualified personnel and lack of personnel motivation
Economic	High operation costs of disposal site management	Costs of designing and constructing a landfill project
Institutional	Compliance to environmental regulations	Institutional instabilities such as; frequent changes in municipality personnel, frequent changes in ministry of environment personnel
Physical	Availability of disposal site	Lack of a disposal site
Political	Political motivations of the municipal authority	Political conflicts and instabilities within municipal authority
Psychological	Trust in technology	Lack of trust in technology
Technological	Risks associated with improper management of disposal sites	Complexity of technology

4.3.2. Drivers for Private Firms to invest in the LFGTE Technology in Turkey

According to our case-based findings, drivers (or facilitators) of LFGTE technology in Turkey can be summarized in four sub-topics;

- Availability of high amount of organic wastes
- Availability of a renewable energy Feed-in-Tariff subsidy of the government
- A long-term agreed upon sustainable business model with the municipality

- Availability of a local network connection to the municipal authority in the project area

Drivers of LFGTE diffusion have different weights in different phases (periods) of diffusion. Most often mentioned drivers for private firm adoption of LFGTE technology is summarized in **Table 20**.

Table 20 Often Mentioned Drivers for Private Firms to invest in LFGTE Sector

	PHASE I (2005-2011)	**PHASE II (2011-2015)**	**PHASE III (2015-2020)**
Administrative	Partnership with local firms	**Partnership with local firms**	Partnership with local firms
Economic	**Long term-sustainable business agreement with the municipality**	**The Feed-in-Tariff Mechanism**	**The increase in the USD currency rate**
Institutional	Produce "value" from waste	Produce "value" from waste	Produce "value" from waste
Physical	**Availability of high amount of organics in disposal sites**	Feasibility of smaller sites (due to increase in FiT)	Increase in amount of wastes due to increase in population
Political	Expectations of environmental regulations in line with harmonization with EU acquis	**Increase of the FiT with the REL** **Enforcement of the Landfill Regulation**	**Local elections in 2014; change of status for 14 municipalities** **End of the FiT applications in 2019**
Psychological	To be the pioneer in the sector	To be a distinctive firm	To get in line before the subsidy ends
Technological	Availability of foreign consultants The gas can be stored to produce electricity in profitable hours	Availability of technical knowledge and trained personnel	Technology has been proven successful

The drivers indicated in blue color are emphasized as the most influential drivers for LFGTE technology diffusion for each phase.

Secondary data from the YEK list of 2020 and results of our case studies indicate that; the *amount of municipal wastes and a long-term agreed upon sustainable business model* with the municipality were the major driver for the early adopters (Phase I) in the LFGTE technology in Turkey. Between 2011-2015 (Phase II); The influence of *local connections* has gained importance whereas the *Feed-in-Tariff* was clearly the major driver of LFGTE investments. With increase of FiT from 5,5 Euro cent to 13,3 USD cent; project scale has dropped to a minimum of 200 tons/day. Influence *of environmental regulations, availability of the FiT* and help of *local connections* has been major factors to facilitate LFGTE in provinces with established landfills during this period. After 2015 (Phase III); The amount of wastes was not the major influencer for investments in this period. The distinctive feature of this period is that *there has been a sharp increase in the USD currency* rates in Turkey[40]. In addition to this, increase in the number of successful facilities has motivated inexperienced small players to enter the market. Mostly*, the status change of municipal authorities and the end date of FiT* have played a major role in diffusion of LFGTE in this phase in addition to the *increased rate of the USD currency*.

4.3.3. Barriers for Private Firms to invest in the LFGTE Technology in Turkey

According to our case-based findings, barriers (or obstacles) of LFGTE technology in Turkey can be summarized in five sub-topics;

- Delays caused by bureaucratic procedures
- Lack of available organic waste input
- Improper conditions of the disposal site (non-licensed dumpsite, distance from the grid/city etc. depending on the business contract)

[40] The USD currency has changed from 2,4 TL/USD in January 2015 to 3,1 TL/USD in October 2015. By the end of 2016, the USD currency rate has hit 3,5 TL/USD.

- Costs associated with auxiliary plant operations due to demands of the municipal authority (mechanical separation, disposal site operations, leachate treatment etc. depending on the business contract)
- High share given to the municipalities from sales return

The results have shown that, barriers to LFGTE diffusion have changed weight with time as the sector developed and exogenous factors have changed. Between 2005-2011 (Phase I); Physical factors have not been a major barrier in Phase I. The influence *of bureaucratic procedures and lack of technology knowledge* were the most effective obstacles for technology diffusion. Between 2011-2015 (Phase II); In Diyarbakır, from the remaining 6, neither an LFGTE plant nor a landfill has been constructed due to conflicts of the local politics and the government policy in the province. Municipalities of İzmir and Eskişehir experienced delays in LFGTE adoption due to; indecision in the disposal technology (the factor of waiting for a better technology to emerge) and bureaucratic procedures due to contrast of local politics with the central government politics. Erzurum has the physical limitation due to lack of a landfill site. Mersin has also suffered from political dispute between the local and central administrations. In addition to this, districts in Mersin are located far from each other which has made; planning, design and construction of landfills difficult. Therefore, majority of barriers in the second phase of diffusion were related to; *bureaucratic delays due to political dispute between local and central authorities*. It shall be kept in mind that, *presence of a landfill* is always prerequisite for LFGTE implementation. Turkey has issued its first "Landfill Regulation" in 2010. When it was the end of 2014; only a 64% of municipal wastes were disposed in landfills and 30% was disposed in dumpsites ((MoEU, 2016) which means, lack of landfills might have been a limiting factor for the development of the LFGTE sector in this period. After 2015 (Phase III), barrier of bureaucratic delays has been mostly removed with the change of status of 14 provincial municipalities to "Metropolitan Municipalities". By this law, municipal unions have been closed and responsibilities of all disposal site operations are managed from a single local authority. We have summarized most often mentioned barriers for private firm adoption of LFGTE technology in **Table 21**.

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Table 21 Often Mentioned Barriers for Private Firms to invest in LFGTE Sector

	PHASE I (2005-2011)	**PHASE II (2011-2015)**	**PHASE III (2015-2020)**
Administrative	**Long bureaucratic procedures**	Lack of local affiliations **Long bureaucratic procedures**	Lack of local affiliations Long bureaucratic procedures
Economic	High upfront costs to invest in large scale projects	Profit oriented demands of municipalities High operation and maintenance costs	Severe competition with increasing rates of share given to municipalities High operation and maintenance costs
Institutional	Lack of environmental regulations	Increased operational costs due to environmental regulatory compliance	Increased demands of environmental regulations
Physical	Lack of landfills	Lack of landfills	**Market saturation**
Political	Political conflicts between the local and the central authority	**Political conflicts between the local and the central authority**	Political conflicts between the local and the central authority Lack of long-term policy
Psychological	Hesitation of success	Disappointment due to inequal treatment of different cases by environmental authority	Lack of trust to policy makers and public institutions
Technological	**Lack of technological knowledge**	Import dependency	Import dependency

The barriers indicated in blue color are emphasized as the most influential barriers for LFGTE technology diffusion for each phase.

According to our field research, we were able to conclude that all cases agree that the market has reached a saturation limit, but they have slightly different perspectives as barriers to technology diffusion. According to the early adopters of technology, the major barrier to technology diffusion is *extremely high shares given to municipalities from the electricity sales*. Accordingly, municipalities have stopped looking for technical experience of the firm and increased the weight of "share from profit" in the tender criteria. This has been often mentioned as "non-feasible" and "a barrier before the progress of the sector". For the late adopters; the major barrier in further diffusion of technology is the *end of Feed-in-Tariff mechanism* and demand of municipalities to include construction and operation of other environmental technologies at the disposal site as a part of *environmental compliance requirements*[41]. Our findings suggest that; the influence of environmental permits regulation has been a discouraging factor for investor firms. A typical problem of the sector is high operation and maintenance costs, but this was not excessively mentioned because for the time being the FiT mechanism balances *costs associated with operational difficulties* of the technology. On the other hand, firms think that if there is no more FiT or any similar mechanism to support these facilities, municipalities will be left with scrap machinery in hand, when private firms exit from the market after 2030. Finally, physical limitations are remarkable at this stage as; there are only 24 provinces left in Turkey without an LFGTE plant.

[41] In 2014, the environmental permits regulation was issued in Turkey. According to this regulation, municipalities must install mechanical separation units at the landfill sites in order to get a landfill operation license. It has been also a common practice that municipal authorities included the mechanical treatment plant construction and operation in the ToR of the LFGTE tenders.

CHAPTER 5

CONCLUSIONS and POLICY IMPLICATIONS

In this chapter we have presented a summary of our research, discussed our findings towards problems associated with LFGTE diffusion and concluded our remarks with policy proposals and recommendations for future research in this field. In the first section to this chapter we have summarized the core problems addressed with our research and presented policy recommendations to improve the situation. Secondly, we have summarized results of our research and concluded our discussion. In the final section we have discussed limitations of this study and have given our humble recommendations for future research in the similar field of interest.

5.1 Problems and Policy Recommendations

Our analysis of influencing mechanisms of LFGTE diffusion in Turkey has shown that; the renewable energy feed-in-tariff mechanism (YEKDEM) has fulfilled its purpose for technology diffusion by the end of the second phase of diffusion (i.e. 2015). Since 2015, the feed-in-tariff (FiT) mechanism acts as a tool to compensate shortcomings of solid waste disposal system in Turkey. In the third phase of diffusion, presence of the FiT has resulted in a shift of municipality aim from “disposal site management” to “making money from waste”. Only few firms in the market (especially early adopters) have installed more advanced technologies and developed their own know-how for plant operations. However, the presence of the FiT has interfered the competition of technologies (Hall and Khan, 2003) in the last phase of diffusion and resulted in a lock-in (Kemp and Volpi, 2008; Rio et.al., 2010) to the LFGTE technology.

There are already firms in the LFGTE market that carry out R and D activities, implement advanced technologies and invest in social, institutional innovations. On the other hand, a majority of firm apply singular LFGTE investment, with the main motive of making profit for private firm and the municipality. There are shortcomings of the municipal solid waste management system, mostly related to operational costs. The municipalities have relied on the feed-in-tariff to overcome financial difficulties associated with the cost burden of the SWM system.

As a result of this research we have identified that;
- Lack of qualified personnel and lack of personnel motivation
- Costs of designing and constructing a landfill project
- Institutional instabilities such as; frequent changes in municipality personnel, frequent changes in ministry of environment personnel
- Lack of a disposal site
- Political conflicts and lack of long-term political stability within municipal authority
- Lack of trust in technology
- Complexity of technology

Have been major barriers in front of LFGTE diffusion in Turkey. The municipalities have overcome the physical barriers of "site selection and construction of a landfill" mostly by the help of EU funds. Municipal administrations which are in political dispute with the government has faced delays in construction of landfill sites. The problem of lack of trust in technology was overcome with time as more LFGTE projects has been implemented and the technology has proven to be successful in exemplary facilities. Problems associated with institutional instabilities, frequent change of municipal personnel and lack of long-term political stability within the municipal authority is still going on.

Major barriers for firms to implement LFGTE technology within municipal authorities can be summarized as;

- Long bureaucratic procedures

- High operation/maintenance costs and high rates of share given to municipalities
- Lack of long-term stable environmental policy and continuously increasing demands by environmental regulations
- Political conflicts between the municipal authority and the government
- Lack of trust in policy makers and public institutions due to experiences of unprofessional and unstable applications
- Import dependency to machinery and equipment
- Physical saturation of the market

At the time being, the LFGTE market is saturated as there are only 24 provinces in Turkey without an LFGTE investment. Initial facilities have the right to benefit from the FiT until the end of 2030. Most of the contracts between municipalities and the private investor will be finished right after end of the FiT. Private firms will leave operation of landfill sites to the premises of the municipal authority after the terms of contract is over. Early adopters of the technology, firms which define their core business as environmental management have a vision to sustain their operations in the waste management sector even if there is no FiT subsidy. Energy firms which have been established only for the purpose of LFGTE implementation on the other hand, have no longer vision for the waste management sector after the FiT support is cut.

Applications to the initial FiT mechanism is over as of 2020. A new market-based instrument is being planned by the MoENR. The electricity sector opinion is in favor of continuation of the FiT with amendments in definition of “Biomass”. For biomethanisation plants, the investment costs are calculated including the mechanical separation units for a 10 year of payback time as 19,07 USD-Cent/kWh with a Feed-in-Premium model. In addition to this, the Electricity Producer’s Association (2018) states that there is a need for additional support to cover high operational costs, after the end of the 10-year subsidy. The workshop paper also includes suggestion that; high share of profits of municipalities is unbearable for firm and regulation of waste management is required in order to secure sustainable waste input to these facilities (Association of Electricity Producers, 2018). We agree with the reflection paper that;

regulation of waste management activities is required. Not only for the security of biogas power plants but also future sustainability of municipal waste management. We, however, argue that; LFGTE plants should no more supported by government subsidies.

Secondary regulations for the environment (i.e. Landfill regulation, Communique of compost, communique of mechanical separation, zero waste regulation etc.) have been in force after the initiation of the feed-in-tariff. Our hypothesis is that; the feed-in-tariff instrument which have been introduced without considering its environmental impacts, has resulted in a lock-in to the marginal environmental innovation and has been a barrier in front of radical changes. Accordingly, problems associated with the LFGTE technology diffusion are framed as;

- The presence of FiT has resulted in a lock-in to LFGTE technology.
- The role of FiT in technology diffusion has ended. Now its role is to compensate shortcoming of the solid waste disposal system in Turkey.

In order to address these problems, we are convinced that, an evolutionary policy framework which would complement the neo-classical subsidy scheme of the government should be introduced. In order to remediate the technology lock-in problem after the FiT is over;

- Technical and institutional lack of firm capabilities should be increased to generate endogenous means for adoption of diverse technology and business models
- A favorable investment ecosystem which would allow flourish of variety of SWM technologies in different level of waste hierarchy should be designed

Therefore, development of technologies, advance from one technology to other might be flexible when the "time comes". It is difficult to measure which technology option is more environmentally friendly and which one will prevail the other in the future. But, as one of our participants from the case study has said that; "…. *we will be speaking of a different waste after 20 years."* The population will increase, waste

production per ton will increase, content of the waste will change. Firms will have to upgrade their systems with modifications accordingly.

"Radical eco-innovations probably lead to greater environmental benefits than incremental ones and should then be prioritized. The barriers to radical eco-innovations are more systemic, more related to a wide array of factors, and thus more difficult to eliminate. This makes the combination of policy measures more relevant in the case of systemic eco-innovations" (Rio et.al, 2010).

The United Nations global environment outlook in the context of the 2030 agenda, includes linkages between environmental quality and human rights, health and wellbeing[42]. The vision for 2050 stated in the EU 7th Environment Action Program[43] relates a healthy environment to an innovative circular economy. The waste management is linked to the low-carbon development, sustainable use of natural resources, protection of biodiversity. Both documents address importance of improvement of local governance within the context of sustainable cities. While preparing technology policy recommendations we have relied on long-term global visions of the United Nations and the European Union.

In order to design the technology policy, we have defined our criteria for policy framework. First; the policy objectives shall be in harmony with the national waste management action plan of Turkey. Secondly, they shall not conflict or overlap with policies of other government authorities. The policy mix also must be in harmony with the 11th National Development Plant of Turkey and finally the Zero-Waste Initiative Program of the government has to be included in the policy mix. Our objectives with technology policy are;

- To improve capacity of private firms and,

[42] For more information on United Nations 2030 Agenda, one may check https://sustainabledevelopment.un.org/ (last visited on 01.01.2020)

[43] https://ec.europa.eu/info/energy-climate-change-environment/overall-targets/2050-targets_en (last visited on 01.01.2020)

- To establish a technology development environment where actors of the system can sustain and grow;

We have designed focused (micro) policies, framework (macro) policies and blanket policies (meso policy) to address these objectives. Neo-classical theory has its merits with framework policies (i.e. macro policy) where country wide plans and programs are introduced. Neo-classical theory also has its merits in focused policy making (i.e. micro policy) where agent-based strategies are assessed to sketch out optimal pathways for a technology. On the other hand, assumptions of evolutionary theory promise much of a richer environment for blanket policies (i.e. meso policy) where technological spill overs in complex environments is addressed (Lipsey and Carlow, 1998). In Turkey there is already a neo-classical policy scheme to support LFGTE investments. In our policy design we have adopted an evolutionary policy outlook to support the initial neo-classical scheme of policies.

5.1.1. To develop firm capacity

There are 26 investor firms in the LFGTE sector as of 2019. Only two-three of these firms carry out research and development activities. Only about five of them can construct and operate biomethanisation plants. Moreover, only three firms are capable of design, construction and operation of an Integrated Solid Waste Management System. Lack of capabilities of firms holds back the sector from developing to more advanced technologies. While the FiT is present for another 10 years; administrative, institutional, technical and economic capacity of LFGTE firms shall increase in order to be able to survive, grow and develop without the FiT support.

Macro (Framework) Policy

Framework policies aim for a wide range of influence to a target group and/or a group of sectors etc. With framework policies our aim is to; support formation of new product markets in order to increase available economic activities for firms. For this purpose, a whole buying mechanism for a typical product (compost for instance) should be organized. In our field research, we have observed that all cases have mentioned

inefficiency of the compost market. Organization of a nation-wide campaign to buy compost from waste management facilities issued as a part of non-governmental organization under the supervision of the MoEU would make an incremental change in the compost market.

Meso (Blanket) Policy

Blanket policies act as mediator between framework and focused policy (Lipsey and Carlaw, 1998). With blanket policies our aim is to; Increase number of firms that carry out research and development activities and to increase in firm-to-firm diffusion of knowledge in the sector. In order to increase number of firms which carry out R and D activities, these firms should be encouraged. "Green R and D" awards should be organized by a non-governmental organization under supervision of MoEU. As a result of the Green R and D awards results of the activities are publicly disposed, new knowledge is created and disseminated in the sector. In order to increase firm-to-firm diffusion of knowledge, firms should host site visits and workshops at the project locations. Ministry of Environment can coordinate annual workshops where each year a different firm in a different province hosts the event. An event full of half a day of site visit, and half a day of workshop would both increase network relationship of the firms in the sector and also firms can have the opportunity to experience better applications under operation. The MoEU can prioritize the plants to be visited, in line with the development scale of the technology.

Micro (Focused) Policy

Focused policies directly aim at "touching" individual firms. With focused policies our aim is to; Increase firm-based knowledge on the perspective of MoEU on solid waste management and increase firm-based knowledge on advanced technologies applied in developed countries. For this purpose; there should be sector specific training programs on waste management hierarchy, alternative SWM disposal systems, eco-innovations etc. In order to increase firm-based knowledge on advanced technologies; occasions where firms will observe operational facilities in foreign countries and exchange information with foreign experts should be organized.

"Technological assistance programs and trainings provide firms with information on new eco-innovations or train the employees on the new eco-innovations. Such programs could encourage eco-innovation, especially in small and medium-sized enterprises, which usually lack in-house technical specialists" (Rio et.al., 2010). A summary of policy recommendations to increase private firm capacities can be found in **Table 22**.

Table 22 Policy Recommendations to Develop Private Firm Capacities

POLICY LEVEL: MACRO POLICY		
POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
Support formation of new product markets	A nation-wide campaign for utilization of compost should be organized	Campaign organized by cooperation of non-governmental organization under supervision of the MoEU
POLICY LEVEL: MESO POLICY		
POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
Increase number of firms that carry out research and development activities	Firms which carry out R and D activities should be encouraged	"Green R and D" awards; organized by a non-governmental organization under supervision of MoEU.
Increase in firm-to-firm diffusion of knowledge in the sector	Firm-to-firm interaction should be encouraged through organizations	Firms host site visits and workshops at the project locations.
POLICY LEVEL: MICRO POLICY		
POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
To increase firm-based knowledge on the perspective of MoEU on solid waste management	There should be sector specific training programs on waste management hierarchy, alternative SWM disposal systems, eco-innovations etc.	Training programs designed by MoEU experts
To increase firm-based knowledge on advanced technologies applied in developed countries	Occasions where firms will observe operational facilities in foreign countries and exchange information with foreign experts should be organized	Site visits and workshops with sector experts organized by the firms under coordination of the MoEU

5.1.2. Design a Favorable Ecosystem for ISWM Development

Our results have indicated that, lack of a long-term policy, conflicts and gaps in policies of different ministries are often mentioned institutional barriers to LFGTE diffusion. Firms lack trust in the legislative system, they do not strongly rely on the democratic judgement mechanism so that; firms basically trust on strength their local affiliations and good relationship with the municipality for the security of investment. A stable and consistent policy framework (Foxon et.al.,2005) is required for a healthy innovation environment. While designing eco-innovation policies a trade-off between quick end-of-pipe solutions and long-term radical innovations is often encountered (Rio, 2010; Kemp and Volpi, 2008). Similar to diffusion of LFGTE in Turkey, sometimes supporting a technology to have an urgent solution to an environmental problem may be in expense of discouraging more environmental options which would have otherwise adopted. In Turkey, majority of environmental legislations related to municipal solid waste management have been enforced after LFGTE technologies have been already diffused in the market. Therefore, influence of environmental regulations is felt just the last years of the final period of diffusion.

We will benefit both from neo-classical and evolutionary perspectives to design a portfolio of policies (Jaffe et.al., 2005) which include elements of technology policies to complement environmental rules and regulations to make technological advance attractive against interacting cases of energy and environment (such as the climate change).

Macro (Framework) Policy

Our aim with the macro policy is to link incremental innovations and radical innovations on a macro scale. For that purpose, activities of solid waste management facilities should be linked to a radical environmental innovation program. In 2018, the Zero-Waste program has been initiated in Turkey. The Zero-Waste initiative encompasses minimization of wastes at the source, increasing recycling activities, and recovery of value from the waste. Participants to our study have mentioned that "separation at source" conflicts the request of the MoEU to install mechanical

separation plants to all licensed landfills. It is also argued in sector reports (Association of Electricity Producers, 2018) that; firms are not willing to invest in mechanical separation units. However, they are also not willing to invest/donate in public campaigns on waste recycling etc. We recommend that facility operations should be integrated to the Zero-Waste program. Beginning from the facility operations a firm is ought to be; producing less waste, operate the plant more efficiently and contribute to the zero-waste activities (such as trainings, recycling campaigns etc.) in the locality of the project area. With the help of this policy there will be a mutual increase in firm knowledge about incremental innovations and public awareness about waste management.

In addition to this a long-term vision is ought to be established in order to transform the sector toward sustainable patterns of production. The sector has lost its trust to government authorities due to political conflicts, inequal treatment of actors in different regions and lack of long-term stable policies. Long-term visions are also useful to integrate environment and technology policies (Rio et.al., 2010). With the aim of re-building trust of firms to policy makers; a long-term techno-environment policy should be implemented.

Meso (Blanket) Policies

Environmental technologies should be promoted in order to prevent lock-in to suboptimal technologies. Eco-innovation is a necessary tool to reduce environmental pressures from production and consumption activities. Technology policies should act together with the environment policy to balance short term environmental protection and promotion of radical eco-innovation. The aim of environmental policy is not only to promote eco-innovation but to protect the environment at a reasonable social cost. Therefore, government authorities should explicitly focus on promoting eco-innovation (Kemp 2007).

Micro (Focused) Policy

Firms which identify themselves as environmental technology companies are dedicated to improvement of environmental technologies and investment of a diversity

of environmental technologies more than firms which identify themselves as energy production companies. As a micro policy we recommend that administrative standards should be set by the MoEU to firms to establish the philosophy of environmental technology management within the company. Making institutional changes is of course not an easy task and it might take more than a few years to be fully implemented in the company as a firm identity. However, increasing the environmental dedication of firm is possible through a certification and/or audit scheme of the MoEU. The scheme could include but not be limited to employment of qualified environmental engineers, establishment of ISO14001 standards, acceptance of an audit scheme. A summary of policy recommendations to provide a favorable ecosystem for ISSM can be found in **Table 23**.

Table 23 Policy Recommendations to Design a Favorable Ecosystem for ISWM Development

POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
To link incremental innovations and radical innovations on a macro scale	Activities of solid waste management facilities should be linked to a radical environmental innovation program	Declaration of a Zero-Waste integration scheme for firms
To rebuild trust of firms to policy makers	Policies should be prepared including opinion of actors from the sector.	Development of the policy making practices
POLICY LEVEL: MESO POLICY		
POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
To prevent lock-in to suboptimal technologies	Environmental technologies should be promoted	Subsidies in form of tax reduction when cleaner technologies are implemented
POLICY LEVEL: MICRO POLICY		
POLICY AIM	**POLICY RECOMMENDATION**	**POLICY TOOL**
To establish the philosophy of environmental technology management within the company	Administrative, technical and organizational standards should be applied in firms	Standards issued by the MoEU

5.2 Conclusion

Turkey is a developing country that aims to decrease its energy dependency. The country has adopted a Feed-in-Tariff mechanism to support renewable energy technology diffusion in 2005 in order to increase share of renewable resources in its electricity production. The current FiT subsidy, as amended in 2010, has covered a 13,3 USD-Cent/kWh electricity production by biomass plants. Total capacity of biomass power plants in 2018 have reached approximately 500 MWe. Half of this capacity belong the Landfill-Gas to Electricity Power Plants. Landfill Gas to Electricity Technology has been first adopted in Turkey in 2005. By the end of 2019 a total number of 83 LFGTE power plants have been implemented in the country and reached a total capacity of 435 MWe. There is at least one LFGTE plant in 57 of the 81 provinces of Turkey. The technology has reached its physical limits for adoption already by the end of 2019. Despite LFGTE technologies benefit from the same amount of FiT support, they have diffused way faster than other biomass technologies. Our starting curiosity behind this research was the phenomenon of swift diffusion of LFGTE Technologies in Turkey.

We have designed our research around the research questions; “what are the influencers of LFGTE technology diffusion in Turkey?” and “how do these influencers effect the LFGTE diffusion?” In order to find answers to these questions we have adopted a descriptive and exploratory approach and designed a three-pillar inductive research with the aim of describing influencers of LFGTE diffusion and exploring influencing mechanisms to understand the grounded theory (Patton, 2002). The grounded theory methodology aims to extract the theory embodied in the empirical data. The theory building approach has its merits in new areas of research where there is room for contextual discoveries (Masini and Menichetti, 2013). Diffusion of renewable energy technologies is recently an emerging field of research in social sciences. In the first pillar of our research; we have reviewed the literature to learn about the theoretical, empirical and conceptual framework of LFGTE diffusion. Empirical studies on LFGTE diffusion is hardly available in literature. Li et. al (2015) has studied influencers of LFGTE diffusion in the USA and found that market-based instruments such as renewable energy portfolio standards and tax credits were

influential in diffusion of LFGTE technologies in USA. However, there are no studies regarding institutional influencers (Mignon and Bergek, 2016; Jacobsson and Bergek, 2011) of LFGTE technologies. As a part of the grounded theory methodology we continued the literature review (Dunne, 2011) in consistency with the empirical data collection. The second pillar of our research included document analysis as a qualitative method (Bowen, 2009) and in-depth expert interviews. We have reviewed the licensed LFGTE facilities' list that is publicly available in the website of the Electricity Market Regulatory Authority (EMRA). Then, we have read through national policy and guidance documents on renewable energy, climate change and waste management to learn about policy makers' vision. Finally, we have searched provincial environmental status reports and the world-wide-web for technology specific keywords[44] in order to address non-licensed projects. We have accepted information only from official websites of municipalities, firms and or official announcements of public tenders etc. as reliable information. In addition to the document analysis, we have carried out in-depth interviews with four people experienced in the LFGTE sector. Two of the interview participants were from private companies and one was from a Metropolitan Municipality and the other one works for a Municipal Union. We have applied purposive and expert sampling based on the network connections of the researcher with interviewees. As a result of the in-depth interviews, we have learned about; division of responsibilities among actors in the sector and organizational-institutional structure from the perspective of firms and municipal authorities. We have complemented the secondary data we had in hand by the empirical information from the interview results to prepare a "master database" document that includes all cases of LFGTE investments in Turkey with; investor profiles, plant capacities, investment models etc. We have prepared our interviewee profile and the semi-structured interview guideline as a result of the second pillar study. Next, we have begun our field research.

The field research was designed to describe and explore influencing mechanisms of LFGTE diffusion in Turkey. We have designed a multiple-case study in the form of

[44] "We used the Turkish synonyms of "Name of the municipality", "waste to electricity", "waste gas" etc. as keywords for the web-search.

eight semi-structured interviews in order to obtain empirical data from cases. We have used snowball sampling approach and samples a set of 8 participants from a total number of 26 firms in the LFGTE sector. These 8 participants represent; 8 firms which operate 57 of the 83 plants in Turkey. Conversations were recorded and meeting notes were taken during the semi-structured interviews. The interview sessions were then, transcripted and actual phrases of participants were iterated based on the codebook of analysis. Actual phrases are iterated to constructs and constructs are further iterated to themes and aggregate dimensions. We were able to define four aggregate dimensions (public resources, financial resources, accumulation of knowledge and business strategy) as task environment influencers of LFGTE diffusion. Formal and informal institutional dimensions were defined as institutional environment influencers of LFGTE diffusion. The results of our study have revealed that, there are three phases to LFGTE technology diffusion in Turkey. The main prerequisite of LFGTE diffusion is; issue of a tender Municipal authority. Main motivation for a municipal authority to issue a tender are; *to relieve from risks and costs of disposal site management*, and to *profit from the LFGTE operations*. Major limitations to adopt LFGTE services were found to be lack of knowledge about the technology in the first phases of diffusion and bureaucratic delays/political conflicts in the later phases of diffusion. Presence of a landfill and a sustainable amount of organic waste input is a prerequisite for LFGTE adoption at all costs. Firm based drivers for LFGTE diffusion were found to be; *Availability of high amount of organics* in disposal sites and *long term-sustainable business agreement* with the municipality in Phase I of diffusion. *The Feed-in-Tariff Mechanism* in the second phase of diffusion and *the increase in the USD currency rate* together with the *change of status* of 14 municipalities to metropolitan municipality and *end of FiT applications* in 2019. The barriers to diffusion were *long bureaucratic procedures* and *lack of technical knowledge* in Phase I, *political conflicts* between the local and the central authority and *long bureaucratic procedures* in Phase II and *market saturation* in Phase III of diffusion.

As last but not the least; our analysis of influencing mechanisms of LFGTE diffusion in Turkey has shown that; the renewable energy Feed-in-Tariff mechanism has fulfilled its purpose for technology diffusion by the end of 2015. Now its serves as a

tool to compensate shortcomings of the solid waste disposal system in Turkey. Moreover, presence of FiT has resulted in a lock-in to LFGTE technology.

We believe that an interdisciplinary policy based on the needs of local public administration must be designed to promote evolution of LGTE technologies. By evolution we mean a dynamic policy which would not strictly support a technology in favor of another. Therefore, development of technologies, advance from one technology to other might be flexible when the "time comes". We have designed our policy framework for the favor of promoting radical innovations while strengthening the capacity of firms to implement diversity of technologies.

Technology policy can be costly; if it is used as a substitute for, rather than complement, to environmental policy." (Jaffe et.al. 2005). The problem of the LFGTE sector is the eventual lock-in to the LFGTE technology (i.e. lack of technological advance). In order to remediate the technology lock-in problem, we have recommended that;

- Technical and institutional lack of firm capabilities should be increased and
- A favorable investment ecosystem suitable for development of variety of SWM technologies should be designed

We have recommended a policy mix in micro, meso and macro levels with the hope that these would constitute an example to other cases where problems associated with public private partnership investments in regional environmental technology investments.

Findings of our study suggest that; influence of market-based instruments may result in adoption of one technology in expense for another (may be more environmentally friendly) technology in the absence of environmental dimensions in the innovation system. We have purposively selected the LFGTE technology because; it is a technologically simple, end-of-pipe, marginal eco-innovation with complex institutional, political and administrative dimensions. Investigating this technology

with an evolutionary approach has allowed us to focus more on institutional factors, relationship of actors and identify public policy dimensions.

5.3 Limitations and Recommendations for Future Research

In this research we have analyzed influencers of LFGTE diffusion and their influencing mechanisms in Turkey. This research aims to explore influencers (drivers and barriers) of LFGTE diffusion in Turkey. Perceptions of private investors of LFGTE technology is our unit of analysis. We were able to satisfy our curiosity that not only the Feed-in-Tariff but also a series of task based, and environmental-based factors were influential in LFGTE diffusion. One of our major limitations in this study was the technological specificity of the subject.

LFGTE diffusion in Turkey is a relatively undiscovered area of research with a potential of leading further research opportunities in diffusion of other environmental technologies in Turkey. We have followed a qualitative methodology and applied multiple case study approach in our research. We have limitations due to the nature of the methodology and we have some other limitations due to the nature of data sources.

The research methodology (qualitative, quantitative or mixed) is selected based on the context dependency of the research subject (Mouton and Marais, 1996). Qualitative means of analysis are usually preferred for exploring contextual fields of interest such as localities and socioeconomic relationship whereas quantitative methods are used for theory testing research with a more general interest. Case studies are commonly preferred data collection methods in contextual exploratory and descriptive social research. Case study allow the researcher to explore deeper into the phenomenon of interest whereas in-depth interviews allow the researcher to explore beyond expectation with contribution of participant opinion/expertise (Mouton and Marais, 1996). On the contrary to deductive reasoning of positivist research; the main aim of the case study is to develop an in-depth understanding of the contextual interests such as localities and socioeconomic interactions.

In quantitative research the object (data source) and the researcher are not connected but in qualitative research the researcher and the object/study are not separate but interdependent. A qualitative research cannot be thought separately from the experience, perceptions, background and even psychology of the scholar. There is an empathetic interaction between the scholar and the subject studies. That may create a major pitfall of subjectivism in research design and interpretation of data. Nevertheless, validity is within the objectivity of the qualitative study. The researcher with an interpretivist way of thought aims for revealing interpretations and meanings. Therefore, the research is highly influenced by; experience, perceptions, personality of the researcher and the empathetic interaction of the researcher with the source of information (Bhattacherjee, 2012; Patton, 2002). The subjectivity of interpretivism is often criticized by positivists and replicability of results are questioned. However, an interpretivist research does not aim for being “subjective". Exploratory studies usually lead to insight and comprehension rather than the collection of accurate and replicable data. The interpretivist research therefore is oriented towards examining new ideas, suggestions and to be open to new stimuli. Although such an approach may be perceived as less credible, it is useful in understanding social processes, discovering the meanings people attach to social phenomena. Challenges to an interpretivist research is that data collection can be time consuming and data analysis can be quite complex as data collection/analyses are context dependent and not free from the research process. This flexibility may create an illusion for the interpretivist researcher that the results may not emerge to a concise conclusion. For this reason, the researcher may fall into the common pitfall of allowing preconceived hypothesis to influence the research process. Nevertheless, it shall be kept in mind that the goal of such a research is to comprehend not to conclude to general laws and theories.

The nature of qualitative data is usually “soft”, rich and deep and serves to gain new insights of a phenomenon rather than being objective and standardized. Therefore, results are presented in a more narrative perspective in contrast to quantitative analyses where data is presented in tabular form (Mouton and Marais, 1996). The researcher herself is an instrument of the research process. Therefore, the qualitative analysis is a

subjective approach. Beliefs, attitude, interests basically the personality of the researchers is a part of the research (Patton, 2002).

Our major limitations in the preliminary study were lack of publicly available official information for the documentary analysis and reaching municipalities for the interview. Document analysis is usually considered less time consuming then other research methods. However, selection of data is critical for the quality of the document analysis. There is an abundant amount of web pages related to LFG to electricity news in Turkey however, it was time consuming to locate such news in municipality websites. Local news for smaller municipalities includes provocative information which either aimed for "praising" or "vilifying" the municipality. Furthermore, available information sourced do not include the same standard set of information. Therefore we had to check more than a few web pages to complete a set of required information for facilities. We have considered official "municipality web-pages" and official "firm web-pages" as the most reliable source of information.

We have interviewed four experts in order to learn about the general framework before the field study. The "freedom" of the participants within the context of in-depth interviews has allowed us to explore and discuss the subject thoroughly. In such a study it is important to determine the "target" carefully before stepping on to the interview sessions. Sampling and interviewing can go on forever unless the researcher determines "a limit" and assesses if the information retrieved from the study is satisfactory enough to reach the target. This limit, however, is not a quantitative value which can be assessed easily. Instead, we have determined a target which is subjective to the study which is; learning about the general framework of the sector. We have stopped in-depth interviews with experts when we had answers to our target questions; "Who are the key actors in the LFGTE business?", "What are roles of key actors in LFGTE diffusion?" and "What are the relevant legislations to LFGTE investments?" It is worthy to note that interview results of the preliminary study were used as complementary information source to the document analysis. In addition to this, we have used the outcome of preliminary study to cross-check information from the case studies. Information from in-depth interview were used as complementary information

to the secondary data obtained by the document analysis. Therefore, we believe that the limitation of number of expert interviews would not have changed the direction of the research.

Time scarcity and concern for privacy were other important limitations to our research. At times the respondents were in a rush, although they were previously informed that the interview may last about 1 hour. The interview sessions were set to a time about the timing of the interview. Usually the respondents were interrupted with phone calls or requests from colleagues during interview sessions. Generally, the technical personnel are busier and more stressed whereas firm owners/high rank managers are more relaxed and dedicated to give more information. Use of qualitative methods get difficult where respondents are privacy centered, emotional, deeply segmented etc. Sometimes the interviewee extended the conversation and wanted to talk about other topics. Sometimes they misunderstood the question and replied differently. We had to ask the same question in a different manner, after different times again and again. My experience as an environmental engineer had a positive contribution in this manner where at times, when the responded was distracted from the main subject. Using the same technical jargon was helpful in small talk and getting the interview back in track. Being familiar to the technical terminology was also helpful in addressing a question in different ways. However, that brings another limitation which is the relationship between the researcher and the respondent. Interviewing is a social event where a bond is formed between the interviewer and the interviewee. Two respondents knew the researcher from previous projects, or at least they have met during sector get togethers. This professional relationship helped in establishing the first bonding, but we were careful in crafting the interview so that there was no professional conflict of interest between the two parties. For instance, some of the interviewees asked if the researcher works for a private consulting company in the waste management sector. We have overcome the limitation of "trust" by introducing my professional background and aim of doing the research and the scope of the study in a comprehensive manner. All interviewees were acknowledged about the ethical codes of Middle East Technical University (METU). As mentioned before, the field research instruments were approved by the Human Research Committee of Applied Ethics Research Centre

(UEAM) of METU before beginning the research study[45]. The interviewees consent for voluntary participation was received and they were supplied with all necessary information related to background, methodology, purpose and scope of the research before the interview session began.

Even though participants were relieved about the ethical concerns, they still had concerns about their commercial vulnerability. Their concern is mainly due to the increased competition in the market. Firms are reluctant to speak on their current investment strategy, but they do not hesitate to give information regarding the past investments. This was a major limitation for our interviews. Our trial interview before the actual field study was very helpful to understand potential concerns of participants. We have decided to inform the participants about our awareness and respect to their firms' commercial privacy as well as their personal privacy within the warming up speech. This approach has helped the participant to feel relieved about the conversation. Moreover, they were free to ask questions to the researcher about their concerns before the interview began. Therefore, potential hesitations of participants regarding the information exchange were eliminated before the interview sessions as much as possible.

We acknowledge that results of this study will not be directly adopted to other environmental technologies. Nevertheless, we would like to think that this research has cracked the door open for research in diffusion of public eco-innovations in Turkey. Our findings have revealed only one side of the story. An analysis of the sector from perspective of other key actors; municipalities, suppliers, municipal unions, villages where the LFGTE plants are constructed… promise different pathways for further research. Public eco-innovations are often neglected area, but it has been gaining incremental attention recently with development of the understanding that solution of global environmental challenges begins with regional actions. There is a promising potential in the field of regional environmental development for researchers interested in eco-innovation diffusion.

[45] A copy of AERC Approval can be found in Appendix C.

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APPENDICES

A: GLOSSARY

Barriers and drivers to diffusion of innovation: The term **"**barriers and drivers of innovation" is described in the 4th edition of the Oslo Manual as: "*Internal or external factors that hamper or incentivize business innovation efforts. Depending on the context, an external factor can act as a driver of innovation or as a barrier to innovation."* (OECD/Eurostat, 2018). We have used terminology of barriers and drivers to diffusion of eco-innovation is based on the definition of Oslo Manual (2018). We have used the terminology "barrier to diffusion of LFGTE technology" as internal or external factors that hamper LFGTE adoption efforts. We have used the terminology "driver to diffusion of LFGTE technology" as internal or external factors that incentivize LFGTE adoption efforts.

Environmental Technology: There is not a scientific consensus on defitinion of environmental technology but; Environmental Technology is defined as: technologies whose use is less environmentally harmful than relevant alternatives in Kemp and Pearson's "Measuring Eco-Innovation Project Report" (Kemp and Pearson, 2007). Technology refers to the "*state of knowledge on how to convert resources into outputs. This includes the practical use and application to business processes or products of technical methods, systems, devices, skills and practices.*" as stated in the Oslo Manual (OECD/Eurostat, 2018). The EU Environmental Technology Action Plan (ETAP) describes environmental technologies as such "*Environmental technologies encompass technologies and processes to manage pollution (e.g. air pollution control, waste management), less polluting and less resource-intensive products and services and ways to manage resources more efficiently (e.g. water supply, energy-saving technologies)*" [46]. We have accepted definition of ETAP as the main construct of an

[46] ETAP was adopted by the European Commission in 2004. The objective of this ambitious plan is to further environmental technologies to improve the environment and European competitiveness. It

environmental technology. An LFGTE investment may or may not involve operation of series of affiliated environmental technologies (i.e. leachate management, emissions management, odor management etc.) which were referred to during in-depth interviews.

Landfill / Landfill Gas: In OECD statistics glossary a landfill refers to "*the final placement of waste in or on the land in a controlled or uncontrolled way according to different sanitary, environmental protection and other safety requirements*"[47]. Definition of Landfill is adopted from the Turkish National Waste Management Action Plan. A landfill is: Areas where wastes are disposed under determined technical standards excluding recycling, preprocessing and temporary storage and interim storage facilities. (MoEU, 2016). Landfill Gas is defined in the *Regulation* on Documentation and *Support* of *Electricity* Manufacturing from *Renewable Energy* Resources (Official Gazette 28001, dated 21 July 2011) as "*Gas which is produced to generate energy from wastes including garbage*". Landfill gas is generated in dumpsites or landfills. We have used the same terminology of LFGTE independent of its place of implementation. Therefore, we have not considered landfill/dumpsite differentiation as a variable.

Landfill Gas to Energy (LFGTE): The landfill gas can be utilized to produce biofuels, electrical energy and/or heat (US.EPA, 2017). Typical application in Turkey for the landfill gas utilization is electrical energy production in reciprocating engines for small scale applications (i.e. approximately 1 MW installed capacity). In most of the medium scale (1 MW- 5 MW) LFGTE plants, the waste heat from the reciprocating engine operations is utilized in heating of in-situ green houses to produce vegetables and/or flowers etc. There is also an example of utilization of waste heat for municipal solid waste sludge drying in a single plant. Combined cycle systems are applied in medium to large scale (10 MW and more) LFTE plants (more than 5 MW) in Turkey. With combined cycle systems, electricity is produced both from the LFG and the waste

complements the Environment Directorate-General's regulatory approaches and directly addresses the three dimensions of the Lisbon strategy: growth, jobs and the environment.

[47] https://stats.oecd.org/glossary/

heat of the system. In summary, the extent of LFGTE applications in Turkey is limited to electricity generation from the LFG. Other forms of energy production is not primarily aimed for in any plants. As a matter of fact; we mean utilization of Landfill Gas in forms of electrical energy with the term “Landfill Gas to Energy” i.e. LFGTE.

Municipal Waste: Municipal Waste is defined in the Waste Management Regulation as; types of wastes which are sourced from households and/or wastes from offices, industrial and institutions which have a similar content or structure to household wastes. These wastes are classified under the Waste Management Regulation Annex-4 subclass 20 (Waste Management Regulation, Official Gazette 29314, Dated 02.04.2015). Definition of municipal wastes is important because waste is the main input of the landfill which will determine the quality and quantity of the landfill gas. In some dumpsite industrial wastes or wastewater sludges are also accepted as wastes which are not municipal wastes at all. This distinction was made clear to the participants as the influence of “non-municipal” waste input was mentioned during the interviews.

B: INTERVIEW GUIDE IN TURKISH (MÜLAKAT REHBERİ)

GİRİŞ	
1	Profesyonel geçmişiniz ve tecrübeleriniz hakkında bilgi verebilir misiniz? (Eğitim, profesyonel kurslar/eğitimler, sektör tecrübesi, firmada aldığı görevler, firmada çalışma tecrübesi vb.)
2	Firmanızın çalışma alanları ve tarihçesi hakkında bilgi verebilir misiniz?
3	Firmanızın LFGTE projelerindeki tecrübesi (geçmiş projeler, mevcut projeleri vb.) hakkında bilgi verebilir misiniz?
MEVCUT DURUM	
4	Projelerinizin yer aldığı belediyelerdeki atık yönetimi uygulamaları hakkında bizi bilgilendirebilir misiniz? (Bu soru, firmanın çalışma alanındaki ana aktörleri, bileşenleri, sorumlulukların dağılımını ve anlaşma türlerini belirlemek için yöneltilmiştir)
5	Bir belediyenin atık yönetim uygulamalarına karar verme, değiştirme yönünde hareket etmesindeki "temel faktörlerin" neler olduğunu düşünüyorsunuz? Neden?
6	Bir düzenli depolama alanında LFGTE teknolojisinin kurulabilmesi için hangi ön şartların sağlanması gerektiğini düşünüyorsunuz?
7	Atık yönetiminde gelir ve gider kalemleri nelerdir? Sizin yönettiğiniz LFGTE projeleri bu gelir ve giderlerde nasıl değişikliklere yol açmaktadır?
LFGTE KURULUMUNDA ETKİLİ OLAN ETMENLER	
8	LFGTE proje ihalesinin hazırlanması aşamasından bize bahsedebilir misiniz? (Belediye nasıl karar vermişti? Belediye/ler ile iletişime geçip onları bilgilendirmiş miydiniz? Bu teknolojiyi belediyelere tanıtıyor musunuz? Onlar size danışıyor mu vb.?)
9	LFGTE projesi yatırım karar verme sürecinizden bahsedebilir misiniz? (Bu soru, karar verme noktasında etkili olan temel aktörleri, temel etmenleri anlamak için yöneltilmiştir)
10	LFGTE projesinin ihale ilanından kurulumuna kadar geçen süreç hakkında bilgi verebilir misiniz? (Bu süreçteki kilit aktörler, temel etmenler vb.)
YÖNETMELİK ETKİSİ	
11	LFGTE teknolojisinin benimsenmesinde çevreyle ilgili hangi yönetmeliklerin etkili olduğunu düşünüyorsunuz? Neden? (Bu soru, firmaların perspektifinden, hangi ulusal mevzuatın, hangi uluslararası ve yerel mevzuatların LFGTE projeleri ile ilişkilendirildiğini anlamak için yöneltilmiştir)
12	LFGTE yatırımınızda hangi yönetmeliklerin etkili olduğunu düşünüyorsunuz? (Bu soru genel olarak mevzuat çerçevesini anlamak için yönlendirilmiştir.)
13	Halkın atık yönetimi ile olan ilişkisinin projenize olan etkilerini nasıl değerlendirirsiniz? (LFGTE sonrasında atık yönetimi davranışında değişiklik oldu mu? Bilgi seviyesinde, katılım seviyesinde bir değişiklik oldu mu ? vb.)
PROBLEMLER VE POLİTİKA ÖNERİLERİ	
14	Size göre, LFGTE sektörünün en büyük sorunu/sorunları nelerdir? Bu sorunların çözümü için sizin önerileriniz ne olurdu?
15	Sizce LFGTE sektöründe gelişime açık alanlar nelerdir? Bu alanlarda iyileştirme sağlanabilmesi için nasıl önerileriniz olurdu?
16	Sizin tecrübelerinize göre, LFGTE projelerinin karar verme, planlama ve kuruluş aşamalarında etkili olan etmenler nelerdir? Bu süreçlerin iyileştirilmesi için sizin önerileriniz ne olurdu?

C: APPROVAL OF THE HUMAN SUBJECTS ETHICAL COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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03 Nisan 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Erkan ERDİL

Danışmanlığını yaptığınız **Sinem ERDOĞDU'nun "Türkiye'de Çöp Gazından Elektrik Eldesi Yayılımı"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **136-ODTÜ-2019** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız

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D: CODES, CONCEPTS, CONSTRUCTS

D.1 HIGHER ORDER CATEGORY: INFLUENCERS FOR THE MUNICIPAL AUTHORITY

HIGHER ORDER CATEGORY: INFLUENCERS FOR THE MUNICIPAL AUTHORITY		
SUB-CATEGORIES	**CODES/KEYWORDS**	**CONSTRUCTS/CONTEXTUAL MEANING**
Economic	Costs/Burden/Expense	The municipality wants to get over with the costs of disposal site management
	Decrease/less/smaller costs/fee	The feed-in-tariff subsidy serves as a tool for municipalities for by-passing/decreasing the gate-fee charge on citizens
	Higher/aim/look for profit	The municipality wants to make profit by privatizing disposal site management.
	Separate/mixed collection	Collection and transfer cost of wastes is a barrier to separate collection of different waste streams
Technical	Risk/problem/proper/right management	The municipality wants to be free from the risks of disposal site management
Administrative	Knowledgeable/capable of/strong	Municipalities with strong technical background want to upgrade technologies faster
Institutional Political	Reputation/political benefit/aim	Municipalities have political motivations to establish environmental technologies
Administrative Institutional	Example/experience/successful/learn from	Municipal authorities learn from existing facilities
Psychological Technological	Inform/study/ask//explain/share with municipalities	Municipalities learn from firms to get prepared for tenders
Psychological Institutional	Acknowledges/education/society/level	The demand for better environmental management increases with increased level of education
	Culture/our country/people/	Living habits, beliefs and culture of the society is directly related to waste management practices

D.2 HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM

HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM		
SUB-CATEGORIES	**CODES/KEYWORDS**	**CONSTRUCTS/CONTEXTUAL MEANING**
Technical	Store the gas	It is an advantage that gas can be stored to produce electricity in peak hours
	Other streams/wastes/services	Accepting/processing different waste streams generates extra income for facilities
	Other Technologies/incineration/pyrolysis	Alternative processes are not feasible

D.2 HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM (continued)

HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM		
SUB-CATEGORIES	**SUB-CATEGORIES**	**SUB-CATEGORIES**
Physical	Amount/smaller/larger waste/project/organics	Amount of available organic waste input is a prerequisite for investment in LFGTE
	Old/new/established; landfill/dumpsite	The physical characteristics and quality of the disposal site is important for investment decision
Administrative	Partner/brother company/mother company/affiliations	A business partner in the locality of the project area provides a network with the municipality
	Information return/research/learned after/we have seen	Firms learn by doing
	Helped us/supported them/look at us	Active and passive share of knowledge among firms reshape the investment environment
Psychological/Institutional	Motivation/happy/owe/wanted to/eager to/ our responsibility	There are emotional motivations of investors in investment and development decisions
Institutional	Our job/we are a xxx company//firm	Business identity of the firm determines the project design
	Organics limitation/compost/organic waste/decrease organic	Landfilling Regulation enforces decreasing landfilled biodegradable organics, but this enforcement is not applicable in practice
	Rules/change/long-term/period	There is lack of reliable long-term policies prevents further development of technology
	Recycle/material/separation	Mechanical separation unit is established as an enforcement of the environmental regulation, but its operation is not feasible
	Conflict, regulations	There are conflicts between regulations of MoEU and MoENR and within the MoEU regulations
Political	Government, center, law, politics	Macro political environment influences investment decisions
Economic/Political/ Institutional	Carbon credit/price/market	Involvement in the voluntary carbon was profitable but now it is just a prestigious investment for future
Economic/ Administrative	Develop/cover/improve technologies	Diversity of the FiT increased the research and development efforts
Institutional	Model/apply/operate plants/business/process	Firms prefer to attend specific business models due to associated costs and risks
Political/Administrative/Institutional	Provincial directorate/capacity/capability/ lack/adequate	Characteristics of the local and central environmental authority influence compliance to regulations
Political/Administrative/Psychological	Political affiliations/reasons/pressures/relationship	Decision making, tendering, implementation and operation of these projects are highly dependent on political tendencies, affiliations, and acts between firm-municipality and local administration

D.2 HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM (continued)

HIGHER ORDER CATEGORY: INFLUENCERS FOR THE PRIVATE FIRM		
SUB-CATEGORIES	**SUB-CATEGORIES**	**SUB-CATEGORIES**
Political/ Institutional	Approval, bureaucratic, delay, take time	Bureaucratic processes cause time lags in project implementation
Economic	Expect/know about YEKDEM	The definite time frame of FiT subsidy has compensated risks associated with adoption
	Regardless of/no FiT/subsidy	There are alternative financing tools other than the feed-in tariff subsidy
	Rate/import/currency	Currency of the Fit compensated risks associated with dependence on The Foreign Currency
	Small/big city, small/high amount of waste	The amount of the Fit compensates costs of small-scale projects
	Credit/loan/bank	Firms use private equity and long-term loans for upfront costs
	Equity/TUBITAK/develop	Firms use private equity and national research funds for research and development
	Ratio/share/offer	Increased share of municipality profits
	Engine/maintenance/operation /treatment cost	High Operation and Maintenance Costs
Economic	Early/already paid/first	Early adopters have been advantageous in business deals

E: TURKISH SUMMARY / TÜRKÇE ÖZET

Türkiye gelişmekte olan bir ülke olup, enerjide dışa bağımlılık sorununu çözmeyi hedeflemektedir. Ülkenin enerjide dışa bağımlılık sorununu çözmek için geliştirdiği politikalardan bir tanesi de yenilenebilir enerji kaynakları kullanılarak üretilen elektriğin şebekeye satışının sabit fiyat garantisi (feed-in tariff) mekanizması ile desteklenmesidir. Türkiye sabit fiyat garantisini ilk olarak 2005 yılında, yenilenebilir enerji kaynaklarının ülkenin elektrik üretimindeki payını arttırmak için uygulamaya başlamıştır. Günümüzde geçerli olan sabit fiyat garantisi, 2010 yılında güncellenmiş olan fiyatlar üzerinden geçerli olup, biyokütle tesisleri için destek miktarı üretilen Mega-watt saat (MWh) elektrik başına 13,3 ABD dolarıdır. 2019 yılında ülkedeki toplam biyokütle tesisi sayısı yaklaşık 654 MWe mertebesine ulaşmıştır. Bu kurulu kapasitenin yarısını sadece Çöp-Gazından Elektrik Üretim tesisleri (LFGTE) oluşturmaktadır. LFGTE teknolojisinin Türkiye'de ilk olarak 2005 yılında uygulanmaya başlandığı bilinmektedir. 2019 yılında, ülkedeki toplam LFGTE tesisi sayısı 83e, toplam kurulu güç ise 435 MWe mertebesine ulaşmıştır. 81 ilin 57'sinde en az bir LFGTE tesisi bulunmaktadır. 2019 yılı itibarı ile LFGTE teknoloji, fiziksel olarak ülkede yayılabileceği üst sınıra ulaşmıştır[48]. LFGTE teknolojisi, diğer biyokütle tesisleri ile aynı sabit fiyat garantisinden faydalanmış olmasına karşın, diğer teknolojilere nazaran çok daha çabuk ve hızlı yayılmıştır. Bu teknolojinin Türkiye'de yayılmasında gördüğümüz dikkat çekici fark, bizi bu araştırma çalışmasına başlamaya itmiştir. Bu çalışmaya konu olarak LFGTE teknolojisini seçmemizde etkili olan bir faktör de bu teknolojinin, teknik olarak basit, dünyada uzun yıllardır bilinen, boru-sonu olarak tabir edilen, marjinal eko-yenilik teknolojisi olmasına karşın karmaşık kurumsal, politik ve yönetimsel boyutlar ile ilişkili olmasıdır. Bu teknolojinin yayılımının incelenmesinde takip ettiğimiz evrimci bakış açısı özellikle bu karmaşık

[48] LFGTE teknolojisinin kurulabilmesi için öncelikle bir düzenli depolama alanı bulunması ve ayrıca tesise yeterli miktarda (yaklaşık 200 ton/gün kadar) organik atık gelmesi beklenmektedir. Mevcut durumda ülke içerisinde bu şartları taşıyan neredeyse tüm sahalarda LFGTE teknolojisi kurulmuştur. Kurulmayan sahalarda ülkenin makro politikalarının yerel siyaset üzerindeki etkileri, yerel yönetimler ile merkezi yönetim arasındaki siyasi çekişmeler ve/veya düzenli depolama tesisinin henüz kurulmamış olması gibi etmenler bulunduğu görülmüştür.

kurumsal etmenlerin, aktörler arası ilişkilerin ve kamu politikasına ilişkin bulguların tespiti ve değerlendirmesine olanak sağlamıştır.

Bu araştırma çalışması, "LFGTE teknolojisinin Türkiye'de yayılmasında etkili olan etmenler nelerdir?" ve "bu etmenler LFGTE yayılımını nasıl etkilemiştir?" soruları ekseninde tasarlanmıştır. Bu soruların cevabına ulaşabilmek için betimleyici ve keşfedici yaklaşım ile üç aşamalı bir araştırma yöntemi benimsenmiştir. Tümevarımcı bir yöntem izlenen bu araştırma çalışması ile LFGTE yayılımına etki eden faktörlerin tanımlanması ve etki mekanizmalarının keşfedilmesi sonrasında elde edilen veriler ile temellendirilen kurama ulaşmak amaçlanmıştır (Patton, 2002). Temellendirilmiş kuram yöntemi ampirik verinin içerisinde gömülü olan teoriyi açığa çıkarmayı hedeflemektedir. Teori geliştirmeye yönelik bu yaklaşım, henüz yeni olan araştırma alanlarında bağlamsal keşiflerin geliştirilmesinde (Masini and Menichetti, 2013) avantajlar sağlamaktadır. Yenilenebilir enerji teknolojilerinin yayılımı, sosyal bilimler alanında yakın zamanda yoğun olarak çalışılmakta olan bir araştırma alanıdır. Bu çalışma kapsamında, araştırmamızın ilk aşamasında, bu yeni keşfedilen alanın teorik çerçevesini anlamak ve LFGTE yayılımına ilişkin bağlamsal ve ampirik içerik hakkında bilgi sahibi olmak amacıyla literatür taraması gerçekleştirdik. Mevcut yazında, LFGTE yayılımına ilişkin ampirik yazına oldukça az rastlanmaktadır. Örneğin Li et. al (2015) yenilenebilir enerji portföy standartları ve vergi kredileri gibi piyasa temelli araçların LFGTE teknolojisinin Amerika Birleşik Devletleri'ndeki yayılımında etkili olduğunu ortaya koymuştur. Buna karşın, bu teknolojinin yayılımına etki eden kurumsal etmenleri (Mignon ve Bergek, 2016; Jacobsson ve Bergek, 2011) inceleyen bir çalışma bulunamamıştır. Temellendirilmiş kuram yönteminin bir parçası olarak literatür taraması ampirik verinin toplanması ile eş zamanlı olarak sürdürülmüştür (Dunne, 2011). Araştırmamızın ikinci aşamasında, nitel bir araştırma yöntemi olarak belge inceleme (Bowen, 2009) ve sektör uzmanları ile derinlemesine mülakat yöntemi tercih edilmiştir. Belge inceleme çalışması kapsamında, Elektrik Piyasası Düzenleme Kurumu tarafından yayınlanan güncel LFGTE lisanslı tesisler listesi baz alınarak bir temel veri tablosu oluşturulmuştur. Türkiye'nin LFGTE teknolojisine ilişkin ulusal yenilenebilir enerji, iklim değişikliği ve atık yönetimi politikaları incelenerek politika yapıcıların gelecek vizyonuna ilişkin genel bilgi

edinilmiştir. İl çevre durum raporları incelenerek temel veri tablosundaki eksiklikler tamamlanmış ve son olarak da internet üzerinden lisanssız olan tesislere ilişkin araştırma çalışması yürütülmüştür. Teknolojiye özel olan, "çöp", "gaz" ve "elektrik" anahtar kelimeleri kullanılarak yürütülen internet bazlı araştırmada; belediyelerin resmî web-sayfalarında, firmaların resmî web-sayfalarında ve kamu ihale duyuruları gibi resmî açıklamaların bulunduğu sayfalarda yer alan bilgiler çalışma için güvenilir kabul edilmiştir. Belgelerden elde edilen verilerin yanı sıra, LFGTE sektörünü derinlemesine anlamak ve bir sonraki araştırma aşamasının odak noktasını şekillendirmek amacıyla sektörde tecrübeli olan uzmanların görüşlerini alabilmek üzere dört adet derinlemesine mülakat gerçekleştirilmiştir. Mülakat gerçekleştirilen uzmanlardan iki tanesi özel sektör, birisi bir büyükşehir belediyesi ve bir kişi de bir belediye birliğinde görev yapmakta olan, LFGTE projelerinin karar verme, geliştirme ve kurulum aşamalarında tecrübe sahibi olan kişilerdi. Derinlemesine mülakat gerçekleştirilecek uzmanlar, araştırmacının sektör bazlı tecrübesi ve birebir ilişkilerine dayanarak, bilgi ve tecrübeleri nedeniyle özellikle tercih edilmiştir. Derinlemesine mülakat çalışması sonrasında, LFGTE sektöründe belediyelerin ve/veya birliklerin atık yönetim tesislerini ihale süreci ve firmaların ihale aşamasından sonra projenin kurulum sürecindeki tecrübeleri hakkında bilgi edinilmiştir. Bu sayede, incelenen belgelerden elde edilen ikincil veriler ampirik veri ile desteklenmiştir. Derinlemesine mülakat yöntemi sonucunda ayrıca, araştırmanın ana amacı olan "LFGTE teknolojisi yayılımındaki etmenler" ve "etkileme mekanizmalarının araştırılmasında odak noktası olarak "yatırımcı perspektiflerinin" gözetilmesi gerektiği sonucuna varılmıştır. İlk aşama değerlendirme ile birlikte yatırımcı profili çıkartılmış ve yarı-yapılandırılmış mülakatlar için katılımcı profilleri oluşturulmuştur. Yarı-yapılandırılmış mülakatlar "sektörün mevcut durumu", "LFGTE teknolojisine etki eden etmenler", "LFGTE teknolojisi yayılımında mevzuat etkileri", "problemler ve çözüm önerileri" genel başlıkları ile oluşturulan mülakat kılavuzuna göre gerçekleştirilmiştir.

Türkiye'de LFGTE teknolojisinin yayılımında etkili olan etmenlerin tanımlanması ve etkileme mekanizmalarının keşfedilmesini amaçlayan saha araştırması; sekiz yatırımcı firmanın katılımı ile çoklu vaka çalışması şeklinde gerçekleştirilmiştir. Çoklu vaka çalışması kapsamında, her firmadan birer temsilci ile olmak üzere toplamda sekiz yarı-

yapılandırılmış mülakat hayata geçirilmiştir. Yarı-yapılandırılmış mülakat yöntemi, mülakatın kapsamını çalışmanın amacına yönelik olarak genel bir çerçevede kısıtlamakla birlikte, katılımcıların genel başlıklar altında serbestçe görüşlerini bildirmeleri ve konuya araştırma çalışmasının tasarlanmasından önce keşfedilmemiş olan perspektiflerin de dahil edilmesine olanak sağlamıştır. Araştırmaya dahil edilecek vakaların seçilmesine kartopu örnekleme yöntemi kullanılmıştır. İkinci aşama araştırma çalışma esnasında derinlemesine mülakat gerçekleştirilen sektör temsilcileri, yarı-yapılandırılmış mülakatlar ile veri toplanabilecek firmaların profiline ve görüşülebilecek katılımcılara dair araştırmacıya ön bilgi sunmuştur. İlk iki vaka edinilen bu bilgilere istinaden belirlenmiştir. İlk yarı-yapılandırılmış mülakatlarda katılımcılar görüşülebilecek diğer katılımcılara dair fikir sunmuştur. Vaka örneklerinin seçiminde mümkün olduğu kadar az örnek sayısı ile sektörde görülen farklı özellikleri temsil edecek şekilde çeşitlilik sunan vakalar, ulaşılabilirliklerine ve çalışmaya katılım sağlama isteklerine göre tercih edilmiştir. Her sene güncellenen YEKDEM lisanslı firmalar listesine göre Türkiye'de toplamda 26 özel şirket LFGTE sektöründe yatırımcı olarak faaliyet göstermektedir. Tamamlanan örnekleme çalışması sonucunda, görüşme gerçekleştirilen 8 örnek; 8 firmayı temsil etmektedir. Bu 8 firma, ülkedeki toplam 83 LFGTE yatırımının 57sine sahiptir. Ülkedeki toplam kurulu LFGTE santrali gücünün (435 MWe) ise %80ini bu firmalar oluşturmaktadır. Seçilen örneklem kümesi içerisinde; yap-işlet/yap-işlet-devret ve/veya imtiyaz sözleşmesi iş modelleri ile çalışma gerçekleştiren, yabancı yatırımcı ortağı olan ve olmayan, araştırma ve geliştirme çalışmaları yürüten/yürütmeyen, bir ve/veya birden fazla yatırımı olan ve LFGTE yayılım sürecinin farklı aşamalarında bu teknolojiye yatırım yapmış çevre teknolojileri ve enerji firmalarını temsil eden örnekler bulunmaktadır. Yarı-yapılandırılmış mülakat çalışmalarının tamamında konuşma notları kaydedilmiş ve görüşmeler sonrasında katılımcıların kendi cümlelerinden ifadeleri yazıya geçirilmiştir. Daha sonrasında katılımcı ifadeleri anahtar kelimeler (kodlar) ile sınıflandırılarak ifadeler ile betimlenen kurgular ve kavramlar belirlenmiştir. Bu çalışma kapsamında, katılımcıların beyanlarının LFGTE teknolojisinin yayılımına etki eden etmenlere ilişkin, 41 kavramın üzerinde durduğu görülmektedir. Bu kavramlar işaret ettikleri ortak noktalara göre sınıflandırıldığında ise teknoloji yayılımına etki eden 14 tema ve bu temaları içeren toplamda 6 kümelenmiş katman belirlenebilmiştir.

Altı kümelenmiş katman içerisinden dört tanesi (kamu kaynakları, finansal kaynaklar, bilginin birikimi ve iş stratejisi) faaliyet ortamı merkezinde olan etmenlerdir. Formel ve enformel kurumsal katmanlar ise LFGTE yayılımında kurumsal çevre merkezinde etki eden etmenler olarak sınıflandırılmıştır. Çalışma kapsamında katılımcıların tespit edilen tüm etmenlere ilişkin görüşleri tezin 4.2. başlıklı bölümü altında ayrıntılı olarak incelenmiştir. Mevcut durum ve saha çalışmasına ait bulguların özeti ise bölüm 4.3'te sunulmuş ve belirlenen etmenlerin yayılıma olan etkileri bu bölümde tartışılmıştır.

Yerel otoritenin kontrolünde bir "düzenli depolama tesisi" bulunması ve bu tesise sürekli olarak düzenli bir atık girişi yapılıyor olması LFGTE teknolojisi kurulumunun olmazsa olmazıdır. Araştırma sonucunda Türkiye'de LFGTE teknolojisinin yayılımında üç tarihsel faz olduğu görülmüştür. Ülkedeki teknoloji yayılımı incelendiğinde, öncelikli olarak atık miktarı yüksek olan, düzenli depolama tesisi bulunan, büyükşehir belediyelerinde bu yatırımlara başlandığı, sonrasında daha küçük belediyelerin de büyükşehir olmasıyla birlikte ikinci faz yayılımın gerçekleştiği ve ilerleyen safhalarda belediye birliklerinin de düzenli depolama tesislerinin kurmasını müteakiben üçüncü evrede ülkedeki 81 ilin 57'sinde bu tesislerin kurulduğu görülmüştür. Teknoloji yayılımına etki eden etmenlerin ağırlıkları bu fazlar arasında farklılık göstermektedir. Ancak, tüm etmenlerden önce ilk olarak LFGTE yayılımında, bu alanda yetkili olan yerel otoritenin (belediye veya belediye birliği) LFGTE teknolojisinin kurulması kapsamındaki işi ihale etmesi gerekmektedir. Bu bağlamda, öncelikli koşul olan belediyenin işi ihale etmesinde öncelikli etmenler; *bertaraf sahasının işletme maliyeti yükünden ve işletmeden kaynaklı risklerden kurulmak ve ayrıca LFGTE işletmesinden kar etmek olarak belirlenmiştir.* LFGTE teknolojisi yayılımının erken fazlarında, belediyelerin LFGTE teknolojisi kapsamında bir işi ihale etmesinin önündeki en önemli sınırın; bu *teknoloji hakkındaki bilgi eksikliği* olduğu belirlenmiştir. Yayılımın ilerleyen zamanlarında ise teknoloji hakkında öğrenmenin ve bilgi birikiminin artmasına bağlı olarak*, bürokratik gecikmeler ve kurumlar arasındaki politik açmazların* (ve/veya çıkar yayılımın önünde bir engel olarak, çatışması) daha ağırlık bir engel teşkil ettiği gözlemlenmiştir.

Yatırımcı firmaların perspektifinden LFGTE yayılımının ilk fazında öncelikli olarak faaliyet ortamına bağlı olan; *bertaraf tesisinde yüksek miktarda organik atık girişinin olması ve belediye ile uzun dönemli bir iş anlaşmasının bulunmasının* destekleyici olduğu belirlenmiştir. Yayılımın ikinci aşamasında ise *sabit fiyatlı alım garantisi* destek mekanizması başat destekleyici mekanizma rolünü oynamıştır. Yayılımın üçüncü ve son aşamasında; *USD kurundaki sert artış* ve *14 il belediyesinin kanun ile büyükşehir belediyesine dönüştürülmesi* ve *sabit fiyatlı alım garantisinin 2019 yılında sone ereceği bilgisi* etkili olmuştur. Yayılımın ilk fazında; *bürokratik süreçlerin uzun sürmesi ve teknoloji hakkında bilgi eksikliği olması* olarak belirlenmiştir. İkinci fazla yerel otorite ve merkezi otorite arasındaki *politik açmazlar ve/veya çıkar çatışmaları* öncelikli zorlaştırıcı etmenler olarak belirlenmiştir. Yayılımın son fazında ise *pazarın doygunluğa ulaşması* teknoloji yayılımının önündeki en önemli sınır olmuştur.

Bu çalışma kapsamında Türkiye'de LFGTE teknolojisinin yayılımına ilişkin elde edilen bulgular; sabit fiyat alım garantisinin 2015 yılında teknoloji yayılımını destekleme maksadını doldurduğunu ve sonrasında ülkedeki katı atık yönetim sisteminin eksikliklerini tamamlamaya hizmet ettiğini göstermektedir. Ayrıca, sabit fiyatlı alım garantisi Türkiye'de bertaraf tesislerinde; sadece LFGTE teknolojisini uygulayabilen firmaların artışına ve böylelikle LFGTE teknolojisine kilitlenmiş bir katı atık yönetim sisteminin yerleşmesinde etkili olmuştur.

Araştırma neticesinde hipotez olarak; LFGTE teknolojisinin evrimini desteklemek üzere yerel yönetimin ihtiyaçlarını baz alan, disiplinlerarası politikaların tasarlanması gerektiği öne sürülmektedir. Burada, teknoloji evrimi tanımı, bir teknolojiyi diğerine tercih etmeksizin destekleyen dinamik bir politika tasarımına işaret etmek için tercih edilmiştir. Böylelikle "*zamanı geldiğinde*" çevresel anlamda farklı alternatifler sunan diğer teknolojilere doğru geçiş yapılmasına elverişli esnek bir teknoloji gelişimi ortamı sağlanmış olacaktır. Hipotezin işaret ettiği türden bir politika çerçevesine örnek teşkil edecek öneriler tez kapsamında bölüm 5.1 altında sunulmuştur. Politika önerileri, Türkiye'de LFGTE teknolojisinin yayılımına ilişkin tespit edilen temel problem olan "sabit fiyat garantisi destek mekanizmasının teknoloji kilitlenmesine neden olmasına" çözüm getirme amacıyla, firmaların çeşitli teknolojilere yatırım yapmasını sağlayacak

şekilde kapasitelerinin geliştirilmesi ve radikal yeniliklerin desteklenmesi çerçevesinde tasarlanmıştır.

Jaffe'e (2015) göre; Teknoloji politikası, çevre politikalarını tamamlayıcı olmaktansa çevre politikalarının rolünü üstlenecek şekilde kullanılırsa, maliyetli olabilir. LFGTE sektöründeki problem de LFGTE teknolojisine verilen desteğin, bertaraf tesislerinin yönetimindeki eksiklikleri giderme rolünü üstlenmesine bağlı olarak LFGTE teknolojisine kilitlenme olmasıdır. Sonuç olarak; atıkların kaynağında azaltılması, yeniden kullanımı, geri dönüşümü ve atıkların bertaraf edilmeden önce alternatif teknolojiler ile işlenmesi gibi, atık yönetimi hiyerarşisinde daha üst sıralarda yer alan yöntemlerin geliştirilmesinin önüne geçilmiştir. Bir anlamda, desteklenen marjinal çevresel yenilik, zamanla etkisi çok daha fazla olabilecek radikal çevresel yeniliklerin önüne geçmiştir. Bu tez kapsamında, teknolojiye kilitlenme problemini ortadan kaldırmak adına; "Yatırımcı firmaların teknik ve kurumsal kapasitelerinin arttırılması" ve "Çeşitli katı atık yönetimi teknolojilerinin geliştirilmesine elverişli bir yatırım ekosistemi tasarlanması" önerilmiştir.

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