POWERSTEP

Deliverable 5.2: Recommendations for WWTP operators, municipalities and WWTP technology providers willing to engage in renewable energy market

The project "Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration" (POWERSTEP) has received funding under the European Union HORIZON 2020 – Innovation Actions - Grant agreement° 641661

Deliverable	***Recommendations for WWTP operators, municipalities and WWTP technology providers willing to engage in renewable energy market***
Related Work Package:	5
Deliverable lead:	Neas Energy
Author(s):	Neas Energy: Lasse Helleskov Ravn, Michał Jankowski, Lotte Holmberg Rasmussen, KWB: Christian Remy, B&SU: Thekla Heinel
Contact for queries	lra@neasenergy.com
Grant Agreement Number:	n° 641661
Instrument:	Horizon 2020 Framework Programme
Start date of the project:	01.07.2015
Duration of the project:	36 months
Website:	www.powerstep.eu
Abstract	This report analyses the legal framework for marketing of renewable energy produced at a wastewater treatment plant for three different countries (Germany, France, Denmark). Looking at the energy types of electricity (for self-supply or grid supply), heat and biomethane, the report describes taxes, fees, levies, and subsidy schemes which directly affect the potential revenues of the WWTP operator. The analysis shows that there are large differences between the countries that have a decisive impact on the economic attractiveness of the different options. While electricity use for self-supply is favored in case of high purchase costs for grid electricity (e.g. Germany), subsidy schemes for grid supply can also make this option economically relevant. In all countries, the grid injection of biomethane is a viable option which will be increasingly attractive for WWTP operators in the future. Reliable legal frameworks are required to offer stability for long-term investment at WWTP level, which is today often not the case due to the dynamic nature of the energy markets and policies.

Dissemination level of this document

X	PU	Public
	PP	Restricted to other programme participants (including the Commission Services)
	RE	Restricted to a group specified by the consortium (including the European Commission Services)
	CO	Confidential, only for members of the consortium (including the European Commission Services)

Versioning and Contribution History

Version	Date	Modified by	Modification reasons
v.01	25.09.2017	Lotte Holmberg Rasmussen	1st Draft
v.02	30.09.2017	Boris Lesjean	1st review
v.03	10.10.2017	Lotte Holmberg Rasmussen	2nd Draft
v.04	15.10.2017	Christian Loderer	2nd review
Final	19.10.2017	Lotte Holmberg Rasmussen	Based on feedback from Christian Lodere

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Acronyms

BRP – Balance Responsible Party
CH_4 – Methane
CO_2 – Carbon dioxide
CHP – Cogeneration of Heat and Power
CSPE – Contribution au service public de l'électricité (Public Service Electricity Contribution)
CTA – Contribution tarifaire d'acheminement (Supply tariff contribution)
DSO – Distribution System Operator
EC – European Commission
EEG – Erneuerbare Energien Gesetz (Renewable Energy Sources Act)
EnWG – Energiewirtschaftsgesetz (Energy Economy Law)
EPEX – European Power Exchange
EU – European Union
H_2 – Hydrogen gas
KWK – Kraft-Wärme-Kopplung (Combined heat and power)
NL – Norm litres
P2G – Power-to-gas
Pe – Population equivalent
RE – Renewable energy
TDCFE – Taxe départementale sur la consommation finale d'électricité (Departmental Consumption Tax on Electricity)
TCCFE – Taxe communale sur la consommation finale d'électricité (Municipal Consumption Tax on Electricity)
TSO – Transmission System Operator
TURPE – Tarif d'utilisation des réseaux publics d'électricité (Grid operator tariffs)
TVA – Taxe sur la valeur ajoutée (Value Added Tax)
WWTP – Wastewater treatment plant

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Glossary

Balance Responsible Party – Trades electricity at the different markets. Is the link between the markets the TSOs and the trading companies

Biogas – A gas produced via anaerobic digestion of different types of organic waste (e.g. sewage waste). Gas from wastewater treatment plants typically contains around 60-65% of methane, 35-40% of CO_2, and other impurities such as nitrogen gas (N_2), H_2S, siloxanes, and moisture.

Biomethane – Upgraded biogas containing > 98% methane coming from biogas. It can be either produced by cleaning biogas of CO_2 ("scrubbing") or methanation of non-fossil CO_2 with H_2 produced with renewable energy (Power-to-gas or P2G). Biomethane has comparable properties to natural gas.

DSO – Distribution system operator, i.e. operator of the local distribution grid (electricity or gas) serving the final customers

Grid supply – Energy produced at a WWTP and exported to the grid

Fee – Payment to public entities to cover costs of another dedicated part of the system, i.e. with specific dedication of use

Levy – Payment to public entities to cover costs of another dedicated part of the system, i.e. with specific dedication of use

Methanation – Process of converting carbon dioxide or monoxide into methane through hydrogenation, either through biological or physico-chemical methods (P2G)

Methanisation – Last step of biological reaction in anaerobic digestion, i.e. conversion of organic acids into methane. Often used as synonym for anaerobic digestion, i.e. conversion of organic matter into biogas in a biogas plant.

P2G (Power-to-gas) – Process in which hydrogen is produced with electricity (power) and processed with CO2 into methane. If renewable electricity and renewable CO2 is used, the product will be biomethane.

Self-consumption/supply of electricity – Energy produced at a WWTP which is directly consumed on-site to cover the energy demand of the plant

Tax – Payment to public entities without specific dedication of use, i.e. for the general public budget

TSO – Transmission system operator, i.e. operator of a regional or national grid transferring energy between regions over long distances. The TSO is also responsible for the sytem balance of the electricity system.

Upgrading – Process of converting biogas into biomethane, either by separating impurities (e.g. CO_2) or by converting the CO_2 part into biomethane (e.g. by biological or physico-chemical methanation).

1. Introduction

The project POWERSTEP aims to increase energy production at municipal wastewater treatment plants (WWTPs) and thereby enabling an energy-neutral or even energy-positive operation. Hence, WWTP operators have to engage in the marketing of the renewable energy (RE) with the goal of maximizing economic benefits of energy generation. In principle, energy is generated at WWTPs as biogas from sewage sludge in anaerobic digestion, but this form of energy is often converted on-site to electricity and heat (e.g. in a cogeneration of heat and power (CHP) plants) to cover the internal energy demand of the WWTP. The goal of this report is to give insights into the existing regulatory framework for marketing of renewable energy in the form of electricity, heat, or biomethane (= biogas with high content of methane, which makes it comparable to natural gas) in different countries of the EU. This insight should help WWTP operators willing to engage in the renewable energy market to develop an optimum valorisation route for their energy depending on the market framework.

In general, the potential of biogas production at WWTPs via anaerobic digestion of sewage sludge is currently exploited at different levels across EU countries. This report focuses its analysis on three EU countries (Germany, France, Denmark) which represent different levels of implementation of biogas production at WWTPs, but also different regulatory frameworks for renewable energy marketing. While the biogas potential at WWTPs is already widely realized in Germany and also Denmark, France has still a huge potential to be unlocked at WWTPs to generate renewable energy (Table 1).

Table 1: Current status and potential of biogas production at municipal wastewater treatment plants in Germany, France, and Denmark

Country		Biogas production[1] at WWTPs in 2015 (EUROSTAT, DESTATIS)	Potential at WWTP with POWERSTEP (Estimate[2])	Potential realized
Germany	[TJ/a]	19,749	24,433	81%
France	[TJ/a]	2,277	14,782	15%
Denmark	[TJ/a]	914	1,514	60%

[1] *Including external co-substrates*

[2] *Based on 30 NL/(pe*d) and 6 kWh/Nm³ for all WWTP > 10'000 pe*

However, WWTP operators are quite often not familiar with the regulatory framework that governs the marketing of renewable energy in their respective country. If the POWERSTEP concept is implemented across Europe, more WWTPs will have to engage in marketing of renewable energy and choose the most economic route for its valorisation.

The purpose of this report is to describe the regulatory framework that influences investment in and operation of biogas valorisation routes at WWTPs. The report will help plant operators increase their knowledge regarding the available options for both implementation and/or operation of the technologies.

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An existing anaerobic digestor to produce biogas from sewage sludge will be the point of departure for the report. With the biogas, there are different possibilities for valorisation at a WWTP that will be analyzed in this report (Figure 1):

- A CHP unit to produce electricity and heat from the biogas on-site. These products can either be used to cover the internal energy demand of the plant (self-supply), or they can be sold to on different electricity markets through a BRP or to external district heating networks.
- A biogas upgrading unit to clean the biogas for CO_2 to natural gas quality by scrubbing of CO_2 and other impurities, converting it into biomethane (= pure methane from biological sources, comparable in its quality to natural gas). This biomethane can then be injected into the gas grid.
- A Power-to-Gas (P2G) unit using a methanation process. This process uses electricity to operate an electrolyzer to produce hydrogen and oxygen from water. In a second step, hydrogen and CO_2 from the biogas are converted to biomethane (CH_4) by a biological or catalytic process. The P2G approach enables the use of electricity e.g. from RE sources during times of low prices to produce biomethane, which can be easily stored in existing infrastructure (i.e. the gas grid)

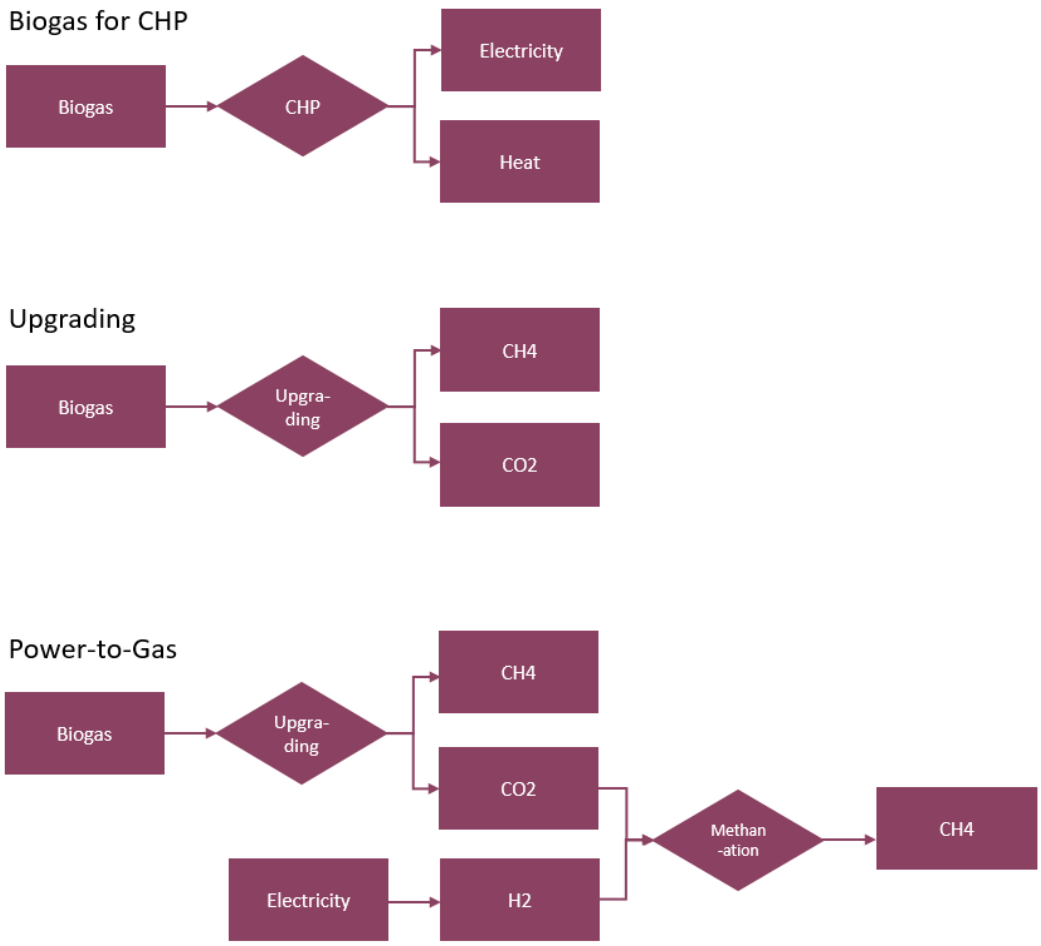

Figure 1: Different routes for biogas valorisation at WWTPs analysed in this report

These technologies are chosen because they are common technologies to valorise biogas from WWTPs. They reflect the basic principles of energy valorisation routes and are available at commercial scale. Similar technologies exist for conversion of biogas into electricity (e.g. microgas turbines), but the products of valorisation (electricity, heat, or biomethane) are the same.

This report is structured as follows:

- The first part briefly presents **European Commission (EC) directives** that are relevant for the energy sector and for waste water treatment plants. These policy measures give an overarching policy framework for renewable energy management, and are translated into national regulations for each EU country.
- The main part of the project is the **analysis of the regulatory framework conditions in Germany, France and Denmark** affecting the marketing of energy from WWTPs. The analysis covers the marketing of the different forms of energy (electricity, heat, biomethane) and explains legal instruments such as taxes, fees, levies, or subsidy schemes which are relevant for the marketing routes.
- For marketing of dynamic electricity demand and supply ("smart grid operation"), access of the **balancing markets** may also be an option for WWTPs. A short analysis of the main features of the balancing market is provided to show the different markets and options. For a more detailed analysis of the potentials in the day-ahead market, the reader is referred to Deliverable D3.4 of the POWERSTEP project.
- The last chapter summarizes **other support instruments** for renewable energy marketing beyond subsidy schemes for energy sale, such as investment subsidies or regional, national and international networks to promote the use of renewable energy and gain political support for WWTP operators.
- The report closes with a summary listing main **conclusions of the analysis and some recommendations to policy makers** to improve the market conditions for renewable energy from WWTPs.

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2. Directives of the European Commission

This chapter summarizes the most relevant Directives of the European Commission (EC) that are related to the production of renewable energy in form of biogas, electricity and heat at WWTPs. The EC Directives lay out the general policy approach in the respective areas and define the regulatory framework for the national regulations, which is then implemented into specific laws and ordinances in the member states influencing the existing market conditions in all countries.

Overall, there are a number of EC Directives which promote the use of renewable energy sources and efficient energy usage with CHP units, which directly relate to biogas production and usage at WWTPs. However, the Directives address the WWTP sector only indirectly in combination with other sources of renewable energy, showing that there is no common EC policy on how to promote energy produced at WWTPs. Although sewage gas is explicitly named as renewable energy in the related Directive, an integrated strategy or policy approach for energy from WWTPs is lacking. Finally, the existing EC Directives would enable member states to develop dedicated policy frameworks for the promotion of energy from WWTPs under the keyword of renewable energy, but they do not provide a dedicated strategy or instrument for this task.

2.1. Climate and energy package 2020 ("20-20-20 targets")

In 2007, the EU accommodated the 2020 climate and energy package becoming a global frontrunner in the decarbonization of the energy sector. In consequence, the legislation encompassed three main targets for the year 2020:

- 20% increase in energy produced from renewables
- 20% enhancement in energy efficiency
- 20% cut in greenhouse gas emissions (compared to 1990 level)

Within the POWERSTEP project, all three aspects of the climate and energy package (i.e. renewable energy production, energy efficiency, and greenhouse gas emissions) are addressed and will be improved for WWTP operation

2.1.1. 20% increase in energy produced from renewables

Directive 2009/28/EC for energy from renewable sources (EU 2009)

Targets of the 20-20-20 strategy are not the same for all countries. Accordingly, EC introduced the Renewable Energy Directive (2009/28/EC) establishing a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy ("20% in EU 2020") and for the share of energy from renewable sources in transport ("10% in 2020"). In particular, the Directive asks the member states to introduce support schemes and cooperation and sets up national renewable energy action plans. The member states are obliged to contribute to meet EU goals in respect to their economic development and capabilities. Progress towards national targets is measured every two years when EU countries publish national renewable energy progress reports. Regarding energy products from WWTPs, this Directive explicitly states that "sewage treatment plant gas" is defined as energy from renewable sources in Article 2a. Hence, it can contribute to the targets of the Directive.

2.1.2. 20% enhancement in energy efficiency

Directive 2012/27/EC for 20% improvement in energy efficiency (EU 2012)

This Directive mandates energy efficiency improvements within the European Union. The Directive introduces legally binding measures to encourage efforts to use energy more efficiently in all stages and sectors of the supply chain. It establishes a common framework for the promotion of energy efficiency within the EU in order to meet its energy efficiency headline target of 20% by 2020. EC member states have to prepare a National Energy Efficiency Action Plan every three years and report on their progress in the different sectors (i.e. industry, residential, services, public, transportation, electricity and heat generation). The Directive also paves the way for further improvements thereafter.

2.1.3. 20% cut in greenhouse gas emissions

European Union Emissions Trading System cutting emissions by 20% (EU ETS) (EU 2009b)

The EU ETS is the cornerstone of the European Union's drive to reduce its emissions of man-made greenhouse gases which are largely responsible for warming the planet and causing climate change. The system works by putting a limit on overall emissions from covered installations which is reduced each year. Within this limit, companies can buy and sell emission allowances as needed. This 'cap-and-trade' approach gives companies the flexibility they need to cut their emissions in the most cost-effective way.

2.2. Combined heat and power generation

Directive 2004/8/EC for combined heat and power generation (EU 2004)

This Directive promotes the use of highly efficient combined heat and power units to improve the efficiency of electricity and heat production. Member states are encouraged to provide support schemes for CHP units to enable their widespread implementation, with the Directive setting rules on guarantees of origin, efficiency criteria, administrative procedures, and other issues. For CHP units at WWTPs, this Directive directly led to the setup of national support schemes in some member states which gave financial incentives to build and operate CHP units.

2.3. Electricity

Directive 2009/72/EC for internal electricity market (EU 2009c)

This Directive establishes common rules for the generation, transmission, distribution and supply of electricity, together with consumer protection provisions, with a view to improving and integrating competitive electricity markets in the EC. It lays down the rules relating to the organisation and functioning of the electricity sector, open access to the market, the criteria and procedures applicable to calls for tenders and the granting of authorisations and the operation of systems such as transmission or distribution systems, including the request for unbundling of electricity production and

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grid operation. In relation to electricity produced at WWTPs, the Directive ensures transparent and non-discriminatory access of new entrants to the market. In addition, the concept of "smart grids" is introduced to limit the costs for grid expansion for regulating the fluctuations in the electricity market. Again, this Directive explicitly defines "sewage treatment plant gas" as energy from renewable sources in Article 2.

2.4. Gas

Directive 2003/55/EC on the internal market for natural gas (EU 2003)

This Directive defines the general rules for the internal gas market in the EU. It enables member states to organize the gas market in terms of market and grid access, transmission, storage, distribution and supply. In relation to WWTP biogas, it states that third party access to the grid has to be granted under defined regulations which are non-discriminating. The Directive also enables member states to impose rules in the gas market to promote environmental protection and combat climate change, which can be directly related to the usage of renewable gas sources such as WWTPs.

Directive 2009/73/EC for internal gas market (EU 2009d)

This Directive establishes common rules for the transmission, distribution, supply and storage of natural gas. It lays down the rules relating to the organisation and functioning of the natural gas sector, access to the market, the criteria and procedures applicable to the granting of authorisations for transmission, distribution, supply and storage of natural gas and the operation of systems. The rules also apply in a non-discriminatory way to biogas and gas from biomass, i.e. sewage gas from WWTPs.

Trading scheme for transnational trade of biomethane under development

There is no existing trading scheme for cross-border trade of biomethane with the EU. Currently, complex legal issues and organisational processes are standing in the way of cross-border trade in biomethane, mainly due to the different national certification schemes for biomethane. The harmonisation of these certification schemes is a pre-requisite for an internal market for biomethane within the EC. The EC project "greengasgrids" (2011-2014) addressed these aspects of an internal biomethane market and provided recommendations on the future development (www.greengasgrids.eu). In 2016, Germany and Austria have started a cooperation to harmonize the national certification schemes and allow for transnational trade of biomethane, which creates an initial interface to start for that purpose. In June 2017, national biogas certification schemes in Germany and Denmark announced that they will make an agreement to acknowledge each other's certificates for biomethane to allow for cross-border trade.

2.5. Energy products taxation

Directive 2003/96/EC for taxation of electricity and other energy products (EU 2003a)

This Directive sets a framework for taxation of electricity and other energy products, e.g. gas or other fuels. It defines the energy products to be taxed and the minimum amount of taxes, listing also an extensive number of exemptions which are related to specific products or member states. For taxation of energy products from WWTP, the Directive states that exemptions from minimum tax are applicable for electricity generated from biomass or from products produced from biomass (e.g. sewage gas) and also for electricity or heat from combined heat and power units.

3. Regulatory framework for Germany

The legal framework of energy management in Germany is highly complex, mainly due to the deregulation of the public energy market in the 1990s and the on-going political "energy transition" to increase the use of renewable energy (RE) sources for energy production. This process is framed by a variety of relevant laws and regulations for the energy market, energy efficiency targets, energy taxes, and the management of RE in electricity and heat supply including the production of combined heat and power. In total, there are currently 62 laws and ordinances (> 1600 pages) which affect this sector in Germany (Seibert-Ehling 2016).

For the wastewater sector, five main laws are relevant for energy production and consumption at the wastewater treatment plant (WWTP):

- **Energiewirtschaftsgesetz – EnWG** (EnWG 2017) (Energy Economy Law)
- **Erneuerbare-Energien-Gesetz – EEG** (EEG 2017) (Renewable Energy Sources Act)
- **Kraft-Wärme-Kopplungsgesetz – KWKG** (KWKG 2016) (Combined Heat and Power Act)
- **Stromsteuergesetz – StromStG** (StromStG 2016) (Electricity Tax Law)
- **Energiesteuergesetz – EnergieStG** (EnergieStG 2017) (Energy Tax Law)

Whereas the EnWG regulates the general energy market (e.g. consumption and production of energy, sales, grid management, etc.), the EEG is focused on the promotion and management of RE in form of rules for grid supply, subsidies for RE, and taxes for other energy sources to cover the societal cost of the energy transition. For combined heat and power (CHP) generation, the KWKG regulates subsidies for energy from CHP units to promote this very efficient use of energy sources at smaller scale. The StromStG regulates the taxable use of electricity, also including the waiving of electricity tax for self-consumption. Sewage gas is also a combustible gas according to the EnergieStG, but is currently freed from this tax. However, this may change in the near future due to a new draft of the EnergieStG due in 2018.

The following chapter describes the basics of energy prices in Germany including federal subsidies and taxes, and the consequences of specific features of the regulatory framework for WWTP operators who would like to engage in the RE market.

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3.1. Production of electricity at the WWTP

For the WWTP operator, there are two options when producing electricity at the WWTP (e.g. from biogas valorisation in a CHP unit):

- Using electricity for **self-supply**, i.e. covering the electricity demand of WWTP operation
- Selling electricity **to the grid**

3.1.1. Self-supply with CHP electricity

If electricity is used for self-supply at a WWTP, this amount of electricity can avoid the purchase of grid electricity from the market. Hence, the economic benefits of self-supply are highly affected by the final price of purchasing electricity on the market, and which parts of that can be saved with self-supply. The final price for purchasing electricity on the German market is affected by a variety of fees and taxes (Table 2: exemplary data from Schiebold and Siebeck 2016, updated with latest EEG fee).

Table 2: Elements of purchase price for electricity from the grid in Germany (data from Schiebold and Siebeck 2016)

Element	Amount [€/MWh]	Description	Recipient	Potential savings with self supply
Purchase price	35	Estimate as actual electricity price on the market	Electricity provider	Yes
Grid fee	20-25	Fee for grid usage, depending on region (StromNEV 2005)	DSO	Yes
EEG fee	69	Levy to cover the costs of the energy transition	DSO	40% EEG fee to be paid for new CHP, 0% for existing CHP
Electricity tax	21	Tax on electricity consumption	Federal budget	Yes
Concession fee	1	Levy to cover concession costs of grid operation in public areas	Cities and communities	Yes
Miscellaneous fees	1-2	Levy to cover specific features of energy market	DSO, others	Yes
Net sum	**147-153**			
VAT (19%)	28-29	Value added tax on electricity consumption	Federal budget	Yes
Gross sum	**175-182**			

Hence, the market price is only 20% of the final price to the customer, whereas fees for grid usage (14%) and especially the EEG fee (36%) in combination with electricity tax (12%) and VAT (16%) are responsible for the major fraction of the final price (Figure 2).

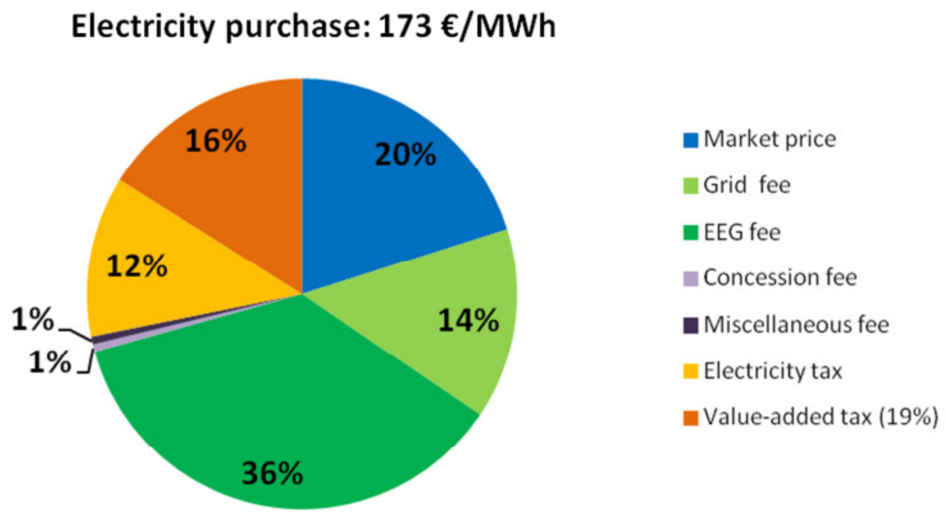

Figure 2: Example of price structure for electricity purchase from the grid in Germany (data from Schiebold and Siebeck 2016)

However, regulations for self-supply from CHP units running on biogas also imply specific EEG fees and obligations to follow:

- Self-supply from new CHP units is burdened with a reduced EEG fee (40% or 25 €/MWh).
- Self-supply from existing or re-powered CHP (up to +30% of capacity) is fully waived from EEG fee (existing or approval for operation before August 2014 (BNA 2016)). From 2018 onwards, the repowering of CHP leads to the loss of this privilege, and a 40% EEG fee will apply for repowered CHPs. Comparably, modernisation or replacing of an existing CHP (e.g. after full depreciation or ending of EEG remuneration time) will lead to a 20% EEG fee from 2018 onwards.
- If EEG fee should be reduced or fully waived, operators have to monitor production and self-supply in 15min intervals to prove the matching of power profiles, unless technical conditions are such that this can be deemed to be always the case. Furthermore, the grid operator has to be notified about the self-supply in monthly and yearly intervals; if not notified, a certain amount of EEG fee falls due.
- KWK bonus is no longer applicable for self-supply with larger CHP > 100 kW_{el}

These regulations decrease the attractiveness of self-supply of a WWTP when building new CHP units, and impose new obligations to WWTP operators who are using their CHP for self-supply.

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Legal definition of self-supply

For the potential waiving of EEG fees in case of self-supply, the exact legal definition of "self supply" is crucial to enable access to this economic privilege. Hence, the EEG 2014 includes a precise legal definition which lists the conditions that have to be fulfilled to claim the privileged status of "self-supply". These conditions have also been extensively discussed in the latest publication of the federal grid agency on that topic (BNA 2016).

In particular, the following conditions have to be met according to the latest version of EEG (EEG 2017):

- The producer of electricity and the end consumer have to be an identical natural or legal person.
- The electricity produced has to be consumed in "actual spatial relation" in a functional term, i.e. locally close to the production location and without using a public grid. This criterion is checked on a case-by-case basis, but usually applies for any self-supply on the same premises of the operator (i.e. on the same property).

Previous versions of the EEG have defined less strict conditions for self supply, so that existing RE systems at WWTPs (e.g. CHP plants constructed before 2014) may have access to self-supply privileges beyond the definition above.

3.1.2. Grid supply of CHP electricity

If electricity from CHP units > 100 kW_{el} is sold to the grid, the operator has to engage in direct marketing, which usually means that a third party takes over the sale of this electricity. For direct marketing, several rules apply:

- The WWTP operator has to announce total amount of delivered energy to the grid operator and the federal grid agency.
- The electricity producer has to set up a bilateral contract with the grid operator for electricity transport, and specific regulations have to be followed in terms of grid connection, safety, and supply management
- For direct marketing, the producer can claim an additional management premium to partially cover the extra costs of this marketing instrument (e.g. for trading, prognosis, risks in day-ahead market). This premium in currently set at 2€/MWh for CHPs on remote control and is paid by the DSO.
- A bonus for avoided grid usage can be claimed (12 €/MWh), as the decentralized production of electricity is supposed to reduce costs for grid operation at regional level. This bonus is currently under discussion and may be fully phased out until 2021.

During direct marketing, two major instruments are available for subsidies: the EEG scheme and the KWK scheme. Both schemes cannot be combined, so the operator has to decide which subsidy scheme is optimum for the specific conditions (i.e. either EEG or KWK).

For the EEG scheme, the following features apply:

- Direct marketing in EEG is incentivized with an additional market premium on top of the current market price of electricity if the unit is able to operate in remote control, usually by the direct marketing party.
- The market premium for WWTP electricity is the difference between market price and a fixed value. This value is defined at 65€/MWh (< 500 kW_{el}) or 57 €/MWh (500-5000 kW_{el}) in 2017, and is guaranteed for 20 years of operation. For new units, the fixed values will be annually decreased step-wise by 1.5%.

For the KWK scheme, the following rules apply:

- Electricity produced in CHP units is subsidized by a KWK premium for 30,000 full operating hours.
- The operator has to prove a high overall energy efficiency of the CHP unit, i.e. combined usage of electricity and heat. The actual definition of "high efficiency" is related to the EU regulation 2015/2402 (EU 2015) and has to be calculated on a case-by-case basis. This condition effectively means that a high share of heat has to be utilized at the WWTP.
- The KWK premium is currently between 50 €/MWh (100-250 kW_{el}) and 44 €/MWh (250-1000 kW_{el}). CHP plants > 1 MW have to take part in a public tender to receive a KWK bonus, while self-supply is forbidden.
- In case of negative electricity prices at the EPEX, no KWK bonus will be paid.

Figure 3 summarizes the market framework for valorising electricity produced at a WWTP in Germany. In case of grid supply, the WWTP operator has to decide between the EEG and KWK subsidy schemes. Due to the complex rules and frequent changes in the subsidy schemes, the future situation for grid supply is highly difficult to predict, which adds a high factor of uncertainty to this marketing option.

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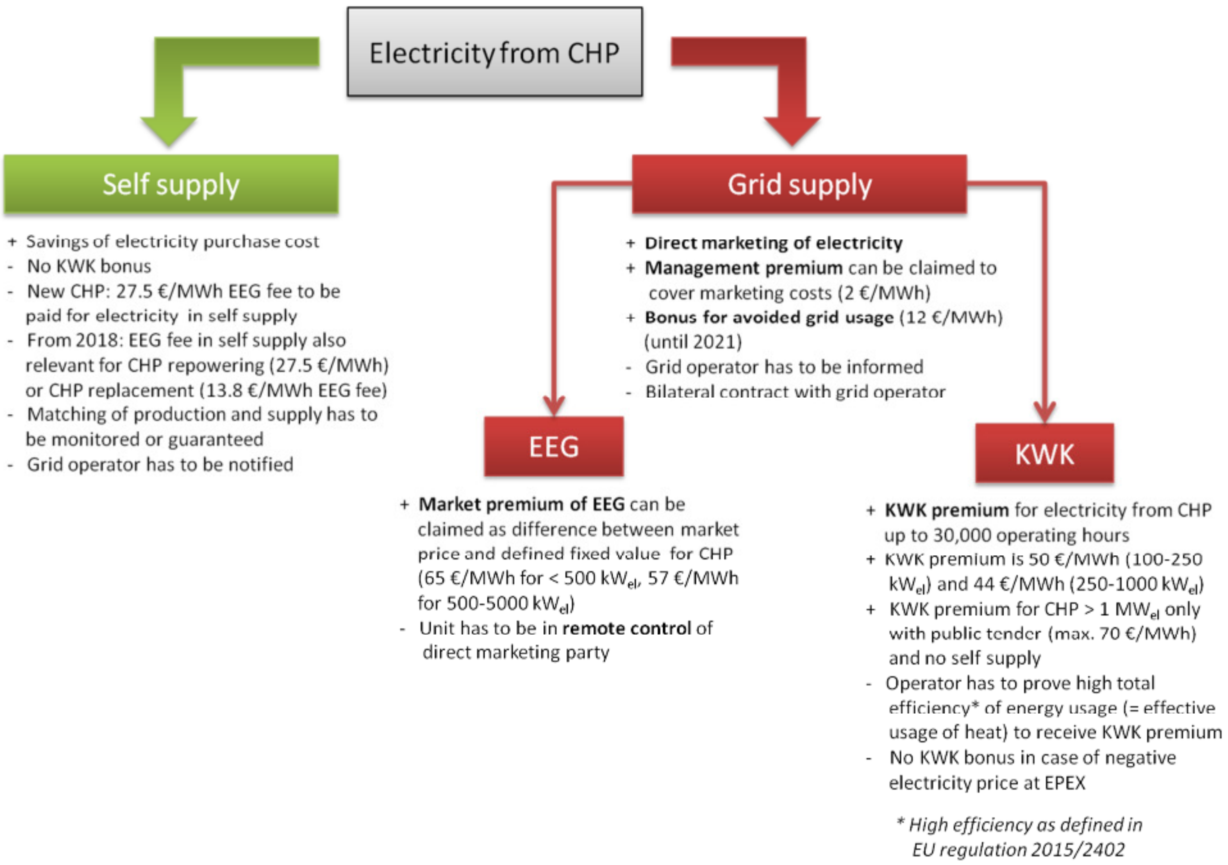

Figure 3: Market framework in Germany for electricity from CHP for self-supply and grid supply (status in 2017 for new installations)

3.1.3. Balancing market for on-site production of electricity and load-shifting

A higher share of flexible production capacity of electricity is another feature that is subsidized separately by the EEG to help in balancing grid instability. The EEG offers an annual flexibility supplement of 40€ per kW_{el} installed over 20 years for the CHP capacity which can be marketed fully flexible. However, this supplement only applies if >50% of the CHP capacity is NOT used continuously, e.g. for self-supply or constant heat production, and if specific conditions of flexibility are met (e.g. adequate storage facilities to store produced gas). An external assessment of these flexibility features is required to certify that the CHP capacity is eligible for the flexibility supplement. Today, this instrument is not seen as very relevant for a WWTP operator, as they usually install CHP capacity based on their gas production and to cover their own electricity demand. Accessing the flexibility market would mean to install CHP capacity only for this purpose and to match biogas production and flexible demand. However, the flexibility supplement may become more relevant while implementing the POWERSTEP concepts, as WWTPs will then produce >100% of their energy demand and thus have excess biogas to valorize in the balancing market.

If load shifting of energy demand from the grid is possible at the WWTP, the WWTP operator can claim subsidies for an "a-typical net usage". This feature means that the maximum uptake from the grid is limited during high-load times (e.g. midday) to 70-80% of the annual maximum load of the WWTP. By shifting the maximum electricity demand of the WWTP away from peak demand in the grid, costs for maintaining grid stability are lower, which is rewarded by a reduced load-dependent grid fee ("Leistungsentgelt" in €/kW) for the WWTP (StromNEV 2005). This grid fee is reduced proportional to the reduction in maximum load during high-load times which are defined by the local grid operator. An exemplary load-dependent grid fee of 70 €/kW could thus be reduced by 20-30%, i.e. 14-21 €/kW.

3.2. Production of heat for external supply

In general, the market for heat has less complex regulations than the electricity market, which leads to a simpler and more stable price structure. Natural gas and fuel oil are the main energy sources for heat production, and the heat market is thus strongly correlated with the fuel prices. Due to the high losses during physical transport of heat, the actual heat price is heavily depending on the local heat demand and supply and if suitable consumers and grid connection is available. The current price for heat is 20-50 €/MWh for both purchase and sale. Regarding heat produced in CHP units, no subsidizes for heat sales are applicable (e.g. for export to a district heating network). However, KWK subsidies may be applicable for financing the connection to heating or cooling networks or storage facilities

3.3. Production of biomethane for grid injection or as biofuel for vehicles

3.3.1. Legal framework for injection

The legal, organisational and quality requirements for grid injection of biomethane are regulated in a specific ordinance (GasNZV 2017). In addition, fees for injection and transport of biomethane via the gas grid are regulated in another ordinance (GasNEV 2017). Investment costs for grid connection to enable direct injection of biomethane into the gas grid have to be mainly covered by the grid operator and can be allocated to the entire network costs.

If direct injection of biomethane into the natural gas grid is targeted, the product has to comply with the strict quality standards defined in DVGW Technical Rule G 260 (DVGW 2013) regarding the heating value and density (measured in "Wobbe-Index"), the content of impurities (e.g. H_2, O_2, H_2S, NH_3, siloxanes), moisture, and pressure. The required gas quality depends on the geographical location of injection, as the different grid sectors in Germany have different gas quality (i.e. low calorific gas or "L-gas" and high calorific gas "H-gas"). The injected gas may be supplemented by additives to reach a specific quality (e.g. adding LPG to raise heating value for usage in H-gas grid). Biogas upgrading has to comply with specific standards concerning internal losses of CH_4 to the atmosphere ("methane slip"). At the point of injection, gas volume, heating value and quality have to be monitored continuously. The grid operator is responsible for pressurizing and odorisation of the injected biomethane.

If biomethane is directly used as biofuel for vehicles without grid injection, quality requirements are defined in DIN 51624 (DIN 51624 2008) regarding the content of CH_4 (> 80 Vol-%), H_2 (<2%), O_2 (< 3%) and other impurities.

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3.3.2. Status of upgraded digestor gas and PtG products produced at a WWTP

In general, marketing of biomethane is third party business, and no specific subsidy scheme exists (such as EEG for electricity). Prices will be agreed on between the parties and are determined by supply and demand. However, the legal status of the gas is crucial for the economic valorisation of biomethane produced at the WWTP, which implies the availability of subsidies for the biomethane or related products (e.g. electricity produced from this gas).

The following rules apply for biomethane produced at the WWTP:

- According to EnWG definitions, gas from renewable sources such as a) WWTP operation and b) P2G based on electricity and CO_2 from predominantly (>80%) renewable sources has the status of "biogas" (EnWG 2017). Hence, both biogas from anaerobic digestion of sewage sludge and also P2G biomethane produced from CO_2 originating from biogas and using RE sources (e.g. electricity from CHP units running on biogas, or solar/wind energy from the grid) is accepted as "green" biomethane. They can be valorized accordingly, if the renewable origin of utilized electricity and CO_2 is proven by the WWTP operator. This implies a variety of privileges in terms of grid management, i.e. privileged connection and injection, the option to use biomethane balancing for marketing, the elimination of feed-in fees, and a fixed payment for avoided grid costs.
- If biomethane is injected into the grid, the related amount of gas extracted from the grid at another location is regarded as biomethane ("biomethane balancing"). A mass balancing system has to be used to prove this balancing option (e.g. https://nabisy.ble.de), which implies a calculation of annual mass balances (i.e. times of gas injection and use do not have to overlap). This injected gas can thus contribute to the political goals in the German heat and transport sectors to fulfill minimum quotas of RE usage, and can be marketed accordingly. A calculation of biomethane prices for final customers in Germany in 2014 indicates that biomethane is marketed at a 50-80% higher price than natural gas in the heat sector (Adler et al. 2014). Assuming current market prices for industrial customers in the natural gas market at 32 €/MWh (DESTATIS 2017), this will result in a potential revenue of 47-58 €/MWh for biomethane sale in the industrial sector.
- Biomethane which is produced in P2G units by using electricity from renewable sources is also labeled as "storage gas" in EEG definitions (§3 Nr. 42 EEG). If this biomethane is used to re-produce electricity (e.g. in an own CHP unit), this electricity can receive subsidies as RE according to the original source of energy, following the "market premium" model of EEG for the original RE sources (e.g. sewage gas, solar, wind, …). Again, injection and use have to be proven by a balancing model, which can consider biomethane input from this year or earlier (= storage function for more than one year).
- P2G units which start operation until 2026 are exempt for grid fees for 20 years.

However, the implementation of P2G technology in Germany may still be further promoted with a couple of specific regulations and policy actions:

- P2G units are currently defined as "ultimate consumers" of electricity, and can thus be affected by fees for electricity consumption for this group as defined in the EnWG (e.g. EEG fee, grid fee). However, they should be seen as "storage technology" of the energy system which would make them exempt of these fees and improve their economic feasibility.
- The EEG subsidy scheme does not promote local P2G technology over direct grid supply of excess renewable electricity. In fact, current EEG "hardship provision" fully compensates lost profits of RE suppliers during times of excess supply of electricity into the grid, thus favoring excess supply of electricity to the grid over intelligent storage schemes such as P2G. The phase-out of this compensation tool would make storage technologies such as P2G more attractive for RE providers.
- Marketing of P2G biogas could be improved by granting it the definition of "biofuel" as stated in latest EC guidelines. The listing of P2G biomethane as biofuel (e.g. in BImschG) would enable the marketing of this biomethane in the framework of climate goals in the transport sector.

3.4. Summary of regulatory framework for Germany

Currently, legal regulations and subsidy schemes favor the use of WWTP energy for electricity production to cover the electricity demand of the WWTP (= self-supply). Due to the high price of electricity (> 170 €/MWh), which is mainly determined by taxes and fees (80%) and only partially by the market price (20%), self-supply is an attractive option to avoid these significant costs by producing electricity on –site to cover the demand of the WWTP, for example in a CHP unit. This option will get less attractive in the future as fees will be raised on electricity used for self-supply, but it may still form a viable option for energy valorisation. In contrast, electricity production for grid supply is less attractive due to the low market price for electricity and the limited subsidy schemes, which enable a maximum revenue of 70-90 €/MWh depending on the selected subsidy scheme. In addition, electricity sale is connected to specific conditions such as direct marketing by third parties, remote control of production, and proof of high efficiency in energy usage in case of using the combined heat and power subsidy scheme.

Heat valorisation is not subsidized in Germany, and the economic viability of this route heavily depends on local prices, suitable customers in the vicinity of the WWTP or an existing connection to a heating network, e.g. for district heating. Typical revenues for heat are 20-50 €/MWh depending on local demand and seasonal factors.

Grid injection of upgraded biogas as biomethane is currently not subsidized, but can yield stable revenues in the range of at least 47-58 €/MWh. This route is further promoted by privileged connection and injection into the gas grid, which also lowers the financial burden of grid connection for the WWTP operator. Due to the stable legal conditions in the gas market and potential rising demand of "sustainable" biomethane for fulfill political targets for the decarbonisation of the heat and transport sector in Germany,

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this route will potentially get more attractive for WWTP operators in the coming years. In addition, P2G technologies are seen as an important building block of the energy transition in Germany and will receive further political support in the next decade, making them an interesting technology also for the WWTP sector.

Final recommendations for WWTP operators in Germany for optimised valorisation of biogas can be summarized as follows:

- Use available biogas at the WWTP to cover self-supply of electricity and heat (e.g. using a CHP plant)
- Valorize additional biogas (e.g. produced in the POWERSTEP concept) via grid injection or biofuel production in combination with P2G systems.

4. Regulatory framework for France

An overview of the legal framework for the continental France will be presented in this chapter containing various regulations and laws related to the energy sector which are relevant for WWTP operators. The regulations concerning energy management in France are quite complicated. The support schemes are based on varying factors used for the calculations of purchase obligation contracts and top-up primes.

For the wastewater sector, the relevant regulatory framework for energy production and consumption at the WWTP includes:

- **Code de l'énergie (Energy Code) (legifrance.gouv.fr 2017c)**
- **Code de l'environnement (Environment Code) (legifrance.gouv.fr 2017f)**

The French Energy Code contains laws and regulations concerning the entire energy sector in France, including the general organization, future development and integration of renewables. Consequently, the subsidy framework for WWTPs is completely defined and explained in this legal act setting the support schemes for all biogas production types, CHPs and biomethane production. Furthermore, the Energy Code includes *Loi de transition énergétique pour la croissance verte* (Law on Energy Transition for Green Growth) composed of action plans that enable France to contribute more effectively to the climate goals, the environmental protection and to strengthen its energy independence when offering the energy at a competitive cost. The current energy targets were also fixed by *Loi de programmation fixant les orientations de la politique énergétique / Loi POPE* (Law fixing energy policy) stabilizing the development of renewables in France.

The Environmental Code includes the environmental aspects such as waste treatment, emissions trading (referring to ETS) or pollution management are described in the Environment Code. It does not influence the subsidy scheme directly, but it does affect the overall functioning of a WWTP plant.

4.1. Electricity cost at WWTP

Historically, there was only one price category for electricity regulated by the state-owned company Electricity of France (EDF). This was divided into three different tariffs in relation to the voltage applied:

- *Blue tariff* (3 – 36 kVA) fixed premium and one or more kWh prices according to the options chosen by the consumer
- *Yellow tariff* (36 – 250 kVA) applies after paying a part of the investment in the transformer station delivering the electricity in a low voltage. The *yellow tariff* differs two seasons (summer, winter), full hours and off-peak hours, i.e. four different prices for kWh can be found
- *Green tariff* (> 250 kVA) for electricity supplied by a medium or high voltage by a private post belonging to the user company. The tariff distinguishes four modes

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of use (very long-, long-, average- and short use) and five tariff periods. In case of WWTPs, they can be considered in majority as users of *green* EDF tariff.

In 2007, the electricity market in France was liberated and since that point all electricity consumers could choose market offers of other electricity suppliers than EDF. For them, the same taxes and fees are applied, but each supplier is free to set its own price level for the electricity spot price in relation to its production performance.

From 2016, all large electricity consumers had to mandatory switch from state-regulated prices offered by EDF to market offers in order to improve competitiveness of the French electricity market meaning that all high-voltage users in France do not receive a fixed state-guaranteed price any more (CRE 2016).

The final electricity taxes and tariffs for an industrial consumer (consuming 2,000 – 20,000 MWh) in France consist of:

TURPE / TSO and DSO tariffs (*le tarif d´utilisation des réseaux publics d´électricité* TURPE)

Those two tariffs cover the cost of the transmission and distribution of electricity and strictly depend on the type of consumer. Large electricity consumers (consuming >7GWh/year) are entitled to receive a special type of contract called *Contrat d´Accès aux Réseaux publics de Distribution CARD* (between the consumer and DSO) and *Contrat d´Accès aux Réseaux publics de Transport CART* (between the consumer and TSO) where they specify the technical, legal and financial conditions for the grid access. This set of contracts is called "a unique contract" as many factors are set individually between the high-voltage consumer and both TSO and DSO.

The tariff is composed of the annual fixed coefficient for each kW installed and a variable part for the kWh consumed (choisir-son-fournisseur-electricite.com 2016, Eurostat 2017).

CTA - Supply Tariff Contribution (*la contribution tarifaire d´acheminement* CTA)

This tariff finances pensions for the staff working in the electricity and gas industries. The amount of the CTA is equal to 10.14% of a fixed part of the TURPE tariff charged by the electricity system operators when the demand is below 250 kVA and 27.04% of TURPE for large consumers over 250 kVA (CRE 2016).

CSPE - Public Service Electricity Contribution (*la contribution au service public de l'électricité* CSPE)

The tax on electricity consumption applying to all types of consumers supporting the sustainable transition of the French energy sector. The value of this tax is constantly growing (Ministère de la transition écologique et solidaire 2017).

TCCFE - Municipal Consumption Tax on Electricity (*la taxe communale sur la consommation finale d'électricité* TCCFE)

The regional levy on the electricity consumption exercised by municipalities that have the freedom of choosing the level of the tax. For small industrial consumers (36-250 kVA), a fixed rate of 0.25 EUR/MWh must be multiplied by two factors: 1) the so-called "y factor" (from 01 January 2015 the value equals 1.0625) and 2) the "x factor" for which the national government defined the value of the multiplication for the factor as 0, 2, 4, 6 and 8.

Large industrial consumers (>250kVA) are exempted from paying this levy (IAE 2017).

TDCFE / Departmental Consumption Tax on Electricity (*la taxe départementale sur la consommation finale d'électricité* TDCFE)

The departmental levy on the electricity consumption set individually by each of 101 different departments in France. Similarly, as in the TCCFE case, large industrial consumers (>250 kVA) are exempted from this tax, however small industries (36-250 kVA) pay 0.25 EUR/MWh to the state's budget multiplied by two factors: 1) the "y factor" (from 01 January 2015 the value equals 1.0625) and 2) the "x factor" for which the French departments can choose freely within three available values: 0, 2 and 4 (IAE 2017).

TVA / VAT Value Added Tax (*la taxe sur la valeur ajoutée* TVA)

Since 2014, the full rate of 20% applies to all taxes for large consumers. However, VAT can be fully reimbursed for electricity purchases with commercial purpose (i.e. WWTP operation) (CRE 2016).

Table 3: Components of the electricity price in France for an industrial consumer (consuming 2,000 - 20,000 MWh)

Element	Amount [€/MWh]	Description	Recipient	Potential savings with self-supply
Purchase price including retail	43	Average industry price 2016 (Eurostat)	Electricity producers and suppliers	Yes
TSO and DSO tariffs (TURPE)	16.2	Tariffs cover the cost of transmission and distribution. Large electricity consumers are entitled to receive a special type of contract.	La Commission de régulation de l'énergie CRE (Energy Regulation Commission)	Probably yes when a unique contract is applied
Supply tariff contribution (CTA)	4.4	Tariff financing pensions of employees hired in the electricity and gas sector	?	?
Public service electricity contribution (CSPE)	22.5	Tax on electricity consumption supporting renewables in France	State's budget	Yes (for small producers with capacity under 1MW)
Municipal consumption levy on electricity (TCCFE)	0 – 2	Municipal levy on the electricity consumption	Municipalities	Yes (for industrial consumers > 250 kVA)
Departmental	0 – 1	Departmental levy on the	Department	Yes (for great

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Element	Amount [€/MWh]	Description	Recipient	Potential savings with self-supply
consumption levy on electricity (TDCFE)		electricity consumption		industrial consumers with high-voltage over 250 kVA)
Net sum	86– 89			
VAT (20%)	0	Fully refunded for purchases with commercial purpose		Yes (is fully reimbursed also with grid supply)
Gross sum	86 - 89			

Source: references in text

Figure 4 shows a pie chart with percentage components of the total electricity cost for an industrial consumer in France.

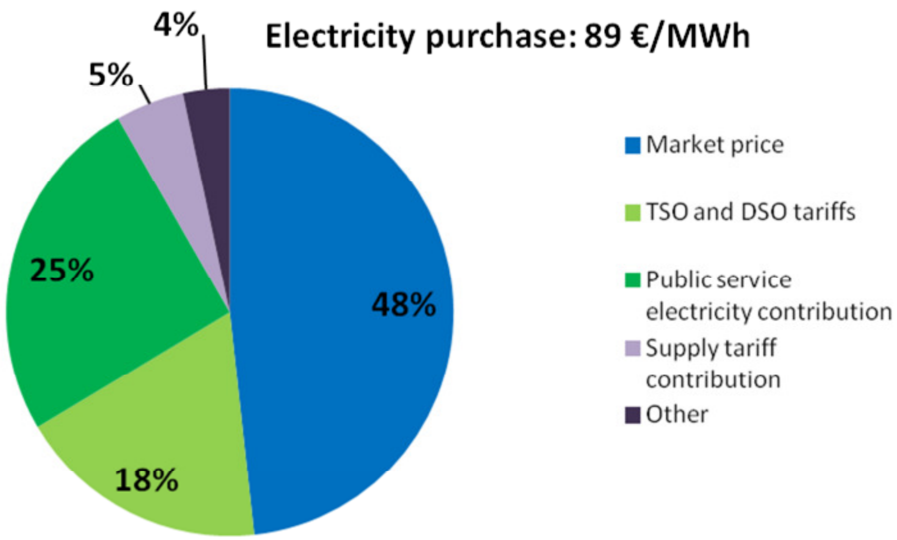

Figure 4: Electricity price components for electricity supply from the grid in France as percentage of the total cost

4.2. Self-supply with electricity

In France, the self-consumption of electricity was not forbidden, but at the same time it was not legally recognized until a new law of the Energy Transition from 17 August 2015 came in life. A new legislation published 24 February 2017 sets a concrete framework for self-supply in France when using renewables for electricity generation (Laurent 2017).

According to the new law, a self-consumption can be partial, individual or collective. Consequently, a biogas producer on a WWTP who decides to use its own electricity is legally entitled to receive a tax exemption from the CSPE and TDCFE tax. However, this law concerns solely small producers with a capacity lower than 1 MW (or production lower than 240 million kWh per year). Unfortunately, large WWTPs cannot benefit from other exemptions at the moment and it is unlikely to change in the near future (fournisseurs-electricite.com 2017).

Due to the current level of the purchase obligation tariff, self-supply is not economically interesting most of the times and producers prefer to generate electricity and sell it to the grid than to consume it on site (CRE 2017).

4.3. Electricity production from biogas at WWTP

A new tariff decree validated by the European Commission was published in the Official Journal of 10/05/2017 (legifrance.gouv.fr 2017b). It defines the support scheme for the electricity produced from biogas on WWTP.

At present, there are different types of financial support depending on the capacity of a WWTP:

1. Facilities with capacity lower than 0,5 MW are entitled to receive a subsidy contract[1] with a <u>fixed price</u> for each MWh generated
2. Those between 0,5-12 MW can receive a <u>top-up subsidy</u>[2] and are affected by fluctuating electricity spot prices
3. WWTPs over 12 MW cannot benefit from any kind of support when generating electricity

In both cases of purchase obligation and top-up subsidy, the contract is given for 20 years of operation. However, there is a cap of 120,000 hours in full power operation, when the financial aid is given. In consequence, once this number of hours is reached, the contract automatically expires.

Furthermore, in order to receive any kind of financial support, the producer is obliged to apply to the Regional Directorate for Environment, Planning and Housing (*Direction régionale de l'environnement, de l'aménagement et du logement* – DREAL) including all necessary information listed in Decree n°20041-410 from 10 May 2001 such as production technology, capacity, annual production, number of operating hours etc. (following articles R. 314-3 and R. 314-4 of the Energy Code). The eligibility to the contract is evaluated each year by informing DREAL about the annual production alternatively deducting the part used for self-supply (CRE 2017).

In addition, during the application for subsidies for the electricity production, all units with capacity over 0.3 MW must conduct a pre-feasibility study for biogas upgrade, if they are located in a municipality served by the public natural gas grid. When the results show that biogas upgrade is more economically feasible than electricity generation, they are not entitled to receive neither a top-up subsidy nor a subsidy contract. The feasibility study includes the potential flow production and the cost of connecting to the natural gas grid (legifrance.gouv.fr 2017b).

[1] Subsidy contract (fr. *Contrat d'obligation d'achat*)

[2] Top-up subsidy (fr. *Complément de rémunération*)

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4.3.1. Subsidy contract and top-up subsidy

Figure 5 presents an overview of the subsidy scheme for electricity generation on WWTPs to explain both the subsidy contract and the top-up subsidy depending on the capacity installed.

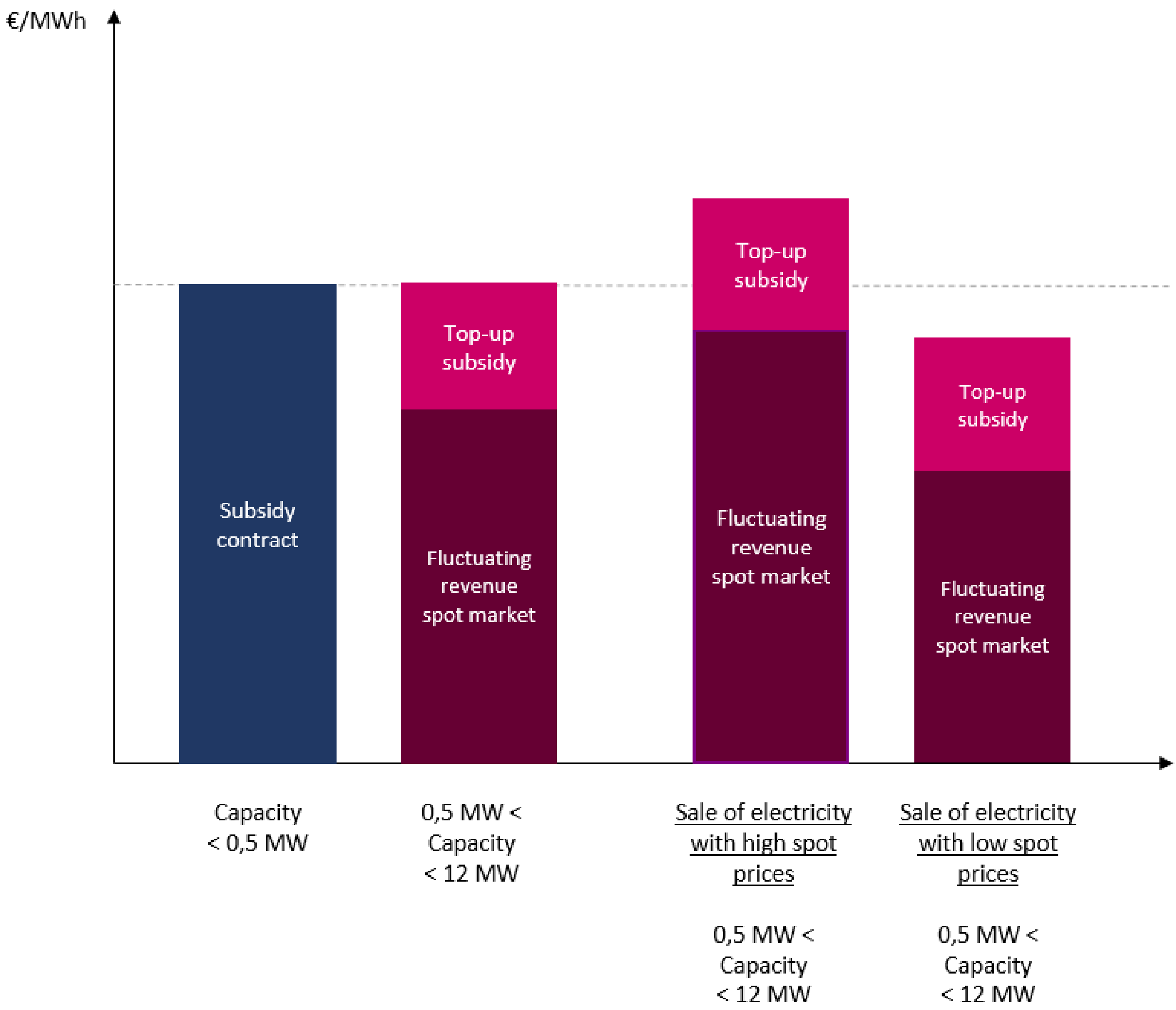

Figure 5: Overview of the subsidy contract and top-up subsidy for electricity production from biogas at WWTP

For small capacities below 0.5 MW the biogas producer is guaranteed the same amount of money for each MWh generated (which is called a subsidy contract). The calculation of the subsidy is done via a complex formula including i.e.:

- The total number of hours with positive or equal to 0 price on the spot electricity market
- The reference tariff set by the government in relation to the capacity installed (Table 4)
- The management prime of 2€/MWh
- The capacity prime

Table 4: Reference tariff value vs. installed electrical capacity for electricity produced at WWTP in France

Electrical capacity installed Pmax (MW)	Value of the base tariff TDOC (the interpolation applies for other proportional cases) (€/MWh)
≤ 0.2*	175.4
0.5*	141.8
≥ 1*	70.9

* - for intermediate values, the linear interpolation is applied

It is however important to notice that those four factors are only an outline of many other coefficients involved in the calculation. Therefore, giving a precise value of the subsidy should lean against the concrete assumptions and cannot be simply generalized.

The top-up subsidy mechanism of support concerns CHP units installed on WWTPs with the capacity between 0.5-12 MW. It consequently consists of selling the produced electricity on the French spot market and receiving a sort of additional compensation calculated through a similar formula as in the subsidy contract. The main difference consists of adding the volatility of the spot electricity market in form of the annual average of spot prices. The target value of the top-up subsidy is the level necessary to reach profitability for the producer. Here, the average of fluctuating market electricity prices is included, changing constantly the final top-up subsidy paid. If a WWTP operator sells the electricity for a better price than the average spot market price, they can increase their profit. Conversely, if their sale price is below the average spot price, they will lose profit. This simplified sensitivity of the top-up subsidy can be seen in Figure 5.

The producer is guaranteed a certain amount in relation to the capacity installed, thus it has two revenues from the sale of electricity itself (spot price and top-up subsidy) and the guaranteed capacity on a production site.

The detailed description of the calculation is included in the appendices.

4.3.2. Negative price prime

According to the article R. 314-39, beyond first 70 hours with negative prices (consecutive or not) in the day-ahead market within a calendar year, every installation which does not produce in such hours is entitled to receive a prime involving the capacity installed, the number of negative spot hours and the reference tariff (legifrance.gouv.fr 2017e).

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4.4. Production of heat

The heat can be produced exclusively in the boiler or together with generating electricity on a CHP unit. It can be self-consumed, sold to a private third party or to the public district heating network or to publicly owned buildings (e.g. a town hall).

The current legislation offers a VAT reduction for the heat sale of 5.5% (instead of 20%) if more than 50% of the heat is produced from biomass, geothermal, waste or energy recovery (legifrance.gouv.fr 2017h).

It is important to notice, that the public sector involves two different legal regulations regarding the heat sale.

In the case of heat production solely dedicated to public service and the district heating networks (e.g. supplying a town hall), the sale of heat is described by the Public Procurement Code if the building or buildings to be heated are public facilities belonging to the same public owner (legifrance.gouv.fr 2017g).

In the case of a district heating networks, where the public sector is simultaneously a network operator, the supply of all or part of the heat can be negotiated freely (outside the Public Procurement Code). However, when the district heating system is operated autonomously as a legal entity, the heat from biogas can be sold to the public service through a private contract (legifrance.gouv.fr 2017h).

4.5. Production of biomethane for grid injection

4.5.1. Legal framework for injection

The biomethane must be injected in accordance with the conditions laid down in Articles R. 121-50, Articles R. 433-15 to R. 433-20 and the provisions of *Title V* of *Book V* of the Environment Code as well as the requirements of the network operators and the specifications, taken in pursuance of those prescriptions (legifrance.gouv.fr 2017f).

The injected gas has to fulfill certain conditions specified in Article 8 from *Décret n°2015-1823 du 30 décembre 2015 - art. 6 (V)* (legifrance.gouv.fr 2017a).

All producers supplying gas to an entry point of the grid must take all measures to ensure that the higher calorific value is kept within the limits set by the Minister of Energy, and that the other characteristics of the gas delivered comply with the requirements of the Transmission System Operator (legifrance.gouv.fr 2017a).

In France, there are two qualities of gas in the grid. In Northern France (around 10% of the market), the calorific value of the gas is at around 9.8 kWh/Nm^3 whereas in the rest, the calorific value equals the average of 10.9 kWh/Nm^3 (GrDF 2016).

Furthermore, the following can be summed up between the biomethane producer and the system operator:

1. A connection contract describing the connection conditions, in particular the financial conditions relating to the investment necessary to connect the producer to the natural gas network, is the sole responsibility of the producer and cannot be reimbursed by the system operator,
2. An injection contract describing the injection conditions such as safety, control and quality monitoring. It must also specify the financial conditions

relating to the services provided by the network operator concerning the operation and maintenance of the injection installation, including the control of the quality of the gas and the determination of the quantities possible to inject (legifrance.gouv.fr 2017a).

The injected flow must be continuously adapted to the absorption capacity of the network. The producer must provide a system for load-shedding in case of inadequate flow rate or non-conformity of the gas quality. The direct emission of biomethane into the atmosphere by this load-shedding system is strictly prohibited.

Every MWh of biomethane injected into the natural gas grid receives a so-called *garantie d´origine* (biomethane certificate) containing the place of injection and wastes used for its production. The party responsible for issues certificates in France is Gaz Réseau Distribution France (GrDF) (GrDF 2016).

4.5.2. **Subsidy contracts**

The French legislation regarding financial aid for biomethane production differs for various types of biogas producers. In this part, the focus will be specifically set on WWTPs.

According to legifrance.gouv.fr 2017a on 12 April 2017, there have been changes in biomethane regulations in France. There are currently two sets of rules for the purchase of biomethane appealing to the installations opened before and after 31 December 2011. For the purpose of this report, the latter one will be based on D. 446-8 from the French Energy Code as the report concerns the current market conditions for new installations (legifrance.gouv.fr 2017d).

Before grid injection of biomethane, all producers are obliged to comply with certain regulations in order to receive a subsidy contract.

Firstly, the digester cannot be heated by fossil energy. The process must be done via biogas/biomethane produced on that installation or with use of residual thermal energy from WWTP. Furthermore, the power consumption of the purification system and, where applicable, the treatment of the vents must be less than 0.6 kWh_e / Nm^3 of biogas to be treated. The purification system should include functional units for desulphurization, decarbonation and drying of biogas, whether they are separated during the purification process or not.

Secondly, the purchase tariff is calculated based on a maximal production capacity of WWTPs (Table 5) alternatively coupled with input prime in relation to the biomethane production flow (Table 6). For WWTPs, the calculation formula includes also several other factors and coefficients i.e. the age of the production site or the date of signing the contract (necessary to calculate the subsidy over a certain time horizon).

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Table 5: Reference tariff coefficient vs. production capacity for grid injection of biomethane in France

Maximal production capacity	Reference tariff coefficient (€/MWh)
≤ 50 Nm^3/h	95
50 Nm^3/h - 100 Nm^3/h*	95 – 86.5
100 Nm^3/h - 150 Nm^3/h*	86.5 – 78
150 Nm^3/h - 200 Nm^3/h*	78 – 73
200 Nm^3/h - 250 Nm^3/h*	73 – 68
250 Nm^3/h - 300 Nm^3/h*	68 – 66
300 Nm^3/h - 350 Nm^3/h*	66 – 64
≥ 350 Nm^3/h	64

* - for intermediate values, the linear interpolation is applied

Table 6: WWTP input prime in France

Maximal production capacity	Input prime (€/MWh)
≤ 50 Nm^3/h	39
50 Nm^3/h - 150 Nm^3/h*	39 – 24
150 Nm^3/h - 250 Nm^3/h*	34 – 21
250 Nm^3/h - 350 Nm^3/h*	21 – 1
≥ 350 Nm^3/h	1

* - for intermediate values, the linear interpolation is applied

Biomethane purchase tariff

By summing up multiple values, the maximal sale tariff price of a MWh gas produced on an upgrading unit in relation to the flow capacity is presented in Figure 6.

The maximum value is given for a small production capacity and equals 134 €/MWh (this is the sum of the reference tariff of 95 €/MWh and WWTP input prime of 39 €/MWh).

The minimal value concerns large production units of over 350 Nm^3/h receiving 65 €/MWh (64 €/MWh for to the capacity installed and only 1 €/MWh for input prime).

The same as in the electricity production case, the owner must submit an annual report to the DREAL. The report must include a summary of the operation data of the installation containing the documents showing the nature and proportions of the inputs used by the facility and the electricity consumption of the wastewater treatment system. Where appropriate, it must also provide information on the additional volumes of propane or butane when biomethane is injected into the natural gas networks (legifrance.gouv.fr 2017a).

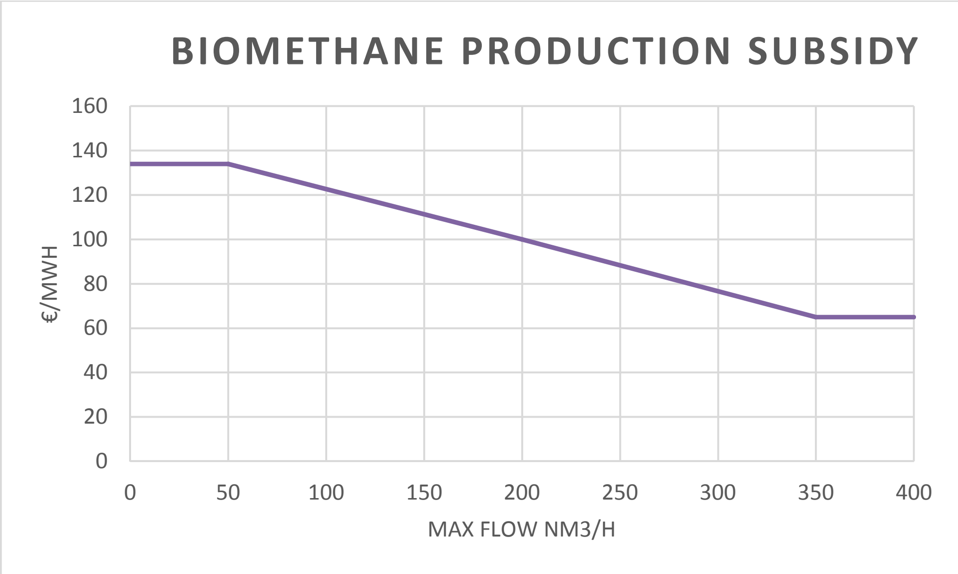

Figure 6: Purchase tariff of biomethane on WWTPs in France in relation to the flow produced

4.6. Status of upgraded digester gas and P2G products produced at a WWTP

Leaning on ADEME's forward-looking scenarios, two recent independent studies have estimated that P2G is expected to emerge by 2030 and the decarbonized surplus of electricity by 2050 would allow the annual direct injection of 35 TWh of biomethane coming from electrolysis in the current gas network (GrDF 2017).

4.7. Summary of regulatory framework for France

At present, self-supply of WWTPs with electricity is not as interesting in France as in other countries, since the tax exemption concerns only small producers. Selling the electricity to the grid is economically more cost-effective.

When it comes to the electricity production from biogas on WWTPs, there are two support schemes for different capacities of CHPs installed on WWPTs.

Small WWTPs (below 0.5 MW) can receive a subsidy contract fixing a stable purchase price for the generated electricity which makes the operation comfortable and secures small producers having typically less financial resources.

Larger WWTPs (0.5 – 12 MW) are entitled to get a top-up subsidy which comprises the volatile spot electricity price. This gives an uncertainty, but also an opportunity to earn more money when a WWPT is managed intelligently and tries to sell the electricity for better prices than the average. Furthermore, the calculation formula includes a guaranteed coefficient in relation to the available capacity on a CHP unit.

Large WWTPs (over 12 MW) do not receive any support. They are more likely to upgrade the biogas than to generate electricity.

Regarding biogas upgrade, all WWTPs are entitled to receive a subsidy contract regardless of the production size (conversely to the electricity generation on a CHP unit). The subsidy is calculated in relation to the flow capacity and the input use for

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biomethane production. The purchase tariff varies from 134 €/MWh to 65 €/MWh depending on the production flow.

5. Regulatory framework for Denmark

In Denmark, the state promotes production of biogas through subsidies that the TSO Energinet.dk pays out to the power plants or companies using biogas instead of natural gas. The state institution Danish Energy Agency has the responsibility for the rules on subsidies for biogas (DEA 2017). The subsidies were politically decided by all parties except one in the Energy Agreement from 2012. The supported biogas applications are

- Power generation
- Heat
- Upgrading or purifying biogas supplied to natural gas or urban networks
- Process objectives in industry
- Transport

For the wastewater sector, the most relevant laws are:

- **Elafgiftsloven (Electricity tax law) (Danish Ministry of Energy Utilities and Climate 2016b)**
- **Lov om fremme af vedvarende energi (Renewable energy law) (Danish Ministry of Energy Utilities and Climate 2016b)**
- **Lov om Naturgasforsyning (Law on natural gas supply) (Danish Ministry of Energy Utilities and Climate 2016b)**

The electricity tax law regulates the energy tax on electricity consumption and VAT exemption rules for VAT-registered companies. The renewable energy law states among others the additional price support for the different renewable energy sources including use of biogas for energy production. In Denmark, the use of biogas is subsidized in relation to how it is used e.g. for electricity production, heat production or transportation.

The law on natural gas supply includes a chapter that describes the regulations for supply of upgraded biogas to the natural gas grid. This influences the operation of a P2G plant.

This chapter will analyze electricity costs for the WWTPs, the subsidy schemes for power generation, heat generation and upgrading or P2G usage for biogas and lastly biomethane certificates.

5.1. Electricity cost at WWTP

The fixed electricity costs consist of:

DSO tariff: The tariff varies from one DSO to another as the DSO tariff is a payment to operate the distribution grid in the respective location. The voltage level of grid connection and annual electricity consumption determines the specific DSO tariff. In general, the DSO tariff is lower if a consumption unit is connected to a higher voltage level because the payment is related to the grid usage. Some grid operators operate with time variable grid tariffs with higher tariffs during peak hours and lower tariffs during off peak hours. For the whole country as an average the DSO tariff was 29 and 16 €/MWh for 100,000 and 250,000 kWh/year respectively (Dansk Energi 2017).

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TSO tariffs: The system, grid and balancing tariffs are paid to Danish TSO (Energinet.dk) to cover their expenses to purchase reserve power and for maintenance of the high voltage grid. It is regulated once every year. In 2017, the TSO tariffs are 9.60 øre/kWh and 12.91 EUR/MWh, respectively (Energinet.dk 2017c).

PSO tariff (Public Service Obligation): Energinet.dk is obligated to promote environmental friendly electricity production, distributed CHP production, grid connection of wind turbines and research and development for environmental friendly electricity production. Most of the PSO covers the payment to environmental friendly electricity production e.g. subsidy for wind turbines. The PSO tariff is adjusted on quarterly basis in relation to forward prices (Energinet.dk 2017c). In November 2016, the government decided to grdually phase out the PSO tariff until 2022. The cost of the PSO will gradually be moved from the electricity bill to the Financial Act thereby moving the PSO cost from electricity consumers to the tax payers (Danish Ministry of Energy Utilities and Climate 2016b).

Electricity tax: VAT-registered companies can have most of the electricity tax reimbursed if the electricity is not used to produce space heating, hot water or comfort cooling. The full electricity tax is 122.38 €/MWh (2017) but most the payment can be reimbursed if the electricity consumption is considered as "process electricity". If the tax is reimbursed, the actual payment is only 0.54 €/MWh (SKAT 2017).

VAT: In Denmark, the VAT is 25% but WWTP can have the VAT fully reimbursed.

Table 7: Components of the electricity price in Denmark (references in text)

Element	Amount [€/MWh]	Description	Recipient	Potential savings with self-supply
Electricity price	31	Forward base load price (Q4-2017) on Nordic power market (September 27, 2017) (Nasdaq 2017)	Electricity provider	Yes
DSO tariff	4-51 (13 for 250.000 kWh)	Covers the cost of operating the distribution grid. Large difference depending on yearly consumption and part of Denmark. Jan.1, 2017	DSO	Yes
TSO tariff	11.2	Consists of a TSO grid tariff, a system tariff and a balance tariff.	TSO	Yes
PSO tariff	12.9	Tariff to promote environmental friendly electricity production (Q3-2017)	TSO	Yes
Electricity tax	0.54	Tax on electricity consumption after reimbursement	State budget	Yes
Net sum	**68.64**	For average DSO 250.000 kWh/year Min/Max: 56.64-106.64 €/MWh		
VAT	0	Fully reimbursed		

Figure 7 illustrates a circle diagram of the total cost divided between the different price components in percentage. When electricity tax and VAT are reimbursed, the biggest component is the market price. The total electricity price is gradually reduced as the PSO tariff is phased out, which will reduce the electricity costs up to 22%.

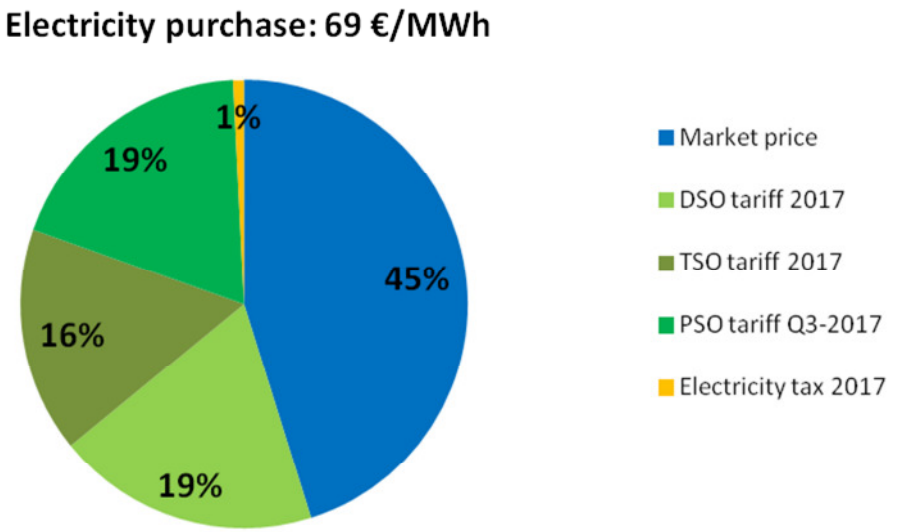

Figure 7: Electricity price components in Denmark as percentage of total cost

5.2. Electricity production from biogas at WWTP

In Denmark, electricity production from biogas is subsidized. CHP units installed at the WWTP that produce electricity to the grid receive a subsidy. The subsidy consists of three components (see Table 8). The first one is either 79,3 øre/kWh together with the spot price or 43,1 øre/kWh as a subsidy on top of the spot price. With the latter possibility, the plant can participate on the electricity markets. Furthermore, there are two subsidies of 26 and 10 øre/kWh. All subsidies are subject to changes depending on the index prices, spot prices, gas prices and a simple cutback starting from 2013.

1) Component 1a and 1b are main subsidies for biogas production sites when generating electricity. Once a year plants using 94-100% biogas can choose between 1a and 1b.
    a. 1a: When producing electricity on site at a biogas plant, the producer is guaranteed to be paid at least 793 DKK/MWh electricity, which consists of the value of the spot prices and the subsidy supplementing these prices to the constant amount.
    b. For plants below 94% (component 1b): When production mixes biogas with other gases, the subsidy drops to 431 DKK/MWh for the biogas component.

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2) Component 2 started at 26 øre/kWh. It fluctuates depending on the spot price. If the market electricity price increases in relation to a base price, component 2 decreases. The reversed mechanism applies if the electricity price decreases.
3) Component 3 is annually reduced by 2 øre/kWh from 2016.

Table 8 show the development in the different components.

Table 8: Price components for electricity generation with biogas in Denmark

Subsidy (øre/kWh)	2012	2013	2014	2015	2016	2017
Component 1a: Electricity production > 94% biogas	79.3	80.2	80.6	81.0	81.4	81.6
Component 1b: Electricity production < 94% biogas	43.1	43.6	43.8	44.0	44.2	44.3
Component 2: Subsidy 26	26	21.7	15.1	30.7	33.6	48.1
Component 3: Subsidy 10	10	10	10	10	8	6

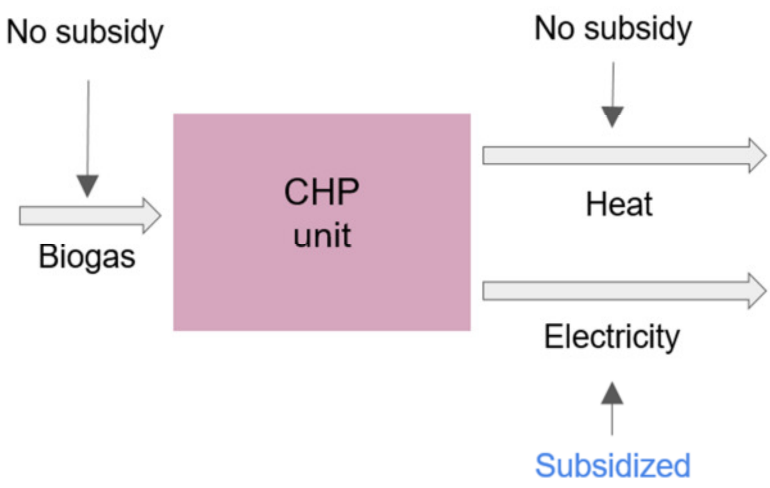
Subsidy (€*/MWh)	2012	2013	2014	2015	2016	2017
Component 1a: Electricity production > 94% biogas	106,73	107,94	108,48	109,02	109,56	109,83
Component 1b: Electricity production < 94% biogas	58,01	58,68	58,95	59,22	59,49	59,62
Component 2: Subsidy 26	34,99	29,21	20,32	41,32	45,22	64,74
Component 3: Subsidy 10	13,46	13,46	13,46	13,46	10,77	8,08

*Rate 7.43 DKK/€ (June 27th, 2017)

Electricity production at a CHP unit.

The biogas producer can apply for subsidies for electricity generation that differ in relation to the volume of biogas used for this process. There are two schemes for over and under 94% biogas content.

Heat production is not subsidized when electricity is.



5.3. Production of heat

It is possible to obtain subsidy for biogas used for heat production if the biogas is not subsidized through other schemes. The subsidy is provided for the energy content in the biogas. Table 9 illustrates the price components. Component 1 does not apply for heat.

Table 9: Subsidy for heat production from biogas in Denmark. Lower calorific values. Rate 7.43 DKK/€ (June 27th, 2017)

Subsidy	øre/GJ / €/GJ	2016 rates per GJ (øre/GJ / €/GJ)	2017 rates per GJ (øre/€ / €/GJ)
Component 2	26 / 3.50	33.6 / 4.52	48.1 / 6.47
Component 3	10 / 1.35	8 / 1.08	6 / 0.81
Total	36 / 4.85	41.6 / 5.60	54.1 / 7.28

5.4. Production of biomethane for grid injection or as biofuel for vehicles

5.4.1. Grid injection

Biomethane must live up to some quality demands regarding regulatory requirements, calorific value, pressure, temperature and additional demands from the grid owner (Energinet.dk 2014). The owner of the biogas purification plant must request the gas grid operator in the specific area for a grid connection. The grid operator is obligated to build a grid injection facility but the expenses are transferred to the owner of the

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purification plant. The two parts enters an agreement for the grid connection that i.e. includes implementation cost, operation costs, amount and quality of delivered gas (Energinet.dk 2013).

5.4.2. Biomethane subsidy scheme

As mentioned in the introduction, there are two approaches of upgrading the biogas at the WWTP: upgrading and P2G. In Denmark, there is a subsidy scheme for upgraded biogas (= biomethane) that is injected in the gas grid. In the renewable energy law, biogas is defined as gas produced from biodegradable biological waste in an anaerobic environment (Danish Ministry of Energy Utilities and Climate 2016a).

The exact subsidy scheme consists of three price components that are regulated differently. Companies that supply upgraded biogas to the natural gas grid can get a subsidy of 79 DKK, a price subsidy of 26 DKK, and a subsidy of 10 DKK per GJ gas (DEA 2017). Table 10 illustrates the price components (upper calorific value):

1) Component 1 is annually indexed in relation to the net price index.
2) Component 2 is regulated in relation to the development in the natural gas price and a basis price. If the natural gas price increases in relation to a base price, component 2 decreases. The reversed mechanism applies if the natural gas price decreases.
3) Component 3 is annually reduced from 2016 by 2 DKK/GJ lower calorific value and expires in 2019.

Table 10: Subsidy for upgraded biogas in Denmark (Energinet.dk 2017b)

Subsidy (DKK/GJ)	Base	2013	2014	2015	2016	2017
Component 1	79	79.9	80.3	80.7	81	81.3
Component 2	26	21.7	15.1	30.7	33.6	48.1
Component 3	10	10	10	10	8	6
Total	115	111.6	105.4	121.4	122.6	135.4

Subsidy (€/GJ)	Base	2013	2014	2015	2016	2017
Component 1	10.63	10.75	10.81	10.86	10.90	10.94
Component 2	3.50	2.92	2.03	4.13	4.52	6.47
Component 3	1.35	1.35	1.35	1.35	1.08	0.81
Total	15.48	15.02	14.19	16.34	16.50	18.22

*Rate 7.43 DKK/€ (June 27th, 2017)

The producer of biomethane produced from upgrading obtains the subsidy for the gas that is injected in the grid. Energy producers, using biomethane as fuel for energy production cannot obtain the subsidy due to the definition of the law. Biomethane from P2G is not produced from biodegradable waste but from hydrogen and CO_2. Therefore, the owner of a P2G plant running on will therefore only receive subsidy for the energy content coming from the biogas.

5.4.3. Biomethane certificates

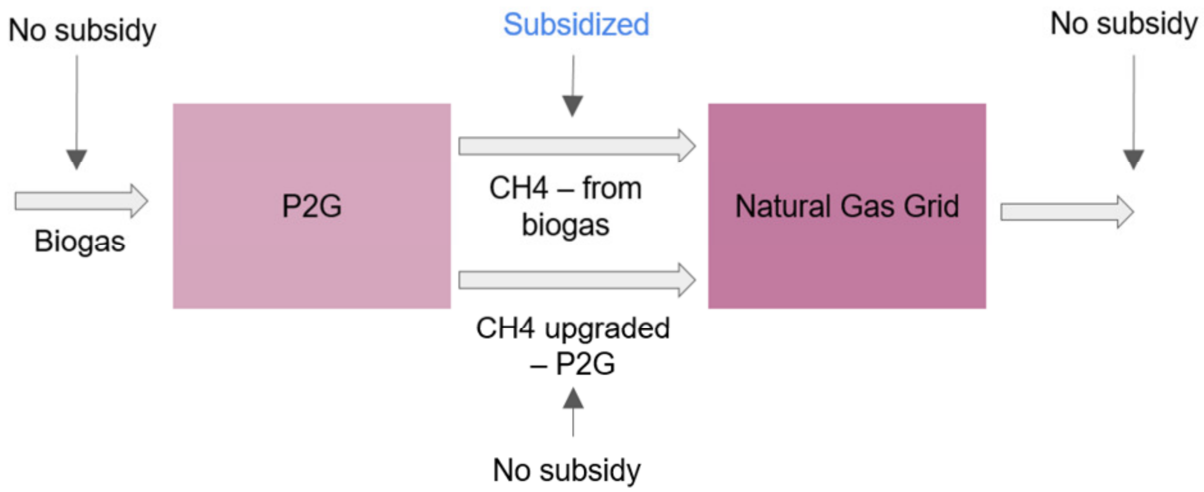
The producer of upgraded biogas can also receive a certificate for the biomethane injected to the grid. In Denmark, Energinet.dk manages a green gas certificate scheme (Energinet.dk 2017a). The owner of a biogas upgrading plant receives 1 certificate per MWh of grid injected biomethane. The certificates can be sold separately of the physical delivery of gas.

The buyer of a certificate is guaranteed that 1 MWh biomethane is injected to the gas grid. The value of the certificate depends completely on supply and demand. Entities that are included in the CO_2 quota settlement can offset their CO_2 accounts from buying certificates. The CO_2 content in natural gas is 205 kg/MWh. Currently, it is not possible to receive certificates for biomethane produced by P2G, which is a major barrier for P2G implementation.

Biomethane production

Biomethane production from anaerobic digestion is subsidized in Denmark (comprising three price components).

Biomethane production through methanation (P2G) is only entitled to receive a part of subsidy for the energy content from the biogas-derived source.



5.5. Summary of regulatory framework in Denmark

In Denmark, biogas is subsidized depended on the use of the biogas. In general, the subsidy schemes for the different use of the biogas are designed to provide the same

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level of financial support. However, subsidy for heat production is slightly lower than for both electricity and biomethane production.

For electricity production, the regulations favor grid supply and not self-supply because it is possible to get tax exemptions for electricity consumption. Heat production is subsidized when the heat is produced from biogas, but it is not possible to get subsidy for both electricity and heat production from co-generation (CHP).

Biomethane injected to the grid is subsidized and it is possible to sell biomethane certificates. P2G does not fall within current subsidy scheme for upgraded biogas.

6. Principles of electricity markets

When a WWTP has electricity consumption or production it can participate in different electricity markets. The aim is to consume electricity from the grid in the hours where the prices are low and produce in the hours when the prices are high. Also, the WWTP can participate in other markets where extra revenue can be made.

In this chapter, a short overview of the principles of these electricity markets will be presented. Historically, the markets in every country have been different. However, presently there is a cross border merging of the markets taking place.

The purposes of the electricity markets are to link buyers and sellers and to balance the electricity system at all times. Balancing can be done both by adjusting production and consumption, but historically mostly done by means of production. There are different electricity markets which have specific characteristics in planning time, activation time and the way they are payed. This chapter will not go into detail since that is out of scope of this report. However, at short presentation will be given about the overall functioning of the different markets to give an overview of the principles. If WWTPs are interested in participating in any of the markets they cannot do it themselves but should engage in business with a balance responsible party that is an actor that has the assignment of trading on the different electricity markets.

Figure 8 shows the principle for the electricity markets.

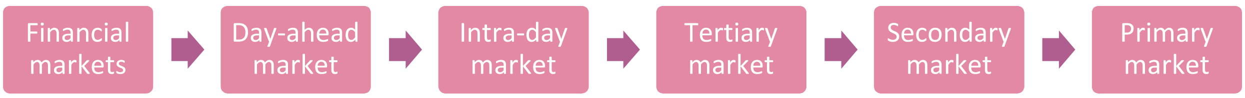

Figure 8: Components of the electricity market

The first market is the financial market, where electricity can be bought or sold several years or months ahead. This is useful if the WWTP wants to secure prices for future electricity production to or consumption from the electricity grid. Prices for the future vary from day to day.

Before the day of operation (= meaning the day where electricity is produced or consumed) most electricity is traded at a day-ahead market which is the backbone of the markets. If a WWTP has a valid prognosis for its production and consumption, then it should be traded in the day-ahead market in order to sell when the prices are highest or lowest to increase profits or reduce costs. A detailed analysis of this option is available in deliverable 3.4 of POWERSTEP.

After the closure of the day-ahead market there can be imbalances because of faults in the prognoses or breakdown of plants or cables. These imbalances are handled either in the intra-day market where electricity can be traded up to one hour before the hour of operation or in the balancing markets for system services. As a rule of thumb, the balancing markets can be divided in primary, secondary and tertiary reserves which are all offered to the TSO through a balance responsible party.

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The rules for the balancing markets are relatively complex but the goal is simply to keep the physical balance in the system otherwise it might break down. It is the assignment to the TSO to keep the system balance and to keep the costs down. This is also the goal for those units that cause the imbalances. As opposed to this the production and consumption units that want to deliver the services would like to make or save as much money as possible. Entso-E is the association between the European TSOs and they have defined a terminology (Table 11).

Table 11: Terminology of the balancing markets

Reserve	Terminology
Tertiary – Balance equalization	Manual Frequency Restoration Reserves (mFRR) Replacement Reserves (RR)
Secondary – Frequency restoration	Automatic Frequency Restoration Reserves (aFRR)
Primary – Frequency stabilization	Frequency Containment Reserves (FCR)

In the different markets, there can be either an availability payment or an activation payment or both.

When imbalances in the system is foreseen the TSO order the tertiary reserves mFRR through the balance responsible parties that can start or stop production and consumption units that they have as their customers. Often the units have to be activated within 15 minutes of ordering.

If further imbalances are foreseen, then the secondary reserves – the aFRR will be activated. The last reserve to be activated is the primary reserve – the FCR. Both secondary and primary reserves operate on deviations in the frequency, whereas the tertiary reserve is activated to prevent frequency deviations.

The CHP units and P2G plants (electrolyzers) can in principle participate in all the markets. What gives the best financial outcome will depend on the market an also the subsidy rules in the different countries. In countries like Denmark it will be very valuable to sell electricity to the market, whereas in Germany it is important to use as much possible of the electricity that the plant produces for self-supply.

Sometimes the most relevant will be the day-ahead market. In the other markets, there might be some limitations that can render this impossible. For example, the Austrian, Swiss, Dutch, Belgian, French and German TSO's procure primary reserve in a common market. West Denmark is planned to be coupled to this market in the nearest future. In this market FCR cooperation is a weekly auction with only one product i.e. a weekly symmetric product. The auction takes place on Tuesday afternoon and applies for the next delivery week. This means that it will be very difficult for WWTPs to bid in this market because of necessity of knowing the operation plan a week ahead. However, if possible, both production and controllable consumption units can supply primary reserves when the prequalification procedure conducted by the TSO is accepted. The minimum lot size in the market is 1 MW and the service is symmetric, which means that the unit must be capable of regulating +/- 1 MW.

7. Instruments to support the implementation of energy-related measures at a WWTP

The implementation of energy-related measures at WWTP can be supported by public funds on European and on national level. As the preconditions and the volume of possible projects will vary widely, in the framework of this chapter we will provide selected suggestions for potential funding sources as examples to encourage the target group to consider and evaluate this option.

7.1. European Grant Schemes

The European Union provides funding opportunities to support energy efficiency, the use of renewable energy sources and with the aim to trigger investment in these fields.

7.1.1. European Structural and Investment Funds (ESI Funds)

The main target of the European Structural and Investment Funds is to invest in job creation, the European economy and the environment. The majority of funding provided by the European Union to the member states is provided through these funds, which are mutually managed by the European Commission and the member States. In the context of the climate and energy related goals of the European Union ESI Funds focus on investments in energy efficiency, renewable energy, smart energy infrastructure and sustainable transport.

Each Member State defines the use of these funds in a partnership agreement, which has to be in line with the political targets of the European Union and is approved by the European Commission.

The content of these partnership agreements is available at:

https://ec.europa.eu/info/publications/partnership-agreements-european-structural-and-investment-funds_de

ESI funds are often used to establish regional funding programmes, which can be approached for projects regarding the implementation of energy-related measures at a WWTP.

7.1.2. European Energy Efficiency Fund (EEEF)

The main goal of the European Energy Efficiency Fund (EEEF) is to support EU member states in achieving the EU energy targets in order to promote a sustainable energy market and climate protection and mitigate climate change. This means for the 2030 targets a 40% cut in greenhouse gas emissions compared to 1990 levels, at least a 27% share of renewable energy consumption and at least 27% energy savings compared with the business-as-usual scenario.

In this context, the EEEF especially focusses on projects related to energy efficiency, small-scale renewable energy and public urban transport. The target group of the funds are regions, city councils, universities, public hospitals and other public entities located in the Member States of the European Union.

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The EEEF, which is a public private partnership, invests directly in projects as well as in financial institutions, which in turn finance eligible projects. The portfolio of the fund includes various financing instruments, like for example loans, senior debt, mezzanine, equity, leasing structures and forfeiting loans and other financial products. The financing will be implemented according to market conditions and he financing need of potential projects should be preferably in the range of 5 million € to 25 million €.

The preconditions for eligibility are a clear municipal link, the commitment of the municipality to mitigate climate change, primary energy savings of at least 20% and the use of proven technologies.

More information can be found at http://www.eeef.eu.

7.1.3. European Fund for Strategic Investments (EFSI)

The European Investment Fund (EFSI) is a joint initiative of the European Investment Bank Group (EIB Group) and the European Commission with the target to mobilise funds from the private sector for strategically important investment projects in the EU. It is one of three pillars of the European Commission's investment plan for Europe, the so-called Juncker Plan. The idea of the fund is to trigger investments, to offer professional investment advice and to create an investment-friendly environment.

The scope of the fund is to support economically viable projects for example in the field of renewable energies and resource efficiency. Target groups of the funds are public institutions, private companies, banks, other funds and investment platforms.

The EFSI provides project loans or loans for research and innovation to local authorities, public sector entities or other government entities. Smaller projects can also be financed from funds provided by connected partner institutions from EIB implementation loans.

More information can be found at http://www.eib.org/efsi/how-does-a-project-get-efsi-financing/index.htm.

7.2. National and Regional Grant Schemes

On the level of Member States and regional level different grant schemes are operated which can be used to finance energy-related measures at WWTP. In the following some selected examples for Germany shall be presented.

In Germany especially on the level of the federal states (“Länder”), several funding programmes are available which target on energy efficiency and wastewater treatment.

Interested organisations in Germany can consult the Funding Database of the Federal Ministry for Economic Affairs and Energy (http://www.foerderdatenbank.de) in order to analyse if for their investment project for an energy positive WWTP subsidies are available.

Resource-efficient sewage disposal NRW II (ResA II)

The focus of this funding scheme, which is valid until 31.12.2022, is to encourage necessary investments in the maintenance and development of the waste water infrastructure to protect the water and the environment. Funding priority 2 is aimed at the topic of energy saving measures and resource efficiency on public sewage systems. It provides grants up to 50% for expert investigations on energy saving measures and for energy saving and resource efficiency measures at public sewage systems. In combination with the program "NRW.BANK.Supplementary program.Water", which provides supplementary loans, up to 100% of the financing can be provided.

The following entities with a duty to dispose waste water are eligible for funding: municipalities, municipal associations, municipal institutions, industrial and commercial enterprises and other legal entities governed by public law insofar as they carry out tasks pursuant to Sections 46 and 52 Paragraph 2 as well as Section 53 of the Land Water Law for sewage disposal companies.

Further information can be obtained at: https://www.nrwbank.de/de/foerderlotse-produkte/Ressourceneffiziente-Abwasserbeseitigung-NRW-II-ResA-II/15874/nrwbankproduktdetail.html

Reduction of CO_2 emissions and resource conservation through renewable and efficient energy use (Rhineland-Palatinate)

The state of Rhineland-Palatinate, with the support of the European Regional Development Fund (ERDF), is funding investment and non-investment measures in the field of innovative climate and resource-conserving technologies and strategies.

Support will be granted for information and motivation measures for economic actors to mobilise them for climate protection and assist them in reducing their CO_2 emissions, the Implementation of climate protection investment measures in public buildings, implementation of integrated strategies for CO_2 reduction in municipalities and model and demonstration projects which support the establishment for new technologies for CO_2 and resource protection.

Eligible applicants are legal entities of public and private law. The projects must contribute to the climate protection targets of the European Union, the Federal Republic of Germany and the State of Rhineland-Palatinate.

Model and demonstration projects must go beyond the state of the art and have to prove high innovative content, model character and transferability. Energy and storage concepts in sewage treatment plants using hydrogen are explicitly mentioned in the current funding conditions. Funding up to 50% of the eligible expenditure can be granted.

More information can be found at: https://www.energieagentur.rlp.de/service-info/foerderinformationen/foerderprogramm-verringerung-der-co2-emissionen-und-ressourcen-schutz/

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8. Conclusion and outlook

Energy produced at a WWTP can be valorized in different ways depending on the form of energy (biomethane, electricity, heat) and the local market framework. Despite the common EC policy framework to promote the use of RE, existing national regulations for RE marketing show large variations between countries, mainly due to specific national policy strategies and targets. In particular, national market conditions can favor certain routes for valorisation of WWTP energy with highest economic benefits in one country, and hamper or even prohibit the economic same route in another country. Hence, this report analysed the market framework in three different EC countries (Germany, France, Denmark) to identify favorable routes for WWTP energy valorisation per country. Based on the actual market conditions in 2017, four different options for energy valorisation have been analyzed: electricity for self-supply, electricity for grid supply, heat for grid supply, and biomethane for grid supply. Taking into account all relevant components of the market (e.g. market price, fees, subsidy schemes), the expected range of revenue was determined for all four options and can then be compared between the routes.

This analysis is based on the effective legal regulations in 2017. Due to frequent changes in the national legislation of the RE sector, the presented results have to be seen as "snapshot" of the situation in the respective countries. However, the findings illustrate the current situation of WWTP operators who are willing to engage in energy marketing with their plants. They also indicate that changing legislation can be a major barrier for implementing innovative processes for energy production at a WWTP, as the market conditions cannot be predicted for a sufficient length of time to allow for a safe investment.

Beside the energy valorisation, the report also discussed options for WWTP operators to engage in dynamic energy management, i.e. shifting electricity supply and demand according to current market prices or offering capacity for load balancing to grid operators. This option of engaging into the RE market is affected by certain pre-conditions that have to be met (e.g. flexibility of consumption and production patterns) and require a sound prediction of the future energy profile of the WWTP at least 24-48h ahead. As long as this prediction cannot be realized at many WWTPs without prohibitive efforts, the economic potential of accessing the day-ahead market for electricity remains relatively low.

8.1. Comparison of renewable energy market frameworks in Germany, Denmark, and France

The legal and market frameworks in the investigated countries differ significantly between countries, but also between types of energy product (i.e. electricity, heat, biomethane). This has direct consequences for the economic incentives for WWTP operators to valorize their energy products following different routes, such as electricity production for self-supply or grid, heat production for self-supply or grid, and upgrading of biogas to biomethane for grid injection.

Table 12 summarizes the most important frameworks for the different routes for energy valorisation in the countries, together with the expected revenue that can be realized for the different options.

Table 12: Market framework for energy valorisation routes of WWTP operators in Germany, Denmark and France in 2017: exemplary revenue from production of electricity, heat and biomethane [€/MWh]

Country	Electricity for self-supply	Electricity for grid supply	Heat for grid supply	Biomethane for grid supply
Germany	140-160	69-77 (EEG) 91-97 (KWK)	20-50	47-58
Conditions	*Avoid electricity purchase cost, partial EEG fee applies*	*Direct marketing, remote control, high efficiency needed for KWK bonus*	*Local market price, no subsidies*	*Marketing as "green" gas, no subsidies, privileged connection and injection*
France	86-89	70-175	Negotiation	65-134 + market price + biomethane certificate
Conditions	Avoided purchase cost, exemption from CSPE and TDCFE for small producers below 1 MW		VAT exemption from 20% to 5.5%	
Denmark	50-107	183	73	5 + market price + biomethane certificate
Conditions	*Avoided electricity purchase cost, low tax on WWTP electricity consumption*	>94% biogas use, ~30% of revenues are depending on market spot price	Subsidy for either electricity or heat sale	~35% of revenues are depending on market spot price, P2G biomethane not subsidized, Certificate value unknown

For Germany, covering WWTP electricity demand with self-supply is the most economical option due to the high electricity price in the market, which can be avoided with self-supply. For grid supply of electricity, subsidy schemes have been reduced in recent revisions of the RE energy laws, so that this route is becoming less attractive. Potentials in heat sale are heavily depending on local conditions (demand) and availability of heating grids (e.g. district heating) nearby. Biomethane production may be a viable option for the future due to the constant prices at the gas market and the rising demand of "green" gas for policy targets in the heating and transport sector.

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For France a new legislation published 24 February 2017 sets a concrete framework for self-supply in France when using renewables for electricity generation (Laurent 2017). Due to the current level of the purchase obligation tariff, self-supply is not economically interesting most of the times and producers prefer to generate electricity and sell it to the grid than to consume it on site (CRE 2017).

For Denmark, there is a high value for selling electricity to the grid. Also biomethane production is valuable and most new 'regular' biogas plants are being equipped with upgrading.

8.2. Recommendation for policy development of market framework

Based on the analysis of the regulatory and market framework of three EC countries, recommendations can be derived to improve incentives for WWTP operators to engage in innovative energy management and thus realize the potential of renewable energy generation originating from municipal wastewater. In principle, different forms of energy can be produced at a WWTP (i.e. electricity, heat, biomethane), and the profitable marketing of these products is affected by different taxes, fees, and subsidy schemes. The analysis of this report leads to the following findings:

- **Marketing routes of WWTP energy are heavily influenced by national subsidy schemes, taxes, and fees** on the different forms of energy. Hence, existing national regulations have a huge impact on the economic feasibility of these individual routes. Depending on the existing conditions in the country, certain routes of valorisation are favoured while others are less attractive.
- The decision between self-supply of the WWTP with its own electricity and delivery of electricity to the grid will be different between the analysed countries. While **self-supply is generally beneficial in countries with high electricity price** (e.g. Germany), **grid supply is attractive if subsidized** in equal or higher amounts (e.g. Denmark).
- **Marketing of WWTP energy as biomethane is becoming more attractive** in the analysed countries, as this form of energy can be used for many different fields (e.g. electricity, heating, transport). Hence, policy measures are in place or being developed that promote this route of energy valorisation at WWTPs.
- Investment in different routes of energy valorisation technology (e.g. CHP, P2G, grid injection of biomethane) requires **stable market conditions** to enable a reliable prediction of payback time. Frequently changing regulatory conditions in the energy market (i.e. subsidies, taxes, and fees) hamper the uptake of innovative technologies and strategies at WWTPs to improve their energy management.

To promote the implementation of new and innovative strategies and technologies increasing the energy recovery from municipal wastewater, the following general recommendations can be made:

- Energy products from WWTPs are a reliable source of renewable energy without negative implications on other environmental sectors. Hence, they should at least **receive similar political support than other forms of renewable energy** such as wind, solar, or biogas from other biomass sources. **Subsidy schemes, taxes and**

fees should be at least equal to other forms of renewable energy and not discriminate WWTP energy in the field of renewable energy marketing.

- As in other sectors, WWTP operators require stable conditions to be able to safely invest in the different routes of energy valorisation. Consequently, major changes in the respective regulatory framework should be minimised to larger timeframes (10a) to **provide a reliable legal environment** for those operators willing to engage in the renewable energy market.
- WWTP can offer a reliable element of flexibility on the electricity market, using their potential for flexible production and (to a certain extent) consumption of electricity. Hence, they should be **recognized as valuable building block in the energy transition to stabilize the electricity grid operation** and level the dynamic production profile of other renewables (e.g. solar, wind).

The P2G approach seems to be particularly attractive for WWTP operators, as the potential revenue for biomethane production is more stable than the fluctuating conditions on the electricity market. In addition, electricity generated in excess of self-consumption will probably not be economically competitive against the decreasing production costs of other renewable sources of electricity (e.g. wind, solar). Hence, **public policies should strongly encourage the production of biomethane at WWTPs** to contribute to the climate targets for the transportation and heating sector.

To promote the implementation of P2G at WWTPs, this technology should be further incentivized by the following policy actions:

- **P2G units should be regarded as "storage technologies"** of the energy system. Hence, they should be excluded from any fees and taxes of normal "ultimate consumers" of electricity, as they provide a valuable flexibility service to the energy system.
- **Subsidy schemes** of renewable energy should not promote excess grid supply of electricity, but rather **support local storage concepts using P2G**.
- Marketing of P2G biogas could be improved by **granting it the definition of "biofuel" as stated in latest EC guidelines**. The listing of P2G biomethane as biofuel would enable the marketing of this biomethane in the framework of climate goals in the transport sector.

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10. Appendices

10.1. Grid supply for CHP electricity in France

10.1.1. Top-up prime calculation (for capacity 0,5-12 MW)

The calculation of the top-up prime is complex and requires multiple input data as follows:

$$TP = E_{elec} \, (T_e - M_0 + P_{management}) - Nb_{capa} * Pref_{capa}$$

1. TP – top-up prime
2. E_{elec} – The annual sum of positive or equal to 0 spot price hours for the day-ahead delivery on the French electricity spot market, volumes allocated by the Transmission System Operator, if necessary, with a formula calculating losses or a settlement agreement to the equilibrium perimeter designed by the producer on its installation. These volumes of electricity are net of the consumption of auxiliaries necessary for the operation of the installation during the production period.
3. T_e – The reference tariff (which can be calculated according to the formula displayed below under *Reference tariff*) expressed in €/MWh
4. M_0 – The reference market price, equal to the arithmetic average over an annual period of positive and null prices for the day-ahead market on the French electricity spot market expressed in €/MWh
5. $P_{management}$ – is a constant unit prime of 2€/MWh
6. Coefficients Nb_{capa} and $Pref_{capa}$ are determined by:

   Nb_{capa} which is a number of MW with guaranteed capacity $Nb_{capa} = 0{,}8 * P_{max}$ where P_{max} is a total installed capacity

7. $Pref_{capa}$ is a market price of the capacity expressed in €/MW, defined as an arithmetic average of prices observed on the auction sessions held during the calendar year and preceding the following year of delivery. For the first year of operation, $Pref_{capa}$ is null.

<u>Calculation example:</u>

The top-up prime for a WWTP of 0.5 MW capacity for the first month of its operation after the top-up prime contract enters into force in January 2017:

$$TP = E_{elec} \, (T_e - M_0 + P_{management}) - Nb_{capa} * Pref_{capa}$$

E_{elec} = 8758 h, sum of positive or equal to 0 spot prices in 2016 in France eex.com 2017

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T_e = 141.8 €/MWh, see the *Reference tariff* calculation

M_0 = 73.49 €/MWh eex.com 2017

$P_{management}$ = 2 €/MWh

$Nb_{capa} = 0.8 * P_{max} = 0.8 * 0,5 = 0,4$ MW

$Pref_{capa}$ = 0, due to the first year of operation

TP = 8758 h (141.8 €/MWh – 73.49 €/MWh + 2 €/MWh) – (0.4*1 MW) * 0

TP = 8758 h (70.31 €/MWh) – 0 = 615,774.98 €/MW

Since the capacity is only of 0,5 MW, so the total yearly allocated subsidy equals 307,887.49 € which gives

35 €/MWh.

10.1.2. Negative prices

Furthermore, according to the article R. 314-39, beyond first 70 hours with negative prices (consecutive or not) calculated in a day-ahead market within a calendar year, every installation which does not produce in such hours is entitled to receive a prime equal to:

$$Prime_{negative\ price} = P_{max} * T_e * n_{negative\ price}$$

Where:

T_e – a reference tariff (which can be calculated according to the formula displayed below under *Reference tariff*), expressed in €/MW

$N_{negative\ price}$ – a number of negative spot prices on a day-ahead market beyond first 70 negative hours during a calendar year (consecutive or not) when the installation does not generate electricity

<u>Calculation example:</u>

The negative prices prime for a WWTP of 0.5 MW capacity for the first month of its operation after the top-up prime contract enters into force in January 2017:

$Prime_{negative\ price} = P_{max} * T_e * n_{negative\ price}$

P_{max} = 0,5 MW

T_e = 141.8 €/MWh, see the Reference tariff calculation

$n_{negative\ price}$ = 2 h, the number of negative hours

$Prime_{negative\ price} = 0,5 * 141.8 * 2 = 141,8$ €

10.1.3. Reference tariff

The reference tariff T_e expressed in €/MWh out of VAT is defined as:

$$T_e = a * L * T_{DOC}$$

8. The coefficient ***a*** is equal 1

9. ***L*** is a coefficient indexing the level of the reference tariff during the contract's lifetime from 1st January each year. The coefficient ***L*** is expressed in form of:

$$L = 0.58 + 0.1\,\frac{ICHTrev{-}TS1}{ICHTrev{-}TS1a} + 0.32\,\frac{FM0ABE0000}{FM0ABE0000a}$$

Where:

ICHTrev – TS1 – the last definitive value of the hourly cost index, published 1st January each year and revised monthly for all employees in the mechanical and electrical industry, in January 2016 this value equaled 118,5 insee.fr 2017a

FM0ABE0000 – the definitive value of the production price index for the French industry on the French market for all industries, published 1st January each year and revised monthly, in April 2017 this value equaled 108 insee.fr 2017b

ICHTrev-TS1a and ***FMABE0000a*** – the definitive values of indexed ***ICHTrev – TS1*** and ***FM0ABE0000*** known on the date when the contract enters into force

T_{DOC} – a level of the base tariff expressed in €/MWh defined as follows:

The value of T_{DOC} is fixed over a contract's lifetime. It is defined in relation to the electrical capacity installed P_{max} according to the table 3.

Table 13 Reference tariff value vs. installed electrical capacity

Electrical capacity installed P_{max} (MW)	Value of the base tariff T_{DOC} (the interpolation applies for other proportional cases) (€/MW)
≤ 0,2	175.4
= 0,5	141.8
≥ 1	70.9

It is important to notice that from 1st July 2017, the value of T_{DOC} decreases by 0,5% every trimester. The French Commission of Energy Regulation emphasizes that it would have been preferable to set up a digressive pricing system that evolved with the pace of development of installations as is the case for photovoltaics in France French Commission of Energy Regulation 2016

<u>Calculation example 1:</u>

The reference tariff for a WWTP of 0.5 MW capacity for the first month of its operation after the top-up prime contract enters into force in January 2017:

$T_e = a * L * T_{DOC}$

a = 1

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$$\mathbf{L} = \mathbf{0.58} + \mathbf{0.1}\,\frac{\mathbf{118.5}}{\mathbf{118.5}} + \mathbf{0.32}\,\frac{\mathbf{108}}{\mathbf{108}} = \mathbf{1}$$

$\mathbf{T_{DOC} = 141.8}$ **€/MW**

$\mathbf{T_e = 1*1*141.8 = 141.8}$ **€/MWh**

Calculation example 2:

The reference tariff for a WWTP of 3 MW capacity for the first month of its operation after the top-up prime enters into force in April 2017:

a = 1

$$\mathbf{L} = \mathbf{0.58} + \mathbf{0.1}\,\frac{\mathbf{118.5}}{\mathbf{118.7}} + \mathbf{0.32}\,\frac{\mathbf{108}}{\mathbf{106.9}} = \mathbf{1.0031}$$

$\mathbf{T_{DOC}}$ **= 70.9 €/MW * 3 MW = 212,7 €**

$\mathbf{T_e}$ **= 1*1.0031*212,7 = 213,3642 €/MWh**

It is important to notice that the value of the denominators have changed. The subsidy is calculated for the month of April 2017 where the contract went into force in January 2017 being a reference for the calculation.

10.2. Purchase obligation contract (for capacity below 0,5 MW)

In case of the purchase obligation contract the same formula applies as for ***TP*** calculation, but E_{elec} is equal to the reference tariff T_e. By removing the volatile spot electricity price, the biogas producer is guaranteed the same amount of money for each MWh generated. However, this concerns only small WWPT with maximal capacity of 0,5 MW.

10.3. Production of biomethane for grid injection in France

In line with new rules, the purchase obligation contracts are subject of annual indexation tailored by a coefficient K defined as:

K = 0,5 * ICHTrev-TS / ICHTrev-TSO + 0,5 * FM0ABE0000 / FM0ABE0000a

Where:

ICHTrev – TS1 – the last definitive value of the hourly cost index, published 1st January each year and revised monthly for all employees in the mechanical and electrical industry, in January 2016 this value equaled 118,5 insee.fr 2017a

FM0ABE0000 – the definitive value of the production price index for the French industry on the French market for all industries, published 1st January each year and revised monthly, in April 2017 this value equaled 108 insee.fr 2017b

ICHTrev-TS1a and ***FMABE0000a*** – the definitive values of indexed ***ICHTrev – TS1*** and ***FM0ABE0000*** known on the date when the contract enters into force

Before the injection of biomethane, all producers are obliged to comply with certain regulations in order to receive a purchase obligation contract for biomethane production.

Firstly, the digester cannot be heated by fossil energy. The process must be done via biogas / biomethane produced on that installation or with use of residual thermal energy from WWTP. Furthermore, the power consumption of the purification system and, where applicable, the treatment of the vents must be less than 0,6 kWh_e / Nm^3 of biogas to be treated. The purification system should include functional units for desulphurization, decarbonation and drying of biogas, whether they are separated during the purification process or not.

Secondly, the purchase tariff is calculated basing on a maximal production capacity of WWTPs alternatively coupled with prime in relation to input used for biomethane production. At the moment, the legislation favors small biogas producers using manure for anaerobic digestion. For WWTPs the following formula is applied:

Purchase tariff = S(TBASE+PI)*

Coefficient S

For installations built after 2011, the following values of *S* are given:

Table 14 Coefficient S calculation

When $N < 15$ years	When $N > 15$ years
$S = 1 - Cgen * N/15$	$S = 1 - Cgen$

Where:

N - the number of all years between the date of commissioning the plant or of the main component that has already been used to produce or allowed the oldest biogas recovery and the date of signing of the purchase contract in line with D. 446-8 from French Energy Code.

The producer should provide the purchaser with a proof stating the date or commissioning the installation.

Cgen – defined in the table below:

Table 15 Coefficient Cgen value

Maximal production capacity	*Cgen*
≤ 50 Nm^3/h	0.19
> 50, but < 350 Nm^3/h	0.19 – 0.13 (linear interpolation)
≥ 350 Nm^3/h	0.13

Coefficient TBASE (reference tariff)

Coefficient *TBASE* expresses a function of the maximal biomethane production defined as:

The project "Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration" (POWERSTEP) has received funding under the European Union HORIZON 2020 – Innovation Actions - Grant agreement° 641661

Table 16 Coefficient TBASE value

Maximal production capacity	TBASE (€/MWh)
≤ 50 Nm^3/h	95
> 50 Nm^3/h, but < 100 Nm^3/h	95 – 86.5 (linear interpolation)
> 100 Nm^3/h, but < 150 Nm^3/h	86.5 – 78 (linear interpolation)
> 150 Nm^3/h, but < 200 Nm^3/h	78 – 73 (linear interpolation)
> 200 Nm^3/h, but < 250 Nm^3/h	73 – 68 (linear interpolation)
> 250 Nm^3/h, but < 300 Nm^3/h	68 – 66 (linear interpolation)
> 300 Nm^3/h, but < 350 Nm^3/h	66 – 64 (linear interpolation)
≥ 350 Nm^3/h	64

Coefficient PI (input prime)

Depending on the input used for biogas production, all producers are entitled to different primes.

$$PI = PI1 * p1 + PI2 * p2 + PI3 * p3$$

Where:

$PI1 * p1$ – <u>does not appeal to WWPT</u>

$PI1$ = 5 €/MWh

$p1$ is a proportion (in tonnage of raw material) of municipal waste (excluding materials resulting from wastewater treatment), household and similar waste or waste from out-of-home catering in the total input supply of the facility, calculated on an annual basis;

$PI2 * p2$ – <u>does not appeal to WWPT</u>

$PI2$ value is defined as:

Table 17 Coefficient PI2 value

Maximal production capacity	PI2 (€/MWh)
≤ 50 Nm^3/h	30
> 50, but < 350 Nm^3/h	30 – 20 (linear interpolation)
≥ 350 Nm^3/h	20

$p2$ is the proportion (in tonnage of raw material) of products from intermediate crops and waste or residues from agriculture, forestry, agro-industry or other agro-industries in total input supply of the installation, calculated on an annual basis;

PI3 * p3 – ***appeals exclusively for WWPT***

Table 18 Coefficient PI3 value

Maximal production capacity	PI3 (€/MWh)
≤ 50 Nm^3/h	39
> 50, but < 150 Nm^3/h	39 – 24 (linear interpolation)
> 150, but < 250 Nm^3/h	34 – 21 (linear interpolation)
> 250, but < 350 Nm^3/h	21 – 1 (linear interpolation)
≥ 350 Nm^3/h	1

p3 is the proportion (in raw material tonnage) of wastewater treatment materials (excluding waste or residues from the agri-food industry or agroindustry) treated as digesters in the total input supply of the facility, calculated on an annual basis. legifrance.gouv.fr 2017a

Accordingly, the table below demonstrates all input primes ***PI*** in monetary values:

Table 19 Coefficient PI1, PI2 and PI3 sum-up

Maximal capacity	PI 1	PI 2	PI 3
≤ 50 Nm^3/h	5 €/MWh	30 €/MWh	39 €/MWh
> 50, but < 350 Nm^3/h	5 €/MWh	30 – 20 €/MWh (linear interpolation)	39 – 1 €/MWh (linear interpolation)
≥ 350 Nm^3/h	5 €/MWh	20 €/MWh	1 €/MWh

Purchase tariff application

The purchase price of biomethane varies in relation to waste input and maximal flow capacity. In such case, the previously presented formula is repeated:

Purchase tariff = S*(TBASE+PI)

Where:

Coefficient ***S*** equals 1 due to 15 years of operation

TBASE – reference tariff of around 64 – 95 €/MWh depending on type and capacity of the installation

PI – input prime depending on waste input type

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10.3.1. Simultaneous production of electricity on a CHP unit and biogas upgrade

The rules differ for those specific installations that generate electricity and upgrade biogas at the same time. In such case, the value of P_{max} is computed differently as follows:

$$Pmax = Pchp + \frac{PCS\ biomthane}{1 - W\ injection} * Rchp * Cinjection$$

Where:

10. $C_{injection}$ is is maximal production capacity of biomethane expressed in Nm^3/h
11. $Pchp$ is an electric power installed, expressed in kW
12. $W\ injection$ is a rate of losses of methane when the biogas upgrade is not taking place
13. $Rchp$ is the average electrical efficiency for a CHP unit defined as a gross quantity of the produced electricity (calculated in relation to the input volume of biogas and its calorific value)
14. $PCS\ biomthane$ is a calorific value of biomethane expressed in kWh/Nm^3 different for zone with a low (Northern France) and high (rest of France) calorific value as described in Section 4.3.3.

The difference is in P_{max} calculation affecting the potential level of subsidies only for electricity generation. Biomethane upgrade does not contain this variable, thus it does not change.