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Evaluation of The Benefits of CO2 Abatement Delivered from Anaerobic Digestion in Ireland

Contents

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1. Executive Summary

The report quantifies the economic benefits of carbon dioxide abatement by anaerobic digestion of different waste streams in Ireland.

The anaerobic digestion (AD) industry demonstrates unique carbon dioxide avoidance compared to other renewable energy technologies. There are four known, significant CO_2^{eq} reduction pathways.[1] Only **fossil energy replacement** is generally known and acknowledged by general environmental policies. Recent scientific research has revealed, however, that further contributions from **slurries, manures and biowaste treatment**, **biofertiliser production**, and **soil carbon sequestration** play a major role in the total CO_2^{eq} reduction delivered by the AD industry.

All these CO_2^{eq} mitigation pathways were analysed and quantified in terms of economic values. Specific and total economic values were calculated for all CO_2^{eq} reduction pathways, together with specific benefits which relate only to electricity production.

Cumulative specific economic values, combining synergic effects of AD process and electricity production, are significantly high in all evaluated scenarios of expected CO_2 price. Particularly values related to slurries and manure treatment in the high internal CO_2 price scenario are approaching the lower end of Premiums/Feed-in-tariffs in Europe.

Specific economic values of AD & electricity-production-specific contributions to CO_2^{eq} savings

Scenario	Feedstock	Electricity [EUR/MWh]	CHP [EUR/MWh]
Low scenario	Slurries, manures	162.89	168.02
	OFMSW	164.93	170.06
	Grass	87.49	92.62
Medium scenario	Slurries, manures	202.71	210.03
	OFMSW	205.62	212.94
	Grass	94.99	102.31
High scenario	Slurries, manures	235.88	245.03
	OFMSW	239.52	248.67
	Grass	101.24	110.39

The table above shows the value of CO_2 savings per tonne of feedstock processed by AD plus the energy production and job input benefits, expressed in EUR/MWh.

It is important to highlight that the calculated specific economic values are significantly offsetting any given Feed-in-Tariff and correspondingly reducing the social costs.

In terms of absolute figures, all evaluated scenarios of power production and combined heat and power production exhibit **cumulative annual offsets ranging from 1.1 billion to 1.5 billion Euro by 2030**, depending on the corresponding CO_2^{eq} price.

In addition to quantifiable benefits outlined in this report, there are additional benefits which cannot be easily quantified, nor economically assessed. Among these benefits is flexible use of the natural gas grid for heating, cooling and transport, rural development and sustainable agriculture, improved air quality related to alternative waste treatment pathways.

2. Scope

Nova Energo was hired by Cré and IrBEA to assess the carbon savings which anaerobic digestion could provide in Ireland, if the correct support structures were in place.

3. Introduction

Various options of AD industry potential development in Ireland have been recently assessed.[2] Three different feedstock streams that have the ideal characteristics for AD processing, have been identified in Ireland. They are:

- Organic fraction of source separated municipal solid waste (OFMSW) (brown bin)
- Manures and slurries from animals
- Grass from permanent grassland

Biogas energy can be utilised in various directions, much depending on local conditions, technical constraints, synergic opportunities, technical and economical feasibility. In this evaluation, we focus on biogas utilization in **a)** Power production; **b)** Combined Heat & Power production (CHP); **c)** Transportation sector (as compressed biomethane). Specific energy yields of selected feedstock streams are summarised in the table (Table 1).

Table 1: Specific energy yields of selected feedstock streams[a,3]

Feedstock	Electricity [MWh/ t_{ODM}]	CHP-electricity [MWh/ t_{ODM}]	CHP-heat [GJ/ t_{ODM}]	Transport [GJ/ t_{ODM}]
OFMSW	1.87	1.87	6.74	16.84
Slurries, manures	1.08	1.08	3.90	9.76
Grass	1.33	1.33	4.77	11.92

[a)] *ODM: Organic Dry Matter; equals to (dry matter minus ash)*

An economic assessment of the contributions in Table 1 is important for the appropriate decision makers responsible for developing AD policy in Ireland.

4. Specific Carbon Dioxide Savings in AD Industry

The AD industry provides a complex range of carbon dioxide savings, which should be thoroughly quantified in any attempt to compare the AD industry with other sources of renewable energy. Some further mitigation pathways are still the subject of on-going research.

The specific relative contributions of feedstock streams to CO_2 savings in the energy sector are summarised in the following table (Table 2).

Table 2: Specific relative CO_2 savings of feedstock in energy utilization pathways

Feedstock	Electricity[4] [kg CO_2^{eq}/ t_{ODM}]	CHP-electricity [kg CO_2^{eq}/ t_{ODM}]	CHP-heat[5] [kg CO_2^{eq}/ t_{ODM}]	Transport[6] [kg CO_2^{eq}/ t_{ODM}]
OFMSW	855	855	384	1,233
Slurries, manures	495	495	222	714
Grass	605	605	272	873

Additional GHG emission savings relevant for AD treatment technology, together with particular increments, can easily be expressed in CO_2 mitigation potential per unit of feedstock mass (organic dry matter), and are summarised in the following table (Table 3).

Table 3: Specific contributions to CO_2^{eq} savings of identified AD feedstock streams in Ireland

Feedstock	Treatment [kg CO_2^{eq}/ t_{ODM}]	N-Fertilisers[7] [kg CO_2^{eq}/ t_{ODM}]	Sequestration [kg CO_2^{eq}/ t_{ODM}]	Total [kg CO_2^{eq}/ t_{ODM}]
OFMSW	5,654	99	498	6,252
Slurries, manures	3,275	64	194	3,533
Grass	0	77	244	322

Total CO_2 mitigation potential of selected feedstock contains both, specific relative savings in energy utilization pathways, and the specific relative savings related to special features of AD technology (Table 4).

Table 4: Total specific relative CO_2 savings of feedstock in energy utilization pathways

Feedstock	Electricity [kg CO_2^{eq}/ t_{ODM}]	CHP [kg CO_2^{eq}/ t_{ODM}]	Transport [kg CO_2^{eq}/ t_{ODM}]
OFMSW	7,107	7,491	7,485
Slurries, manures	4,028	4,251	4,247
Grass	927	1,198	1,194

5. Economic Values Delivered by AD Industry, Ireland 2030

5.1 Identification of Additional Values Delivered by Industry

The AD industry is well-established across the EU, and uses mature technologies which contribute to significant reduction of greenhouse gas (GHG) emissions in various sectors of the EU. The generated products (biogas, biomethane and bio-fertiliser[8]) substitute fossil energy, circulate nutrients,[9] mitigate methane emissions in agriculture and help manage wastes.

In this report, the following carbon reduction values delivered by the AD industry have been quantified and evaluated:

- Energy commodity price (electricity only)
- Alternative feedstock treatment
- Replacement of nitrogen fertilisers
- Carbon sequestration related to digestate application
- Jobs[10]
- Dispatchability of electricity production[11]

However, AD is a complex GHG mitigation technology, with further benefits which cannot be easily quantified, nor economically assessed. Among these benefits is flexible use of the natural gas grid for heating, cooling and transport, rural development and sustainable agriculture, improved air quality related to alternative waste treatment pathways. This range of further benefits is not complete since research of this subject is still on-going.

5.2 Carbon Dioxide Price

Price of CO_2 is a crucial parameter in evaluating possible economic benefits of the AD industry. However, there is no single method or price of CO_2 to be used. An internal CO_2 price[12] is a mechanism recently adopted by an increasing number of large and multinational companies.[13] There are several reasons to implement the policy of an internal CO_2 price, with the following key-benefits:

- To avoid intermediary/transaction costs associated with trading permits in national schemes in favour of factoring in these prices internally
- To justify investments that may have smaller margins without a carbon price
- To anticipate government legislation on carbon pricing
- To comply with existing government legislation
- To manage risk for future investments
- To monetise and record social cost

In this evaluation, we anticipated three different scenarios. These scenarios are based upon two different realistic internal CO_2 prices, set-up and implemented by Royal Dutch Shell[14] and Statoil,[15] companies listed among the Fortune Global 500.[16] The third value was determined as a minimal value, anticipated to be more likely in determining carbon prices widely across all sectors.

Table 5: Internal CO_2 price used in this evaluation report

Scenario	Base	Price[a] [EUR/t CO_2^{eq}]
Low scenario	Calculation	25
Medium scenario	Royal Dutch Shell	35.71 ($ 40)
High scenario	Statoil	44.64 ($ 50)

a) 1 EUR = 1.12 USD[17]

5.3 Economic Values Related to Anaerobic Digestion

Economic values related to the anaerobic digestion process contain a set of calculations related to CO_2 mitigation delivered by alternative feedstock treatment, replacing industrial fertilisers, and carbon sequestration in agricultural soil. Corresponding specific values (per 1 MWh) are summarised for each particular energy use (Table 6).

Table 6: Specific economic values of AD-specific contributions to CO_2^{eq} savings

Scenario	Feedstock	Electricity [EUR/MWh]	CHP [EUR/MWh]	Transport [EUR/MWh]
Low scenario	Slurries, manures	92.89	98.02	39.18
	OFMSW	94.93	100.06	39.99
	Grass	17.49	22.62	9.02
Medium scenario	Slurries, manures	132.71	140.03	55.97
	OFMSW	135.62	142.94	57.13
	Grass	24.99	32.31	12.88
High scenario	Slurries, manures	165.88	175.03	69.96
	OFMSW	169.52	178.67	71.41
	Grass	31.24	40.39	16.10

The total values of such a contribution were determined for the 2030 scenario in Ireland (Table 7).

Table 7: Total economic values of AD-specific contributions to CO_2^{eq} savings

Scenario	Feedstock	Electricity [million EUR]	CHP [million EUR]	Transport [million EUR]
Low scenario	Slurries, manures	357.6	377.3	377.0
	OFMSW	24.5	25.8	25.8
	Grass	82.3	106.4	106.0
	TOTAL	464.3	509.5	508.8
Medium scenario	Slurries, manures	510.8	539.0	538.6
	OFMSW	35.0	36.9	36.8
	Grass	117.5	151.9	151.4
	TOTAL	663.3	727.8	726.8
High scenario	Slurries, manures	638.5	673.7	673.2
	OFMSW	43.7	46.1	46.1
	Grass	146.9	189.9	189.2
	TOTAL	829.1	909.8	908.5

Both the specific and the total economic values of AD-specific contributions to CO_2^{eq} savings have to be considered in the corresponding context of the Ireland 2030 Scenario. Whereas slurries and grass utilisation is fully comparable in terms of quantity, the amount of available OFMSW is smaller by one order of magnitude.

5.4 Economic Values Specific to Power Production

Economic values specific to power production were included in this study. However, only three values were successfully determined (Table 8).

Table 8: Quantified economic benefits specific to electrical production

Item	Price [EUR/MWh]
Energy commodity	30
Jobs	20
Dispatchability	20

Specific economic values of AD-specific contributions to CO_2^{eq} savings were combined with economic benefits specific to power production (Table 9). It is important to highlight the fact, that the specific economic **benefits related to electricity production are lower** compare to the specific economic values of AD-specific contributions to CO_2^{eq} savings in all investigated scenarios.

Table 9: Specific economic values of AD & electricity-production-specific contributions to CO_2^{eq} savings

Scenario	Feedstock	Electricity [EUR/MWh]	CHP [EUR/MWh]
Low scenario	Slurries, manures	162.89	168.02
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	Grass	94.99	102.31
High scenario	Slurries, manures	235.88	245.03
	OFMSW	239.52	248.67
	Grass	101.24	110.39

Table 9 shows the value of CO_2 per tonne of feedstock plus the energy production and job input; expressed in EUR/MWh. Table 9 is a sum of Tables 6 and 8.

Total economic value of both, the AD-specific and electricity-production-specific contributions were calculated for the 2030 Ireland scenario (Table 10).

Table 10: Total economic values of AD & electricity-production-specific contributions to CO_2^{eq} savings

Scenario	Feedstock	Electricity [million EUR]	CHP [million EUR]
Low scenario	Slurries, manures	627.0	646.7
	OFMSW	42.6	43.9
	Grass	411.4	435.5
	TOTAL	1081.0	1126.1
Medium scenario	Slurries, manures	780.3	808.4
	OFMSW	53.0	54.9
	Grass	446.7	481.1
	TOTAL	1280.0	1344.5
High scenario	Slurries, manures	908.0	943.2
	OFMSW	61.8	64.2
	Grass	476.0	519.1
	TOTAL	1445.8	1526.4

6. Conclusions

The AD industry demonstrates unique carbon dioxide avoidance compared to other renewable energy technologies. There are four known, significant CO_2^{eq} reduction pathways.[18] Only **fossil energy replacement** is generally known and acknowledged by general environmental policies. Recent scientific research has revealed, however, that further contributions from **slurries, manures and biowaste treatment**, **biofertiliser production**, and **soil carbon sequestration** play a major role in the total CO_2^{eq} reduction delivered by the AD industry.

All these CO_2^{eq} mitigation pathways were analysed and quantified in terms of economic values. Specific and total economic values were calculated for all CO_2^{eq} reduction pathways, together with specific benefits which relate only to electricity production.

Cumulative specific economic values, combining synergic effects of AD process and electricity production, are significantly high in all evaluated scenarios of expected CO_2 price. Particularly values related to slurries and manure treatment in the high internal CO_2 price scenario are approaching the lower end of Premiums/Feed-in-tariffs in Europe.

It is important to highlight that the calculated specific economic values are significantly offsetting any given Feed-in-Tariff and correspondingly reducing the social costs.

In terms of absolute figures, all evaluated scenarios of power production and combined heat and power production exhibit **cumulative offsets ranging from 1.1 billion to 1.5 billion Euro**, depending on the corresponding CO_2^{eq} price.

7. References

1 Note: further scientific research is heavily focusing at the soil carbon sequestration pathways, and the nutrient recovery beyond the nitrogen loop. More CO_2^{eq} reduction pathways may be acknowledged in the future.

2 Biogas Industry for Ireland, NovaEnergo s.r.o., 5th July 2016

3 Standardised ODM values and energy (biogas) yields of feedstocks based on the following research database; http://daten.ktbl.de/biogas/showSubstrate.do?zustandReq=3#anwendung

4 Sustainable Energy Authority of Ireland (SEAI); 457 kg CO_2^{eq} was emitted per 1 MWh of electricity in Ireland (2014); Carbon Content of Irish Electricity Generation Hits Record Low in 2014 - See more at: http://www.seai.ie/News_Events/Press_Releases/2015/Carbon-Content-of-Irish-Electricity-Generation-Hits-Record-Low-in-2014.html

5 Sustainable Energy Authority of Ireland (SEAI); 205 kg CO_2^{eq} was emitted per 1 MWh of heat (natural gas)

6 US Energy Information Administration: 73.2 kg CO_2^{eq} is emitted per 1 GJ of diesel used as a car fuel

7 6 kg CO_2^{eq} per 1 kg of mineral Nitrogen replaced; FP-7 Improved Nutrient and Energy Management through Anaerobic Digestion ; www.inemad.eu

8 Note: only nitrogen fertilizers contribution is calculated. Further emissions savings are legitimately expected. Particular conversion factors are subject to further scientific research.

9 In the case of animal manure, only ½ of nitrogen savings were accounted. This corresponds to an increased nitrogen plant availability caused by anaerobic digestion treatment.

10 Based on 6 jobs per 1 MWh (electrical equivalent) and value of Job Seekers allowance and taxes/employer PRSI paid on a EUR 34,000 per annum salary

11 Brand, B.; Stambouli, A. B.; Zejli, D. *Energy Policy 2012, 47, 321.*

12 Internal Carbon Dioxide Price, COP21 2015, Article 6 on *Creating mechanisms and markets to reduce carbon emissions*

13 437 international companies adopted internal CO_2 price by 2015; www.triplepundit.com

14 Hone, D.; Climate Change Advisor for Shell; http://blogs.shell.com/climatechange/category/carbon-tax/

15 STATOIL; http://www.statoil.com/en/NewsAndMedia/News/2014/Pages/23Sep_UN_Climate_summit.aspx

16 FORTUNE Global 500 (2016), Royal Dutch Shell (4th position), Statoil (145th position); http://beta.fortune.com/global500/list

17 European Central Bank; https://www.ecb.europa.eu/stats/exchange/eurofxref/html/eurofxref-graph-usd.en.html

18 Note: further scientific research is heavily focusing at the soil carbon sequestration pathways, and the nutrient recovery beyond the nitrogen loop. More CO_2^{eq} reduction pathways may be acknowledged in the future.