ANNEX I to the Handbook of small-scale AD technology model

1. Energy Management

The problem of electricity storage at the time of fluctuations in biogas production, on the one hand, and discontinuities in the demand for energy, on the other (both daily and seasonal fluctuations), can be solved by connecting the biogas plant to the electrical (national) grid. When a surplus of electrical energy is produced - it is fed into the grid, and when the demand exceeds production, energy is drawn from the grid. The issues of balancing the energy taken from and delivered to the grid, as well as settlements in this respect with the distribution system operator, are governed by internal regulations of each country (e.g. net-metering).

Technical solutions other than biogas storage systems described in the Handbook, such as systems of energy accumulators, are too expensive for implementation in a small biogas plant.

2. Sustainability evaluation

Models of small-scale biogas plants described in the Handbook on pages 77-89 were subjected to a sustainability evaluation with the use of the SmallBIOGAS software. The following table provides a summary of the analysed models:

Table 1: Small-scale anaerobic digestion models

Model	Substrate			Energy needs (MWh/year)		Energy production (MWh/year)	
	Type	Quantity (t/year)	Costs (EUR)	El	Th	El	Th
30kW WET	Manure/Bovine|Milking cow/Manure very compact	785	0	75,56	325	232,32	352,01
	Manure/Bovine|Milking cow/Slurry	1 507	0				
	Industrial organic waste/ Animal waste/Dairy Industry/ Whey	819	0				
	Industrial organic waste/ Animal waste/Dairy Industry/ Cheese waste	6	0				
	SUM	**3117**	**0 EUR/year**				
60kW WET	Manure/Pig/Pig manure (mixed)	903	0	41,73	139	463,67	702,54
	Manure/Poultry/Chicken manure	33	0				
	Manure /Bovine/Milking cow/Manure very compact	1 541	0				
	Manure/Bovine|Milking cow | Slurry	2 939	0				
	Energy crops/Crops/Cereals/ Maize (whole plant)	434	0				
	SUM	**5 850**	**0 EUR/year**				

100kW WET	Manure/Bovine/Milking cow/Slurry	9 263	0	68,5	181	761,74	1154,16
	Manure/Bovine/Milking cow/Manure very compact	2 160	0				
	Energy crops/Crops|Cereals/Maize (whole plant)	196	40 EUR/tonne				
	SUM	**11 619**	**7 840 EUR/year**				
30kW DRY	**Industrial organic waste/ Vegetable waste/Brewing/Brewers grains**	280	0	157	38,5	228,89	346,81
	Manure/Bovine|Milking cow/Manure very compact	74	0				
	SUM	**354**	**0 EUR/year**				
60kW DRY	Industrial organic waste/Harvesting crops waste/Waste storage/Dust silo waste	43	0	105,6	0	457,29	692,86
	Industrial organic waste/Harvesting crops waste/Other harvesting waste/Discarded grain	17	0				
	Industrial organic waste/Vegetable waste/Milling Industry/Wheat bran	526	108 EUR/tonne				
	Manure/Bovine/Milking cow/Manure very compact	259	0				
	SUM	**845**	**56 808 EUR/year**				
100kW DRY	Industrial organic waste/Animal waste/Food Industry/Offal and manure	2 490	0	875	0	761,99	1154,53
	Industrial organic waste/Animal waste/Other Industries/Sewage sludge from industrial treatment plants	2 506	0				
	Industrial organic waste/Animal waste/Food Industry/Slaughterhouse animal fats	49	250				
	Industrial organic waste/Animal waste/Food Industry/Slaughterhouse animal fats	708	50				
	SUM	**5 753**	**47 650 EUR/year**				

For the sake of sustainability evaluation, 6 scenarios have been defined:

- **No subsidies** (financing structure: 30% own funds, 70% loan) + Energy **self-consumption** (both thermal and electric)
- **No subsidies** (financing structure: 30% own funds, 70% loan) + Energy **sale** (both thermal and electric)
- **No subsidies** (financing structure: 30% own funds, 70% loan) + Energy **MIX: self-consumption/sale of surplus** (both thermal and electric)
- **30% subsidies** (financing structure: 30% subsidy, 30% own funds, 40% loan) + Energy **self-consumption** (both thermal and electric)
- **30% subsidies** (financing structure: 30% subsidy, 30% own funds, 40% loan) + Energy **sale** (both thermal and electric)
- **30% subsidies** (financing structure: 30% subsidy, 30% own funds, 40% loan)+ Energy **MIX: self-consumption/sale of surplus** (both thermal and electric)

Selected parameters of the results of the assessment carried out with the SmallBIOGAS tool are shown in the table below (payback period, investment costs, CO2 reduction).

Table 2: Results of sustainability assessment

	PAYBACK PERIOD (years)						
WET Model (with CHP)	**Italy**	**Spain**	**Ireland**	**France**	**Sweden**	**Germany**	**Poland**
30 kW no subsidies self consumption	13,80	12,33	>15	>15	>15	12,96	>15
30 kW no subsidies sale of energy	6,02	>15	11,11	13,01	>15	7,86	>15
30kW no subsidies MIX consumption/sale	**5,60**	**8,62**	**8,47**	**13,90**	**>15**	**6,27**	**>15**
30 kW 30% subsidies self consumption	9,66	8,63	>15	>15	>15	9,07	>15
30 kW 30% subsidies sale of energy	4,21	>15	7,78	9,11	>15	5,5	>15
30 kW 30% subsidies MIX consumption/sale	**3,92**	**6,04**	**5,93**	**9,73**	**13,99**	**4,39**	**13,09**
60 kW no subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
60 kW no subsidies sale of energy	6,06	>15	11,57	>15	>15	10,90	>15
60 kW no subsidies MIX consumption/sale	**5,93**	**>15**	**10,23**	>15	**>15**	**9,86**	**>15**
60 kW 30% subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
60 kW 30% subsidies sale of energy	4,24	>15	8,10	11,21	>15	7,63	>15
60 kW 30% subsidies MIX consumption/sale	**4,15**	**>15**	**7,16**	**11,59**	**>15**	**6,90**	**13,28**
100 kW no subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
100 kW no subsidies sale of energy	4,91	>15	7,50	13,06	>15	8,57	14,97
100 kW no subsidies MIX consumption/sale	**4,85**	**>15**	**6,92**	**13,41**	**>15**	**7,99**	**13,28**
100 kW 30% subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
100 kW 30% subsidies sale of energy	3,44	>15	5,25	9,14	>15	6,00	10,48
100 kW 30% subsidies MIX consumpt/sale	**3,39**	**>15**	**4,85**	**9,38**	**>15**	**5,59**	**9,30**
	PAYBACK PERIOD (years)						
DRY Model (with CHP)	**Italy**	**Spain**	**Ireland**	**France**	**Sweden**	**Germany**	**Poland**
30 kW no subsidies self consumption	11,04	8,35	14,09	>15	>15	9,59	>15
30 kW no subsidies sale of energy	4,87	12,06	7,76	7,29	>15	5,92	>15
30kW no subsidies MIX consumption/sale	**5,48**	**5,99**	**8,01**	**8,63**	**14,41**	**5,47**	**10,91**
30 kW 30% subsidies self consumption	7,73	5,84	9,87	>15	>15	6,72	10,84

30 kW 30% subsidies sale of energy	3,41	8,44	5,43	5,10	12,37	4,14	>15
30 kW 30% subsidies MIX consumption/sale	**3,83**	**4,19**	**5,61**	**6,04**	**10,09**	**3,83**	**7,63**
60 kW no subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
60 kW no subsidies sale of energy	8,51	>15	>15	>15	>15	>15	>15
60 kW no subsidies MIX consumption/sale	**9,38**	**>15**	**>15**	**>15**	**>15**	**>15**	>15
60 kW 30% subsidies self consumption	>15	>15	>15	>15	>15	>15	>15
60 kW 30% subsidies sale of energy	5,96	>15	>15	13,93	>15	>15	>15
60 kW 30% subsidies MIX consumption/sale	**6,57**	**>15**	**>15**	**>15**	**>15**	**>15**	>15
100 kW no subsidies self consumption	13,94	>15	>15	>15	>15	>15	>15
100 kW no subsidies sale of energy	5,68	>15	10,28	13,35	>15	12,79	>15
100 kW no subsidies MIX consumption/sale	**8,08**	**10,94**	**13,83**	**>15**	**>15**	**11,00**	**>15**
100 kW 30% subsidies self consumption	9,76	11,67	>15	>15	>15	12,74	>15
100 kW 30% subsidies sale of energy	3,78	>15	7,20	9,34	>15	8,95	>15
100 kW 30% subsidies MIX consumpt/sale	**5,65**	**7,66**	**9,68**	**>15**	**>15**	**7,74**	**>15**
	TOTAL INVESTMENT COSTS (Biogas plant + CHP) [EUR]						
WET Model (with CHP)	**Italy**	**Spain**	**Ireland**	**France**	**Sweden**	**Germany**	**Poland**
30 kW	287.427,38	179.852,32	276.550,81	329.132,56	276.550,81	208.983,77	241.936,45
60 kW	480.609,7	331.047,29	392.953,93	571.576,14	392.953,93	400.480,14	426.514,97
100 kW	707.946,16	527.059,52	518.129,30	862.281,71	518.129,30	651.835,96	656.256,60
	TOTAL INVESTMENT COSTS (Biogas plant + CHP) [EUR]						
DRY Model (with CHP)	**Italy**	**Spain**	**Ireland**	**France**	**Sweden**	**Germany**	**Poland**
30 kW	270.455,81	163.705,29	260.658,92	311.435,99	260.658,92	192.270,42	225.212,29
60 kW	450.646,10	301.974,98	365.164,47	540.250,21	365.164,47	370.254,62	396.630,02
100 kW	678.328,46	497.422,82	488.428,03	832.715,57	488.428,03	622.245,46	626.644,76
	CO2 REDUCTION (t/year)						
WET Model (with CHP)	**Italy**	**Spain**	**Ireland**	**France**	**Sweden**	**Germany**	**Poland**
30 kW	158,57						
60 kW	316,47						
100 kW	519,91						
	CO2 REDUCTION (t/year)						

DRY Model (with CHP)	Italy	Spain	Ireland	France	Sweden	Germany	Poland
30 kW	156,23						
60 kW	312,11						
100 kW	520,08						

Comments, remarks and recommendations:

- Essential for the analysis was the demand for energy as defined within each model - the results of analysis for models in which most of the energy can be consumed on the spot will be significantly different than the results for models in which only a small amount of energy is consumed on the spot. In most of the analysed models (except the 30 kW DRY and 100 kW DRY) energy demand is much smaller than the production, therefore in their cases the scenario of energy self-consumption without selling surplus energy should be discarded.
- In countries where energy sales price is significantly lower than its purchase price (e.g. in Spain or Poland for <40 kW plants), it is the most profitable to choose a plant of such a size that makes it possible to maximise energy self-consumption. This is clearly visible on the example of the 30kW DRY model, where demand for electricity is closest to the amount of energy produced by the plant.
- In countries where the sales price of electricity is significantly higher than the purchase price (e.g. Italy, France) the opportunity to sell excess energy can improve the economic result of the project.
- As regards thermal energy, in all countries its purchase price is higher than the sales price, therefore it is more profitable to use the produced heat for self-consumption. It should be noted that prices of thermal energy are generally much lower than the prices of electricity, so their impact on the economics of a project is less than the impact of electricity prices. Nevertheless, in the case of some companies with high demand for thermal energy (e.g. dairies), the meeting of their own demand for thermal energy will be the key element of the biogas project.
- The most optimal solution for all models is a scenario of mixed energy use, i.e. the consumption of energy for own purposes and selling the surplus. Only in the case of France and Spain energy sales prices are higher than purchase prices to the extent that the option of solely selling the energy turns out - for some models - to be slightly more profitable than the MIX option.
- A comparison between different countries shows that where energy prices (sales and purchase) are high, investment in biogas plants pays off more quickly, because energy savings or its sale compensate - in a predictable term - for certain capital expenditures. At comparable investment costs but low energy prices (e.g. in Sweden, Poland), payback periods are much longer.
- The use of expensive substrates (e.g. corn silage, wheat bran, slaughterhouse animal fats) - e.g. in the 60kW DRY and 100kW DRY models make the project not viable - operating costs exceed the potential gains from the sale or consumption of energy. It is advisable to use waste substrates of which the acquisition is not a cost (including the opportunity cost resulting from the resignation of selling them).

Disclaimer: The analysis refers to theoretical models that determine the composition of substrates with specific properties and the energy demand of the company. The analysis was performed based on default values (and hence averaged) included in the SmallBIOGAS tool and defined for each country by the BIOGAS3 project partners. Results of feasibility studies for biogas plants of equal capacities, but using other substrates or substrates with different properties; operated by companies with different levels of demand for electricity and heat; in different countries; under different local conditions - may significantly differ from those presented in the table. The economic result of a project is largely dependent on the purchase and sales prices of electricity, and can also be individually varied even within one country (e.g. depending on the type of entity and the type of tariff). Other important factors affecting the economics of a project are operating expenses, which in each case depend on several factors, such as technological solutions. There was also an assumption made in the analysis that all thermal energy can be consumed on the spot or sold to external recipients, which in many cases is difficult to achieve in real terms.