Economies of scale in biogas and organizational consequences: Common case study

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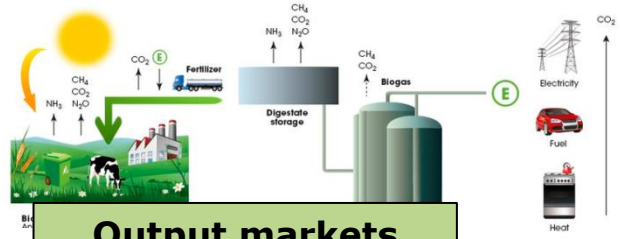
biochain

Scale effects

Logistics



Output markets

Energy markets

Certificates?

Input markets

price

price

price

Bioenergy

Scale effects

Logistics

Input markets

Output markets

Regulation and financing

Output market

Manure treatment

Fertilizer

Output markets

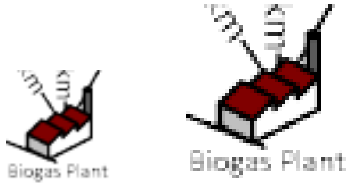
Fertilizer and manure treatment

WP1

Value chain optimisation

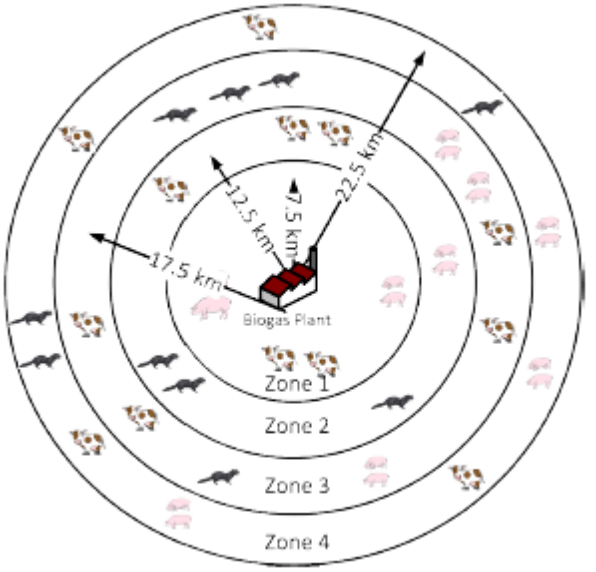
Scale effects – economies of scale

- Collection costs and density of resources
  - trade off between distance and size of resource



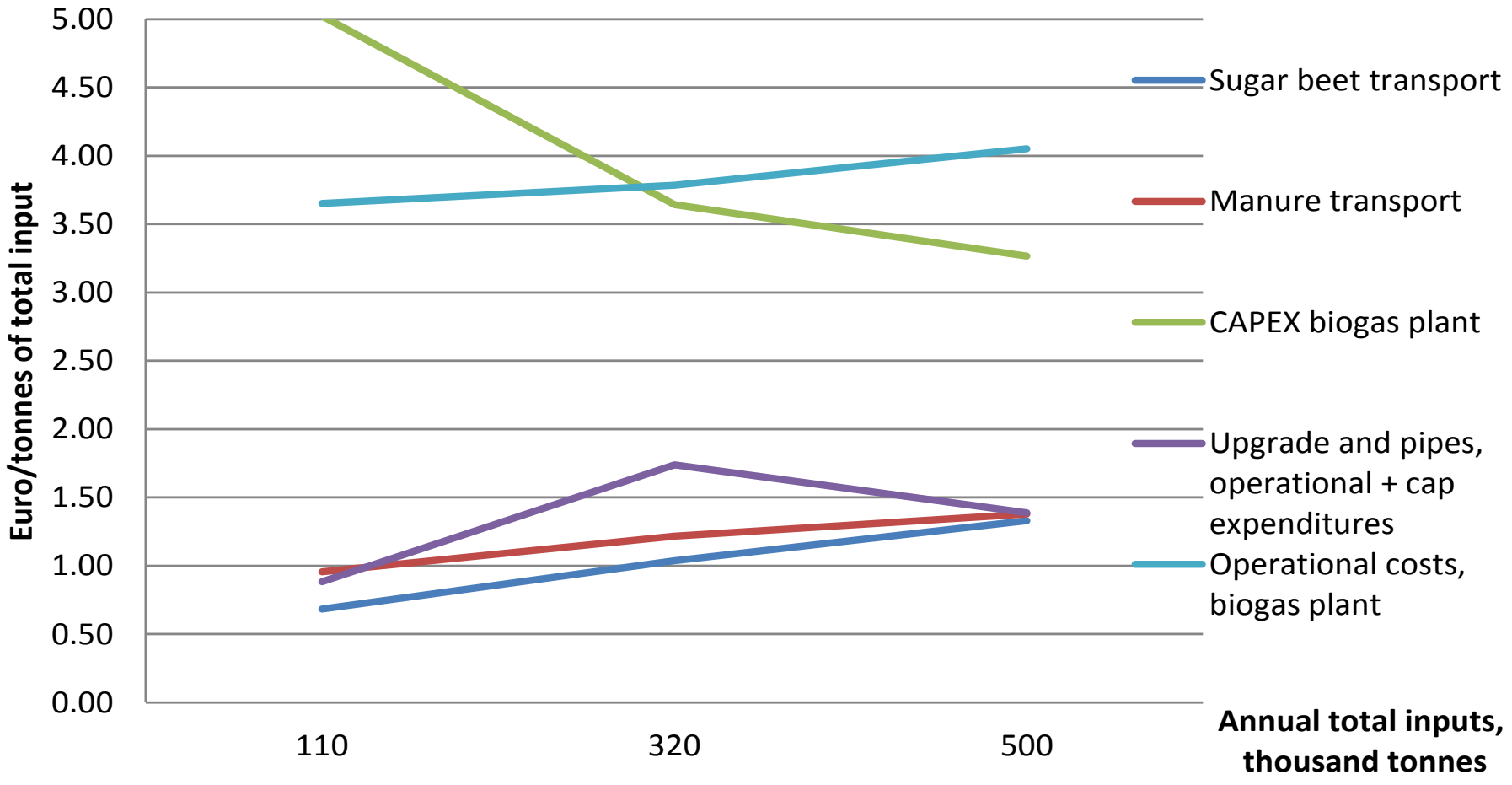
- Scale of biogas plant
  - economies of scale - capex expected

- Scale of upgrading facility and costs
  - storage cost
  - small scale no upgrade
  - large scale upgrade opex and capex



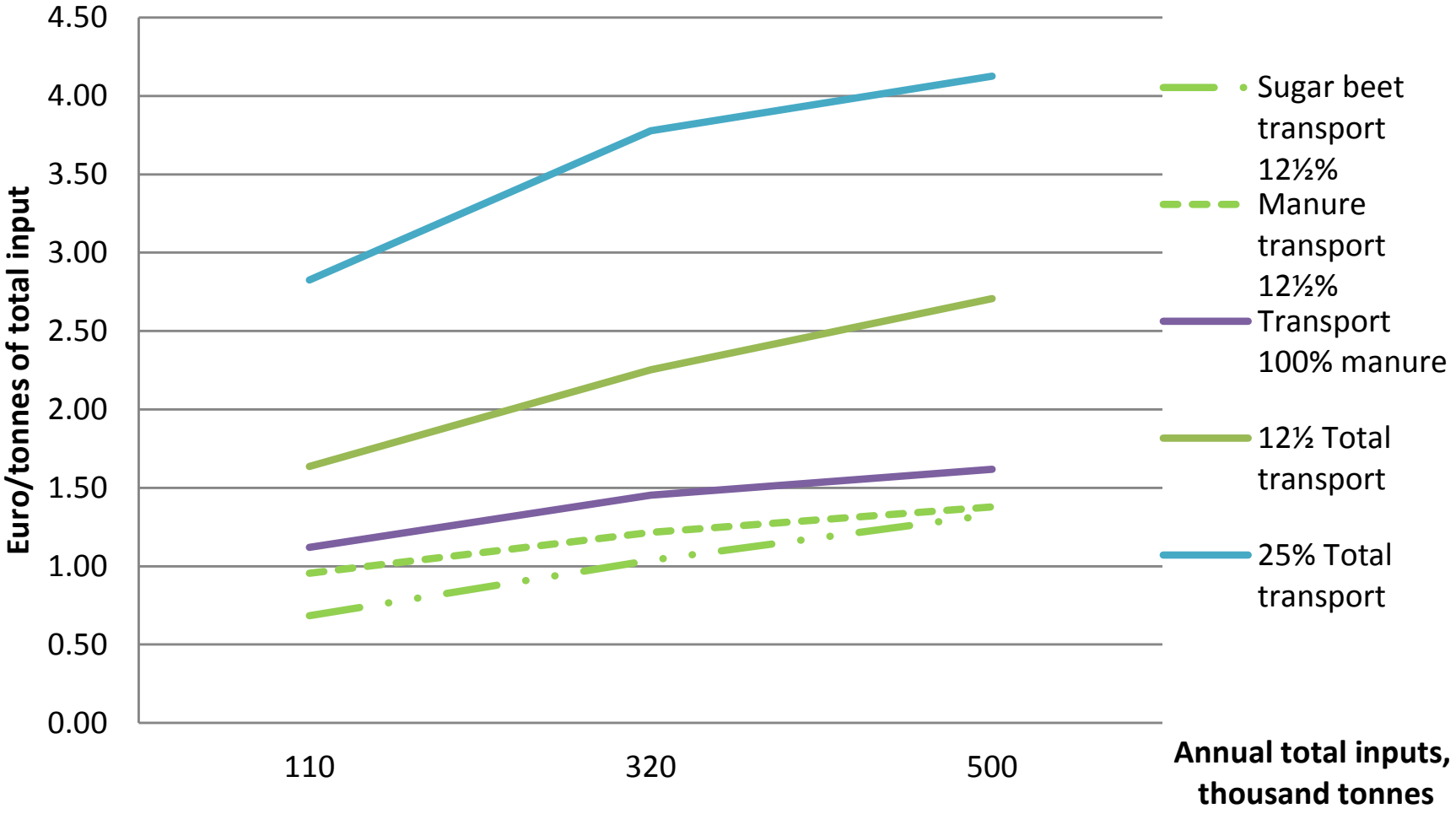
Trade off between rising operational costs (including transport) and reduced capital costs

Cost contribution and scale 12½% sugar beet



Tree scales of plant size and 3 cases of sugar beet inputs

Rising transport cost per unit of input



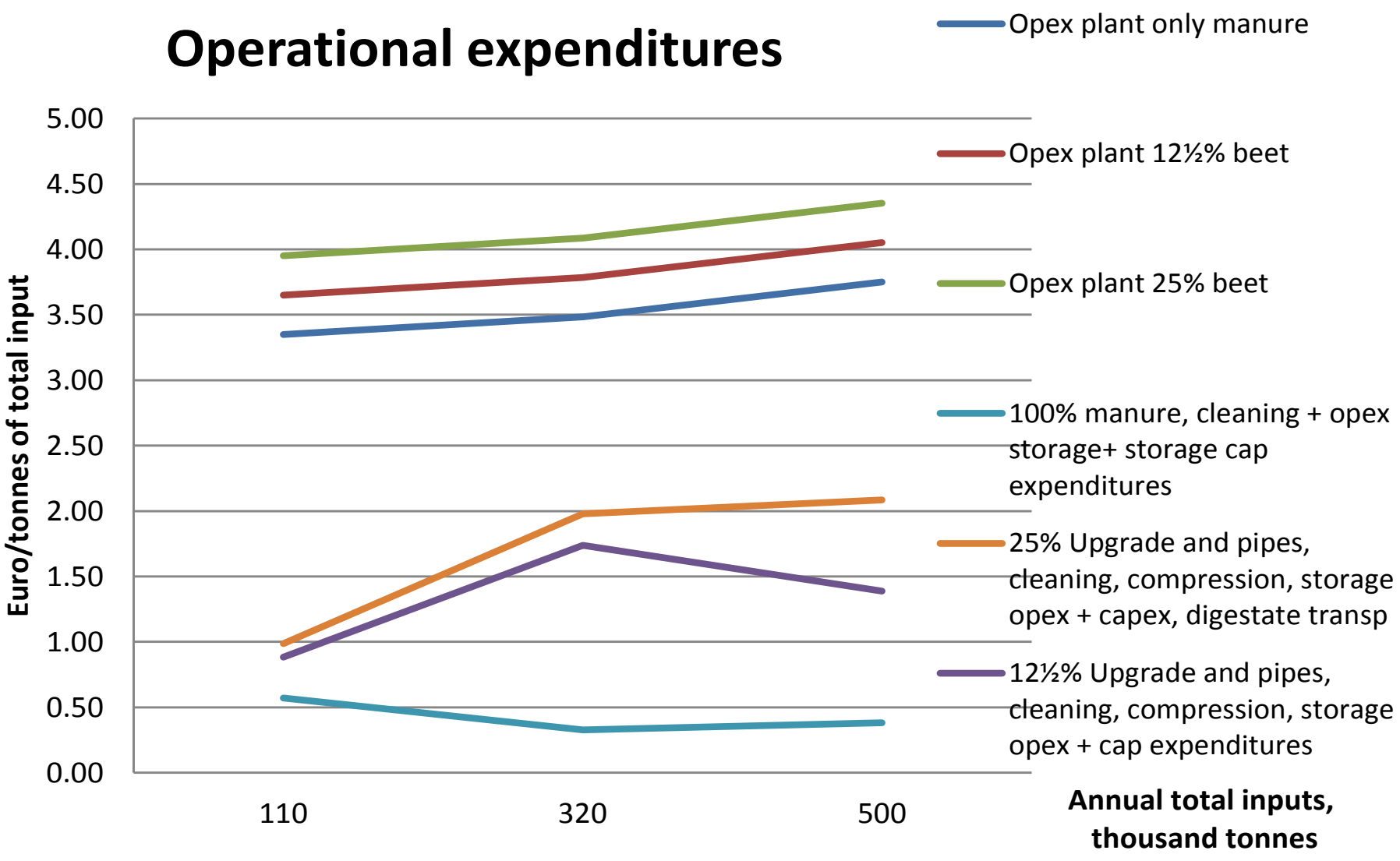
Transport costs: Tree scales of plant size and 3 cases of sugar beet inputs

- **Cost consist of transport time and loading**
  - Loading costs independent of scale but much higher for beet
  - Transport time only dependent on distance (50 km/h)
  - Capacity of beet carrier slightly lower than for manure but hourly costs also lower

- **Scaling up the plant size**
  - Per unit cost increase for all 3 cases because average transport distance increase: from 6 km to 10 km for manure 100%; from 23 km to 61 km for beet in the 12½% case; and from 43 km to 71 km in the 25% case

- **Increasing the share of beet**
  - With increased beet share the unit cost increase a lot - *since the unit cost for beet transport is much higher than for manure*
  - For high beet share the unit cost also increase faster with larger plant size - *because the effect of inceased transport distance is more pronounced for beet* (especially from 110-320kt)

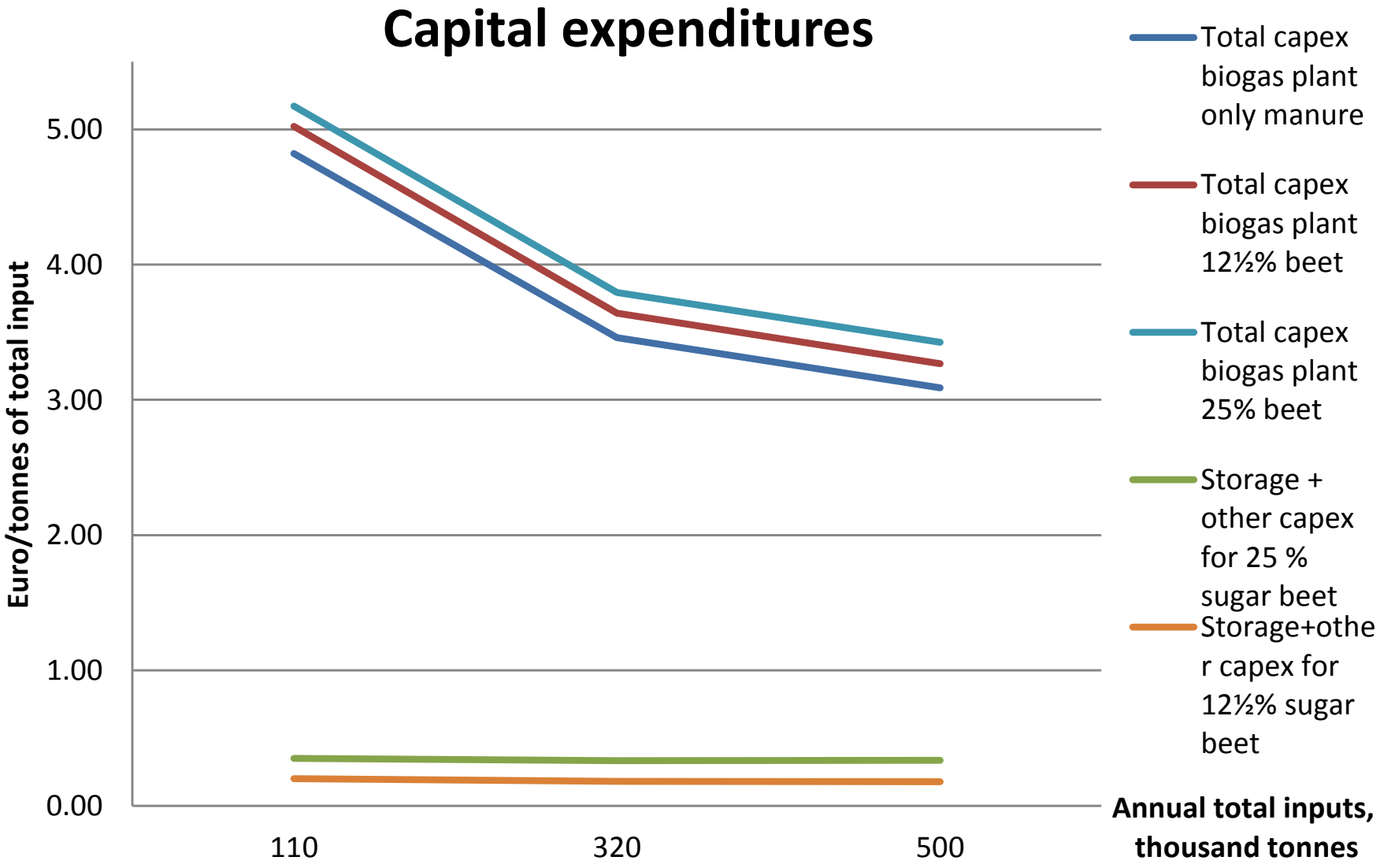
Operational expenditures and scale effects



Operational expenditures and scale effects

- **Operational costs constitute an important part of total costs**
  - includes wages and salary (also for handling of inputs - transport)
  - includes other material inputs than input to biogas reactor
  - includes process heat and electricty
- **Scaling up the plant size**
  - Scale effects for opex at plant are slightly negative as they increase the unit costs (this deserves more attention/check)
- **Increasing the share of sugar beet**
  - only increases the plant unit costs proportionally for all the plant sizes
- **Scaling up plant size involves additional opex at output level**
  - cleaning of gas, storage very little for pure manure
  - cleaing, upgrade and compression (losses) increase when scale shifts to upgrade for natural gas grid
  - shift involve negative scale effect - but from 320 to 500kt positive scale effect for 12½% sugar beet (due to capex of upgrade facility)

Capital expenditures and economies of scale



Capital expenditures show large economies of scale effects

- **Plant size and capex**
  - Economies of scale primarily achieved for this cost component
  - Largest effect from 110 - 320kt size
  - This scale effect outweigh the negative scale effects from transport costs and the slightly negative effect from opex

- **Increasing the share of sugar beet**
  - adds a proportional cost per unit due to investment in storage and pretreatment/handling equipment
  - no cost advantages or disadvantages of scale in this investment (could be further investigated)

Sensitivity and main parameters

- **Transport costs**
  - Concentration of input resources in general - farm structure and economic conditions
  - Sugar beet will be cultivated closer to plant in time
- **Input costs**
  - Price of manure - uncertainty high and regulation dependent (environmental, animal restrictions)
  - Price of sugar beet - dependent on alternative use (biofuel) and cost of alternatives (for cattle etc.) - world market links
- **Output**
  - Volume - uncertainty of given process should be low? at annual output level
  - Price of gas - for upgraded quantity the uncertainty in this 1/3 of revenue is high
  - Price support - if granted/approved it is stable
  - Price digestate etc. - high uncertainty

Scale effect conclusion

- **Cost reducing effect in scaling biogas plant size 110 00 to 500 00 tonnes (capex per unit reduced 35%, 0/100 mix)**
- **Negative scaling effect on transport costs (increase 45% for manure and 96% for sugarbeet)**
- **Net effect (trade-off) result in equal costs per unit of the 320 000 t case and the 500 000 t case: the benefit of scaling to 500 000 t (biogas plant + upgrade capex) is outweighed by the increase in transport costs for both inputs and outputs**

Positive scale effects are only dominate the net result for pure manure case

Overall economic results

Net-income, Euro/Tonnes			
Ratio\Scale	**110**	**320**	**500**
0/100	-0.42	0.72	0.78
12½/87½	3.99	**4.23**	**4.23**
25/75	-4.34	-4.68	-5.03

Table 1 Net annual result per tonnes of inputs

Cost data from modelling of Maabjerg:

Master project thesis: Optimisation of Biogas Production A Socio Economic Value Chain Evaluation

Lau Linnet. August 2013

Table 6.4: Transport economy

	Amount		Price w. NTF [kr/unit]	Total cost w. NTF [kr]	Annualised cost [kr]
Truck	5	trucks	*2.295.000* [a]	11.475.000	811.876
Reinvest	5	trucks		11.475.000	548.474
Distance driven	270.735	km			
Number of trips	14.229	trips			
Diesel use, w. annuity price	94.757	l	*6,77* [b]	641.857	641.857
Time use	10.159	hr	*243* [c]	2.468.552	2.468.552
Time use offloading & filling	4.744	hr			
Time use driving	5.415	hr			
Truck maintenance	270.735	km	*1,82* [d]	493.415	493.415
Pipeline investment	20,00	km	*945.000* [c]	18.900.000	1.337.207
Electricity use - pumpwork	850	MWh	*753* [c]	640.454	640.454
Total				46.094.278	6.941.834
Transport cost manure	445.000	tonne	10,96	kr/tonne	
Transport cost Industry and slurry	170.000	tonne	11,63	kr/tonne	
Transportcost average	615.000	tonne	11,14	kr/tonne	
Transport cost manure gas	9.684.979	m^3	0,50	kr/m^3	
Transport cost industry, slurry gas	7.044.123	m^3	0,28	kr/m^3	
Total cost average	16.729.102	m^3	0,41	kr/m^3	
Average transport distance	19,03	km			

Quite low

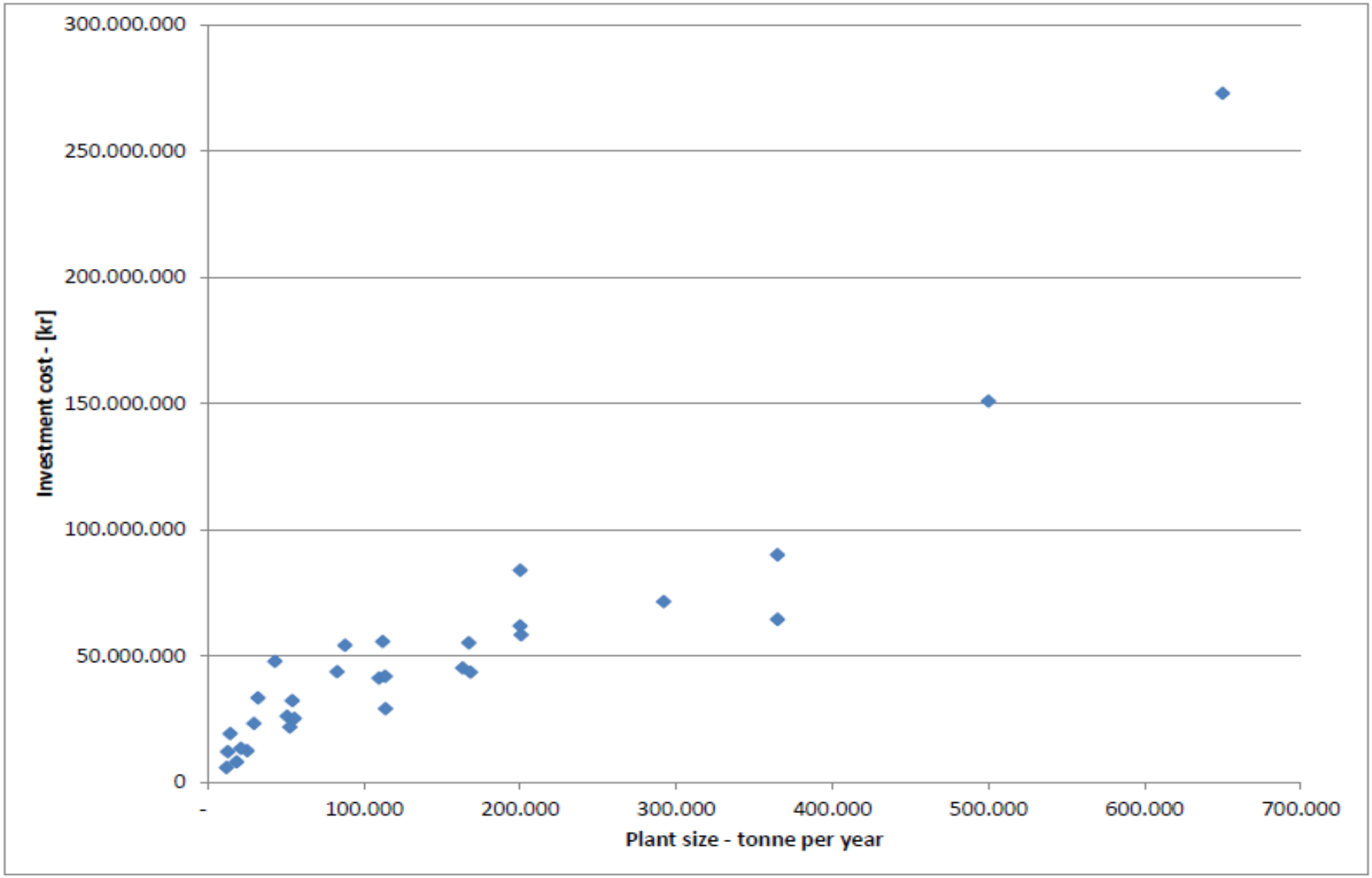
[a] An assumed value based on [19] and information from Grontmij
[b] Annualised value from[4]
[c] [19]
[d] [35]

Scale effect comparison case study with other DK data

May be skipped?

Scale effects – in plant size (investment)

Lau Linnet master thesis project, DTU August 2013



Scale effects DK

(Source: IFRO Rapport 220 , Biogasproduktion i Danmark – Vurderinger af drifts- og samfundsøkonomi , June 2013)

Tabel 2.6 Forventede driftsudgifter for planlagte biogasanlæg

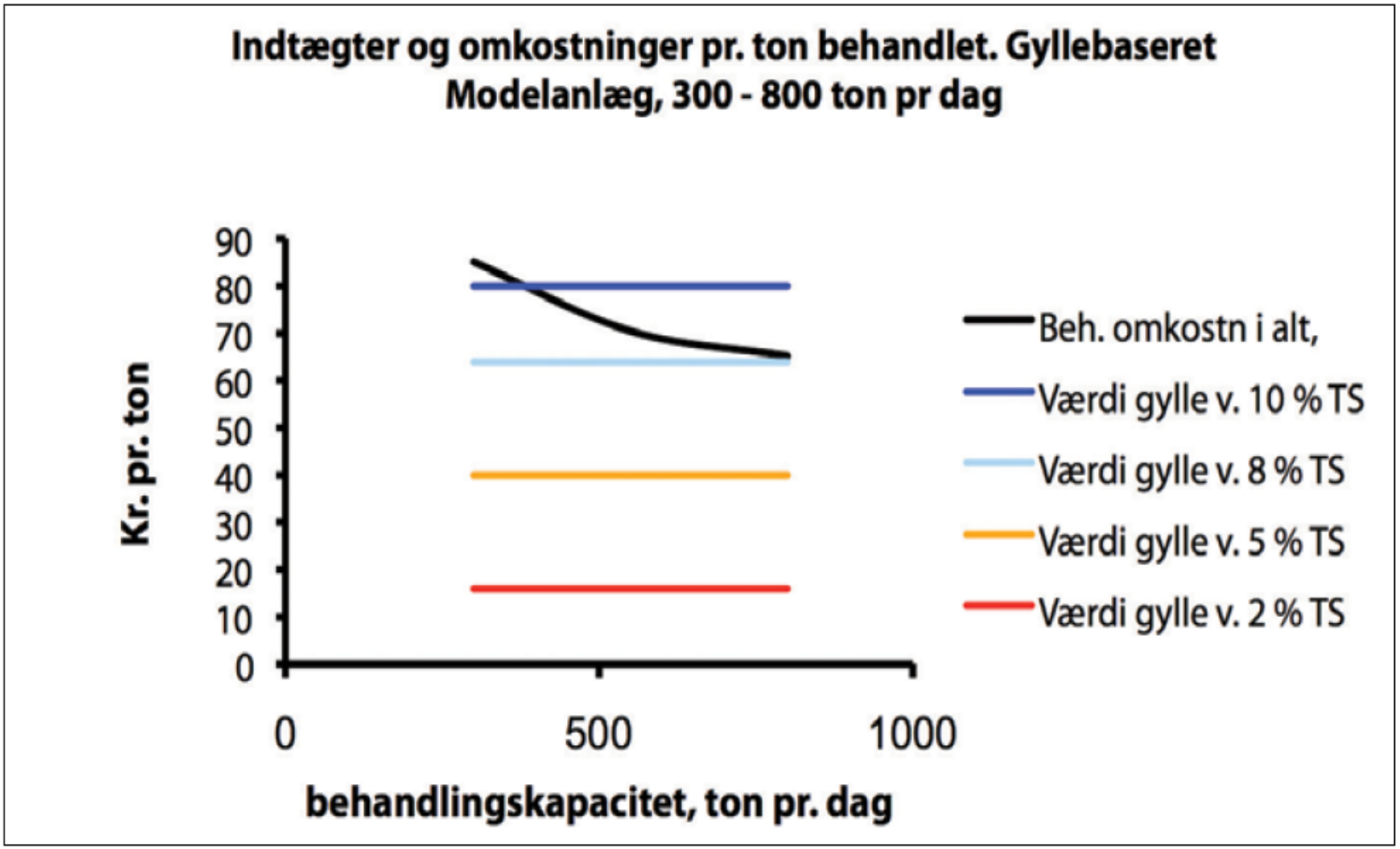
Selskabsøkonomi	Gennemsnits -anlæg	Gennemsnit anlæg < 1000 tons input/dag	Gennemsnit anlæg > 1000 tons input/dag	Økologiske anlæg
Input (tons pr. år)	263.617	192.191	452.546	76.000
Biogas (m^3 pr. år)	10.045.182	8.392.884	15.814.839	2.650.000
Driftsudgifter (1000 kr.)	14.898	19.055	15.479	5.420
Heraf (%)				
- Køb af biomasse	70	73	74	54
- El	4	3	6	4
- Adm. + mandskab	13	9	20	20
- Vedligeholdelse	13	15		22
Driftsudgifter (kr. pr. m^3 biogas)	1,5	1,9	1,2	1,2
Driftsudgifter (kr. pr. m^3 biomasse)	63	83	40	70

Kilde: Egen analyse

Note: Omkostninger for de enkelte poster stemmer ikke med summen, da ikke alle observationer er til stede for alle omkostninger. Der er således nogen usikkerhed på andel af de enkelte omkostningskategorier.

Cost dataDK: Scale effects

Source: Tybirk, K. (red.) 2010. Kogebog for etablering af biogas med 12 faktaark. Agro Business Park/ Innovationsnetværket for Biomasse. November 2010



Figur 2. Behandlingsomkostninger/tilført ton biomasse falder ved større anlæg (sort kurve). Grafen viser desuden værdien af gylle med forskelligt tørstofindhold.

Cost example and sensitivity: inputs an plant

Source: Biomasse til biogasanlæg i Danmark, Agrotech, April 2013

Tabel 27. Balancepris for majs ved forskellig hvedepris, JB 1-3

Majshøst	JB 1-3	9000	FE			
	1 FE	1,17	kg TS			
	kg TS	10530	kg TS			
	TS %	30	%			
	kg frisk	35100				
	Ton frisk	35				
Dyrkningsomkostninger majs	kr/ha	6625	6625	6625	6625	6625
Hvedepris	kr/kg	1	1,25	1,5	1,75	2
DB i hvede efter mask. og arb. Omk.	Kr/ha	1292	2667	4042	5417	6792
Break even salgspris for majs	kr/ha	7917	9292	10667	12042	13417
Break even salgspris for majs	kr/ton	226	265	304	343	382

Forklaring:

JB 1-3 er sandjord, hvor der produceres 9000 FE pr. ha pr. år
1 FE (foderenhed) indeholder 1,17 kg tørstof
De 9000 FE udgør altså 10.530 kg tørstof
TS % er tørstofandelen, her 30 %
Kg frisk er den beregnede mængde friskmasse

Cost example and sensitivity:

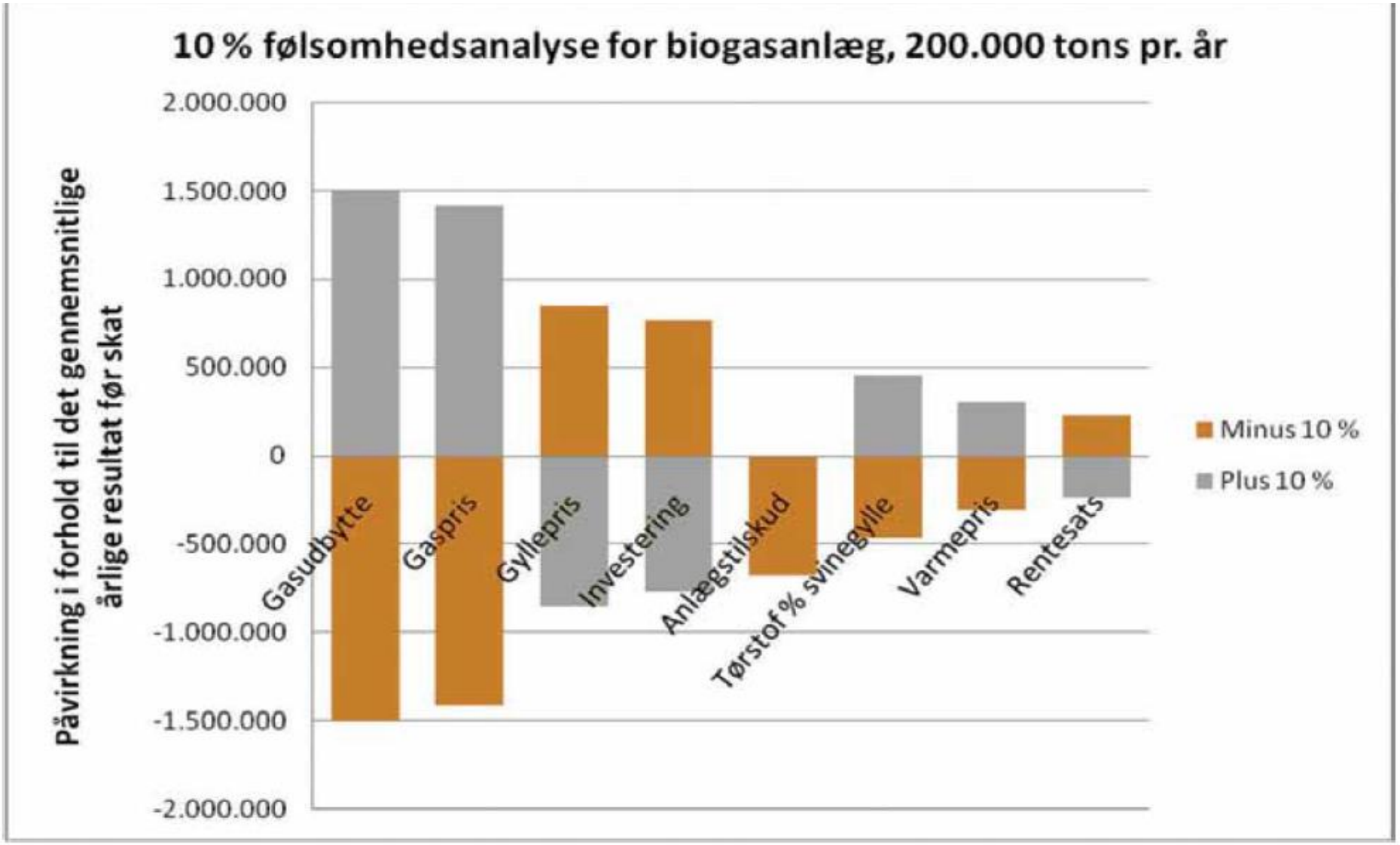
Source: Tybirk, K. (red.) 2010. Kogebog for etablering af biogas med 12 faktaark. Agro Business Park/ Innovationsnetværket for Biomasse. November 2010

Tabel 1.2. Faste forudsætninger

Faste forudsætninger	
Anlægstype	Thermofil
Salgsprodukter	Biogas
Opholdstid primær reaktor, dage	20
Opholdstid, sekundær reaktor, dage	10
Gaspris, standard, kr./Nm3 CH4	4,00
Levetid anlæg, år	20
Lånerente før skat, %	5
Løbetid lån, år	20
Anlægstilskud, %	20 %
Gasledning, km	2
Varmeledning, km	2
Transportpris, kr./ton	20,- / 25,-
Købspris majsensilage, kr./ton	250,-

Cost example and sensitivity:

Example of medium scale plant, Source: Tybirk, K. (red.) 2010. Kogebog for etablering af biogas med 12 faktaark. Agro Business Park/ Innovationsnetværket for Biomasse. November 2010



Figur 3. Illustration af 10% følsomhedsanalyse for biogasanlæg 200.000 tons/år

Planned biogas plant inputs

(Source: IFRO Rapport 220 , Biogasproduktion i Danmark – Vurderinger af drifts- og samfundsøkonomi , June 2013)

Tabel 2.3 Input til planlagte biogasanlæg

Input (%)	Gennem-snitsanlæg	Gennemsnit anlæg < 1000 tons input/dag	Gennemsnit anlæg > 1000 tons input/dag	Økologiske anlæg
Gylle	71,0	66,2	77,2	27,0
Separeret gylle og dybstrøelse	11,7	15,8	8,8	5,6
Prim. slam	1,8	0,3	3,0	
Industri	9,1	9,3	9,5	
Energiafgrøder	4,2	7,9	1,5	
Øvrige	2,3	0,5	0,0	67,4
Sum	100,0	100,0	100,0	100,0

Kilde: Egen analyse

Alternatives for biogas end-use in DK

Upgrade cost?	Upgrade cost 12-25 DKK/GJ?	CHP	Industry
Transport	Upgrading to gas grid	Support fixed 80+26+10 øre/kWh premium 43,8+26+10 correspond to 115 DKK/GJ	Support 75 DKK/GJ
Support 75 DKK/GJ	Support 115 DKK/GJ		
Fuel tax exemption = No	Fuel tax exemption = No	Fuel tax exemption = Yes	Fuel tax exemption = Yes for the process end use, same as nat gas No for heating

+

Investment grant for *biogas plant*

30%