Efficiency Evaluation of Energy Crop Digestion Plants

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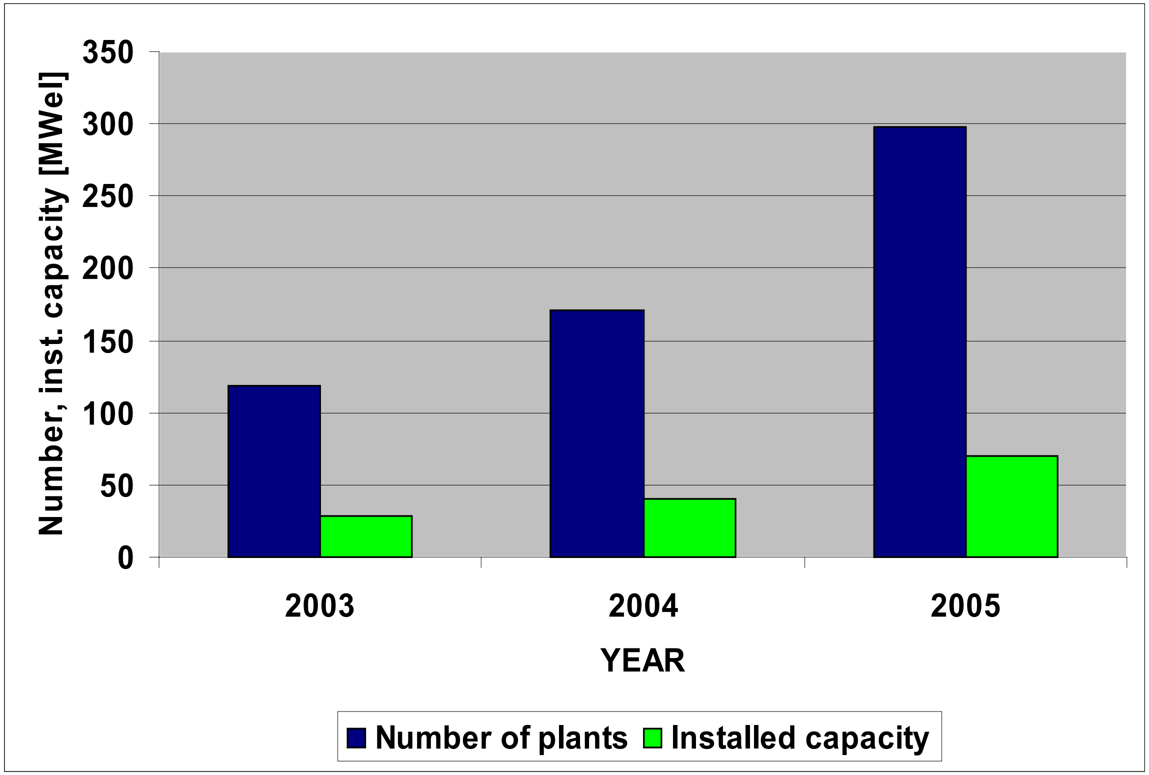
Development of energy crop digestion in Austria



Austrian Eco Electricity Act (2002)
Ökostromgesetz BGBl. I Nr. 2002/149

Inst. capacity (kW)	Feed-in tariff (ct./kWh)*
< 100	16.5
100-500	14.5
500-1000	12.5
> 1,000	10.3

*) 25 % reduction in case of co-digestion of defined co-substrates; consent must be achieved by end of 2004

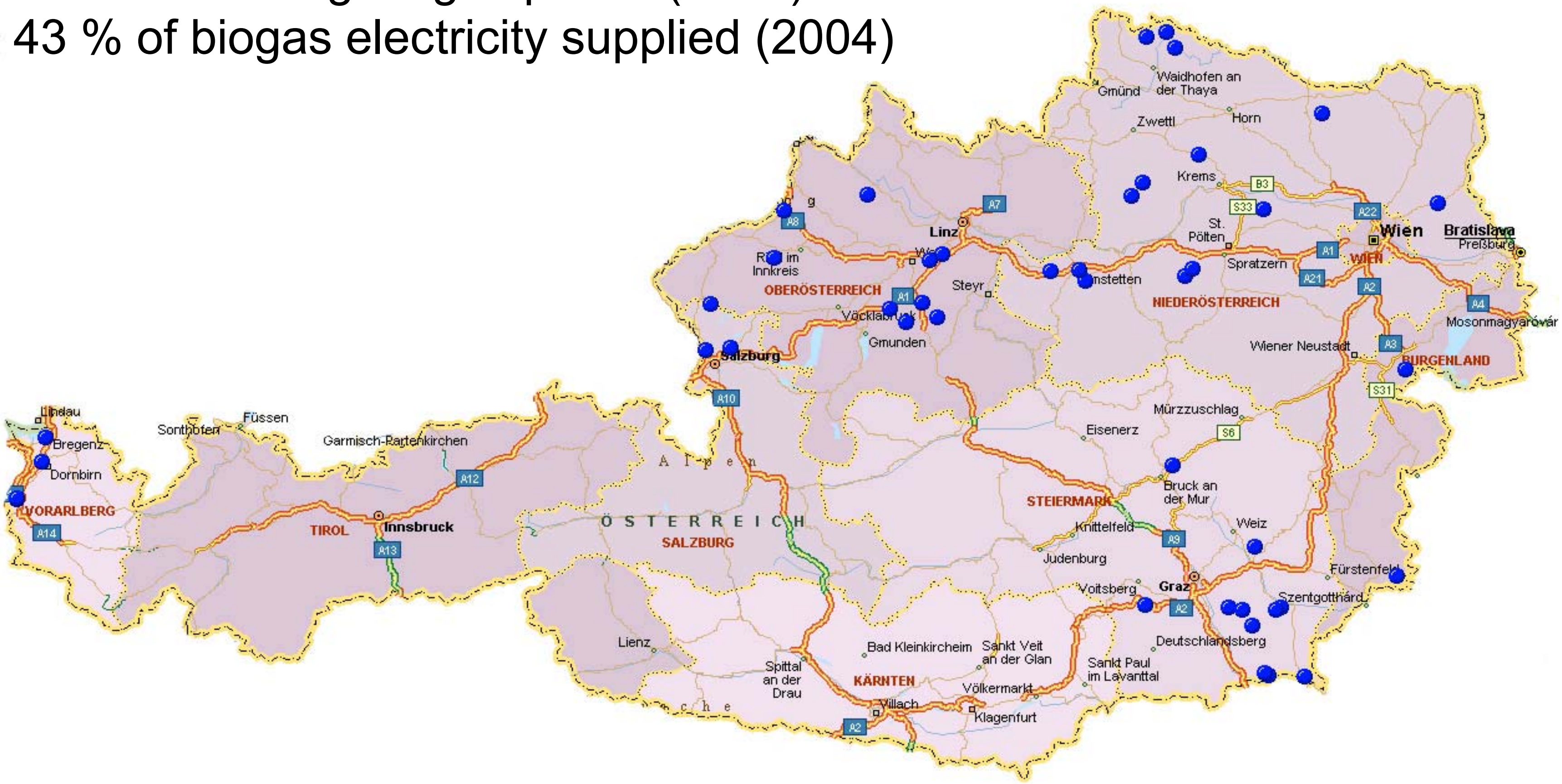
Biogas status and future prospects

COUNTRY	STATUS 2005	POTENTIAL / GOALS
Netherlands[1]	1.08 PJ	2.800 biogas plants theoretically possible; 50-100 new plants until 2010; 10-15 new plants / year
Sweden[1]	0.45 PJ	3 % (2005) resp. 6 % (2010) of fuel consumption replaced
Denmark[1]	3.6 PJ	40 new biogas plants until 2008
Austria	3.8-5.5 PJ[2]	2.4 – 3.7 PJ, to be recovered additionally from landfills, co-digestion, industrial wastes, municipal bio-wastes and renewable biomass
	-	53.1 PJ[3] (38.7 PJ energy crops & 14.4 PJ biowastes)
	5.6 PJ[4]	10.8 PJ[4] (Energy crops), 1/3 techn. feasible, corresponding to 130 biogas plants, each 500 $kW_{el.}$
	-	16.84 PJ[5] to be recovered from renewable biomass by 2019

[1)] IEA Bioenergy, Task 37 Country Reports (2004); [2)] Braun (2004); including landfill gas, sewage sludge, agricultural and municipal by-products & biowastes; [3)] Pölz and Salchenegger (2005); [4)] Hofmann et al (2005); [5)] Kirchmeyr (2005)

1. Representative sample of 41 biogas plants

23 % of existing biogas plants (2004)
43 % of biogas electricity supplied (2004)



2. Parameters applied for evaluation of the biogas plants

General functional description	Measurable process conditions	Calculable variables
SUBSTRATE		
Quality / quantity Transport, Storage Pretreatment Costs	COD[1] TKN[2], NH_4-N TS[3], VS[4]	t / year Costs/year
DIGESTER		
Startup Investment costs, Annual costs Subsidies Process steps, Substrate dosage Digester type Digester equipment Digester mixing	T, Self heating pH, VFA[5], COD, TS, VS TKN, NH_4-N Process energy demand Sludge recirculation	Residence time Hydraulic loading VS degradation Biogas yield
DIGESTATE		
Storage type / cover Treatment / Dewatering Use	pH, COD, TS, VS VFA, TKN, NH_4-N, CH_4-formation Hygienic status	t / year
BIOGAS		
Quantity /utilisation Gas holder, Upgrading	CH_4, H_2S	Calorific value Electrical efficiency
PERSONNEL EXPENDITURE		
SALES REVENUES / OVERALL ECONOMICS		
ECOLOGICAL / SOCIO-ECONOMIC PERFORMANCE		

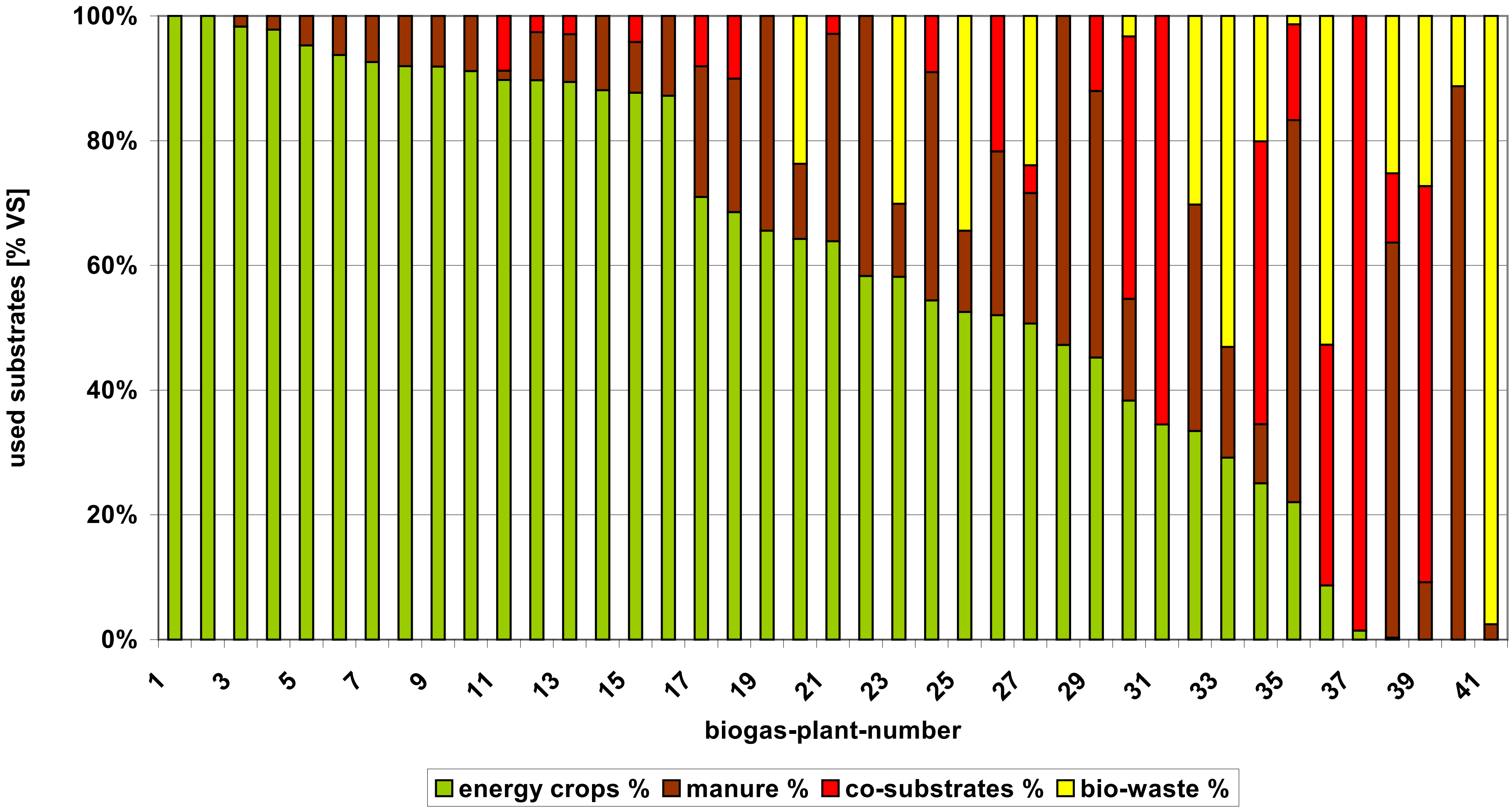
1) Chemical Oxygen Demand; 2) Total Kjelldahl Nitrogen; 3) Total Solids; 4) Volatile Solids; 5) Volatile Fatty Acids

3. Performance figures of the technical monitoring and benchmarking

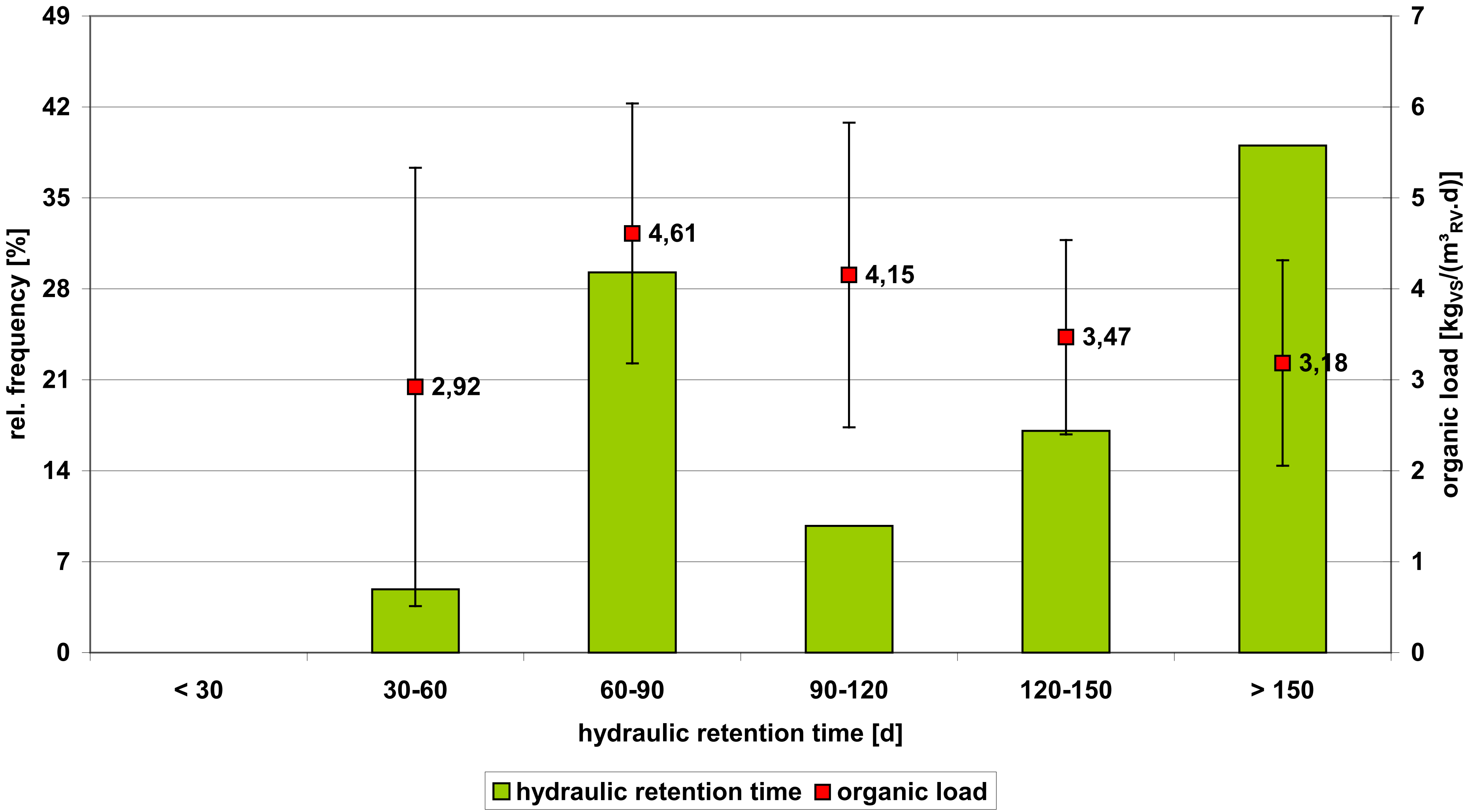
Parameter	Unit	Median[1]	min.	max.
Amount of processed substrate	$t_{Substrate}/d$	13.2	0.8	58.9
Hydraulic retention time	$m^3_{RV}/(t_{Substrate}/d)$	131	44	483
Organic load (dry substance)	$kg_{VS}/(m^3_{RV} \cdot d)$	3.59	1.04	7.97
COD load	$kg_{COD}/(m^3_{RV} \cdot d)$	5.64	1.62	11.95
Amount of VS	t_{VS}/d	2.34	0.33	13.78
Biogas generation	Nm^3_{biogas}/d	1,461	233	10.115
Biogas productivity	$Nm^3_{biogas}/(m^3_{RV} \cdot d)$	0.96	0.22	2.17
Carbon degradation	%	82.8	61.5	96.8
Average biogas yield	Nm^3_{biogas}/kg_{VS}	0.662	0.511	0.878
Methane content in biogas	%	54.8	49.7	67.0
Electrical efficiency	%	31.3	20.7	39.2
Use of heat (related to total input energy $H_{u, biogas}$)	%	16.5	0.0	42.6
Annual use efficiency (related to total input energy $H_{u, biogas}$)	%	47.3	30.5	72.3

RV: Reactor volume; $H_{u, biogas}$: Net calorific value of biogas; VS: Organic matter

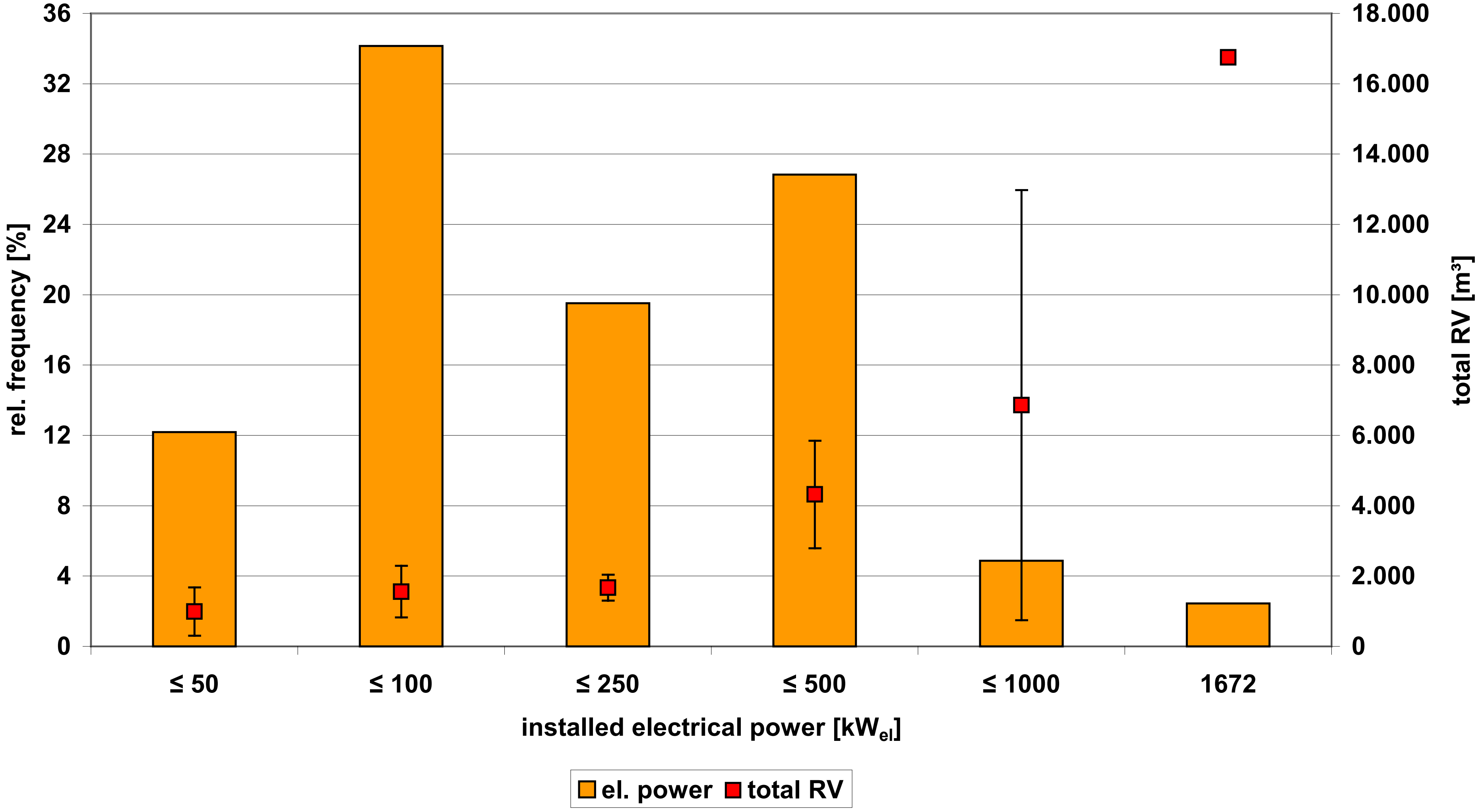
Used substrates (% VS)



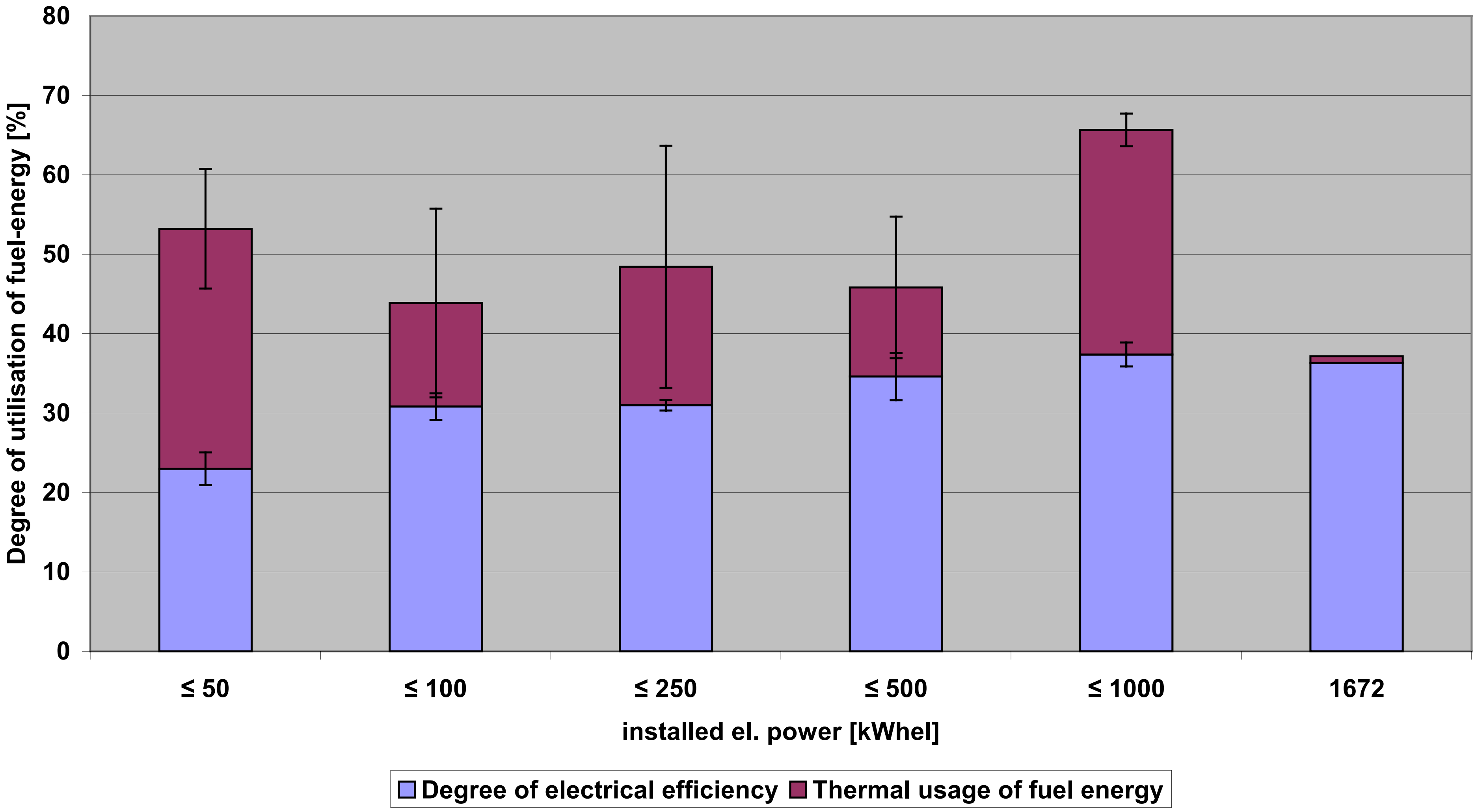
Hydraulic retention time and organic load



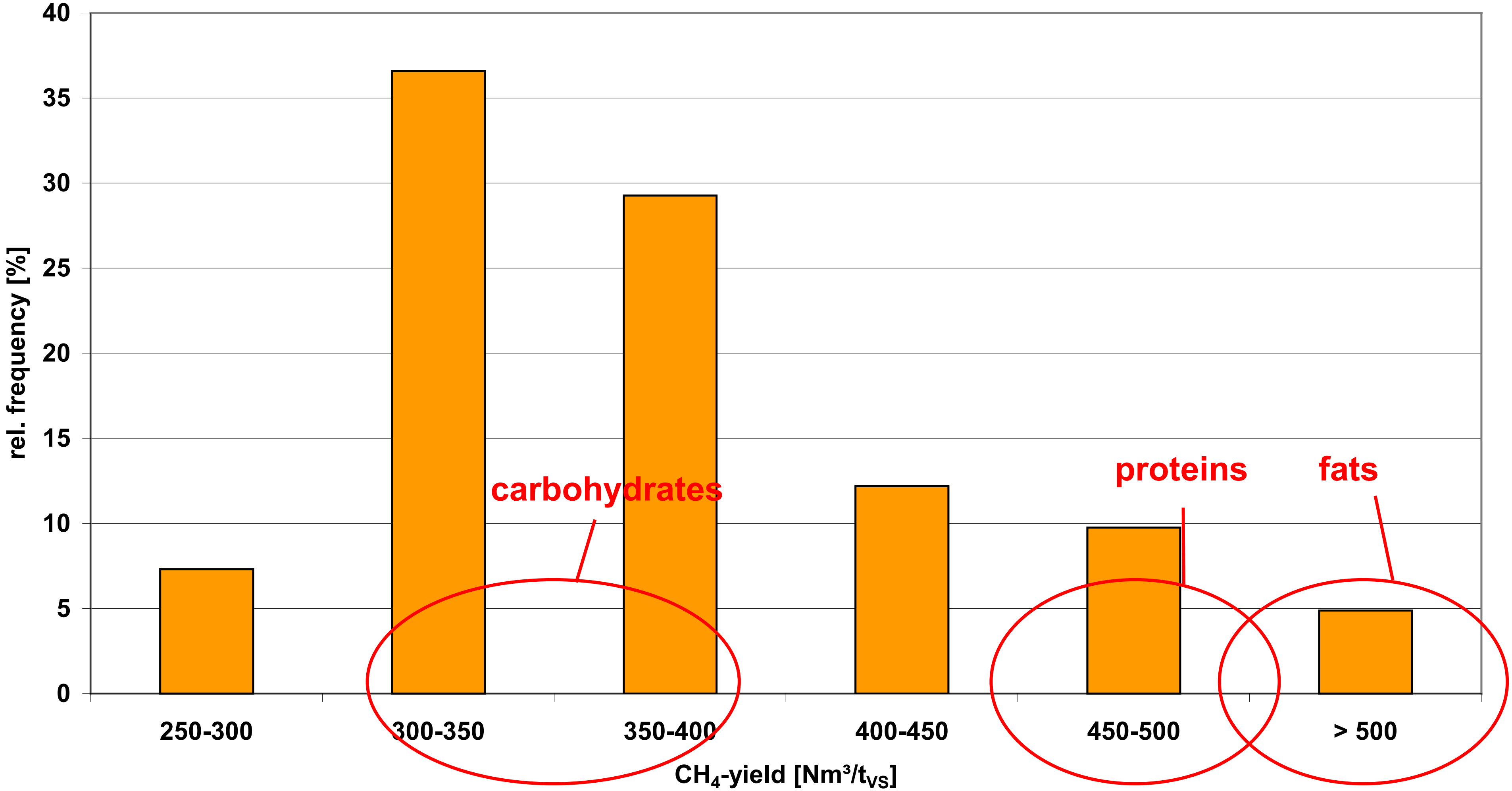
Plant size (kW_{el}) and reactor volume (RV)



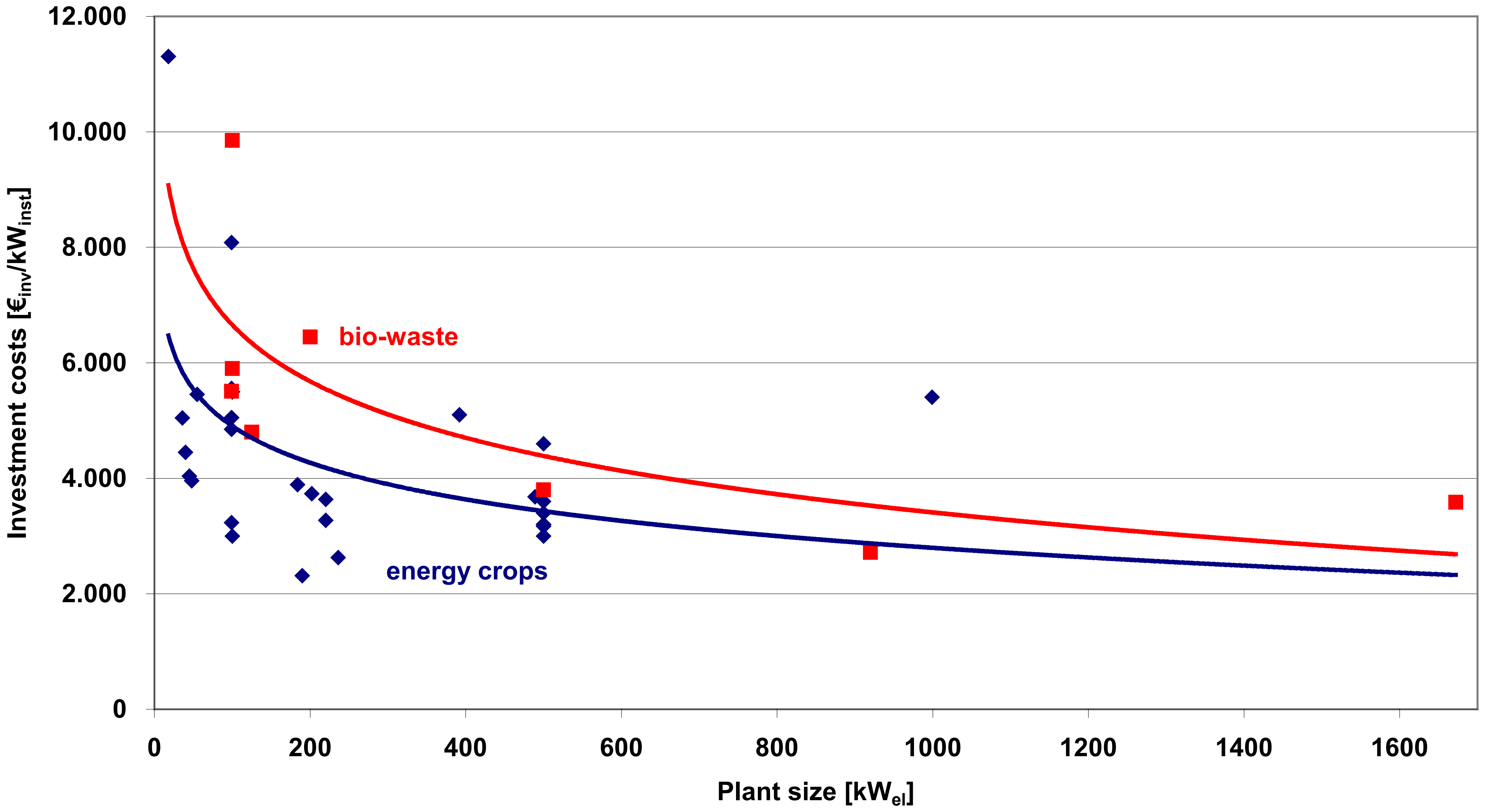
Utilisation of fuel energy



Methane-yield [VS]



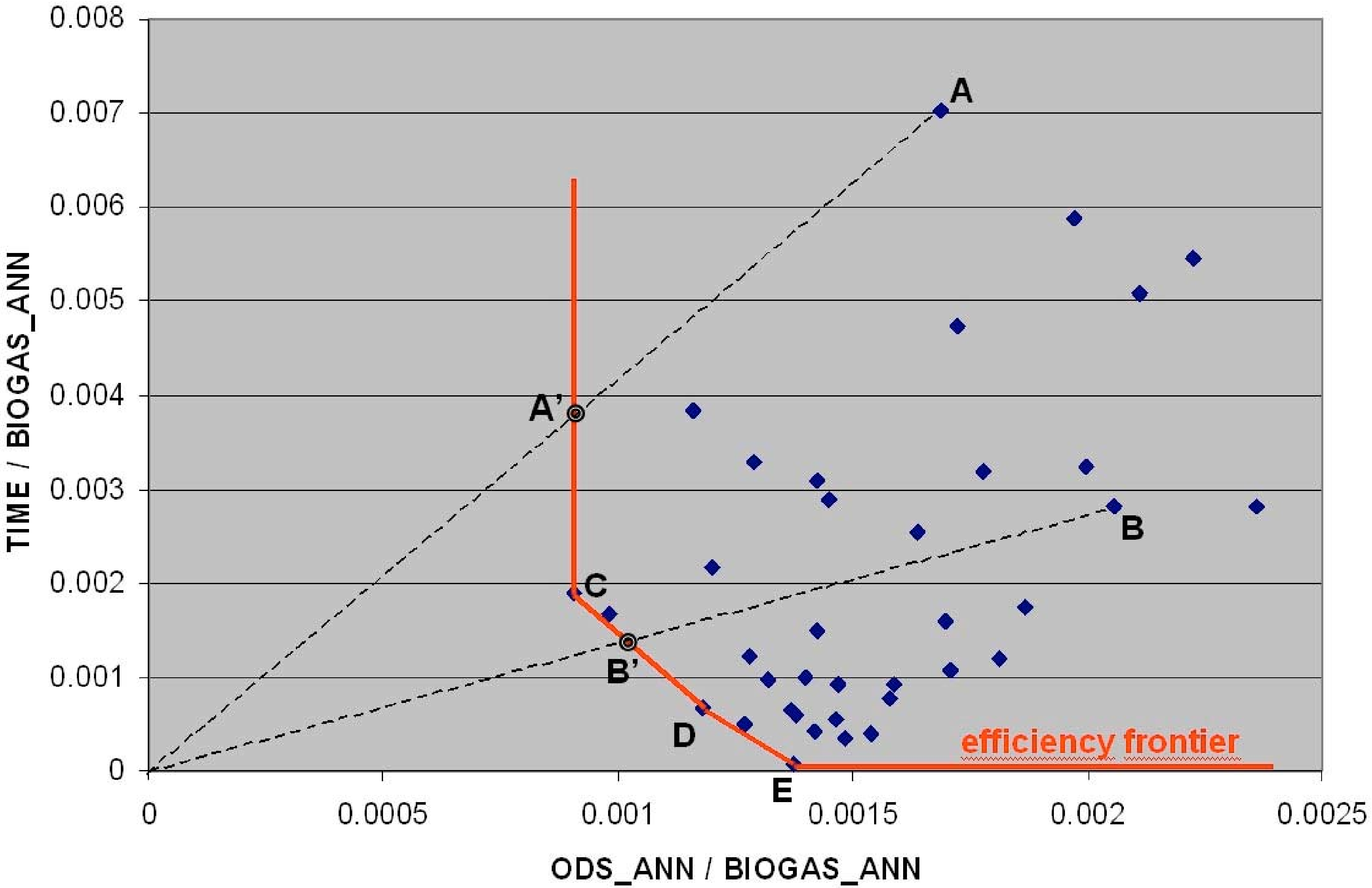
Investvestment costs



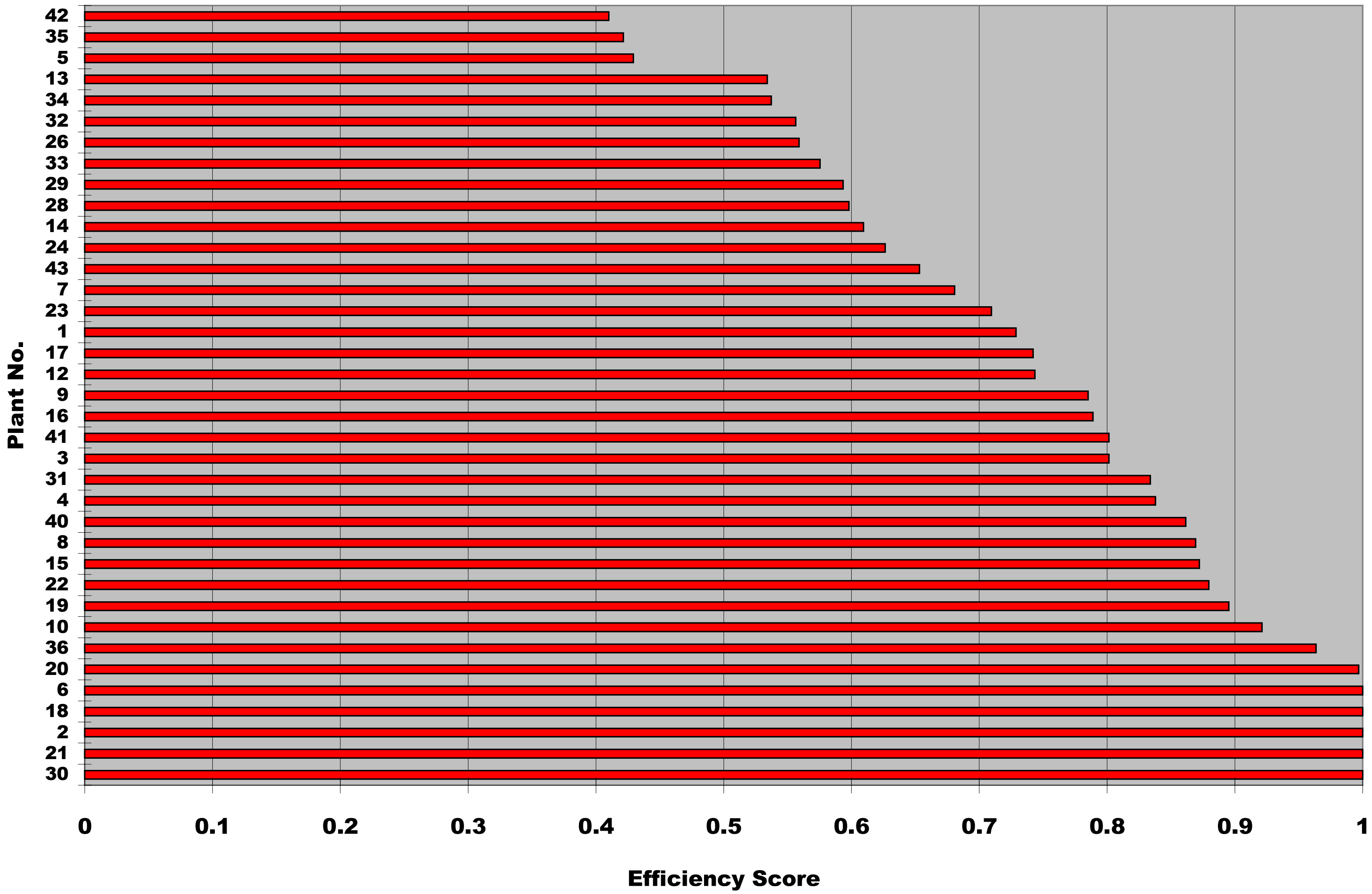
Benchmarking by means of Data Envelopment Analysis (DEA)

- **Best practise benchmarking model**
- **Non-parametric linear programming tool**
- **Comparative efficiency measurement**
- **Production efficiency frontier**

Efficiency frontier

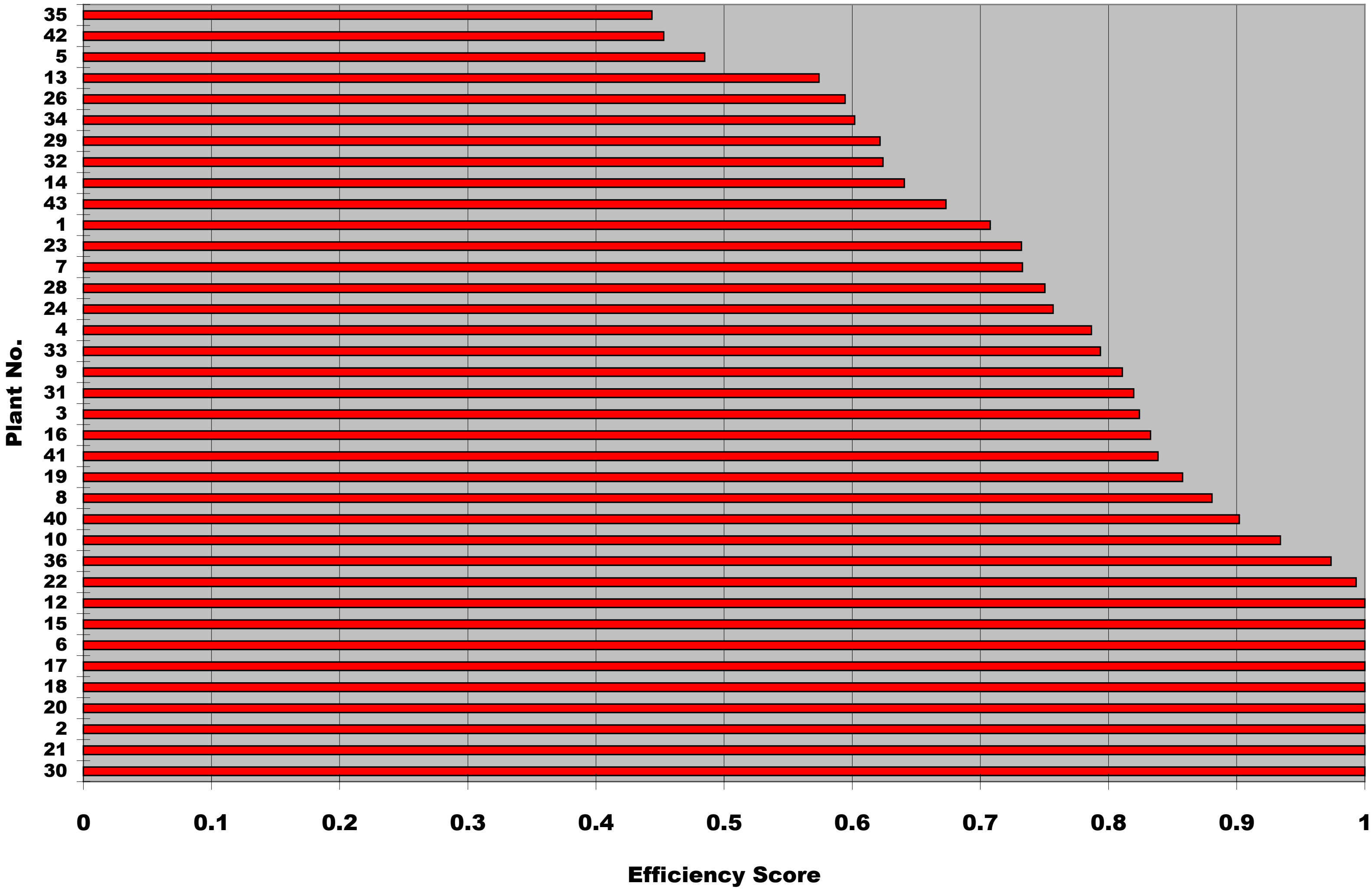


Relative efficiency I



(inputs used: amount of organic dry substance, time effort; outputs used: net electricity production and total heat production)

Relative efficiency II



(inputs used: organic dry substance and time effort; outputs used: electricity fed into the grid, total heat production)

CONCLUSIONS

- A clearer picture of the technical performance of energy crop digestion plants could be drawn
- Reasons for specifically good or poor performing plants must be further investigated in detail
- Environmental- (ecologic) and socio-economic effects of energy crop digestion must be thoroughly investigated
- Experiences from best practice biogas plants can avoid poor technological development and implementation

Thank you for your attention!

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