BiG<EAST
Biogas study tour

Esbjerg 7-9 September 2009

Agricultural biogas production in Denmark

Teodorita Al Seadi, MSc
Research coordinator
University of Southern Denmark
Institute of Chemical Engineering, Biotechnology and Environmental Technology

Content:

- Agricultural biogas production in Europe
- Biomass feedstock for agricultural biogas plant
- Biogas in Denmark
- Farm scale versus centralised plants
- Actual incentives for establishment of biogas plants:
- Planning building and operating a biogas plant
- Biogas pictures

Agricultural biogas production in Europe

Estimated number of biogas plants in Europe (2007):

- 4,242 farm-scale
- >26 centralised biogas plants

Estimated amount of biomass feedstock supplied to the European agricultural biogas plants (2007):

90.0 mill tonnes

of which:

- 55% animal manure
- 21% energy crops
- 24% other organic waste from food industry
- <1% municipal waste

Agricultural biogas production in Europe

Estimated biogas production (2007):

- Annual biogas production from agricultural biogas plants in Europe **1.85×10^9 m3**
- Energy production from agricultural biogas plants in Europe: **50.02 PJ**

Estimated biogas potential

- The potential for biogas based energy production in Europe, originating from animal manure alone is estimated to **827 PJ.**

Background for estimations:

Standard methane content in biogas of 65%

Average biogas yield of 20 m3 per tonne biomass

1000 m3 of biogas = 22 GJ; 1 GJ=10^9J; 1 PJ= 10^{15} J

Example from Denmark

- **Energy conversion efficiency of biogas used for CHP production is about 80%**
    - **40% electricity**
    - **40% utilised heat**
    - **20% losses**
        - **10% used to heat up the biomass**
        - **10% engine loss when using the heat**

Biomass feedstock for agricultural biogas plants

Animal manure and slurries

- Pig manure/slurry
- Cattle manure/slurry
- Poultry manure
- Deep litter

Energy crops

- Maize and maize silage
- Green harvested crops

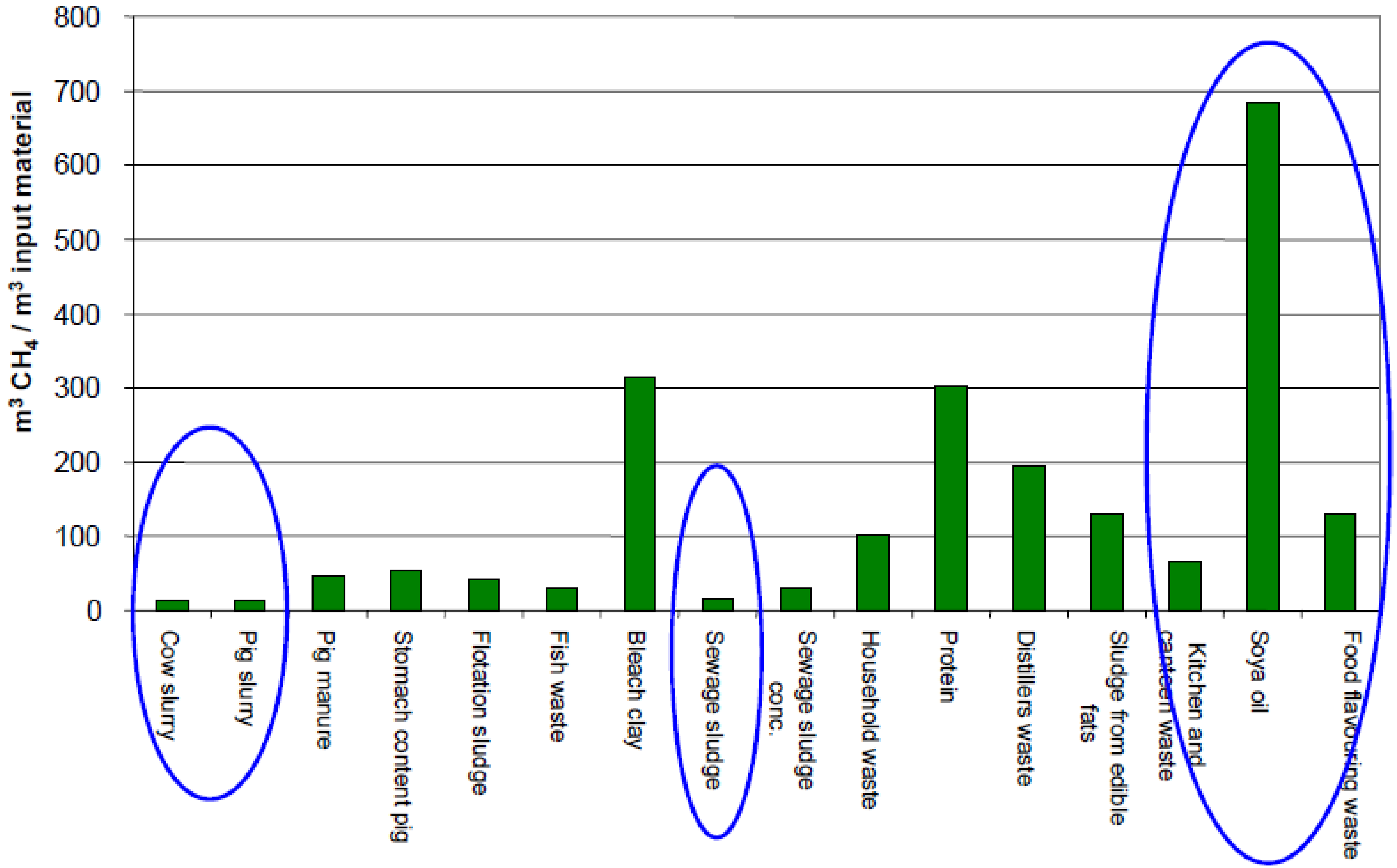
Agro-industrial residues

- Stomach and intestinal content from slaughterhouses
- Flotation sludge and other slaughterhouse waste
- Waste from dairies
- Waste from fish industries (fish waste and fish oil)
- Glycerine
- Residues from vine industry
- Waste from plant oil production
- Waste from sugar industries
- Meat and bone meal

Municipal waste

- Source sorted household waste
- Municipal sludge (waste water treatment plants)

Biomass feedstock for agricultural biogas plants



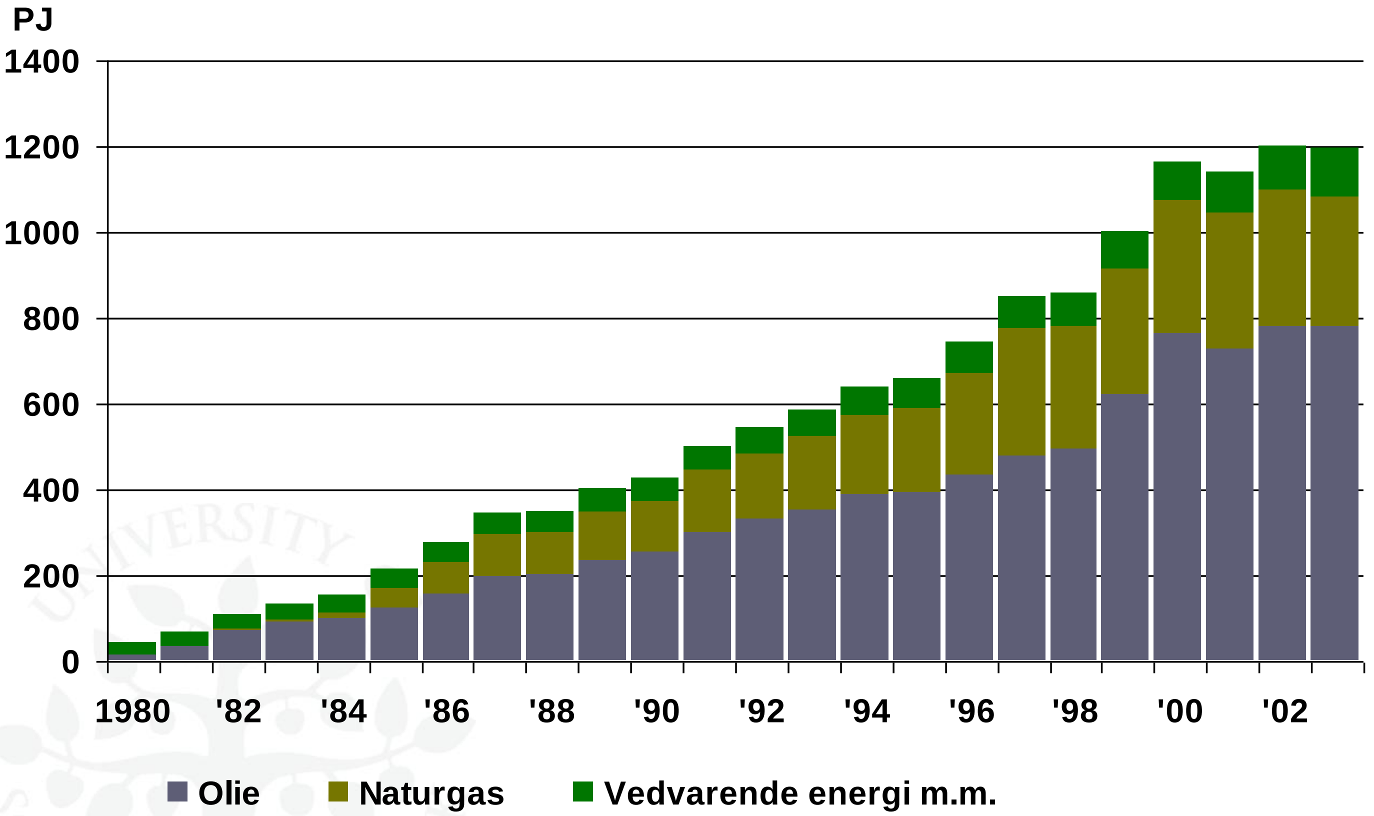
Biogas in Denmark

Type of plant	Nr.	Production PJ	Potential
- Centralised co-digestion	**20**	**1,70**	
- Farm scale plants	**60**	**0,91**	
- 2,14 mill tonnes animal slurry (5 % of the total)			
- 0,4 mill tonnes organic waste			**27,0**
- Waste water treatment plants	**64**	**0,87**	**4.0**
- Industry plants	**5**	**0,14**	**4,5**
- Landfill gas recovery plants	**25**	**0,44**	**1,0**
- Household waste			**2,5**
Total		**4,06**	**39,0**

Biogas in Denmark 2009

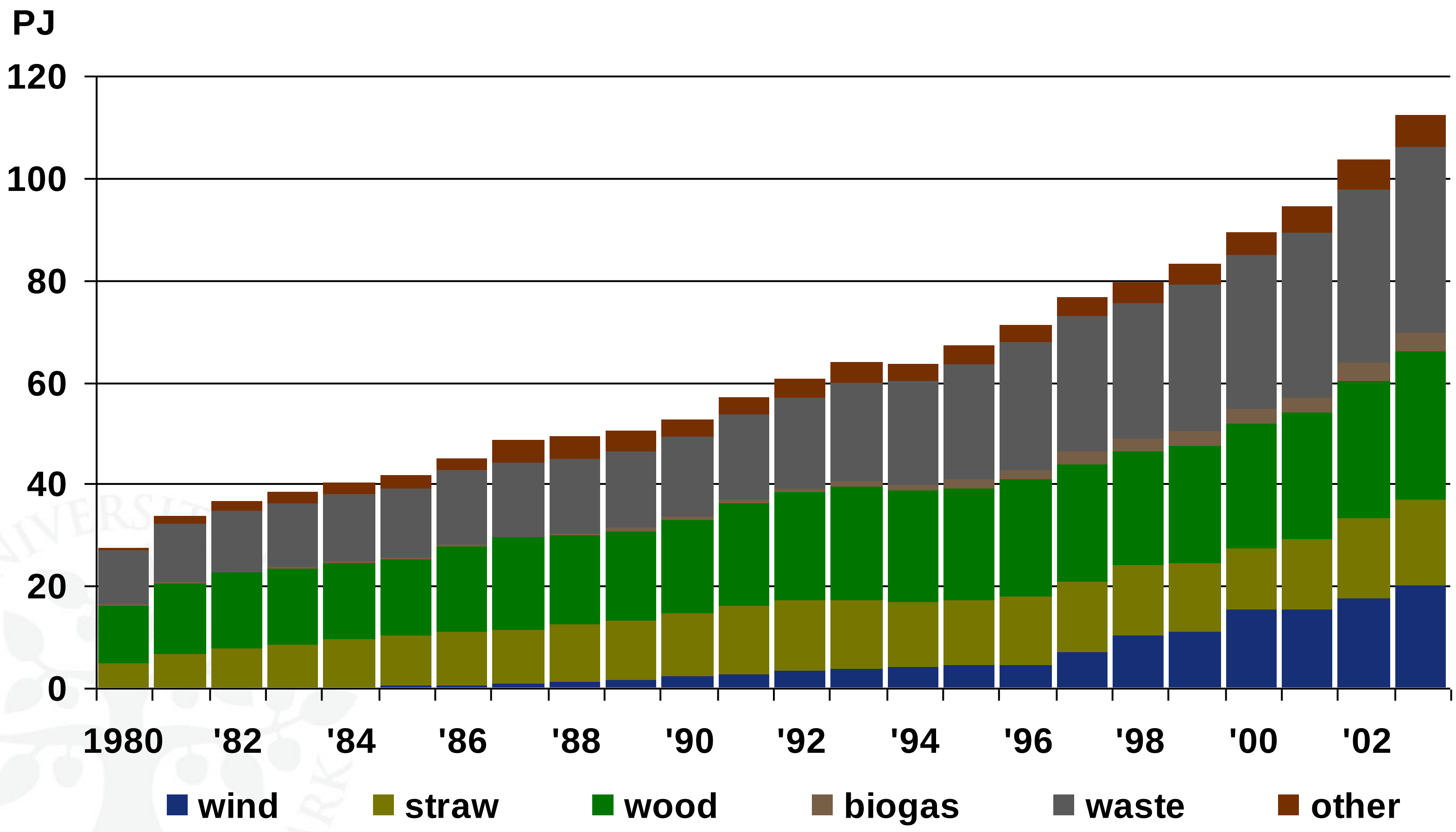
- **Centralised plants**
- **Farm-scale plants**
- New biogas plant projects

Primary energy production in Denmark



112,3 PJ renewable energy, 13,6% of gross energy consumption (850 PJ / year)

Renewable energy production PJ/year



Biomass = 41% of the total renewable energy production

Denmark needs more biogas plants

Why biogas?

Renewable energy and e security of energy supply

- Biogas is a cost-efficient tool for GHG reduction
- Protection of water environment
- Cheap recycling and utilisation of organic residues for energy and fertiliser
- Brings economic and environmental benefits to involved farmers and to the society
- Creates jobs and local development

Manure based biogas is economically and socio – economic feasible if:

- Organic waste is co-digested with animal manure and slurries
- Environmental and economic externalities are taken into account

Necessary framework to achieve the political goal

- Fair electricity prices and price guaranty
- Availability of co-digestion substrates (other than animal slurries)
- Simpler rules for plant approvals and operation
- Supportive overall framework (agricultural, environmental and veterinary legislation)
- Improved public perception of biogas
- Founding for RD&D (externalities, new substrates, pre/post treatment etc

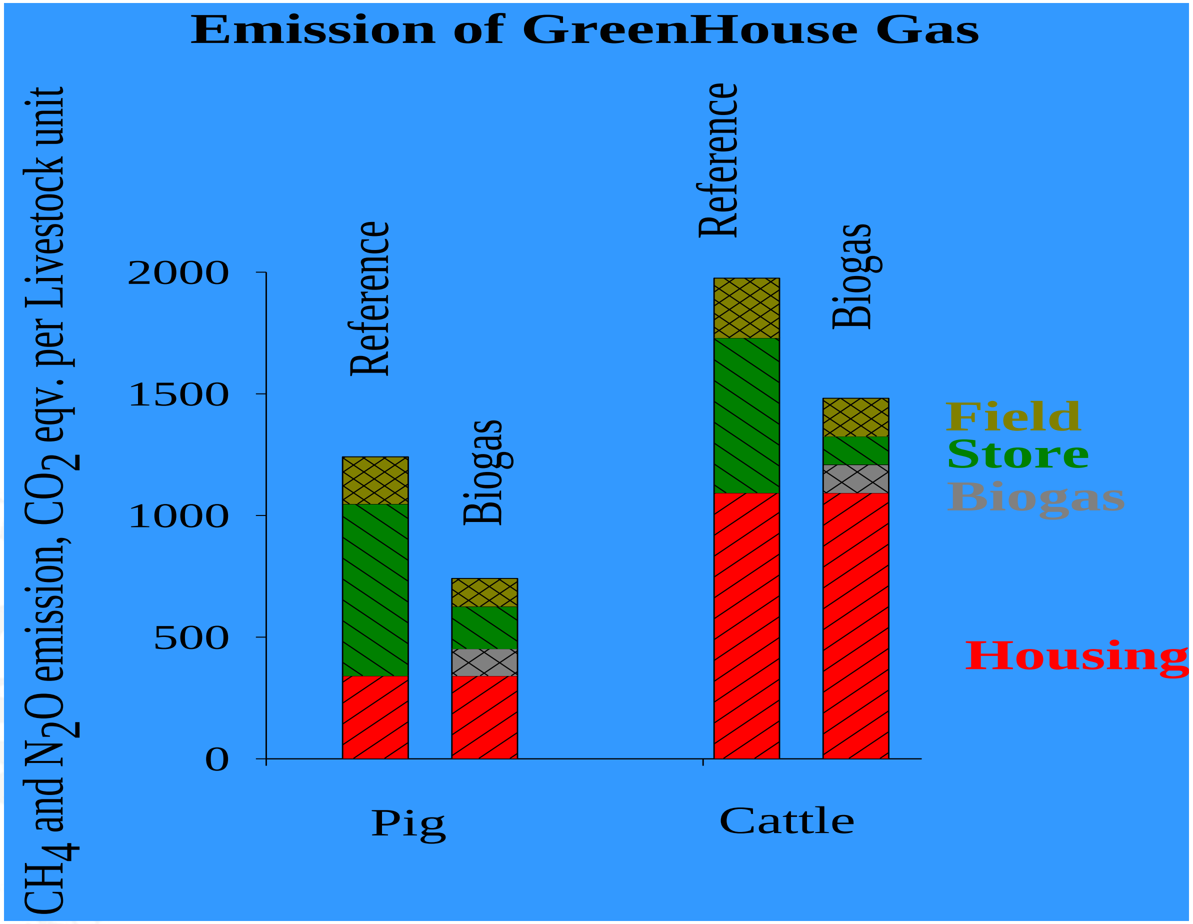
Actual incentives for establishment of biogas plants
(Case: Denmark)

- Socio-economic benefits of biogas production

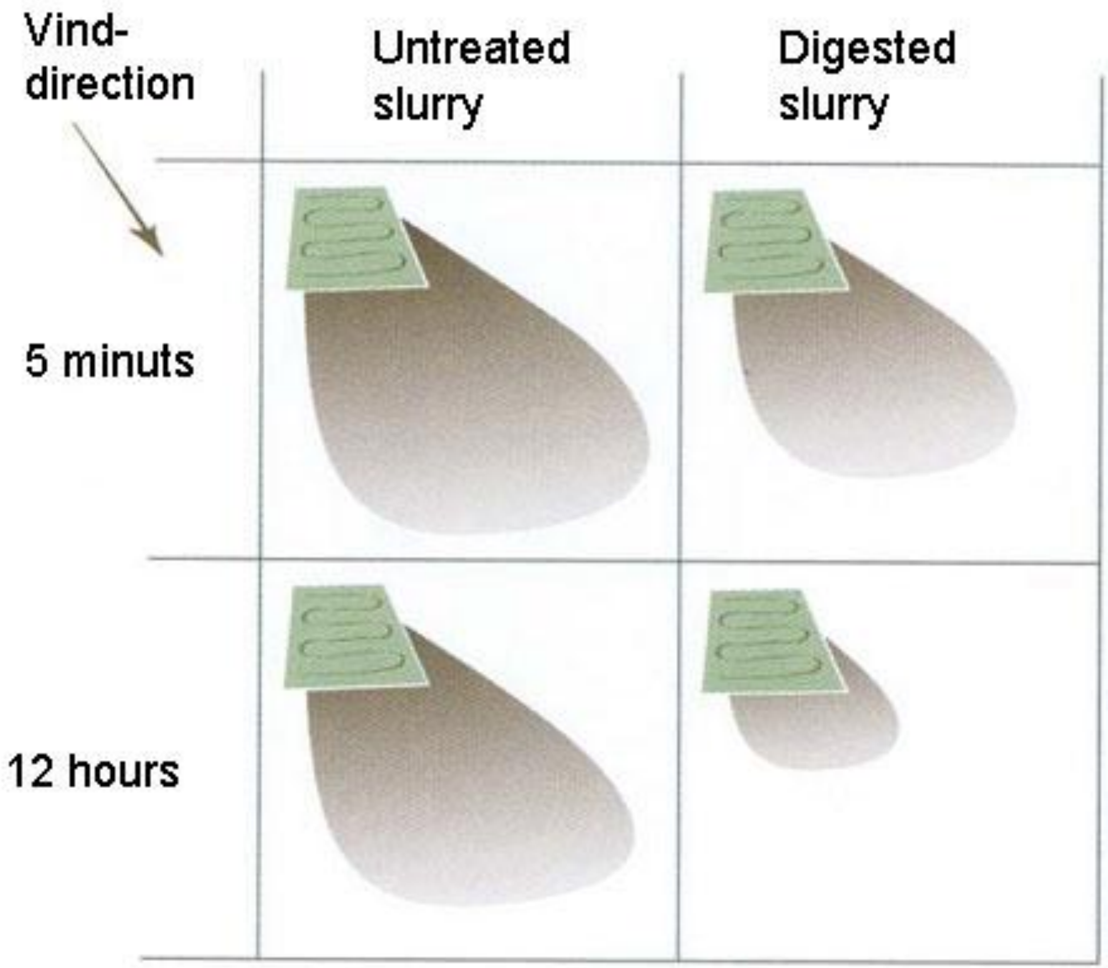
- Fulfilment of environmental policies
  - cheap tool for reduction of GHG emissions (5,37 Euro/tons CO_2 equivalent)
  - 90 kg CO_2 EQ. / t biomass treated

- Agricultural benefits
  - cheap slurry storage
  - less transport
  - less odours and flies
  - less CH_4 emissions from storage and spreading
  - cheap redistribution of slurry (centralised co-digestion)
  - sanitation and pathogens control
  - NPK declaration of digestate
  - high N-utilisation and less N- leaching in digestate
  - possibility of fibre separation

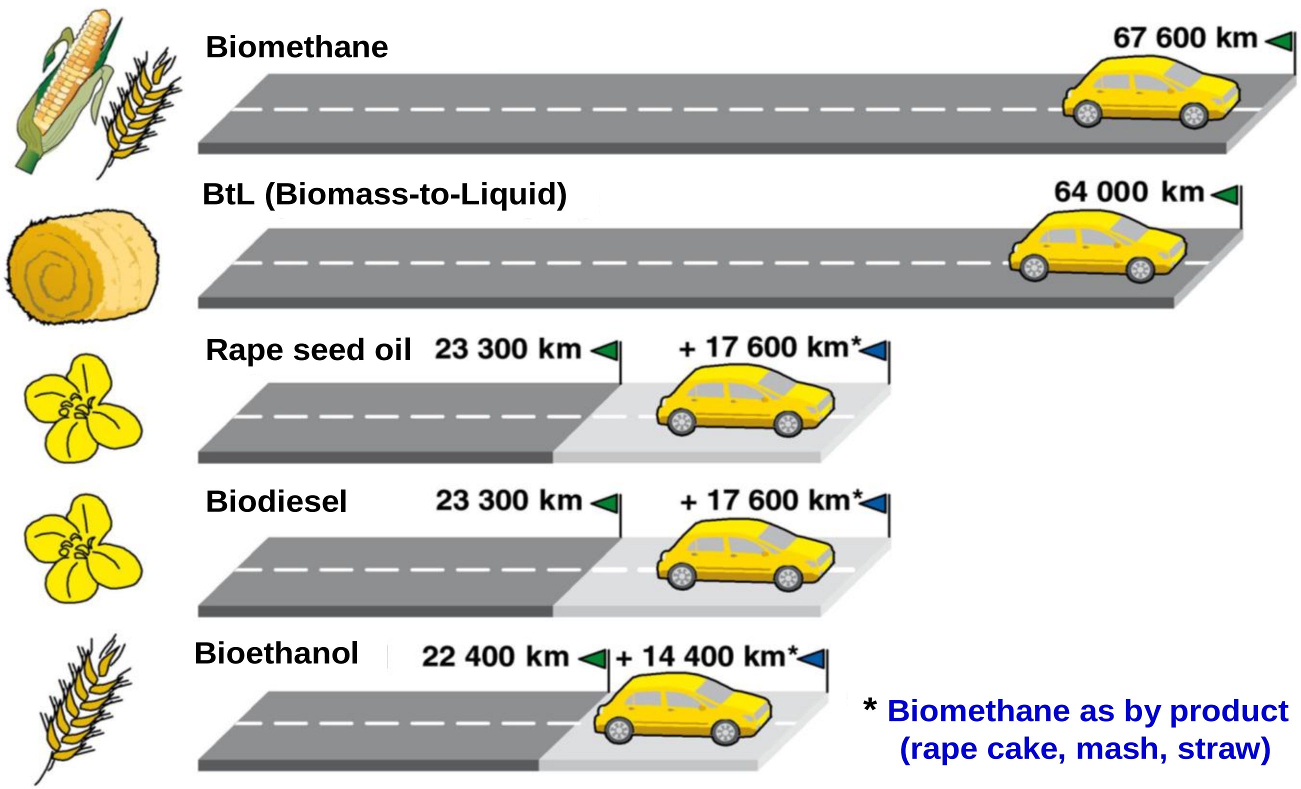
GHG emission, with and without biogas production



Odour reduction by application of digestate



Biogas as vehicle fuel, compared to other biofuels



* Biomethane as by product (rape cake, mash, straw)

Vehicle fuel consumption: gasoline engine 7.4 l/100km, diesel engine 6.1 l/100 km

Biogas and slurry separation

Digestate

↓

Decanter

Fibre fraction ← → Liquid fraction

Fibre fraction

15 % of the initial volume

- 70 % of total P
- 25 % of total N

Decanter

Liquid fraction

- 75 % of total N (most as ammonia)

Problems:

- Costs of drying fibre fraction (50 EUR /t) exceed nutrient value of fibres
- Heavy metals concentrations could be a problem fro utilisation as fertiliser (removal expensive)
- Incineration seen like an alternative (further documentation and approvals necessary)

Biogas in Denmark

- **25 years experience**
  - proven technology
- **Anaerobic co-digestion**
  - manure and organic residues a sound concept
- **Sustainable solutions**
  - energy production and agriculture
- **Developed in close co-operation**
  - agriculture, industry, authorities, research institutions
- **Driven by suitable framework conditions**
- **Ensures further development of agriculture**

Biogas in Denmark

Existing framework

- Price of sold m^3 CH_4: 0,40 Euro
- Heat production: exempted from energy and CO_2 taxation
- Power-production: price guaranty of 0,08 Euro/kWh the next 10 years and of 0,053Euro/ kWh further 10 years (only for plants established before 2007)
- Co-digestion of organic waste - a "must" for a balanced economy of the plant
- Decreasing investment grants

Barriers

- Economy (power prices, gate fees, operation costs, transport)
- Gas yield (dependency of co-digesting organic waste)
- Public image location of site (odours, trafic)
- Approval procedures for establishment

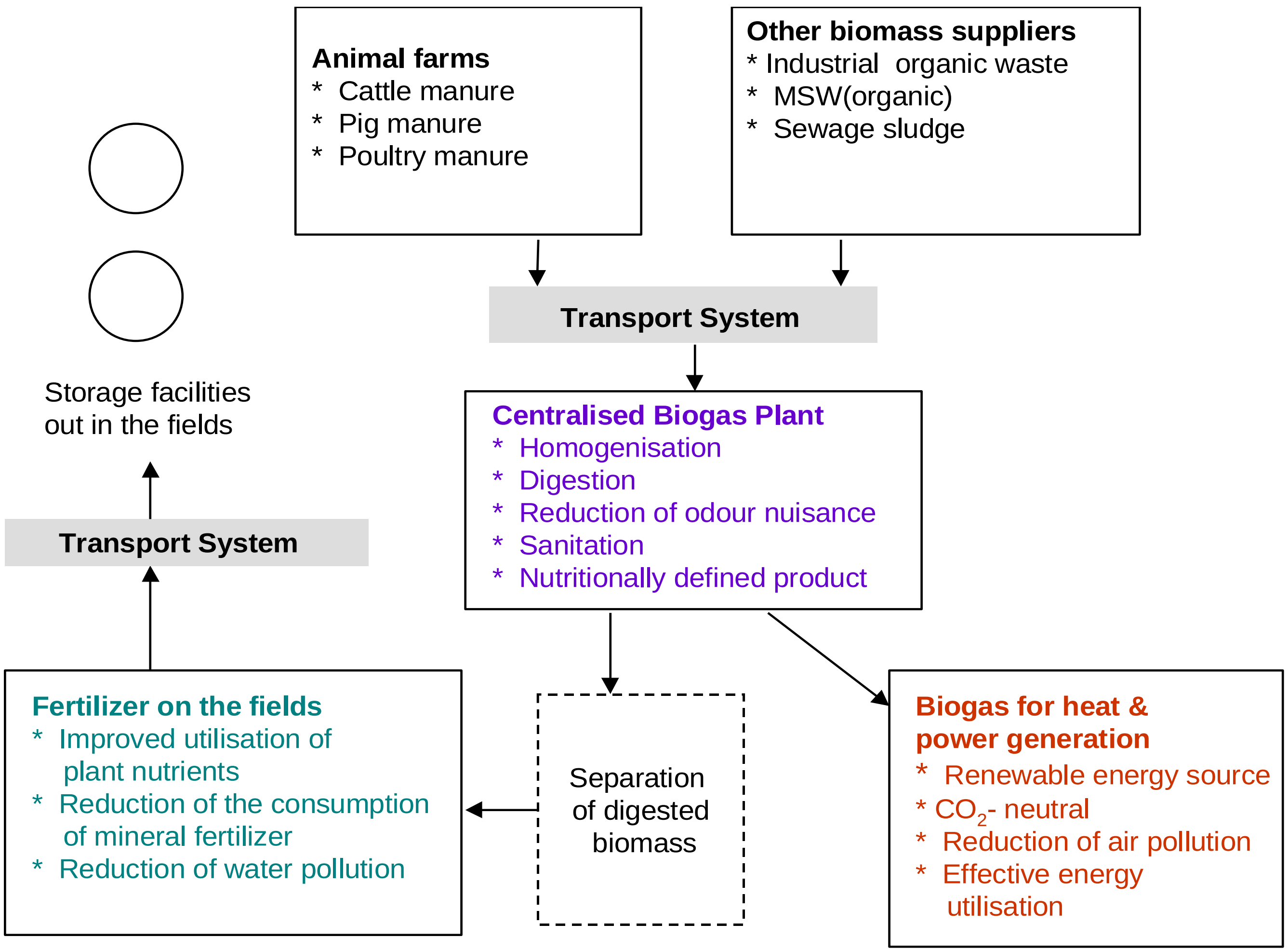
Types of agricultural biogas plants in Denmark

Farm biogas plants

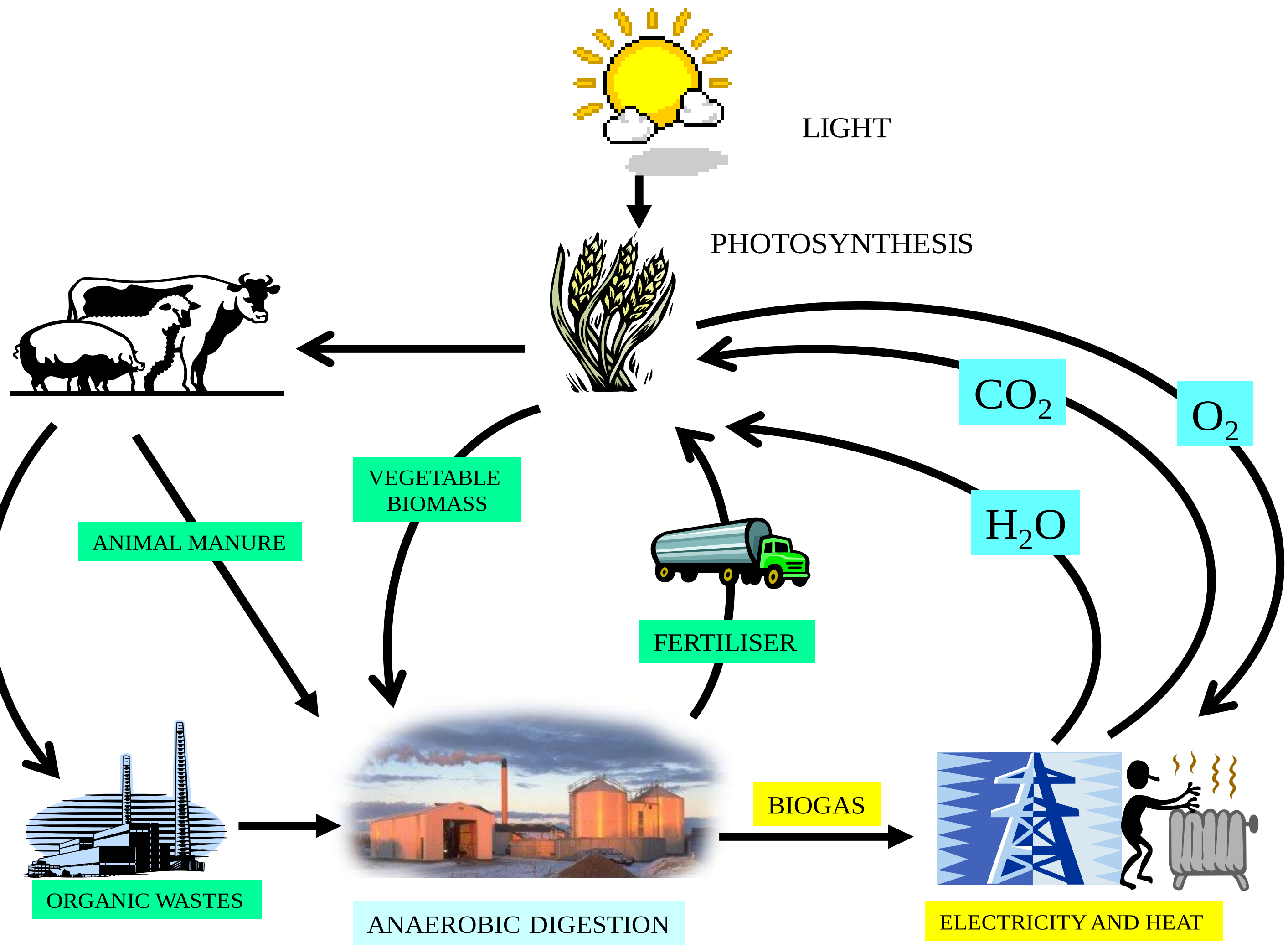
- Almost always located on a farm
- Usually treating biomass produced on the respective farm
- Waste from food industry is co-digested (boost biogas production)
- Biogas used for electricity production (sold to the public grid)
- Heat production used at the farm (process heat) and/or cooled away

Centralized (joint) biogas plants

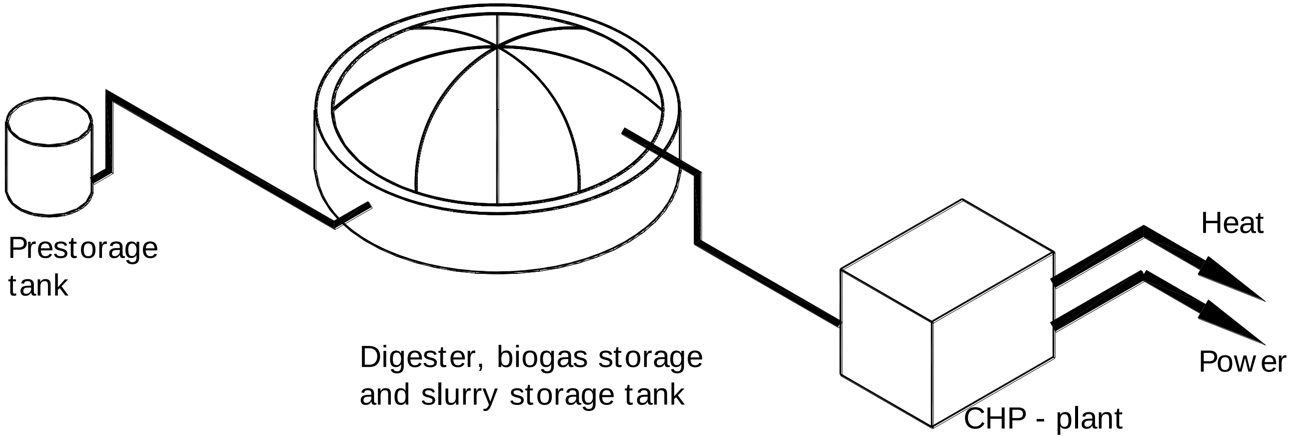
- Co-digesting biomass (animal slurries, manure, vegetable biomass), supplied by several farms
- Located centrally in the farming area
- Co-digesting various wastes from food industries etc
- Biogas used for CHP production
- Electricity sold to the public grid
- Heat typically used for district heating or industrial purposes


Animal farms
* Cattle manure
* Pig manure
* Poultry manure
Other biomass suppliers
* Industrial organic waste
* MSW(organic)
* Sewage sludge
Transport System
Storage facilities
out in the fields
Centralised Biogas Plant
* Homogenisation
* Digestion
* Reduction of odour nuisance
* Sanitation
* Nutritionally defined product
Transport System
Fertilizer on the fields
* Improved utilisation of plant nutrients
* Reduction of the consumption of mineral fertilizer
* Reduction of water pollution
Separation of digested biomass
Biogas for heat & power generation
* Renewable energy source
* CO_2- neutral
* Reduction of air pollution
* Effective energy utilisation

The concept of centralized (joint) biogas plants



Farm scale biogas plant



Farm scale biogas plant

Farm scale versus centralised plants

Farm-scale biogas plants

Advantages

- Technical simplicity(digester can just be "inserted" between the slurry canals and the slurry storage tank)
- Low operational costs (compared to centralized plants)

Disadvantages

- Difficult to utilize heat produced from cogeneration at the farm (especially in summer)
- Requires considerable technical skills and interest from the farmer
- Economical sustainability requires a certain size of the farm

Centralized biogas plants

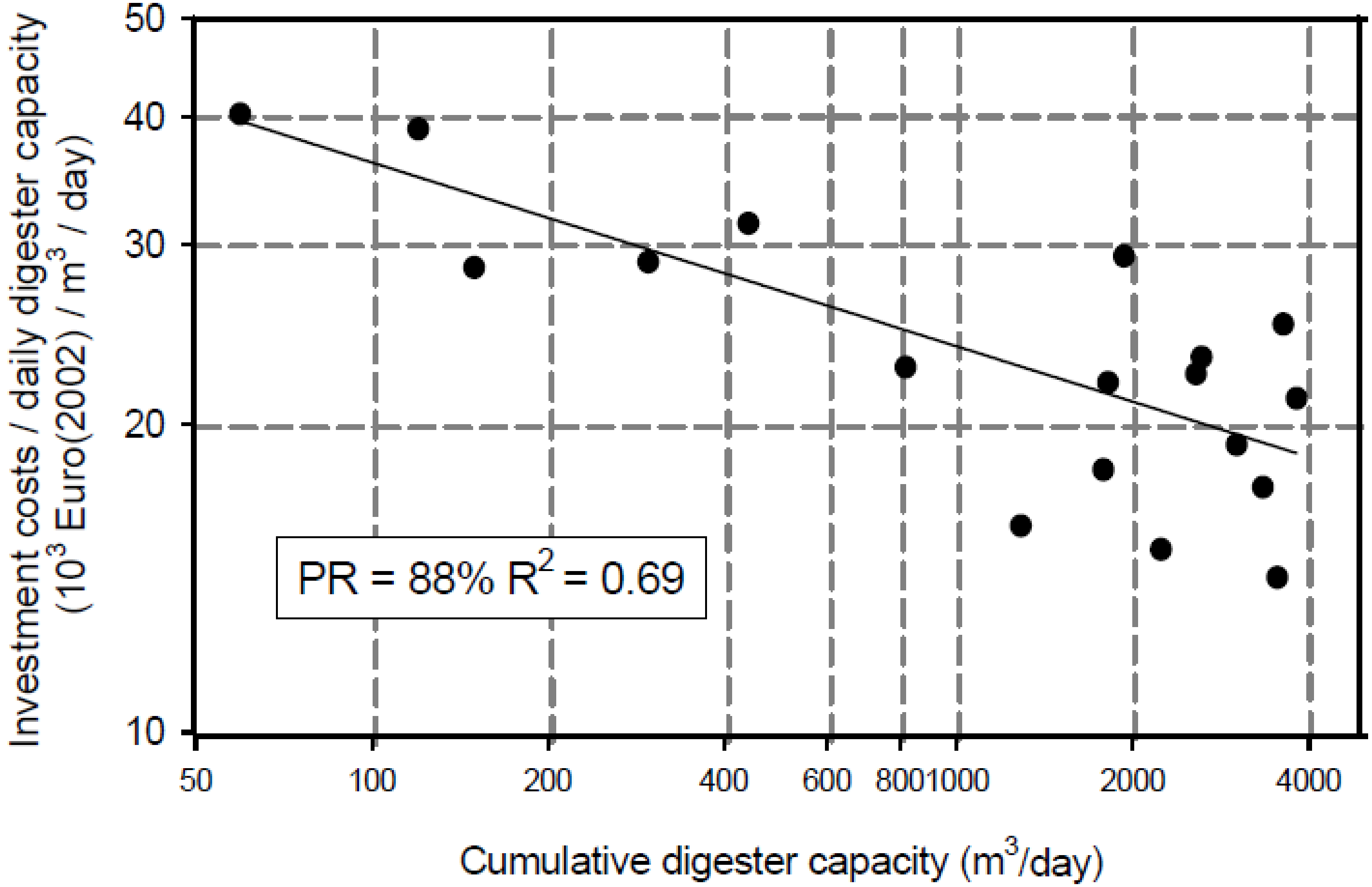
Advantages

• All farms (large and small) can be involved
• Recycling of organic waste products
• Skilled and trained staff
• Better territorial redistribution of distribution of nutrients from animal manure and slurries.
• Economy of scale; (prices per tonne of biomass treated decrease with the size)
• utilizing heat production (district heating)

Disadvantages

• Technically more complex
• Transportation, receiving and loading facilities have to be established
• Higher costs;
  -Higher investment costs
  -Higher operation costs (e.g. transportation costs etc.)
• Often difficult to find a suitable location for the plant
• Veterinary safety: there is a potential danger of spreading of disease between farms (never the case in Denmark)

Investment costs per digester capacity
Case: Danish biogas plants



Planning and building a biogas plant

- Project idea
- Pre-feasibility / Feasibility study
- Detailed planning
- Getting the permits
- Construction of the biogas plant
- Running in period
- Operation and maintenance
- Re-investment, renewal and replacement of components

Defining a concrete biogas project idea

- What is the aim of the biogas project?
- What is the capacity of the investor to realise the project?
- How can continuous and uniform supply of feedstock be ensured?
- Where can the biogas plant be located?

Further planning steps

- Assessment of project feasibility in local conditions
- Defining and evaluating a business plan and a financing strategy
- Involving an experienced planning company
- Involving, from very early stages of the project, **all the other key actors:**
    - local authorities
    - municipalities
    - feedstock suppliers
    - financing companies
    - the public

How to secure continuous feedstock supply

Feedstock supply schemes

Single supplier

A farm or organic waste producer has enough manure, organic waste, agricultural land or all of the above, to provide the feedstock necessary to run the biogas plant

No feedstock supplying problems

Feedstock supply schemes

Several suppliers

Several farms, organic waste producers etc. work together in a consortium to build, run and supply feedstock to a biogas plant

- Cooperative company
- Limited company
- Other form of association

Aim: To secure constant and long term supply of the necessary AD feedstock

How: Every supplier signs a long term contract, stipulating as a minimum:

- *Contract duration*
- *Guaranteed amount of feedstock supply or area of cultivation (for energy crops)*
- *Quality description of the feedstock supplied*
- *Guaranteed quality of the delivered biomass*
- *Payments conditioned by the delivered quantity and quality*
- *Bonus and penalty*

Where to locate the biogas plant

Criteria:

Suitable distance from residential areas
- to avoid conflicts related to odours and increased traffic

- **Consider the direction of the dominating winds**
  - to avoid wind born odours reaching residential areas

- **Easy access to infrastructure**
  - electricity grid - sale of electricity
  - transport roads - transport of feedstock and digestate

- **Investigate the geological condition of the terrain before starting the construction**
  - avoid location in potential flood affected areas

- **Close or central to the feedstock production area (manure, slurry, energy crops)**
  - minimise distances, time and costs of feedstock transportation

- **As close as possible to potential users of the produced heat, or bring potential heat users closer to the biogas plant site (heat demanding industry, greenhouses)**
  - cost efficient heat transmission

NB: The size of the site must be suitable for the activities performed and for the amount of biomass supplied

Getting the permits
?

Start up of a biogas plant

General considerations:

- Must be conducted by experienced people, who are familiar with the design of the plant and with the microbiology of the AD process.
- Should always be done by the company who designed and built the plant
- Use the running in period to train the plant manager and the staff in charge with the plant operation
- Before starting up, the plant owner must check if all the obligations included in the building permission are fulfilled

Start up procedure :

- Filling up the digesters with manure or with digestate from a well functioning biogas plant (inoculation)
- Heating up the feedstock to process temperature
- Starting the feeding up of digesters

The construction of the plant

Entrepreneurs

- A single farmer
- A consortium of farmers
- A municipality

Success criteria

A. Controllable factors = The rightness of the strategic decisions

- Investment costs
- Operation costs
- Technology
- Tendering
  - Operational cost of CHP incl. all services and spare parts (amount/kWh)
  - Maintenance costs of biogas plant in total. (% of investment/year)
  - Own electrical energy demand, including demand of CHP (kWh/year)
  - Average working hours/day of staff (maintenance and feeding the system)

B. Uncontrollable factors

- Interest terms
- Grid access and feed in tariffs
- World market prices for feedstock (e.g. energy crops)
- Competition for feedstock from other sectors

Study/ calculation of profitability

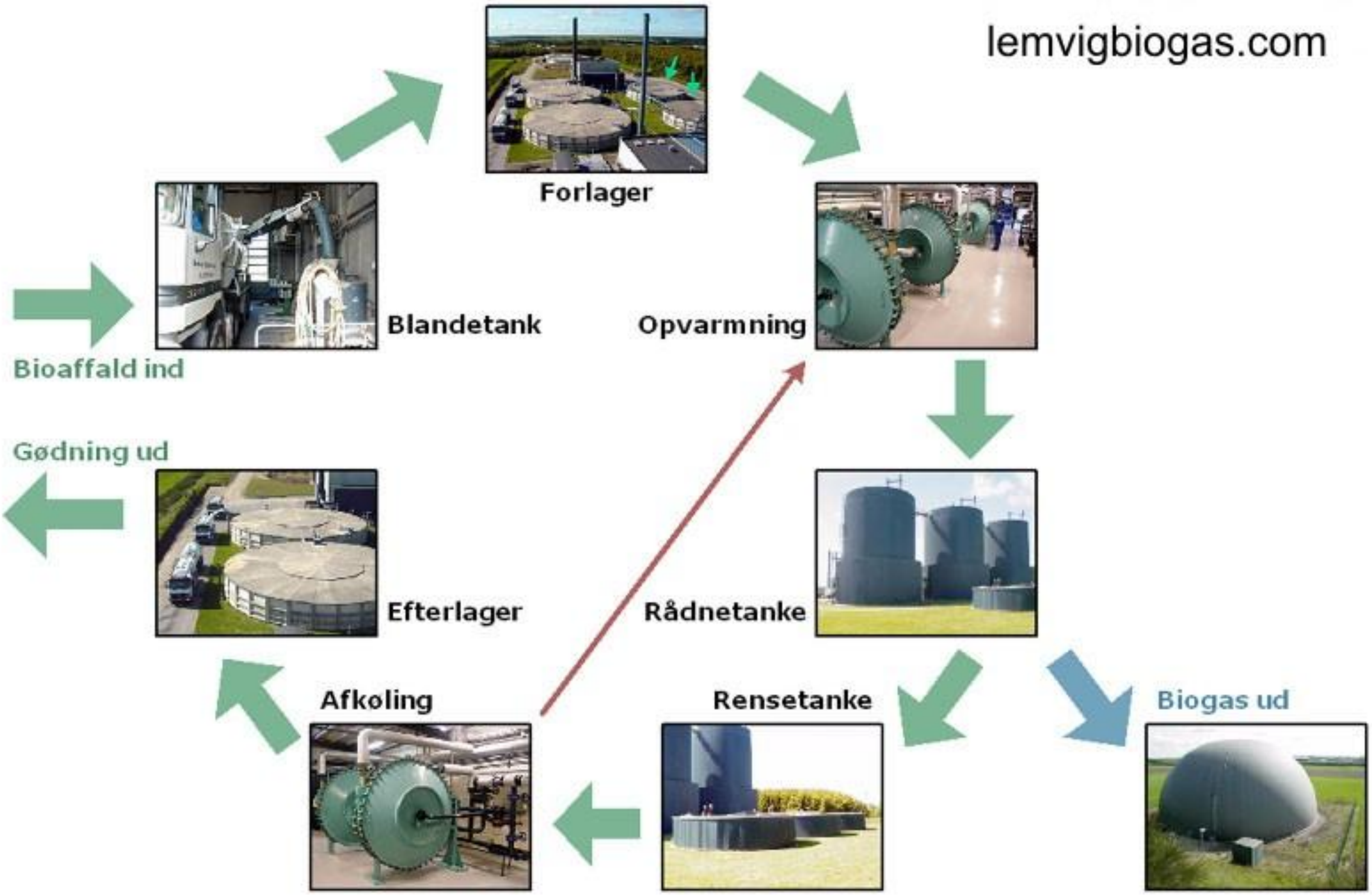
- Often required by the banks
- Normally done by experienced planning/ consulting company (part of the preliminary planning)
- For single farm biogas projects, can be done by the project developer
    - the project developers/ partners get a close view of the project
    - no external costs occurred in case of cancelling the project

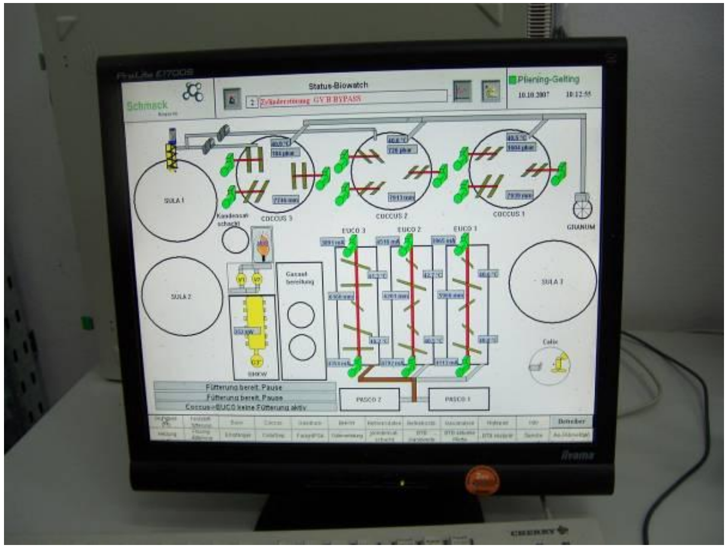
Mandatory to be done by consulting company in case of a biogas plant treating municipal waste more complex handling of feedstock

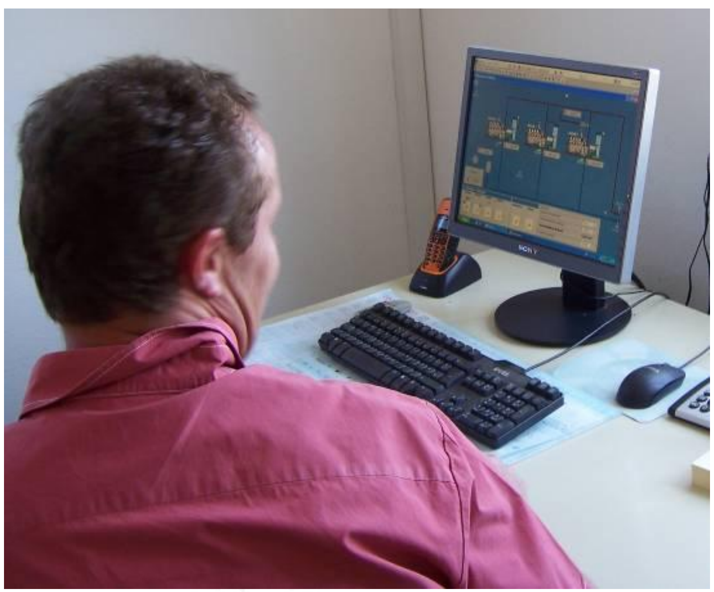
- complex biological stability of the system
- more complex plant design

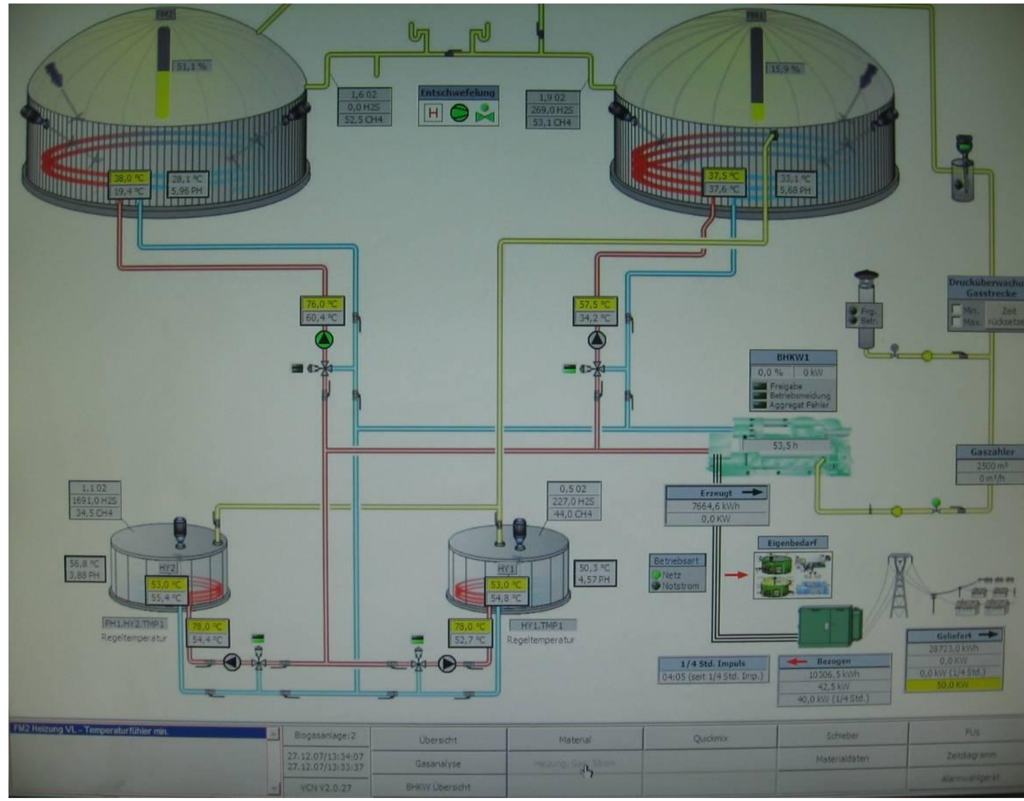
Attention!
Industrial waste suppliers face problems securing long term availability of the feedstock. (rarely contracts for periods longer than five years)

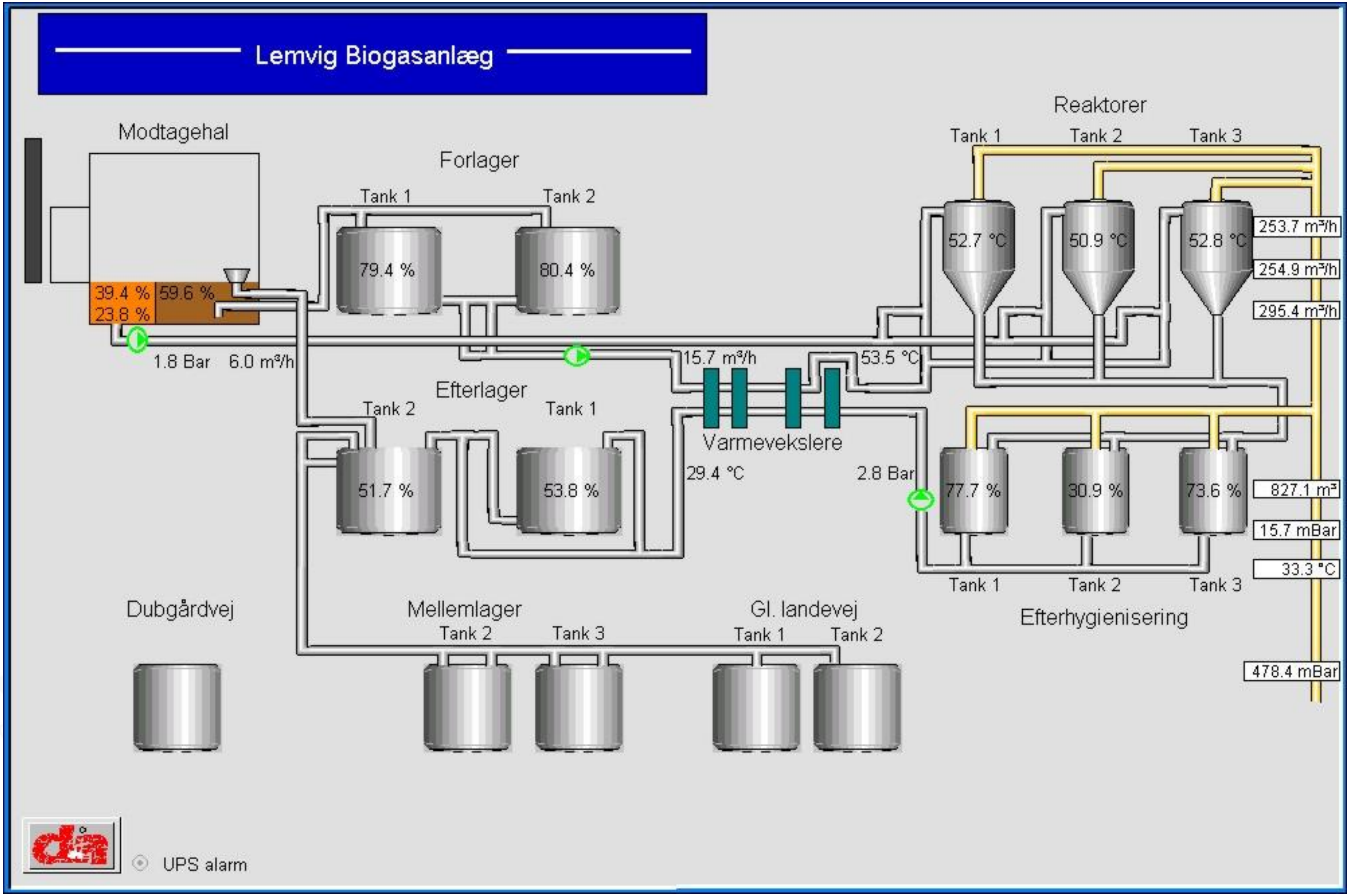
Economic forecast using BiG< EAST calculation model http://www.big-east.eu

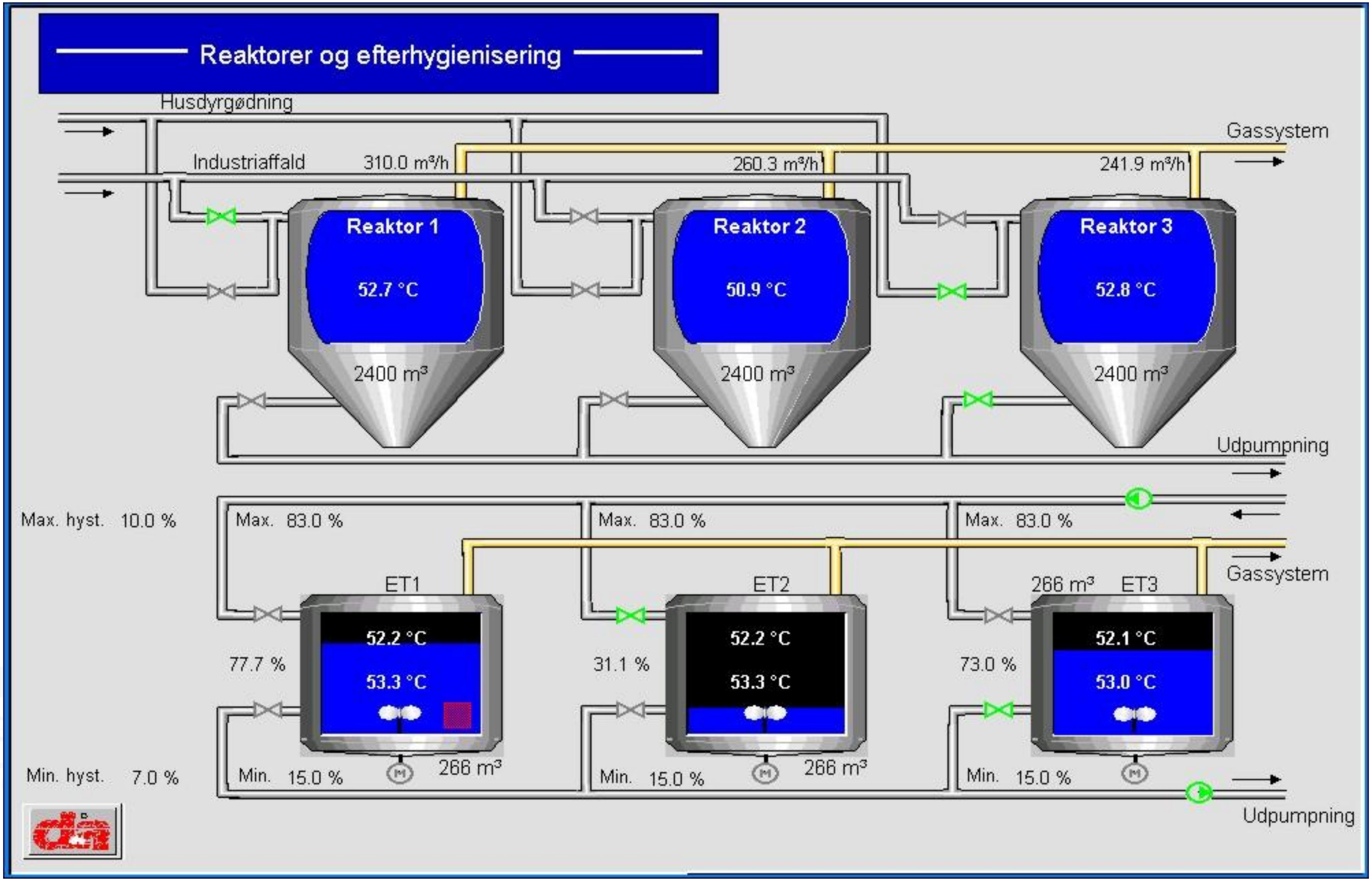

lemvigbiogas.com
Forlager
Blandetank
Opvarmning
Bioaffald ind
Gødning ud
Efterlager
Rådnetanke
Afkøling
Rensetanke
Biogas ud






Entschwefelung
BHKW1
Gaszähler
Erzeugt
Eigenbedarf
Betriebsart
Bezogen
Geliefert
1/4 Std. Impuls
Übersicht
Material
Quickmix
Schieber
Gasanalyse
BHKW Übersicht
Materialdaten


Lemvig Biogasanlæg
Modtagehal
39.4 %
59.6 %
23.8 %
1.8 Bar
6.0 m³/h
Forlager
Tank 1
Tank 2
79.4 %
80.4 %
Reaktorer
Tank 1
Tank 2
Tank 3
52.7 °C
50.9 °C
52.8 °C
253.7 m³/h
254.9 m³/h
295.4 m³/h
15.7 m³/h
53.5 °C
Efterlager
Tank 2
Tank 1
51.7 %
53.8 %
Varmevekslere
29.4 °C
2.8 Bar
77.7 %
30.9 %
73.6 %
827.1 m³
15.7 mBar
33.3 °C
Tank 1
Tank 2
Tank 3
Efterhygienisering
Dubgårdvej
Mellemlager
Tank 2
Tank 3
Gl. landevej
Tank 1
Tank 2
478.4 mBar
UPS alarm


Reaktorer og efterhygienisering
Husdyrgødning
Industriaffald
310.0 m³/h
260.3 m³/h
241.9 m³/h
Gassystem
Reaktor 1
52.7 °C
2400 m³
Reaktor 2
50.9 °C
2400 m³
Reaktor 3
52.8 °C
2400 m³
Udpumpning
Max. hyst. 10.0 %
Max. 83.0 %
Max. 83.0 %
Max. 83.0 %
ET1
ET2
266 m³ ET3
Gassystem
52.2 °C
53.3 °C
77.7 %
52.2 °C
53.3 °C
31.1 %
52.1 °C
53.0 °C
73.0 %
Min. hyst. 7.0 %
Min. 15.0 %
266 m³
Min. 15.0 %
266 m³
Min. 15.0 %
Udpumpning

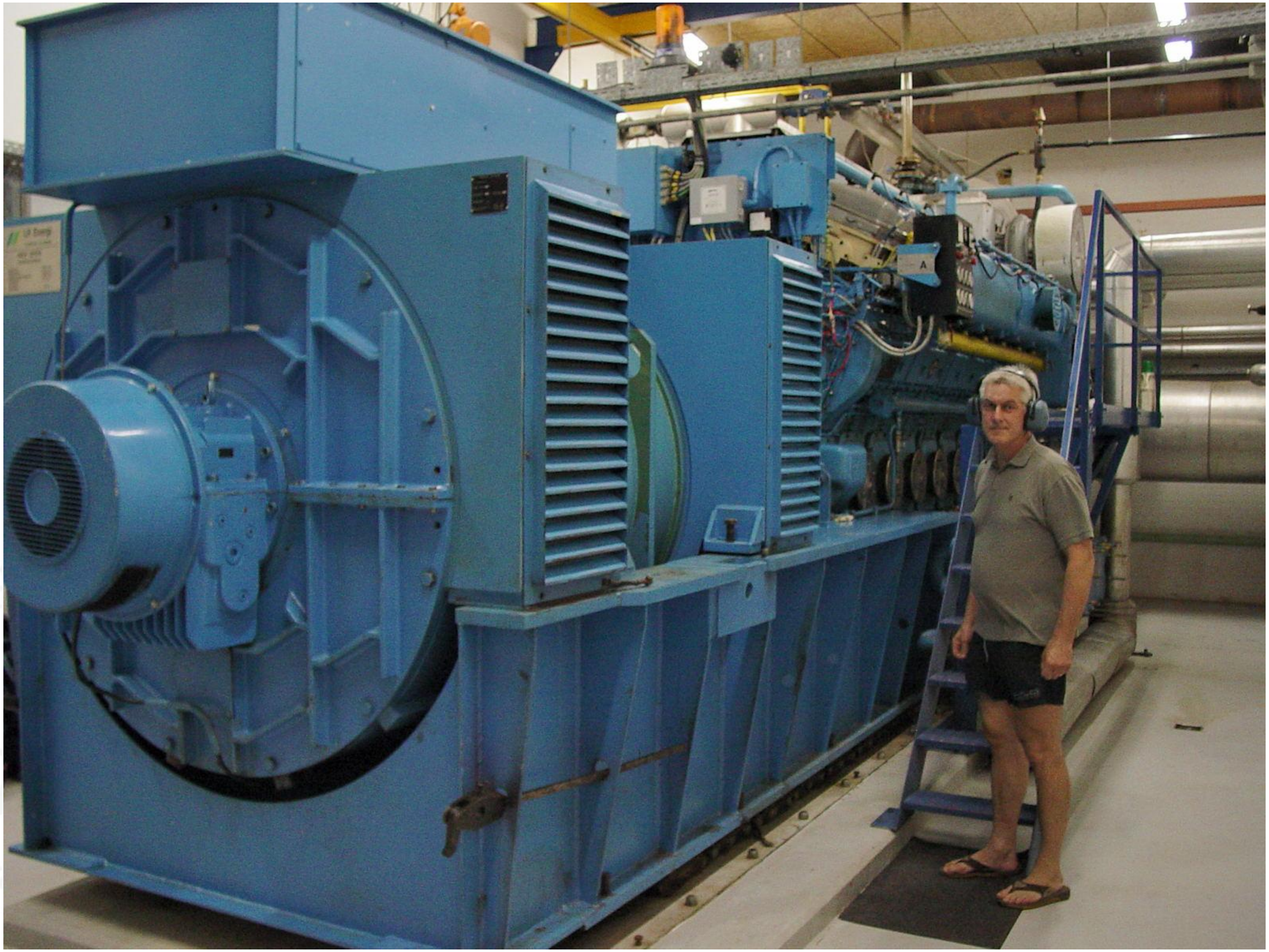

LEMVIG
BIOGASANLÆG
VOLVO
FH12
LEMVIG
BIOGASANLÆG
TZ 92 349

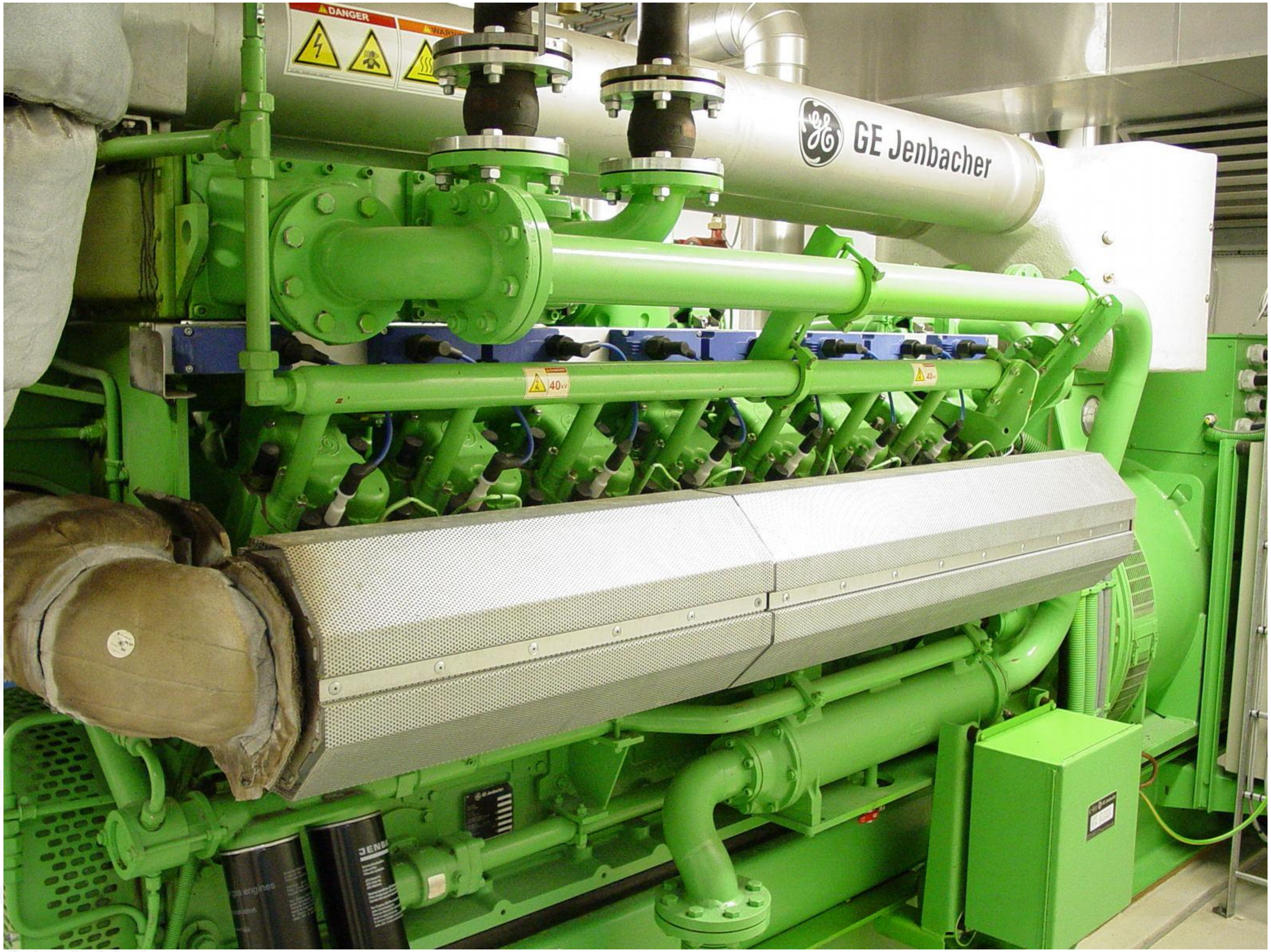
UNIVERSITY OF SOUTHERN DENMARK


LEMVIG
BIOGASANLÆG
LEMVIG
BIOGASANLÆG

UNIVERSITY OF SOUTHERN DENMARK


SIEMENS
OHAUS




DANGER
GE Jenbacher
40 kV