Anaerobic digestion as a means of mitigating CH_4 emissions in agriculture

Who am I?

- Professor of Environmental Technology at the University of Southampton, UK
- Fields of interest:
  - Waste treatment
  - Farm-based sustainable energy systems
- Coordinator of EU FP6 Project CROPGEN (SES6-CT-2004-502824)

Incentives and disincentives to the adoption of AD technology

- Some examples of on-farm and centralised AD digestion facilities across Europe
  - What has made these schemes work
  - Why some schemes are running into difficulty
  - What are the benefits of the schemes
- How have EU and regional policies influenced these?

Finland


Crop drying
Farm house
Digestate storage
Raw slurry storage
Anaerobic digester
Animal housing
Biogas vehicle fuel pump
Silage store
Kalmari Farm


Kalmari Farm digester


FIN YES-156
VOLVO
V70
BI-FUEL
Lanta on polttoaineeni
kulutus: 0,5m3 lantaa tai 60kg keittiojätettä/100km
biokaasuauto.com

Incentives

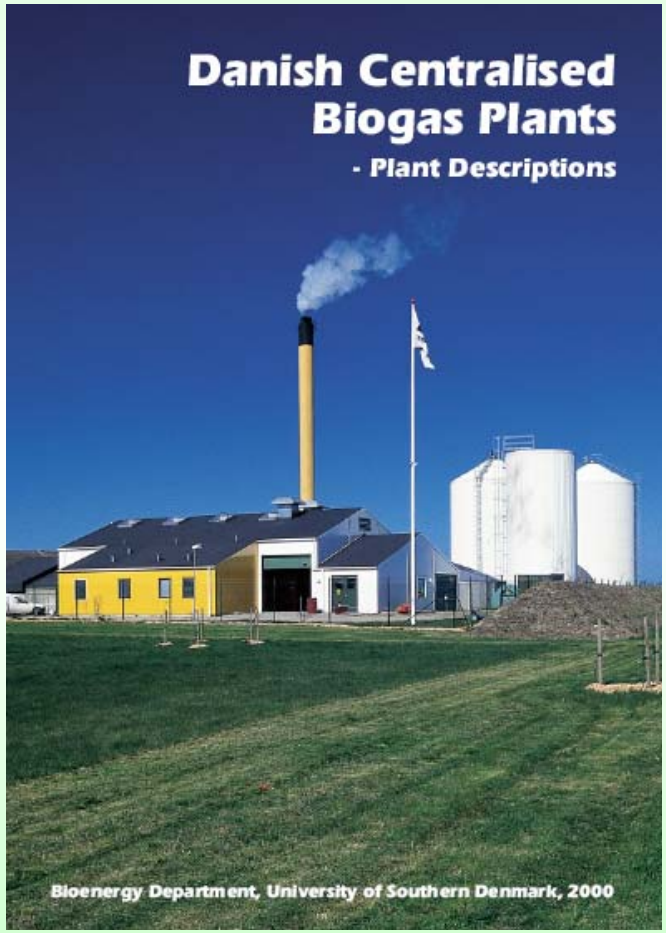
- EU Nitrates Directive (91/676/EEC)
- Environmental Protection Act (2000/86) and Government Decree No 931/2000
- Applies to the whole national territory of Finland
- Provisions on good agricultural practices, storage of manure, spreading and allowable quantities of fertilizers
- Requirement to provide covered slurry storage for 12 months of the year
- Manure may not be spread on frozen land or snow
- Farmers must be signed up to the **General Agricultural Environmental Protection Scheme (GAEPS)** to receive subsidies

Disincentives

- 78 000 farms in the GAEPS scheme
- 1 875 000 hectares (91% of field area)
- The total amount of agricultural waste accumulated in Finland is around 20 million (wet) tonnes, of which cattle dung is 8 million (wet) tonnes
- Only 2 farms currently digest such waste
- Development has relied heavily on individual effort
- No government funding forthcoming and the incentive has been lost

Denmark

- Currently 18 centralised biogas plants large enough to be included in the survey carried out by the Bioenergy Department of the University of Southern Denmark
- Plants are mostly co-operatives involving farmers, municipalities and/or private organisations, with 5 - 80 farmers involved.



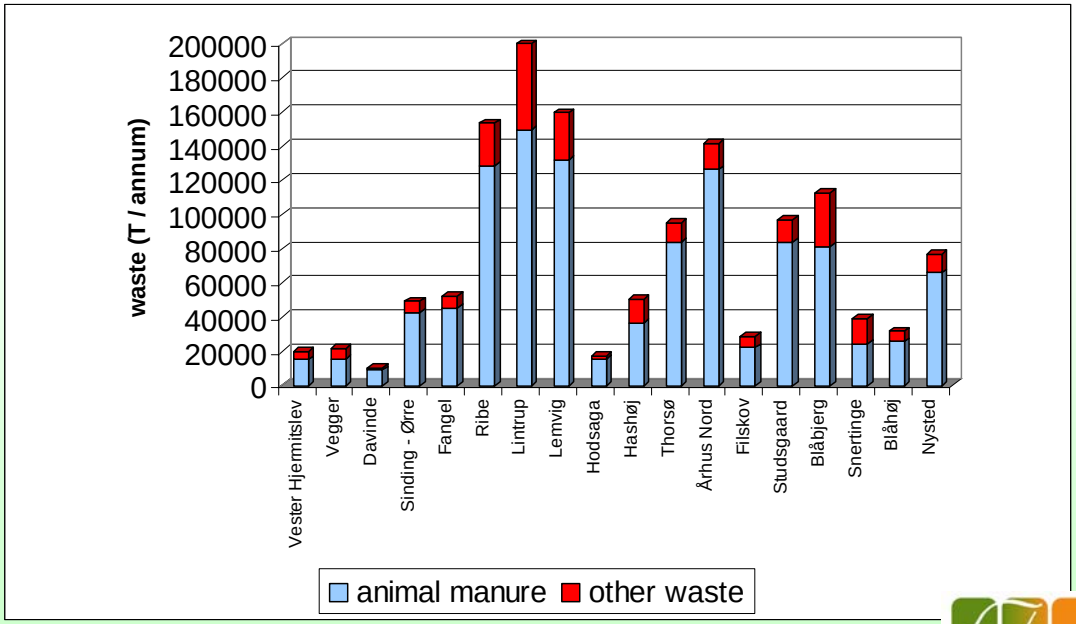
Centralised Anaerobic Digestion

- The Danish Biogas Programme is a good example of an ambitious and consistent government policy for farm management and nutrient control.
- This includes 6-9 month manure storage capacity, plus restrictions on application and on landfilling organics.
- Economic incentives included grants, low-rate long-term loans, tax exemptions and subsidies for bio-electricity currently of 0.079 € kWh^{-1} for established plants (but reducing to 0.053 € kWh^{-1} in 2014).
- Heat sales are also possible through widely available district heating networks for 6-9 months per year.

Type of plant and capacity

- Plants supplied by different manufacturers but all based on a single-phase completely-mixed wet digestion system at either mesophilic or thermophilic temperatures.
- Sizes range from 10,000 to 200,000 tonnes in relation to the waste tonnage that can be accepted.

- Feedstock mainly animal slurry from pigs and cattle, supplemented in all cases by other organic wastes from food processing.



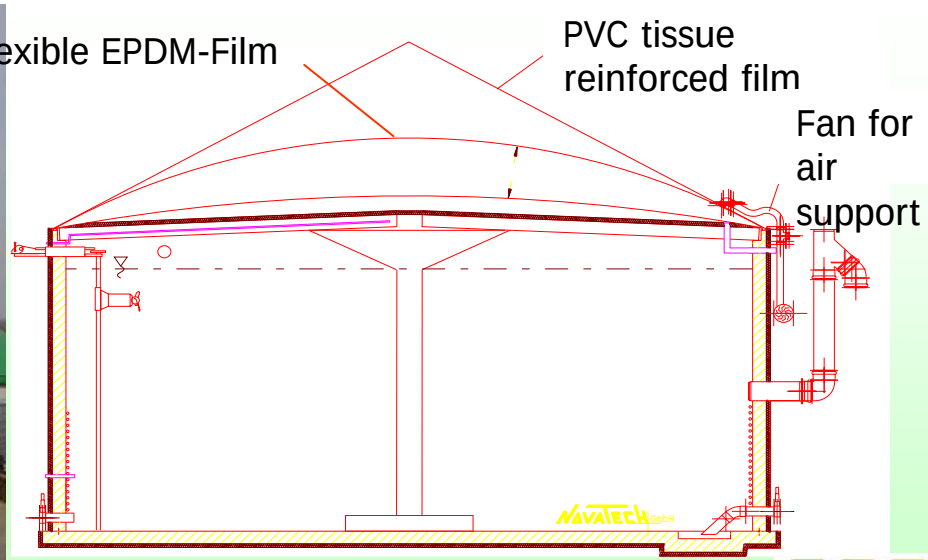
Economics depend on the import of food waste

- These include animal wastes such as intestinal contents (27%); fat and flotation sludge from food or fodder processing (53%); and wastes from fruit & vegetable processing, dairies and other industries.
- On average about 23% of waste is not from farms, but this ranges from 12 to 64% for individual plants.
- Approximately 1.1 million tonnes of manure is treated with 255,000 tonnes of other organic waste.
- This gives 50 million m^3 of biogas with an average yield of 36.8 m^3 $tonne^{-1}$ (wet weight).
- Biogas yield is therefore considerably higher than the normal 20 m^3 $tonne^{-1}$ for slurry alone.

Danish CAD plant

Germany

- 2500 installed farm digesters, with current expansion expected to reach 4000 soon
- Installed electrical generating capacity of 980 MW expected by end of 2005



Incentives

- Renewable energies resource act (‘feed in laws’)
- Guaranteed purchase of biogas (and other renewable) electricity at preferential rates for a 20-year period
- Base price ranges from €0.084 – 0.115 kWh^{-1}
- Bonuses for energy produced from energy crops
- Bonuses for use of heat from CHP
- Bonuses for the use of ‘new technologies’
- Scale down of subsidies from the end of 2005 to encourage efficiency and process development

cropgen

Substrates	Dry matter content (DS%)	Volatile solids (VS%)	Biogas Yield Nm3/T substrate	Methane content (%)
Dairy cow slurry	8	85	20	55
Fattening cattle slurry	10	85	34	55
Pig slurry	5	85	18	60
Chicken manure	25	75	93	65
Meadow grass average from 3 -4 cuts/year	18	91	98	54
Maize silage	33	96	190	53
Grass silage average from 3 -4 cuts/year	**35**	**89**	**183**	**54**
Grain milled	**87**	**98**	**597**	**53**
Corn-Cop-Mix, 5.3% fibre	**60**	**98**	**391**	**53**
Total plant grain silage	**40**	**94**	**195**	**53**
Potato distillery residues	**6**	**87**	**35**	**56**
Vegetable residues	**6**	**87**	**35**	**56**
Rape seed cake	**91**	**93**	**612**	**63**
Canteen residues high fat	**18**	**92**	**90**	**68**
Canteen residues low fat	**14**	**82**	**44**	**69**
Flotation fat	12	90	108	68

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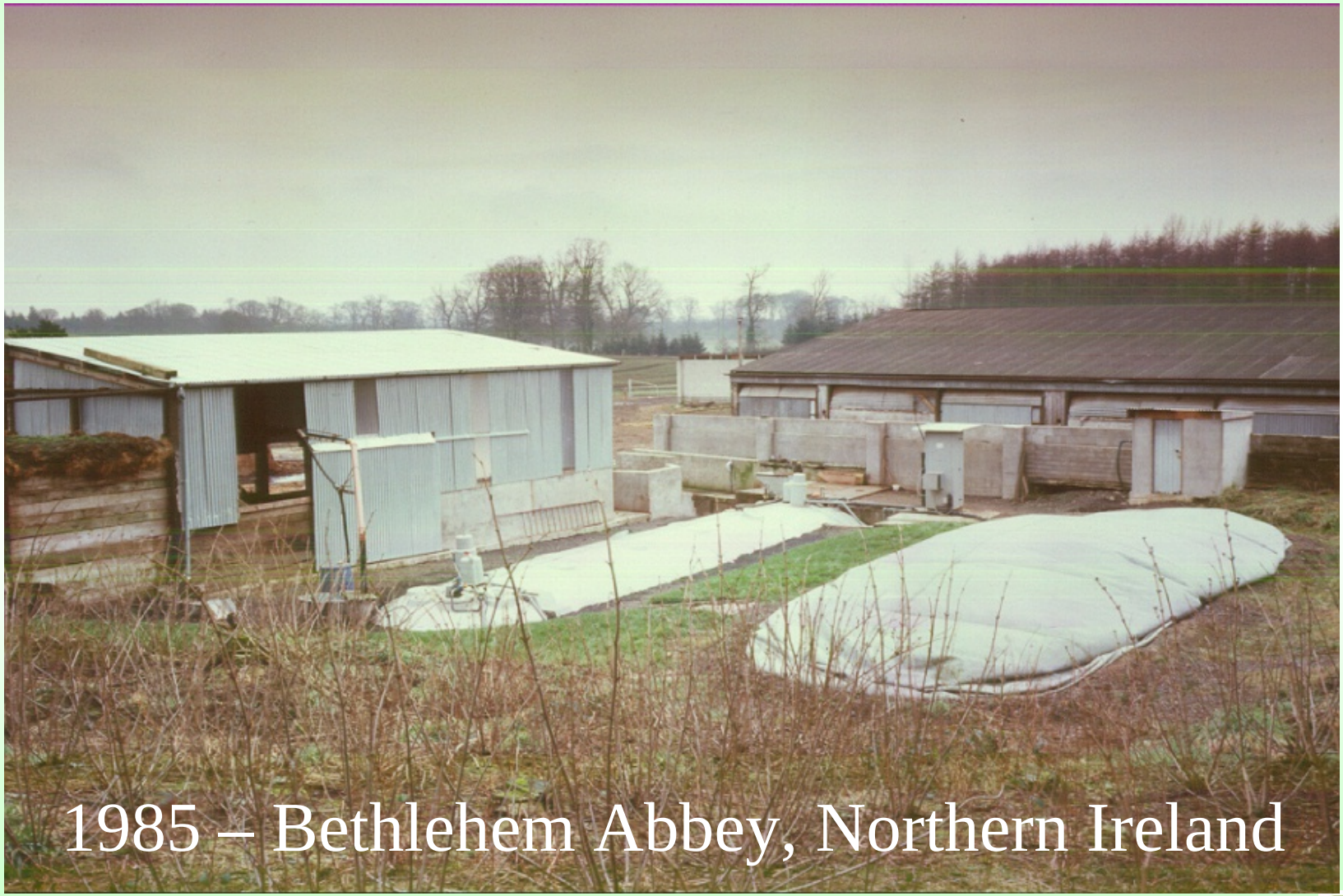
Another German digester!

United Kingdom



1985 – Bethlehem Abbey, Northern Ireland

Bethlehem Abbey

- Originally seen as providing a gateway to large-scale organic farming, integrating (as Cistercian Fr. Jim Conlon would put it) '*more wholesome*' farming of cattle using organic grass/clover/grain feed, with production of organic oats for human consumption from digested liquid fertiliser – Incentive in 1984.
- This unit won the 1986 Pollution Abatement Award from the Royal Society of Arts / Confederation of British Industry and the Department of the Environment.
- In 1987 the system came equal second in a field of 1500 entries in the European Year of the Environment Awards.
- More importantly, the system has operated since 1985 on beef cattle slurry and the unit is still heating the monastery for 220 days a year when the cattle are housed.

United Kingdom

Holsworthy centralised anaerobic digestion plant

Technical specification

- 140 m^3 reception pit
- 2500 m^3 mixing tank – internal impellers
- 84M double helix heat exchangers
- 3 x 20 m^3 pasteurisers – 70^oC for 1 hour
- 2 x 4000 m^3 digesters
- 3000 m^3 site digestate storage
- 2 x biological de-sulphurisation units
- 800 m^3 gas storage
- 2 x 1048 kW Jenbacher 320 gas engines
- 40,000 m^3 digestate storage
- State of the art system following the Danish Co-operative model for a centralised facility (25 farmers – 140,000 tonnes of slurry per year)

Disincentive = regulation

- Under UK regulations all slurry leaving a farm becomes classified as controlled waste
- Waste Carriers License for inter-farm transfer
- Use of the material back on the farm is controlled by the Animal By-Products Regulations and Waste Management Licensing Regulations
- All land on which controlled waste is spread must receive an exemption – a process that can take 35 days
- Licensing fee £545 (794 €) for every 50 hectares = 115 - 145,000 € every year

Disincentive = regulation

- In addition have to comply with Cross Compliance, Single Farm Payment, Water Framework Directive, Nitrates Directive, COGAP
- Perception of the farmer that material he previously spread on the land is now a waste and he needs a license!
- No guaranteed price for energy sales in the UK – scale is variable under the Renewable Obligation Certificates (ROCs) scheme.

Experience

- The material is processed to a very high standard
- The plant is fully compliant with the EU Animal By-Products Regulations
- Regular analysis of digestate and storage until it is most beneficial to be used
- Nutrient value of the digestate is such that many farms now use no mineral fertiliser
- Most of the farmers comment how much their nutrient management has improved since operation of the biogas plant started.

Summary

- Incentives for biogas production using agricultural slurries:
  - Nutrient management
    - Particularly important in NSZs
    - Increased slurry storage may present opportunities
  - Renewable energy production
    - Only economic with the import of other wastes
    - Has relied on grant aid or subsidies for capital investment where energy prices are not guaranteed
    - Can be financially profitable to farmers where prices are guaranteed and attractive to bankers for capital investment
  - Farm hygiene
    - Potential for pasteurisation of wastes reducing risk of the spread of plant and animal disease

Which policy or incentive do we follow to promote biogas technology on farms?

for discussion

Nutrient control and value of product

- Advantages of a digester
  - About half the volatile solids input to the digester is removed as CH_4.
  - Volatile fatty acids in the slurry, which tend to burn grass, are reduced from thousands of mg/l to about 250 mg/l
  - Much of the organic N is converted into ammonia yielding an effluent with 60 - 80% ammonia.
  - Potassium is very soluble and is retained as salts in the liquid phase of the final effluent.

Continued:

- About 1/3 of the available nitrogen is in the microbial biomass i.e. in the solid fraction.
- Phosphorus is very reactive and will stick onto any solids in the system.
- Thus the dewatered microbial biomass acts like a concentrated fertiliser when put on land and has slow release properties compared to mineral fertilisers.
- By separating solids you can therefore separate P and K fractions and use them as needed to balance soil fertility as well as exercising control over nitrogen addition

Disadvantages

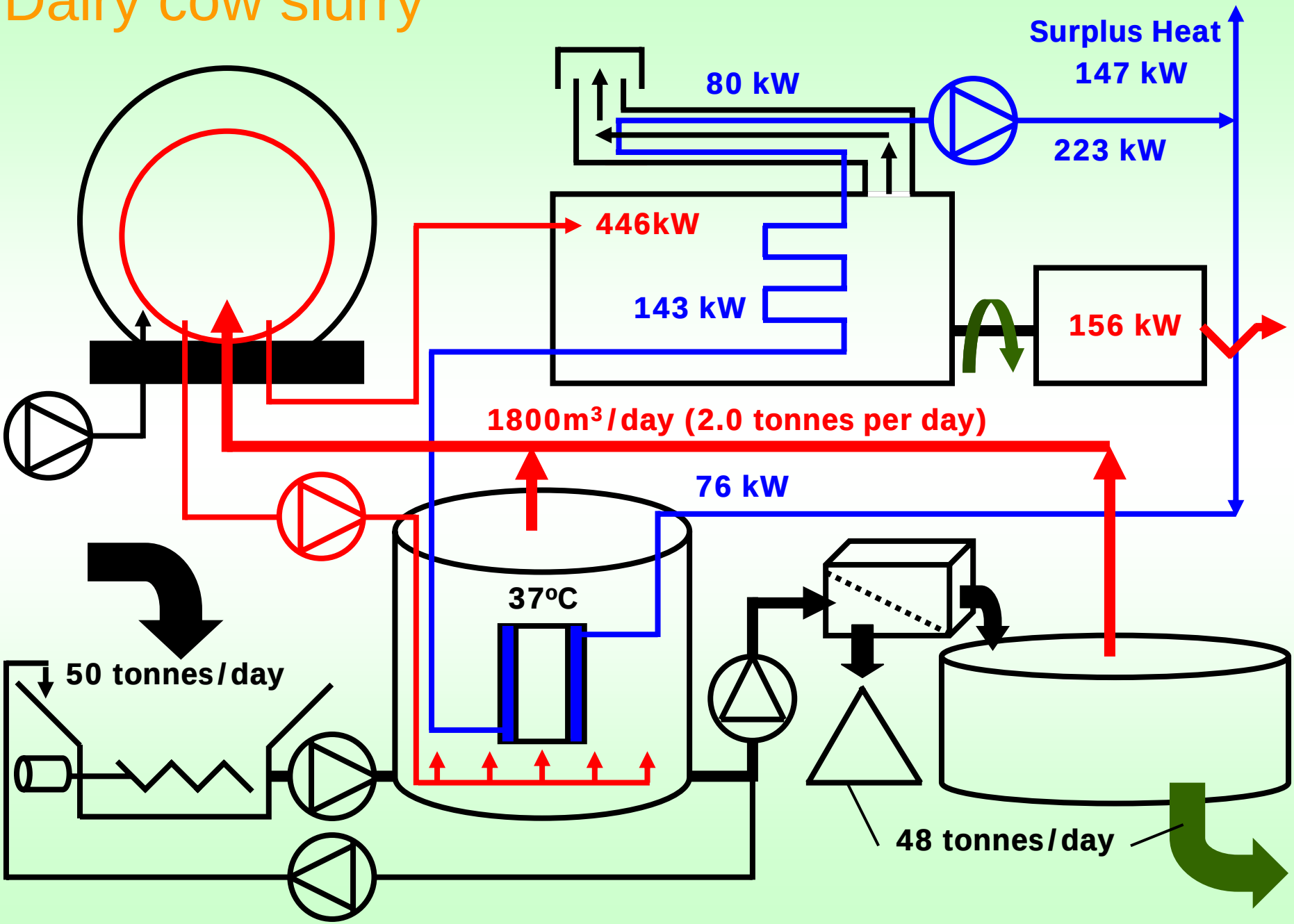
- Cost
- Why do it when I don’t have to?
- Loss of nitrogen on application has further environmental impacts
- Possible requirements for new farm machinery for subsoil injection

Energy production

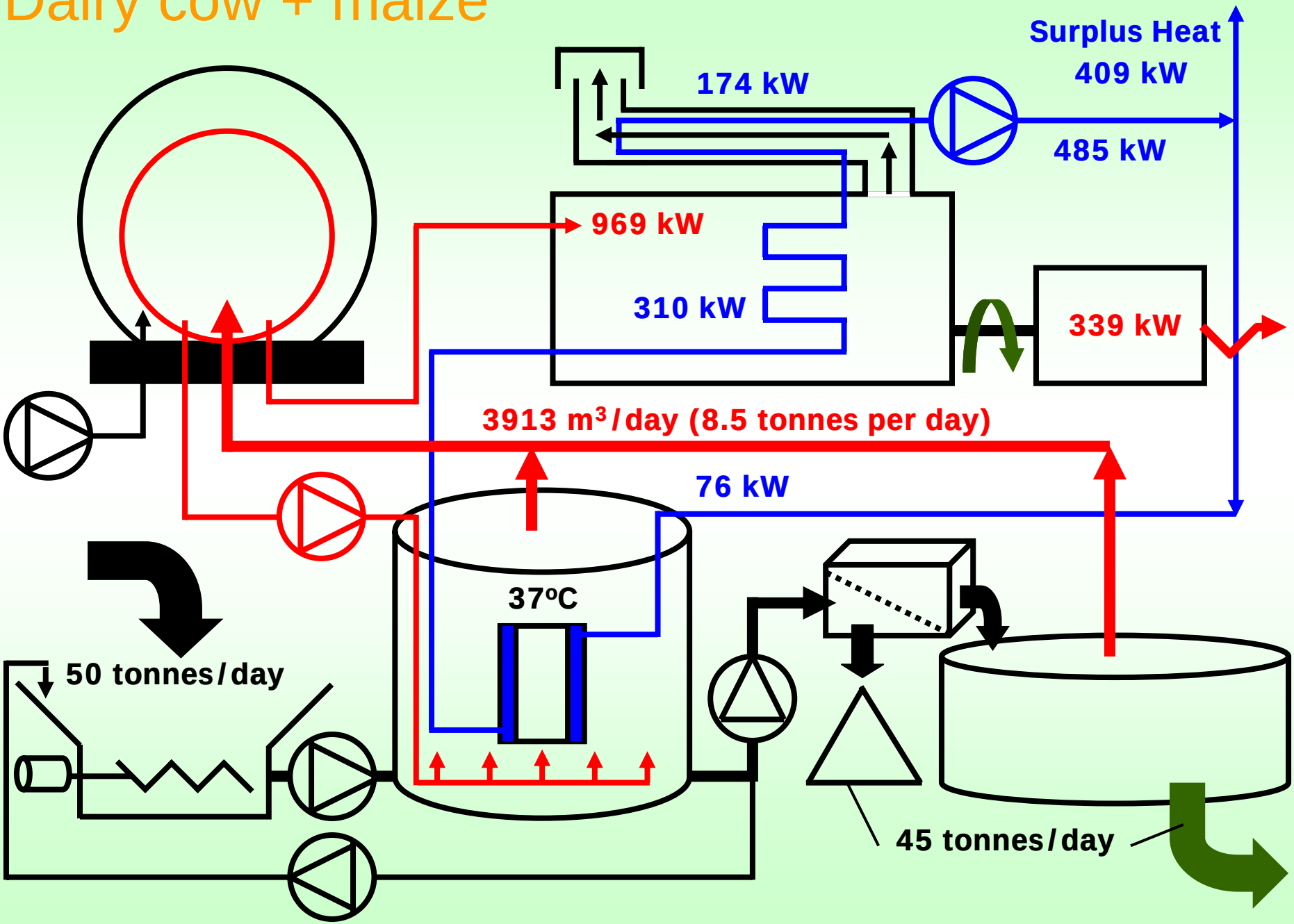
- Energy potential of animal slurries is low (~20m^3 biogas per wet tonne), but there is a lot of slurry!
- 1,250 million tonnes of slurry (current EU production) could yield 5263 GWh as heat, or if converted to electricity 90 GW continuous output
- Replacement of non-renewable energy sources would reduce CO_2 emissions by 2.6 million tonnes if used for power generation

	Dairy cow slurry	Dairy cow slurry + added maize	
Organic Dry Matter	4	8	tonnes/day
Organic Matter Reduction	2	5	tonnes/day
Mass of Biogas	2	5	tonnes/day
% CH_4	55	55	%
Volume of Biogas	1801	3913	m^3/day
Specific Loading Rate	1.48	2.96	kgODM/m^3/d
Digester Capacity	2700	2700	m^3
Hydraulic Retention Time	54	54	days
Volumetric Biogas Production	0.67	1.45	day^{-1}
Specific Methane Production	0.25	0.27	m^3CH_4/kgODM

Dairy cow slurry



Dairy cow + maize



Animal Health and Crop Protection

- Typically a dairy farm with a digester will find the net benefits of digestion expressed as a growth in herd size of about 1/8th to 1/4 in five years, with concomitant net improvements in both soil condition and grass health.
- Organic farming with a digester is not only possible but proven by long-term trials.

Continued:

- Pathogens survive weeks or months in unheated manure storage structures.
- Fresh manure mixed in a storage may be inadvertently field-applied with minimal reduction of pathogens.
- Separating digestate from raw slurry storage provides an additional barrier to ‘short circuiting’ in the system
- Pathogens are reduced in heated mesophilic (37 ^{o}C) and thermophilic (55 ^{o}C) digesters
- Inclusion of a pasteurisation stage (70 ^{o}C for 1 hour) ensures destruction of all animal and plant pathogens.
- Achieving pasteurisation through efficient use of heat exchangers means there is very little energy loss.

Dairy farm digester in Scotland

Built for pathogen control and protection of bathing waters

Other potential promoters of on-farm AD

- Carbon emission trading
- Methane trading - currently not included in European ETS: could this be extended to agriculture in 2008?

Thank you for your attention