Anaerobic Digestion – Benefits and Opportunities

Elaine Groom

QUESTOR Centre

Queen's University of Belfast

Dr. R. E. Groom, September 2007

Structure of Presentation

- Brief introduction of QUESTOR
- Anaerobic digestion
  - Process; Benefits
- Areas of application
  - Biogas potential from waste
  - Biogas as a transport fuel
- Future direction, needs and opportunity

The QUESTOR Centre

An International Industry/University

Cooperative Research Centre for

Environmental Research & Development

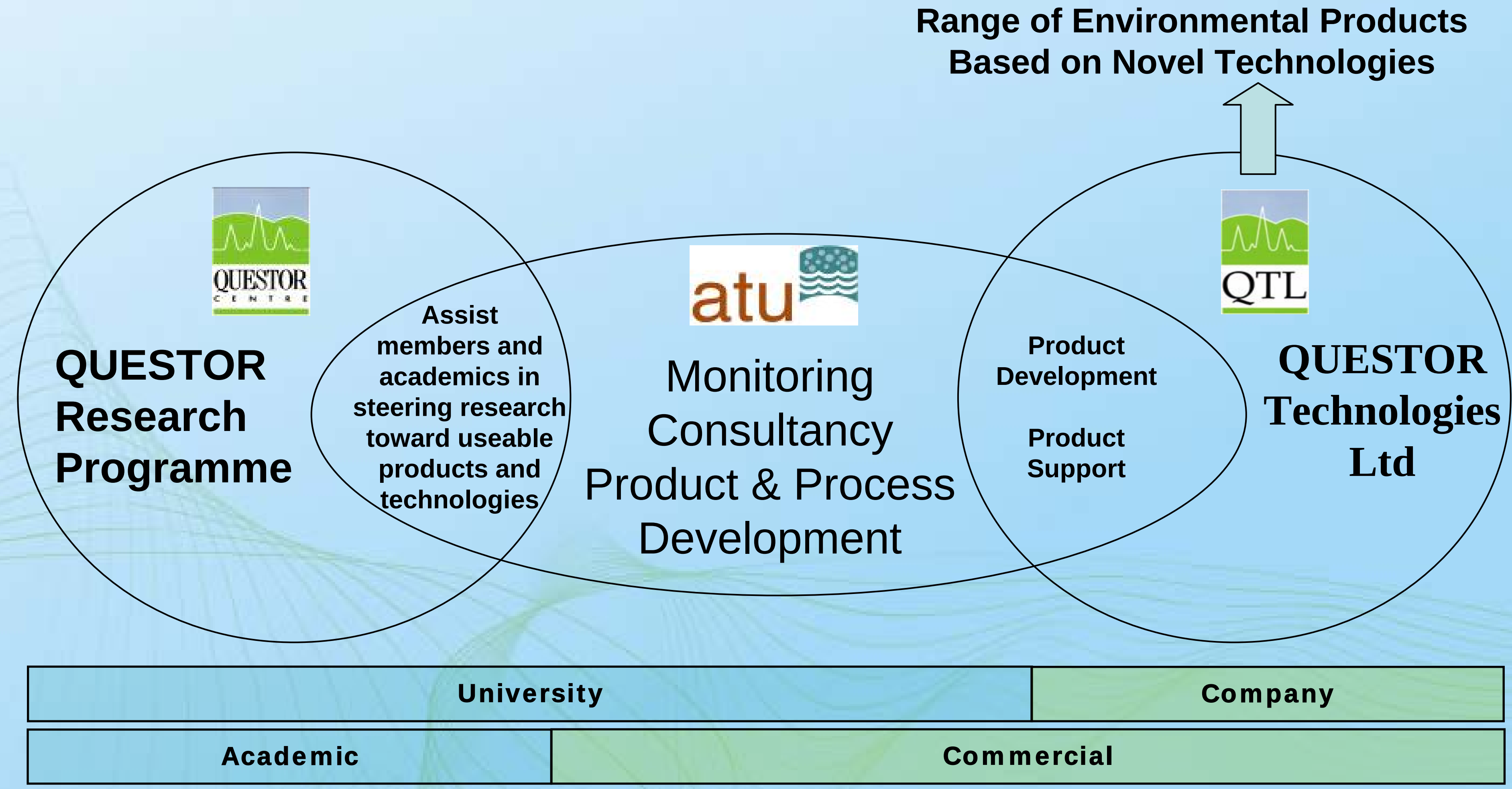
Partner Institutions

Queen's University Belfast

Dublin City University

Stevens Institute of Technology

QUESTOR Technology Transfer



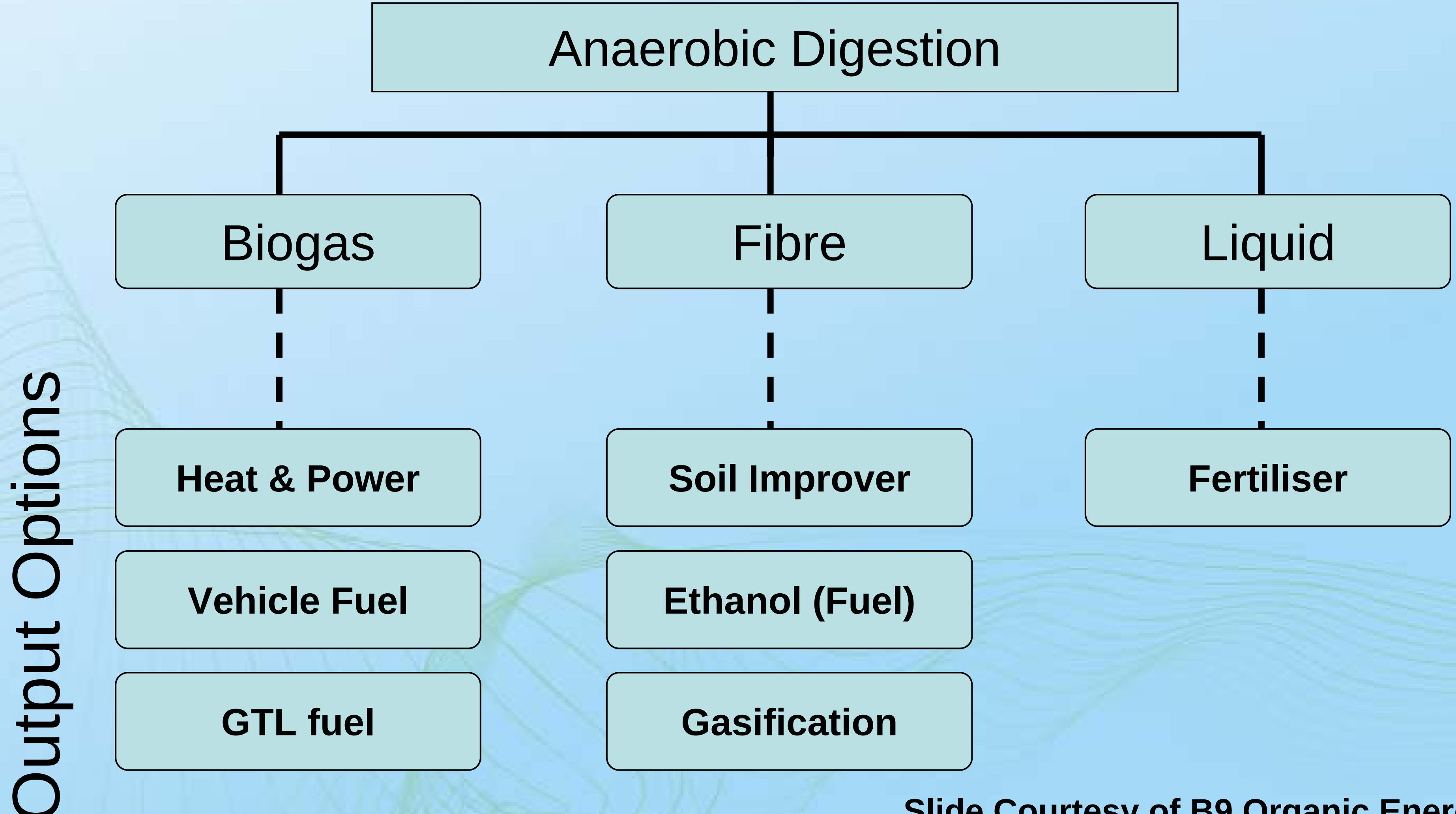
Anaerobic Digestion

- Biological process in which air is excluded
- Temperature
  - 37°C (mesophilic)
  - 55°C (thermophilic)
- Duration 15-30 days, can be much shorter
- Net energy production from treatment process
  - Biogas produced

  (55-70% methane, 30-45% carbon dioxide)
- Flexible feedstock utilisation
- Variable design and deployment

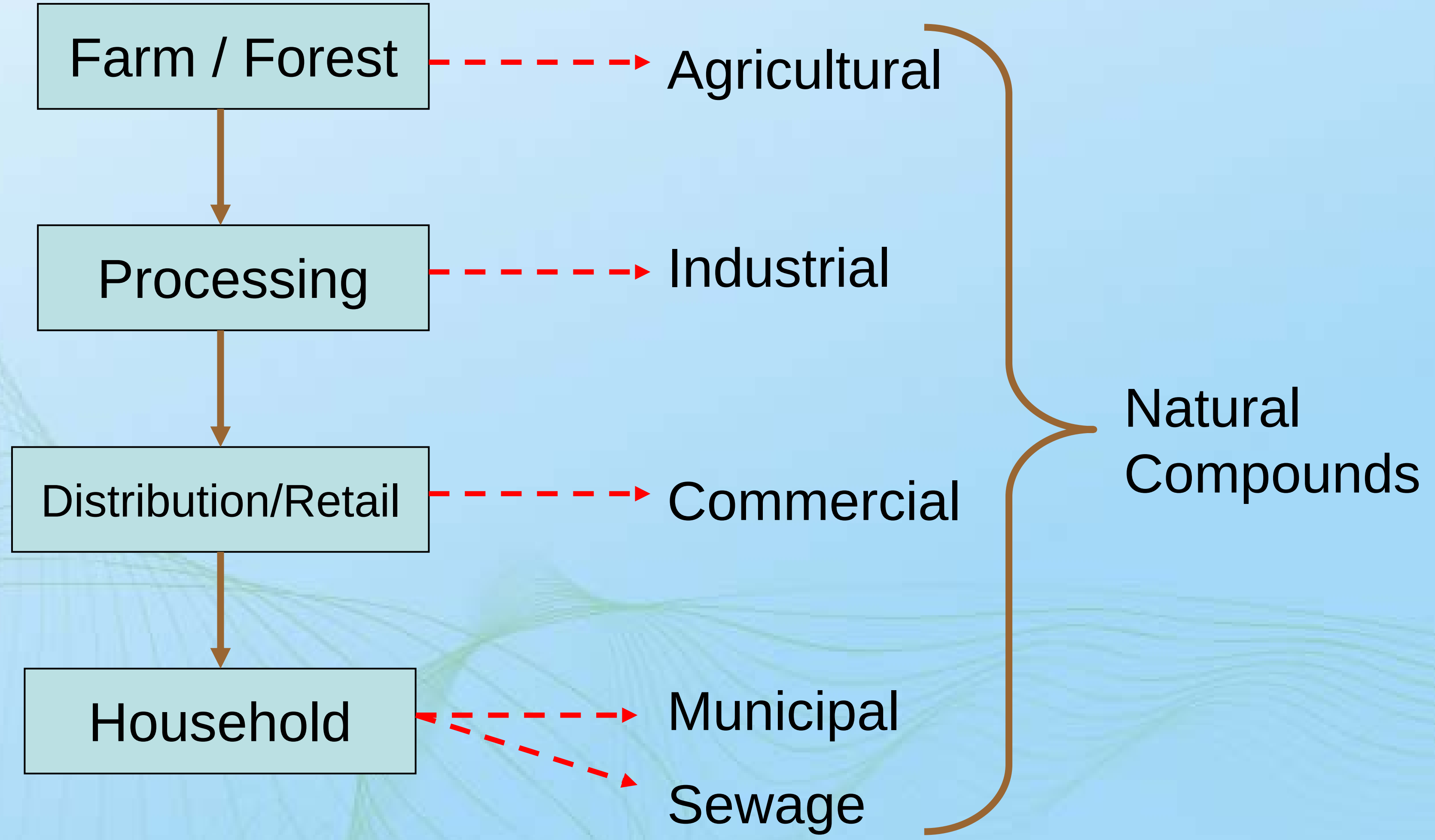
Steps in the AD process

Anaerobic Digestion: Benefits



Slide Courtesy of B9 Organic Energy

Sources of organic waste



Slide Courtesy of B9 Organic Energy

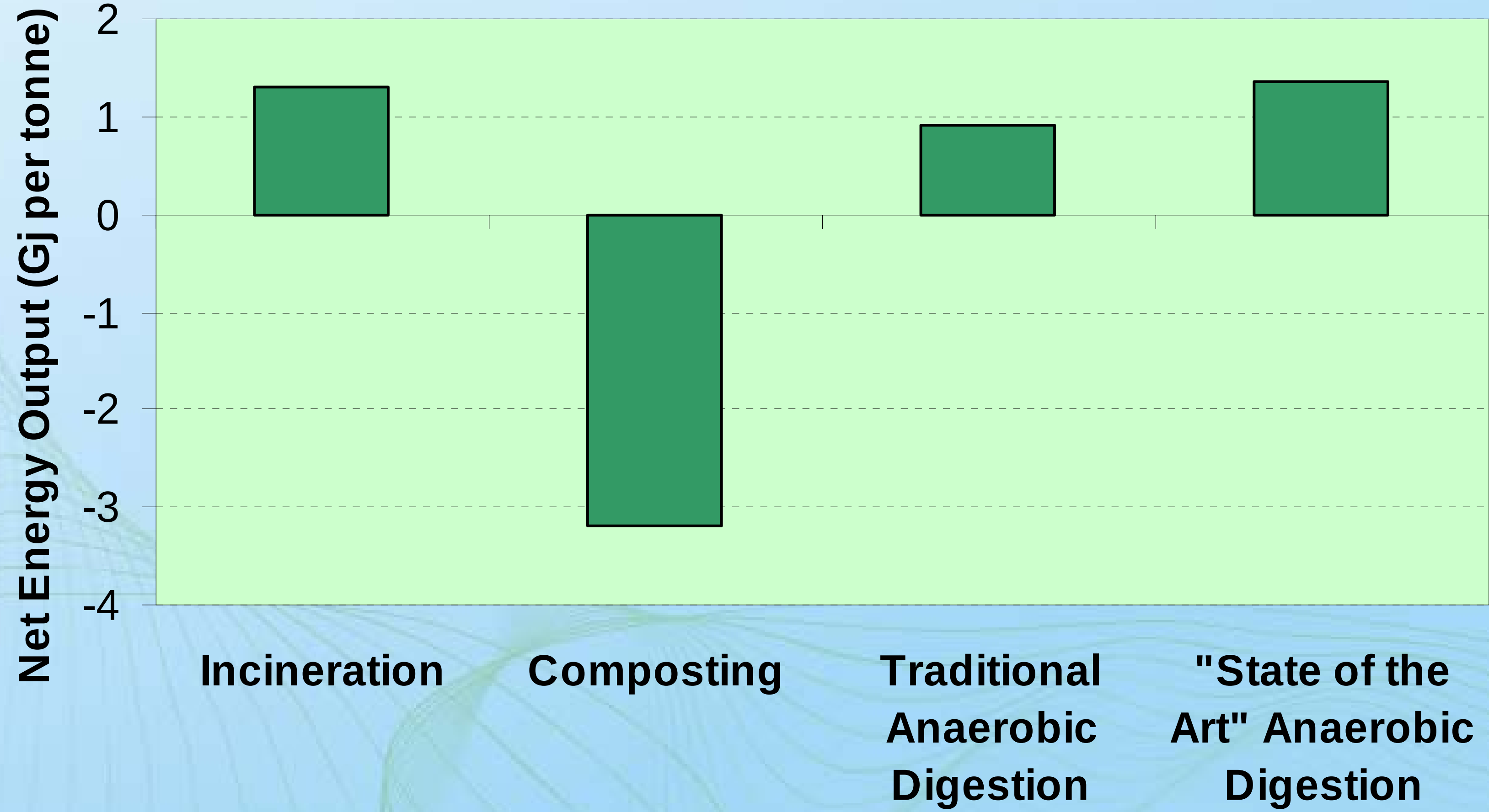
Waste Treatment Processes

Thermal		Biological
• Pyrolysis	No Oxygen	• Anaerobic Digestion
• Gasification	↓	
• Incineration	+ Oxygen	• Composting

Carbon (fuel) + oxygen = Carbon dioxide

Energy comparison Waste Treatment Technologies for OFMSW.

(OFMSW = Organic Fraction Municipal Solid Waste)



Calculations and Graph Courtesy of UK Environment Agency Waste Technology Data Centre

Biogas Potential in Ireland

EPA – National Waste Report – 2004

	Millions of Tonnes	Power Potential (MW)	Electricity Potential (MW)	Millions Of BOE (Barrel of Oil Equivalent)
Agricultural	60	750	250	3.9
Industrial / Commercial	3.2	540	180	2.8
Municipal (Household)	1.8	300	100	1.5
Totals	**65**	**1590**	**530**	**8.2**

Barrel of Oil Equivalent is a standard unit of 1700 kWh (energy)

Slide Courtesy of B9 Organic Energy

Biogas as a transport fuel

- Henry Ford
  - Ethyl Alcohol (ethanol) – fuel of the future (1925)

"There is fuel in every bit of vegetable matter that can be fermented".

Comparison of ethanol and biogas production from wheat in Ireland

	Biogas	Ethanol
Gross energy (GJ/t)	8.84	7.85
Electrical demand (kWh/t)	445	299
Thermal demand (kWh/t)	11.3	1055
Parasitic demands (GJ/t)	1.65	4.876
Energy required in process	18.6%	62.1%
Gross energy (GJ/ha/a)	**74.3**	**66**
Net Energy (GJ/ha/a)	**60.5**	**25**

Murphy JD, Power N; "An argument for using biomethane as a transport fuel in Ireland," (submitted to *Biomass and Bioenergy*).

Land area required to run a Dublin bus*

***28,000 litres of diesel per annum (1008 GJ/annum)**

	Crop t/ha	**Gross Energy GJ/ha/a**	Land required ha/a	Rotation	**Land required (ha)**
Biodiesel from rape seed	4	**42**	24	1 in 5	**120**
Ethanol from sugar beet	50	**105**	9.6	1 in 3	**28.8**
Ethanol from wheat	8.4	**66**	15.3	2 in 3	**23**
Biogas from sugar beet	50	**134**	7.5	1 in 3	**22.4**
Biogas from wheat	8.4	**74**	13.7	2 in 3	**21**
Biogas from silage	**60**	**155**	**6.5**	**6 in 7**	**6.5**

Modified from Murphy JD, Power N; "An argument for using biomethane as a transport fuel in Ireland," (submitted to *Biomass and Bioenergy*).
Energy values: Biodiesel 35MJ/l, ethanol 21MJ/l, biogas 21MJ/m3

How much bioenergy can Europe produce without harming the environment?

European Environment Agency Report No. 7/2006

Adapted from Annex 4 Table A.4	Grass	Sugar Beet	Wheat	Oilseed rape
Erosion	Low risk	High risk	Low risk	Med Risk
Soil Compaction	Low risk*	High risk	Low risk	Low risk
Nutrient Leaching	Low risk*	Med/High risk	Low risk	Med/High risk
Pesticide Pollution	Low risk*	Med risk	Med risk	High risk
Water Abstraction	Low	Varies	High	n/a
Farmland Biodiversity	Good*	Medium	Med/Low	Med/Low

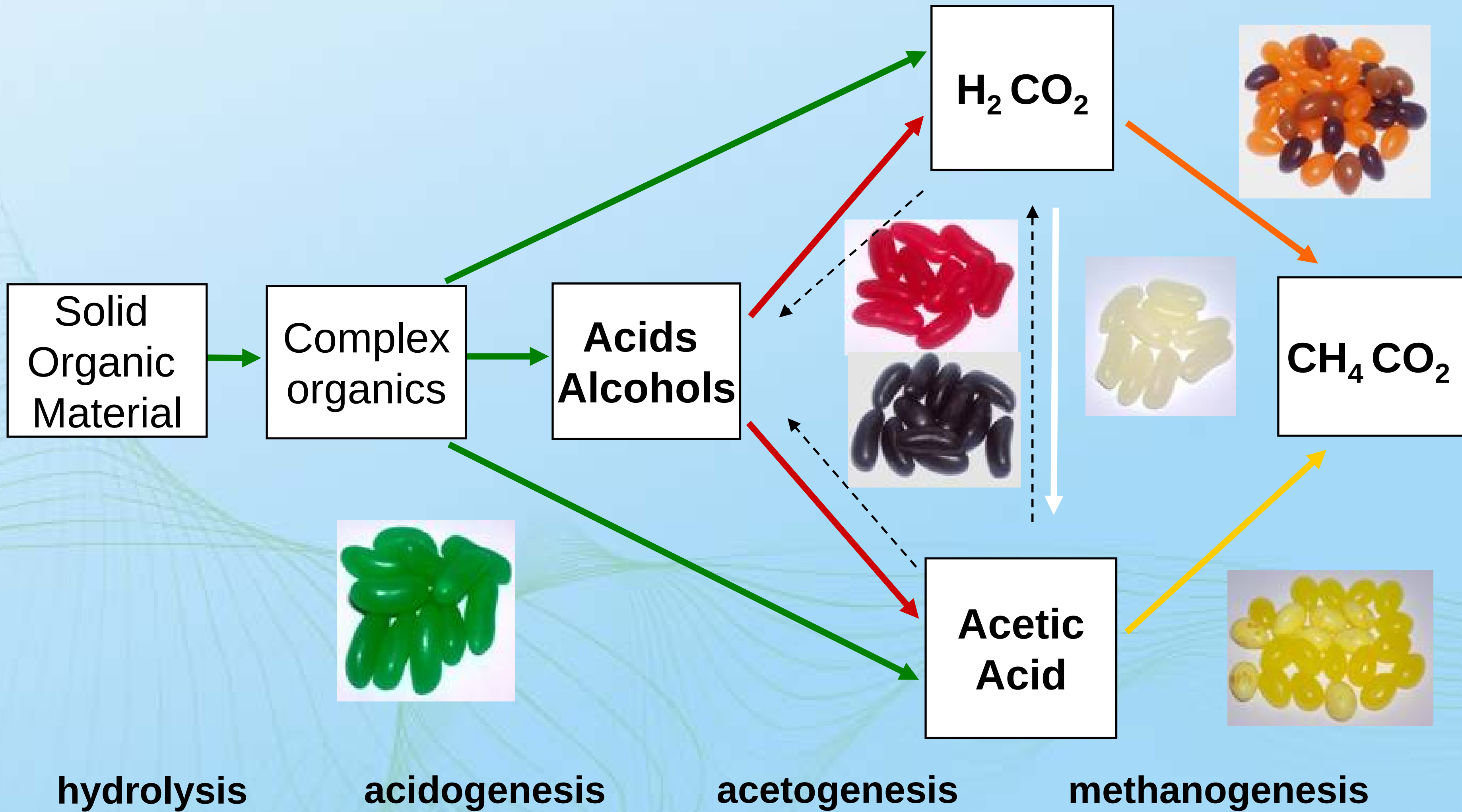
*Temporary grassland less beneficial than permanent

Future direction, needs and opportunity

Jever (75,000 tpa), Germany

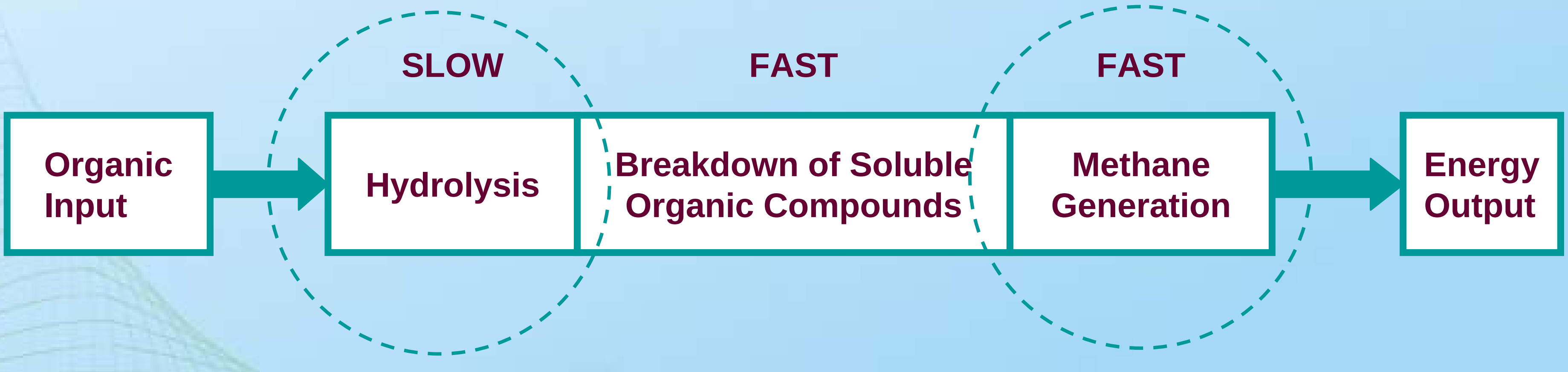
- Chemistry
  - ABPR compliance
  - Pre-treatment (enhanced hydrolysis)
  - Sensors
- Microbiology
  - Understanding
  - Control
- Engineering
  - Innovation in reactor design
  - Smaller, high rate plant
  - Lower cost at small scale

Understanding and control of AD



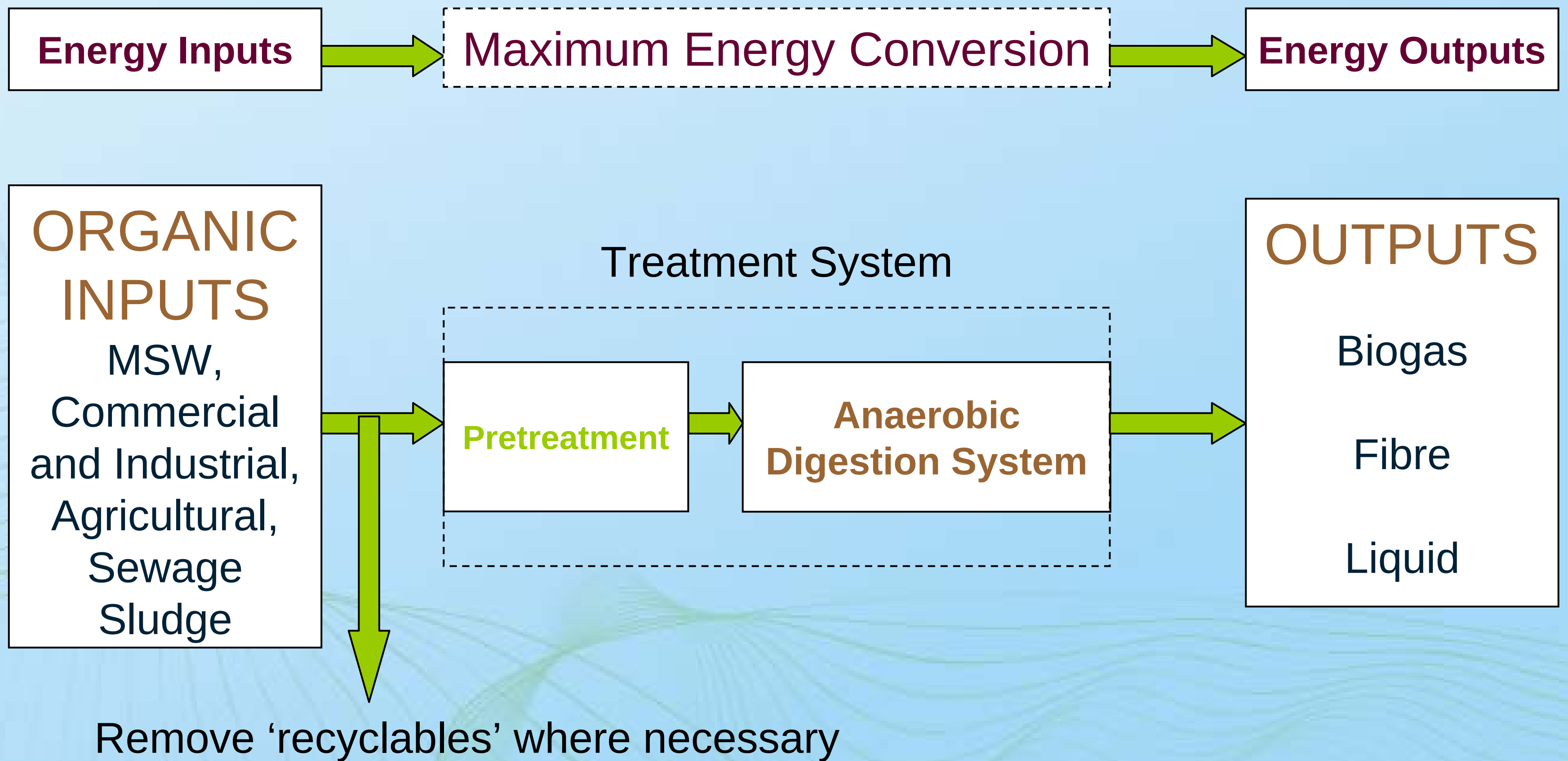
Rate Limiting Steps

Slow solubilisation



Slow growth of methanogenic bacteria

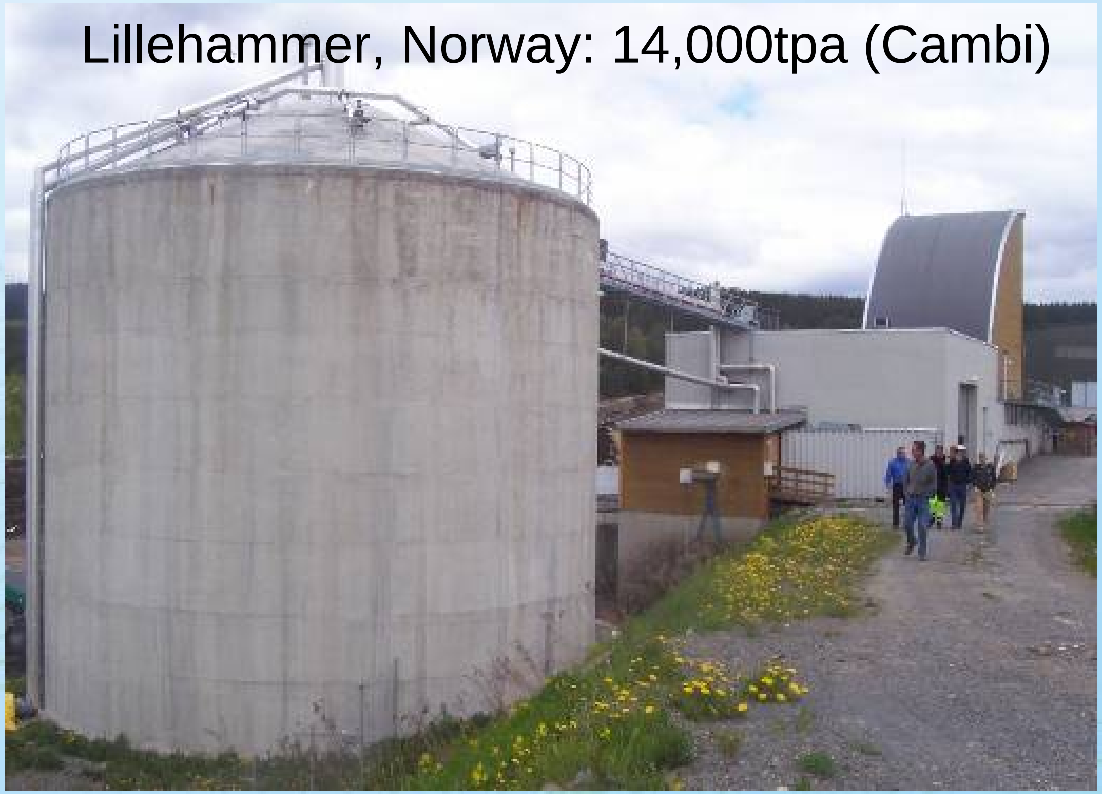
B9 Organic Energy Ltd
Knowledge Transfer Project



Slide Courtesy of B9 Organic Energy

Hydrolytic pre-treatment

Lillehammer, Norway: 14,000tpa (Cambi)



Source separated municipal & industrial waste

- **Innovative pre-treatment technology**
- **Animal By-Products Regulations compliant**
- **Increased Biogas**

Biomass retention

ArrowBio, Tel-Aviv

OFMSW - Hydraulic Retention Time: 3 days

AD: Opportunity in Ireland

Advantages:

- High potential for energy/fuel yield
- Good waste treatment technology
- Proven technology, with room for innovation
- Diverse feedstock sources
- Good environmental sustainability

But:

- Infrastructure requirement (and cost)
- Not high profile as production technology or fuel
- Unfamiliar technology