Biorefining & Bioenergy

AN ENTERPRISE IRELAND & IDA IRELAND INITIATIVE

Sustainable Energy

Opportunities to Improve Competitive Positioning

The Technology Centre For Biorefining & Bioenergy

WWW.TCBB.IE

Sustainable Energy and Bio -Products from Biomass

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ENTERPRISE IRELAND · UNIVERSITY of LIMERICK · UCD DUBLIN · TRINITY COLLEGE DUBLIN · NDP Transforming Ireland · IDA IRELAND · NUI Galway OÉ Gaillimh

Technology Centre Overview

- **An Industrial Development Programme -** funded by Enterprise Ireland & supported by IDA

- **Centre Focus** – collaborative effort of Industrial, Academic and Government institutions to develop and exploit biorefining & bio-energy technologies
  - 12 Post Doctorate Research Staff
  - Supervised by 5 Professor / Sr Lecturer Principal Investigators

- **Centre Membership –** Provides funding for research & commercial development targeted at bio-energy / biorefining issues

- **Centre Structure** – Association of members established by agreement
  - Circa 20 Industry members from various industries
  - Currently Co-hosted by several Irish Universities

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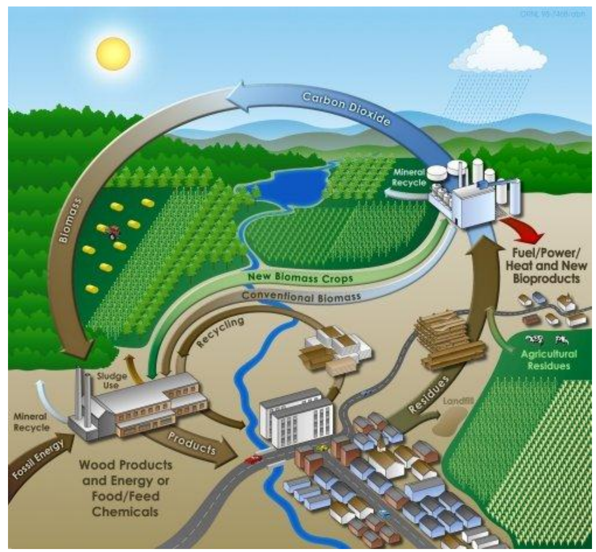
Practical Applications to Improve Sustainability

Successful sustainable development requires integration of a number of elements

Routes to Market

Supply Chain & Feedstocks

Technology Development



EU Framework

National & Local Gov't Regulation

Capital

Getting started is key – modular model - build on success

Drivers Encourage Migration Toward Sustainable Modes of Production

•**Global Drivers –**

- Economic Imperative – finite supply of fossil fuels drive price volatility
- Environmental Imperative – climate change and/or health issues

•**EU & Irish Policy Drivers (Sustainable Development Strategy) –**
Significant body of regulatory / policy initiatives provide increasing incentives

Examples:

- Renewable Energy Directives supported by NREAP's (*RES-E,H,T targets)*
  - ***REFIT tariffs -*** *premium for electricity generation from HE biomass CHP*
  - ***Excise/carbon taxes*** *= pricing differential – renewables vs fossil fuels (CNG)*
- *Waste Management Directives - Recycling & Waste Management Obligations*
  - ***Landfill levy*** *= increasing cost for disposal of wastes in landfill*
- *Air, water & soil quality measures*
  - ***Emissions trading scheme*** *– Cap & Trade carbon emission certs*

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REFIT III Tariff

Key Market Stimulus

- REFIT = Premium Tariffs on "High Efficiency" Renewable Electricity

Mode	Rate / kWh
AD CHP < 500 kWh_e	€.15
AD CHP > 500 kWh_e	€.13
Biomass Combustion CHP < 1500 kWh_e	€.14
Biomass Combustion CHP > 1500 kWh_e	€.12

Renewable electricity generation produces:

- 30%-40% electricity
- 60% - 70% heat
  - *40% - 50% recoverable*

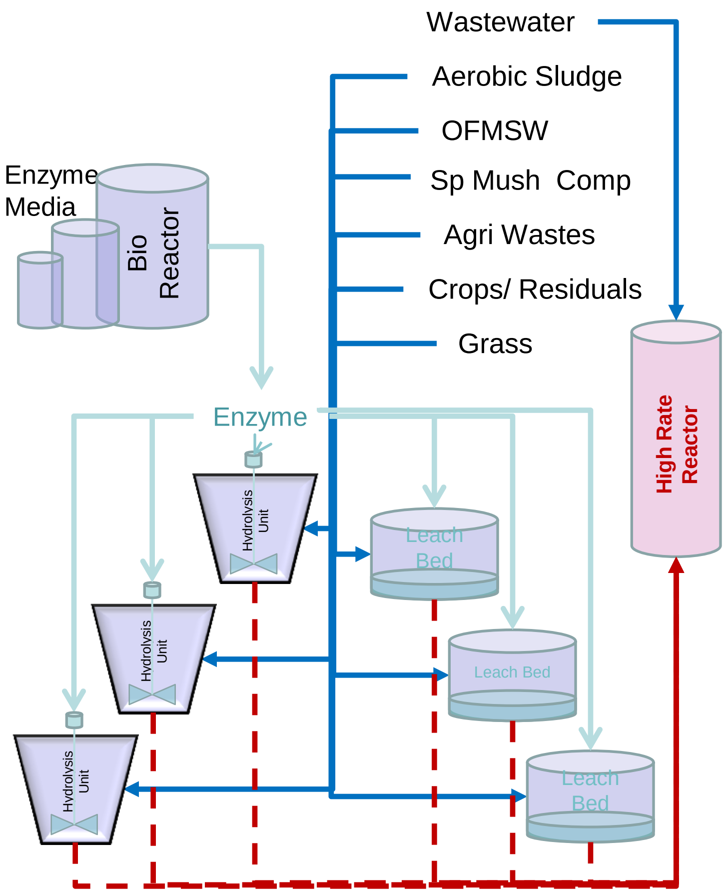
- Regulations require >75% use of input energy to qualify as HE
- Process energy can be considered as useful heat – justification req'd
  - *Rates are less than many EU countries – challenging environment*
  - *Requires monetisation of high % of heat energy value to be economical*

Dairy processing industry can be key industry stakeholder - significant processing heat requirements

Multiple Feedstock Options

Wastes & Residuals	Current Market Circumstance
Organic Black/Brown Bin MSW	*MBT& Landfilled @ significant disposal cost*
Recovered Paper Waste (SRF)	*Exported @ low value relative to potential*
Cattle Slurry	*Stored & landspread*
Poultry Litter	*Combusted or digested*
Straw/Crop residuals	*Mushroom compost/animal bedding*
Spent Mushroom Compost	*Landspread*
Meat & Bonemeal	*Shipped to NE or overseas to process*
Agri Food Process Residuals	*Large variety – disposal varies*
Aerobic Sludges	*Landspread/landfilled @ disposal cost*
Energy Crops	*Requires significant planting & development of market*
Grass/Silage	*Preference for use in Dairy/Beef Industry*
Sugar Beet	*Subject to Quota Renegotiation*
Woody Biomass	*Demand (1.5m M^3) outstrips supply (1.0m M^3)*

Fragmented supply chain may require co-processing of feedstocks to improve production & economics – handling implications for some types of wastes

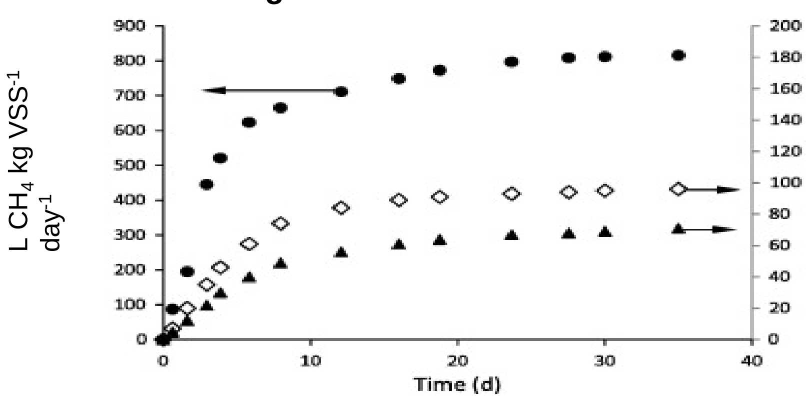


Technology Developments

- **Low cost enzyme systems** *to break recalcitrant solids into easily processed liquids- enable co-processing & expedite digestion / reduce residence time*
- **Integrated process flows** *to improve feedstock flexibility, cost & efficiency*

- **Optimisation of microbial innoculants**
  - *–Reduced operating temperatures*
  - *–Increased tolerance to conditions*
  - *–More productive*

Strong inoculum effect

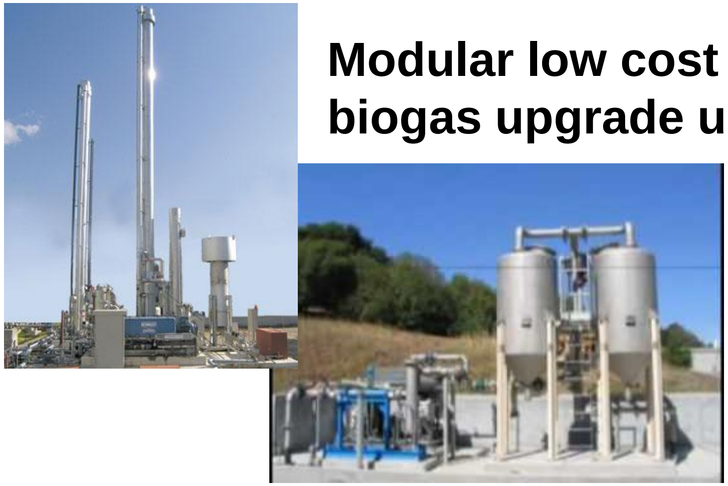


Engineering Developments – Anaerobic Digestion

Improved high rate AD reactors

Improved CHP efficiency

Modular low cost biogas upgrade units



Adoption of bi-fuel / NGV transport

Market Opportunities

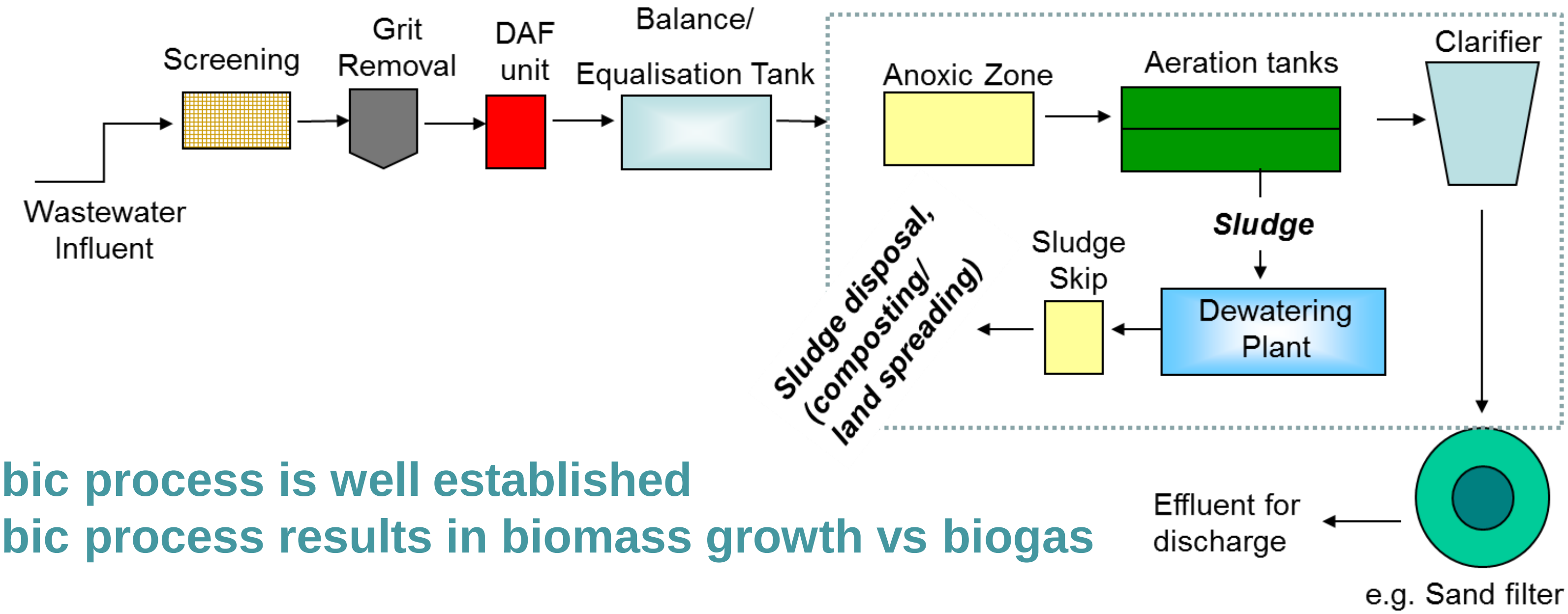
In context of capital investment driven by production intensification together with market developments offer opportunities to reduce energy and/or waste processing costs

Most immediate possibilities:

- ***Processing Plant Waste-to-energy Anaerobic Digestion***
  - *Biogas for heating / cooling*
  - *Biogas for CHP*
  - *Biogas for CNG transport fuel*
- ***Collaborative Projects with:***
  - *Biomass CHP*
  - *Thermal Processing MSW - CHP*
  - *Farm Based Anaerobic Digestion*

Illustration:
Dairy Waste Water Processing

Conventional Aerobic Waste Water Treatment Process



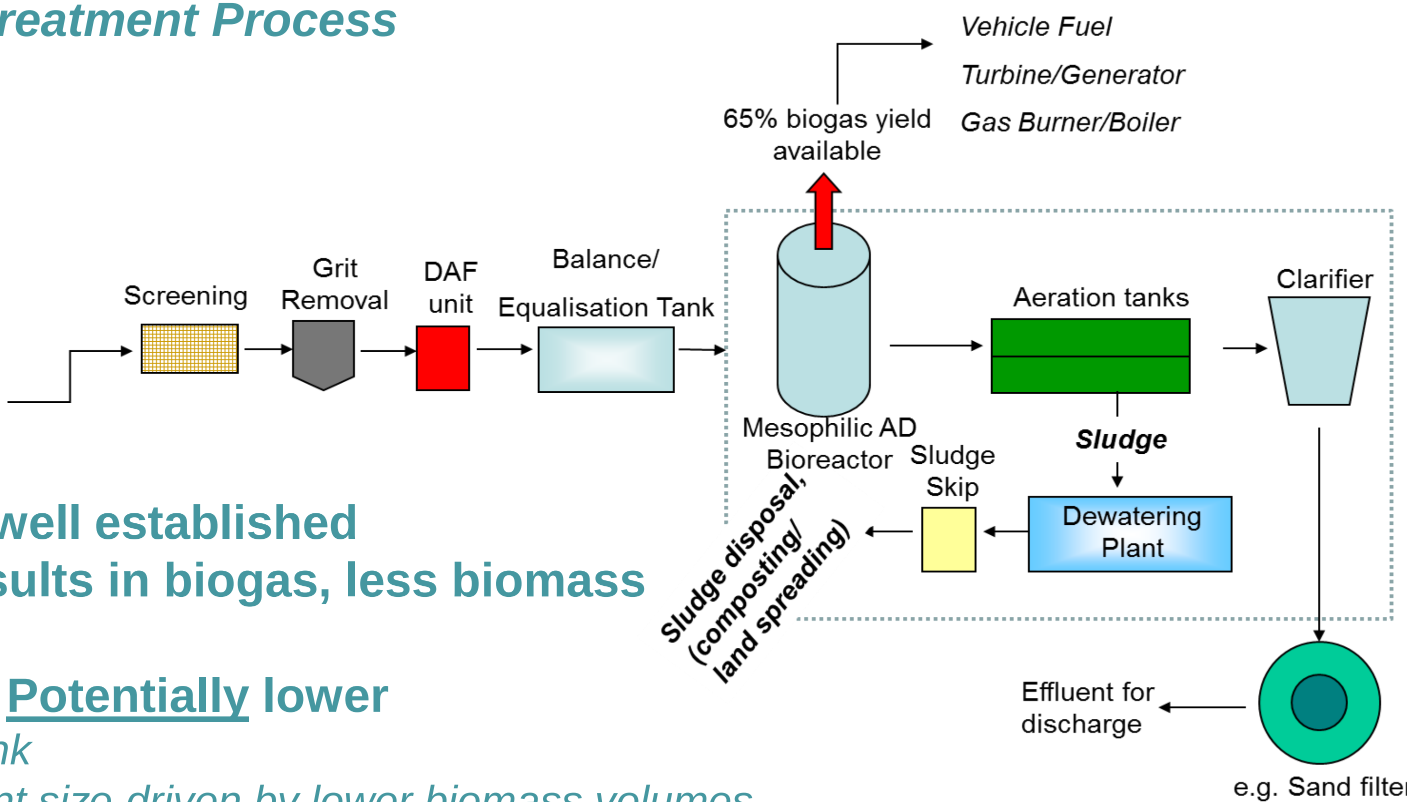
- **Aerobic process is well established**
- **Aerobic process results in biomass growth vs biogas**

- **Capital Costs**
  - *Multiple tanks for anoxic cycling from aerated to non aerated*
  - *Larger tank sized for larger biomass processing volumes*

- **Operating Costs - no realisation of waste-to-energy value**
  - *Energy cost of aeration / biomass movement thru process*
  - *Disposal (transport) costs re land spreading biomass volumes*
  - *Increased plant costs from increased plant size*

Illustration:
Dairy Waste Water Processing

Migration to Mesophilic Anaerobic Digestion Wastewater Treatment Process



- **AD process is well established**
- **AD process results in biogas, less biomass**

- **Capital Costs - <u>Potentially</u> lower**
    - *Single AD tank*
    - *Reduced plant size driven by lower biomass volumes*

- **Operating Costs - <u>Potentially</u> reduced – realisation of excess energy value**
    - *Lower energy cost of biomass movement thru process & reduced plant costs -smaller plant*
    - *Lower biomass volumes results in low sludge disposal costs*

Illustration:
Dairy Waste Water Processing

Hypothetical Plant: Comparison of Aerobic vs Anaerobic WWT

Operating Assumptions	Aerobic	Anaerobic
Avg milk consumption per annum	120,000 M^3	120,000 M^3
Avg waste water produced per annum	300,000 M^3	300,000 M^3
Avg COD removed -4,000 mg/ltr	1,200,000 kg	1,200,000 kg
Avg Biogas produced -.55 M^3/Kg COD removed	-	660,000M^3
Avg CH_4 (60%) = .33 M^3/Kg COD removed	-	396,000M^3
Avg LHV of Biogas @ .0223 GJ/M^3	-	4,089 MWh_T
Avg LHV of Upgraded Bio CH_4 @ .0361 GJ/M^3	-	3,971 MWh_T
Avg Thermal Energy utilised in AD process (approx 33%) MWh_T	-	(1,500) MWh_T
Avg Biomass sludge into dewatering @ 1% Dry Solids	30,000 M^3	7,500 M^3
Avg dewatered Biomass sludge for disposal @ 20% Dry Solids	1,500 M^3	-

Source: TCBB process data and process estimates

Health Warning – Actual Results Dependent on Numerous Factors

- *Feedstock composition, variability and availability*
- *Plant configuration, process flow & operating parameters*
- *IPPC licence conditions & market conditions*

Illustration:
Dairy Waste Water Processing

Hypothetical Plant : Comparison of Aerobic vs Anaerobic WWT

Estimated Incremental Capital Costs - € 000’s	Aerobic	Anaerobic
Prelim/Primary - Screening, Grit Removal, DAF, Balance/Equal tanks = €1.5 / M^3 WW capacity	Common	Common
Aerobic Secondary - 2X400 M^3 Denitrification tanks, 1 X 1,500 M^3 aeration tank, 2 X 500 M^3 settlement tanks, centrifuge & dewatering	1,500	
Anaerobic Secondary - 1X400 M^3 Digestor, 1 X 400 M^3 aeration tank, 2 X 250 M^3 settlement tanks, small centrifuge & dewatering		1,000
Tertiary	Common	Common
Estimated Savings re Anaerobic Capital Costs	**(500)**	

Estimated Incremental Annual Op. Costs - €000’s	Aerobic	Anaerobic
Plant Costs – maint/insurance/elect etc	60	30
Process Materials - pH / P removal (lime/caustic/polymer etc)	46	46
Labour – 1 man yr incl burden	44	44
Biomass Sludge disposal @ €65 per M^3	97	-
Subtotal	247	120
Estimated savings re Annual Anaerobic Operating Costs	**(127)**	

Illustration:
Dairy Waste Water Processing

Extracting Energy Value – Biogas for Heating/Cooling

SEAI Avg. Gas Price – 2nd Half 2011

Band	Range-MWh	€/MWh*
I1	<278	50.40
I2	278-2.8k	45.80
I3	2.8k-28k	39.50
I4	28k-278k	27.00

*SEAI Report - Excludes VAT

- Use of biogas for steam -
  - *Small steam boiler optimised for biogas*
  - *Minor gas scrubbing for use w/ boiler – (burner spec ?)*
- Can be used for low grade process heat / absorption cooling
- Assume recovery of low grade process heat for AD process

Comparative Capital Cost € 000's Euros	
Capital Cost Savings – Anaerobic	(500)
Incr. Capital – Gas Steam Gen	100
Net Savings	**(400)**
Comparative Annual Op Costs € 000's Euros	
Op Cost savings – Waste	(127)
Energy Value – 4,089 MWh_T @ € 39.50 per MWh_T	(162)
Incremental Op Cost – Energy	20
Net Savings per annum	**(269)**

Illustration:
Dairy Waste Water Processing

Extracting Energy Value –
Biogas for Combined Heat and Power (CHP)

SEAI Avg. Elect. Price – 2^{nd} Half 2011

Band	Range-MWh	€/MWh*
IA	<20	198.30
IB	20-500	150.60
IC	500-2k	129.40
ID	2k-20k	97.70
IE	20k-70k	85.60

*SEAI Report - Excludes VAT

- Assume in house use of electricity
- Grid connection – may earn REFIT tariff of €150.00 per Mwh_e
  - *Generates added revenue (€30K)*
  - *Incurs grid connection costs*
- Use of recovered heat for process heating / cooling may add an additional €50K value pa

Comparative Capital Cost € 000's Euros	
Capital Cost Savings – Anaerobic	(500)
Incr. Capital – 200kWh$_e$ CHP	300
Net Savings	**(200)**
Comparative Annual Op Costs € 000's Euros	
Op Cost Savings – Waste	(127)
Electric Value 4,089 MWh$_T$ @ 35%=1,431 MWh$_e$ @ € 129.40	(185)
Thermal Value 4,089 @40%=1,635 assume all used for AD process	-
Incremental Op Cost – CHP	40
Net Savings per annum	**(272)**

Illustration:
Dairy Waste Water Processing

Extracting Energy Value – Biogas for Transport

CNG Transport Fuel - 1 M^3 of CH_4 approx = 1 Ltr Diesel	**€/Ltr**
Diesel Price	€1.60
Less VAT @ 23%	.30
Less Excise/Carbon Tax	.48
Wholesale Diesel Cost	€ .82

- Need CNG Fleet
  - *Vehicle capital cost prem. (reducing)*
  - *Short haul fleet – ltd.refueling options*
  - *NGV's not quite as efficient as diesel*
- Biogas upgrade & delivery
  - Multiple technologies available
  - Specialist skill set
  - Signif'nt capital & op costs – reducing

Comparative Capital Cost € 000's Euros	
Capital Cost Savings – Waste	(500)
Capital – Vehicles 4@25K ea	100
Capital – Gas Upgrade/Deliv'r	1,000
Net Added Capital Cost	**600**
Comparative Annual Op Costs € 000's Euros	
Comparative Op Costs – Waste	(127)
Fuel Value – 396,000 M^3 (less 5% loss) @ € .82	(308)
Incremental Op Cost – CH_4 Upgr'd	150
Net Savings per annum	**(285)**

Transport Fuel Option more likely as part of larger collaborative project

Farm Based AD

Economics Specific to Circumstances

- Has to be tightly managed process
- Need route to market for value premium –
  - *REFIT qualifying CHP – route for monetisation of heat*
  - *Realisation of value as transport fuel*
- Need minimum scale – 10,000 – 15,000 DMT feedstock per annum
- Multiple Feedstocks -
  - *Supplement Cattle slurries (very low biogas productivity)with:*
    - *Poultry Litter*
    - *Food Wastes or Agri Food Process Wastes (gate fee)*
    - *Digestible energy crop (biodiversity requirement?) – cost issue*

Farm based systems will benefit from technology development & access infrastructure

Thermal Processing Options

Pyrolysis & gasification facilitate use of agri / MSW solid wastes – can assist emissions concerns

Advances in traditional biomass CHP generate higher energy recovery & greater efficiency, modular sizing improving economics

Advanced combustion facilitates use of moist feedstocks – agri / MSW fractions

Thermal Processing Options

Solid Waste or Traditional Biomass Heat /CHP

- **Economics – specific to circumstances**
  - *Biomass boilers compete effectively with heating oil*
  - *Biomass CHP can be economical where low cost high energy fuel serves constant heat demand*
  - *Economics of biomass CHP improve with waste feedstock –(disposal cost avoidance circa €160/MT – gate fee/transport/levy)*

ESCO contract – risk management & perception concerns

Collaborative Approach

Optimise Market Opportunities / Industry Development

- **Develop Market Access Infrastructure** –
  - *Biogas collection & upgrade networks – gas grid injection*
  - *District Heating Network - aggregate demand*

- **Clustering Approach - Facilitate efficient production**
  - *Localised concentration - efficient resource processing*

- Leveraging significant technological developments & staff skills
- Catalyst for new industrial development - biorefining
- Benefit from shared capital

Significant EU Support

- **ERDF –** EU Regional Development Funds (circa €600m 2014 - 2020)
  - *Currently in process of defining programme - encourage Irish gov't to establish a bio-based infrastructure programme*
  - *PPP's whereby 50% public funding from ERDF is matched by private invest.*
  - *Examples:*
    - *–ERDF funded District Heating Scheme serviced by private CHP operators*
    - *–ERDF funded biogas collection & upgrading scheme serviced by private AD biogas generators*
  - *Envisage 10 communities with €20M public funds each matched by €20 m private investment = significant development*
- **DG Agriculture & Rural Development –** Considering PPP Programme
- **EIBI –** programme aimed at large scale demonstration projects (€2Bn)
- **EU FP7 Projects –** Research projects & demonstration activities

Much of EU Support is Competitive - Oriented Towards SME's

Consider How Projects are Structured

Summary –

- **Are opportunities where sustainable options are economic to deploy**
- **In current environment these are specific to individual circumstances**
- **Collaborative effort can stimulate market development**

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