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Our network

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for your alternative gas

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Wales & West Utilities

- We are the gas emergency and pipeline service for Wales and the south west of England
- We don’t sell gas; we transport it through our 35,000km network of pipes
- We keep 7.5m people safe and warm – with levels of service, safety and reliability they can trust
- We respond to more than 80,000 gas emergencies a year
- We invest £2m a week connecting new homes & businesses to our gas network & upgrading old metal pipes to new plastic ones
- We employ more than 1370 people & have a contract workforce of around 600
- We are regulated by Ofgem

We are a values-driven business – safety is our number one priority and our customers at the heart of everything we do

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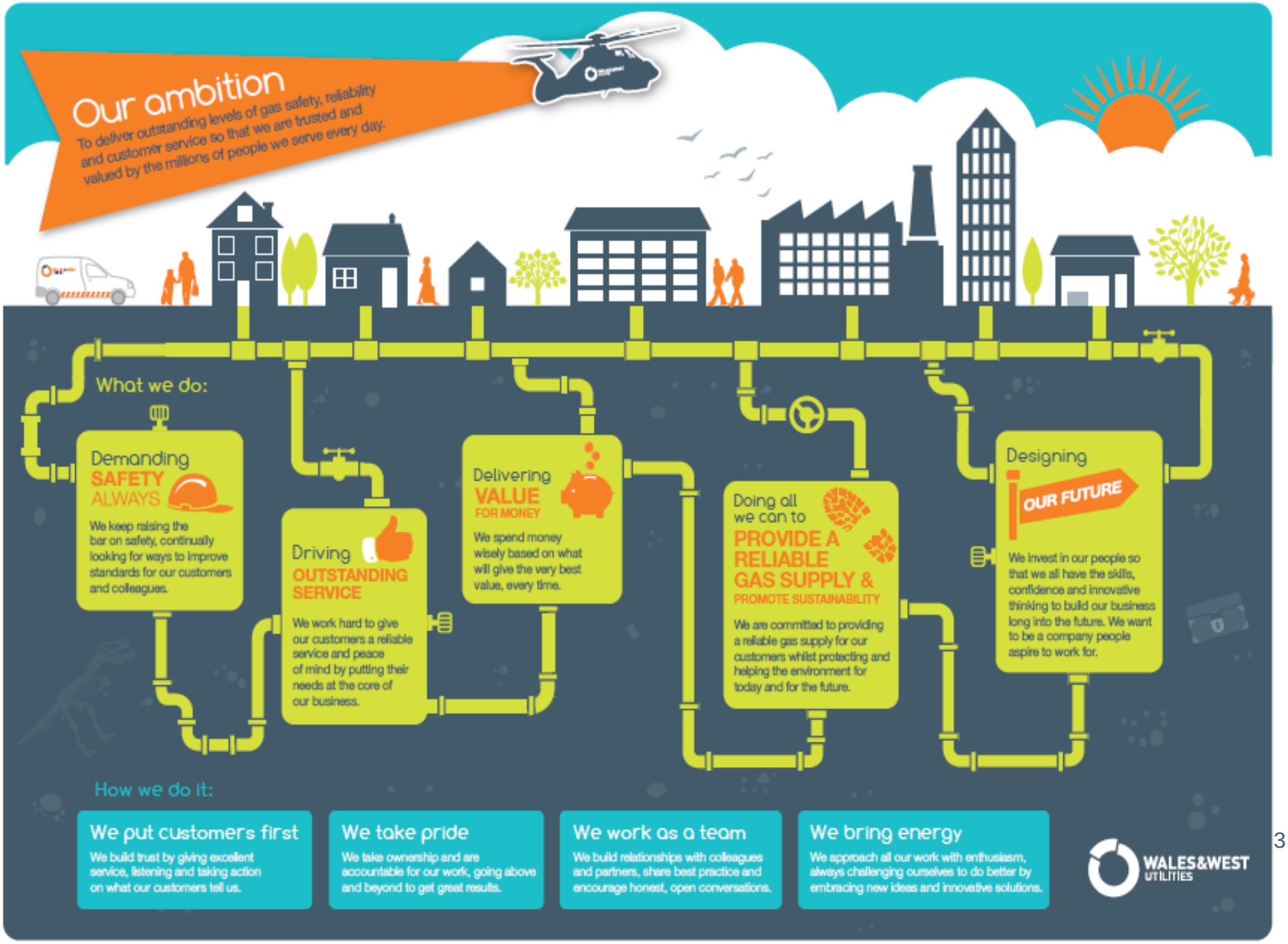
Our ambition
To deliver outstanding levels of gas safety, reliability and customer service so that we are trusted and valued by the millions of people we serve every day.
What we do:
Demanding SAFETY ALWAYS
We keep raising the bar on safety, continually looking for ways to improve standards for our customers and colleagues.
Driving OUTSTANDING SERVICE
We work hard to give our customers a reliable service and peace of mind by putting their needs at the core of our business.
Delivering VALUE FOR MONEY
We spend money wisely based on what will give the very best value, every time.
Doing all we can to PROVIDE A RELIABLE GAS SUPPLY & PROMOTE SUSTAINABILITY
We are committed to providing a reliable gas supply for our customers whilst protecting and helping the environment for today and for the future.
Designing OUR FUTURE
We invest in our people so that we all have the skills, confidence and innovative thinking to build our business long into the future. We want to be a company people aspire to work for.
How we do it:
We put customers first
We build trust by giving excellent service, listening and taking action on what our customers tell us.
We take pride
We take ownership and are accountable for our work, going above and beyond to get great results.
We work as a team
We build relationships with colleagues and partners, share best practice and encourage honest, open conversations.
We bring energy
We approach all our work with enthusiasm, always challenging ourselves to do better by embracing new ideas and innovative solutions.
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Introduction to the day

- Why we're here today – to hear your views
- What we're doing in this arena
- Guest speakers
- Importance of your feedback
- Workshop facilitators

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Westbourne

- Who we are
- Housekeeping
- Agenda

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Agenda

Registration	10.00 – 10.30
Introduction to WWU	10.30 -10.40
Session one: Introduction to Alternative Gas – **Bethan Winter, System Operations Manager, Wales & West Utilities**	10.40 – 10.55
Workshop 1: Levels of awareness of Alternative Gas	10.55 – 11.05
Session 2 (Part one): Connections – **Chris Magness, Green Gas Connections Manager, Wales & West Utilities** Session 2 (part two): Connections – **Bethan Winter, System Operations Manager, Wales & West Utilities**	11.05 – 11.30
Workshop 2: Refining the connections process	11.30 – 11.50
Coffee break	11.50 – 12.05
Session 3 (part one): Moving forward (case studies): • **Lorna Millington, Design Manager, National Grid Gas Distribution** • **Professor Sandra Esteves, Energy and Materials Director, Wales Centre of Excellence for Anaerobic Digestion, University of South Wales**	12.05 – 12.30
Q&A Panel discussion – hosted **by Sarah Williams, Business Improvement Manager, Wales & West Utilities**: • **Chris Clarke, Director of Asset Management, Safety & Environment, Wales & West Utilities,** • **Bethan Winter, System Operation Manager, Wales & West Utilities,** • **Professor Sandra Esteves, Energy and Materials Director, Wales Centre of Excellence for Anaerobic Digestion – University of South Wales** • **Lorna Millington, Design Manager, National Grid Gas Distribution**	12.30 – 12.40
Session 3 (part two): Moving forward (Designing our future) - **Ian Marshall, Green Gas Development Manager**	12.40 – 12.55
Workshop 3: Prioritising our activities	12.55 – 13.15
Close	13.15 – 13.20
Lunch and networking	13.20 – 14.00

SESSION 1:
INTRODUCTION TO ALTERNATIVE GAS

Bethan Winter
System Operation Manager

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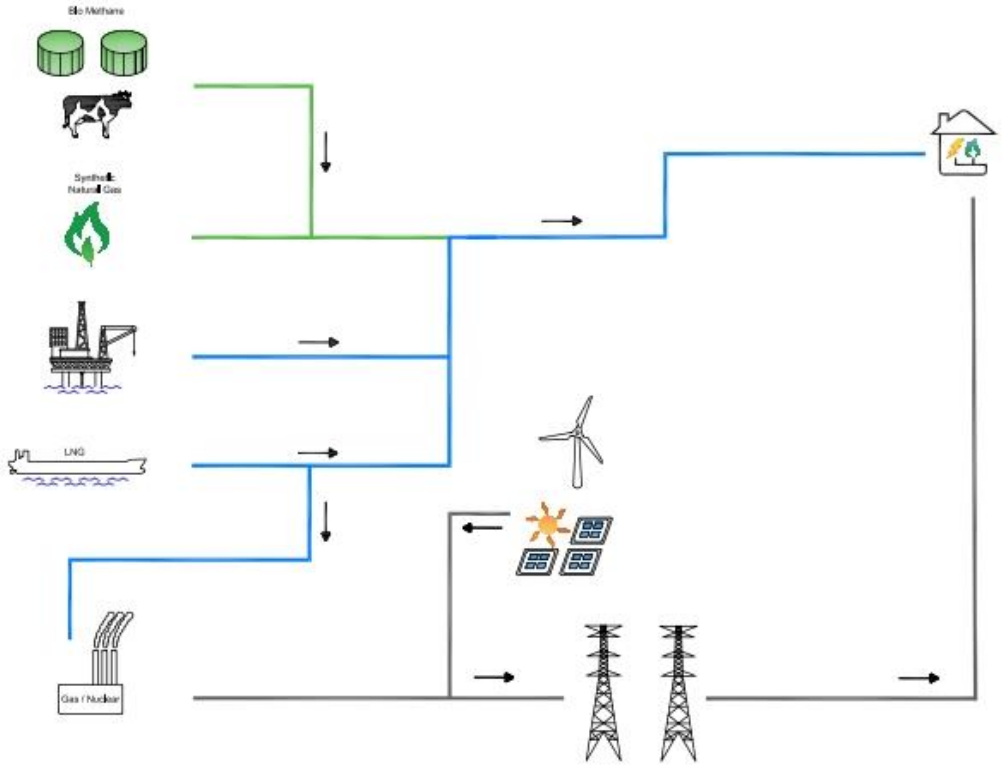
What are alternative gasses?

- Biomethane
  - Methane produced by the fermentation of organic matter
- Bio-SNG or syngas
  - Short for synthesis gas – formed from the gasification of waste material (black bag waste)
- Shale & coalbed methane
  - Shale and coal are source rocks for unconventional gas, producing shale gas and coal bed methane, respectively, using techniques such as horizontal drilling, dewatering and hydraulic fracturing
- Hydrogen
  - Most common element, highly combustible, usually found bound to other elements e.g. oxygen in the form of water

Background to alternative gas – focus on biomethane

- Renewable Heat Incentive (RHI) has been available in the UK since 2011
- First UK biomethane site connected 2011
- Our first biomethane site connected in 2013
- Current alternative gas connections made to our network are all biomethane
  - Other gases may be injected in the future – more on that later

Green gas entry



Key

- Gas
- Electricity
- Green Gas

Feeds directly into the gas network

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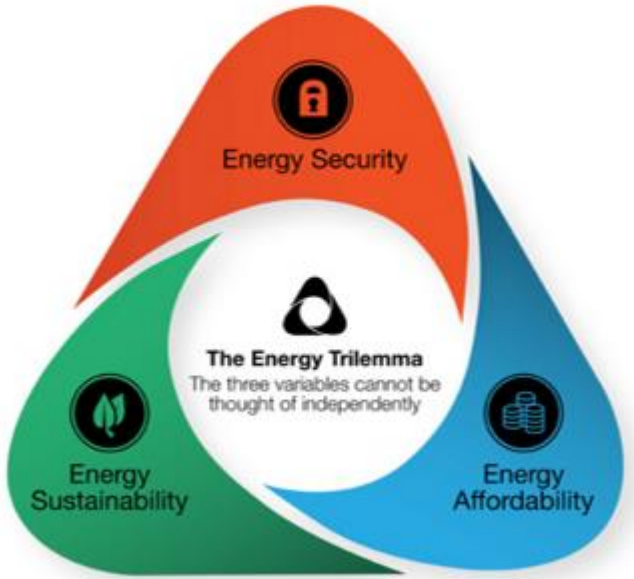
What's in it for the UK?

- New sources of distributed gas are helping to address the 'Energy Trilemma'
  - Support a reliable network (continuity of energy supply for heat, power & light)
  - Assist the UK in meeting its decarbonisation targets
  - At a reasonable cost
  - At a lower cost versus other renewables



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What's in it for you?

- New business opportunity
  - Potential diversification for farmers
- Revenues from gas sales to grid and the Renewable Heat Incentive
- Offers a solution to waste management – industrial, commercial and domestic
- Contributes to your sustainability model, as well as contributing to a greener UK by reducing carbon emissions

WORKSHOP 1

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Questions

- Introductions around tables
- Why are you here today and what do you hope to get out of your involvement?
- What do you believe are the primary advantages of alternative gas for the UK and for you / your company?

SESSION 2 (PART ONE): CONNECTIONS

Chris Magness
Green Gas Connections Manager

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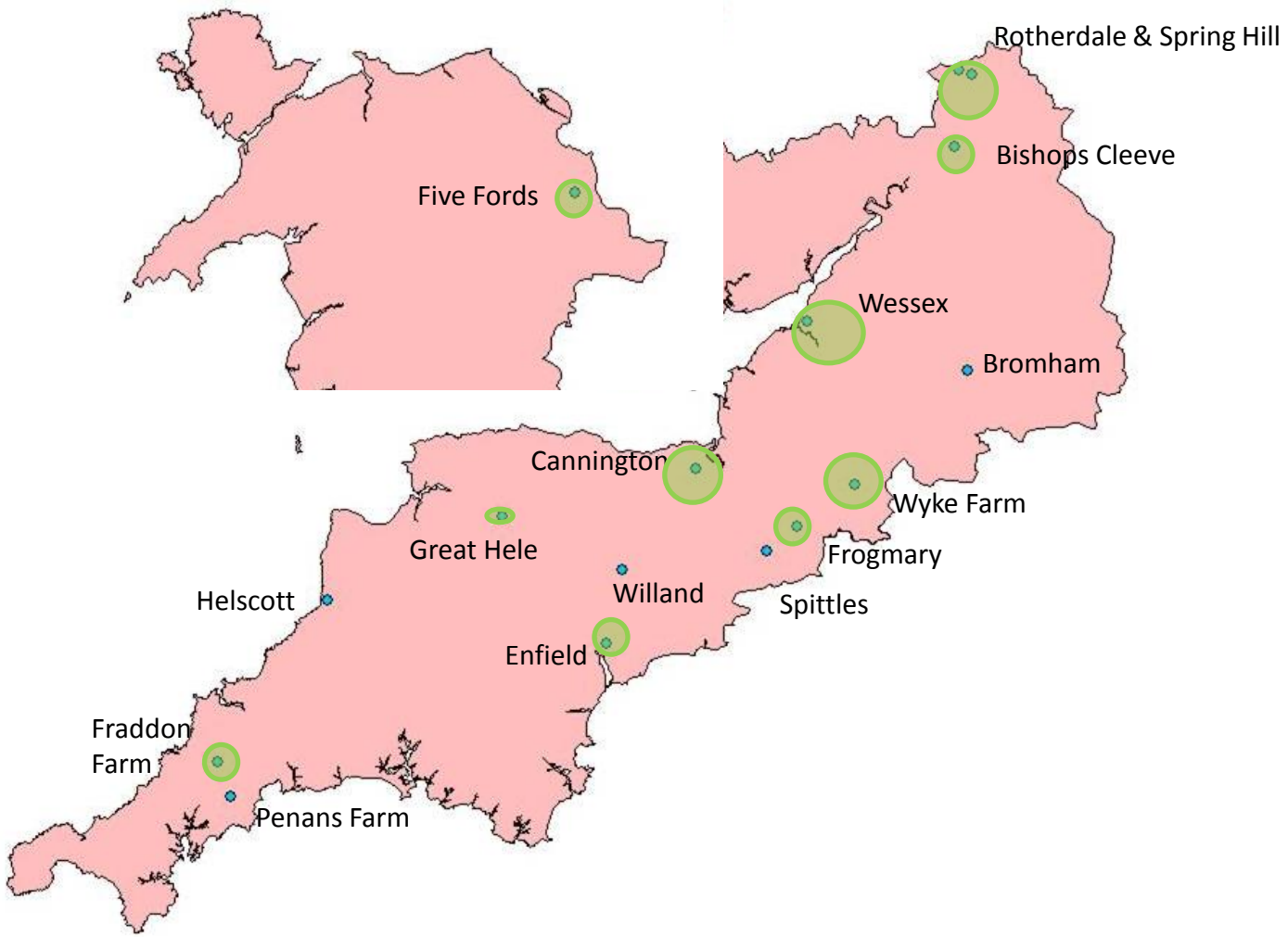
Connections to date



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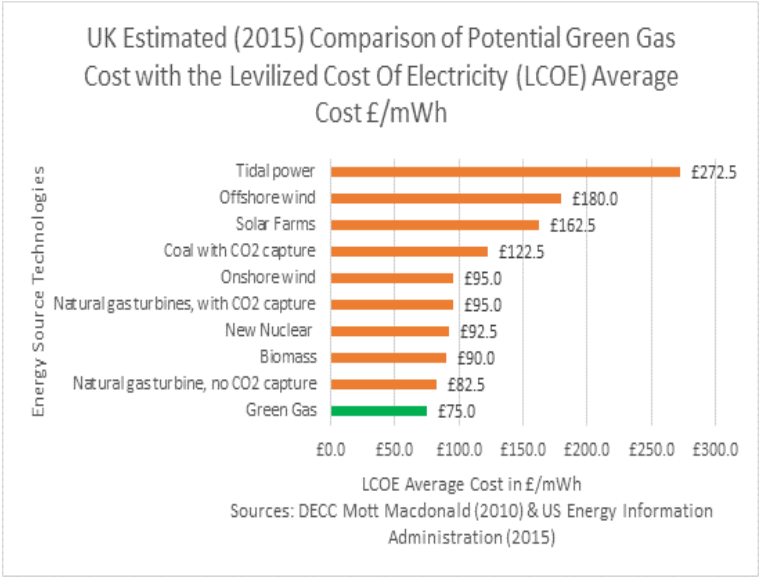
Stats & facts

- To date 16 connections with a maximum booked potential to inject 1.4 TWh
  - For comparison, Swansea Bay Tidal Lagoon estimated at 0.5 TWh @ £1.3b
- 15 connections in the South West
- 1 connection in Wales
- 300+ enquiries
- Feedstocks range from
  - Waste water / sewage sludge
  - Farm and animal waste
  - Food waste
  - Crops
  - Silage



Getting connected

1. Initial enquiry - submitted to the Network Entry/Exit Team to determine closest possible connection point within 10km radius that will likely accept the requested load.
2. Capacity study – This is a more in-depth analysis on the connection point and is chargeable to the customer. It involves looking at flow data if available and running the models at peak and low demand.
3. Acceptance – customer signs acceptance letter and seeks financial backing.

Things to consider

There are lots of activities that the customer and Wales & West Utilities must complete before gas is allowed to flow to grid.

Some of the project elements below are used to make sure that nothing is missed, as timings leading up to commissioning follow a critical path:

- **Connection to Wales & West Utilities network – UIP or Wales & West Utilities**
- Hazardous Operation Assessment
- **GQ8 Assessment**
- Zone of Influence
- GL5
- Pressure Systems Safety Regulations (PSSR)
- **Network Entry Agreement**
- Local Operating Procedure
- Factory Acceptance Testing
- Site Acceptance Testing
- ME2
- ISO10732
- HPMIS
- End to End Testing
- Rhinology
- AMP & PSDB

Gas quality (GQ8)

- GQ8 assessment carried out independently
- Ensures compliance to Gas Safety (Management) Regulations (GS[M]R) and its limits
- Looks at feedstock being used
- Can be partially generic
- Risk-based approach
- Will make recommendation for pre & post commissioning
- Forms part of Network Entry Agreement
- Biogas analysis pre clean-up
- Biomethane analysis post clean-up

Example of GQ8

	Parameter	Requirement	Expected Value	Deviation	Notes	Impact Rating	Likelihood Rating	Risk Rating	Conclusions and/or Recommendations
20	Oxygen content, % mol/mol	<1	<1	>1	The generic assessment assumes that the NEA will permit oxygen up to the limit of the class exemption offered by the HSE. It is assumed that air or oxygen enrichment is practiced to reduce H_2S levels in the biogas. Cause of deviation to high O_2 is assumed to be failure of the air/O_2 injection unit.	3	2	6	Continuous monitoring and alarm are recommended. The generic risk assessment assumes that a diverter valve (DV) is installed and automatic operation of the DV is recommended. Manual closure of the ROV is recommended if the DV fails to operate.
21	Siloxanes content				There is currently no industry-agreed limit for siloxanes, although a tentative value of 0.5 mg Si/m3 has been proposed. The HSE expect that active carbon beds are installed. The generic assessment assumes that the biogas contains siloxanes and that filtration using active carbon beds is practiced.	3	2	6	Spot sampling and laboratory analysis according to the schedule suggested in Appendix C is recommended. Operational monitoring of siloxane levels at the outlet of the first carbon bed to detect breakthrough is recommended if siloxane is present in the biogas.
22	Organohalides content, mg/m^3	<1.5	<1.5	>1.5	The generic assessment assumes that the biogas contains organohalides and that filtration using active carbon beds is practiced,				Spot sampling and laboratory analysis according to the schedule suggested in Appendix C is recommended.

The importance of getting it right

- Making sure of gas quality
  - Make sure the biomethane remains in the GSMR limits.
    - Calorific Value (CV) limits
    - Wobbe number
    - Sooting Index (SI)
    - Incomplete Combustion Factor (ICF)
  - Equipment is managed and maintained to correct standards
    - Maintenance and periodic validation/calibration of
      - CV measurement
      - Flow measurement

Network Entry Agreement

- Legally binding contract
- Sets out all obligations to be met by Wales & West Utilities and the customer
- Includes safety, gas quality and maintenance
- Actions available if things go wrong
- Protects our network and the downstream customer

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Most important thing to remember

Safety is our No1 priority for our customers and our network

SESSION 2 (PART TWO): CONNECTIONS

Bethan Winter
Systems Operations Manager

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Work we have done

HSE
Health & Safety Executive

The Health and Safety at Work etc. Act 1974

The Gas Safety (Management) Regulations 1996

Certificate of Exemption No. 1 of 2013

1. The Health and Safety Executive ("the Executive"), in pursuance of the powers conferred on it by paragraph (1) of regulation 11 of the Gas Safety (Management) Regulations 1996 ("the Regulations"), and being satisfied as required by paragraph (2) of regulation 11, hereby exempts any persons from the duty imposed by regulation 8(1) of the Regulations to convey gas with an oxygen content of less than or equal to 0.2% (molar) in a network as defined by regulation 2(2) of the Regulations.

2. The Executive grants this exemption on condition that any person who conveys gas with an oxygen content above 0.2% (molar) in a network shall ensure that:

   i). the oxygen content of the gas conveyed is less than or equal to 1.0% (molar); and,
   ii). the pipes used to convey the gas are operated at pressures below 38 barg; and,
   iii). the gas conveyed complies with all other requirements and prohibitions imposed by regulation 8(1) of the Regulations (subject to other exemptions to the Regulations granted by the Executive).

3. This certificate shall come into force on 24th May 2013 and shall remain in force until such time as it is revoked by the Executive by a certificate in writing.

Signed by:

A person duly authorised by the Executive to act in that behalf.

Date: 24 May 2013

IGEM

IGEM/TD/16
Communication 1768

Biomethane injection

IGEM

IGEM/TD/17
Communication 1769

Steel and PE pipelines for biogas distribution

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Date of Submission
November 2013

NIA Project Registration and PEA Document

Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

Project Registration

Project Title		Project Reference
Unconventional gases within the onshore gas networks		NIA_WWU005
Project Licensee(s)	**Project Start Date**	**Project Duration**
National Grid Gas Distribution, Northern Gas Networks, Scotia Gas Networks, Wales and West Utilities	Feb 2013	10 Months
Nominated Project Contact(s)		**Project Budget**
Ian Dunston - Wales & West Utilities		£113,220

Problem(s)

There are no standards currently available for the gas collection pipelines for biogas and for injection of biomethane into the gas distribution network.

In addition, there is currently no guidance document for the onshore shale gas industry and how it may form part of the gas supply network. The document will reflect industry best practice as well as legislative requirements. The produced document can be used by all interested organisations involved in the process from local councillors, planning officers, exploration companies etc. The development of onshore Shale gas will form part of the UK gas energy mix and the development of the guidance document and the injection criteria of the biomethane Standard will form the basis for Shale gas injection into the gas distribution network.

Method(s)

IGEM proposes to produce three documents to address these deficiencies. These will be:

IGEM/TD/16 - the IGEM standard for biomethane injection into the gas distribution network;

IGEM/TD/17 - the IGEM standard for biogas pipelines;

IGEM/G/101 the IGEM guidance document on onshore shale gas.

Also, a report relating to the impact of shale gas on the gas distribution networks.

Scope

To produce standards for biogas gathering pipelines and biomethane injection into the gas distribution networks. To produce documents for use within the onshore gas industry and a report relating to the impact of shale gas on the gas distribution networks.

Objective(s)

To provide Network Operators and suppliers/operators of biomethane plants with a UK standard for connection to the gas distribution network. It will include the requirements of any plant in relation to minimum connection, gas odourisation, dewpoint, gas quality measurement etc. This will provide consistency across the gas industry for the benefit of suppliers/operators of biomethane

NIA_WWU005 Created: 27 Jul 2014 Page 1 / 5

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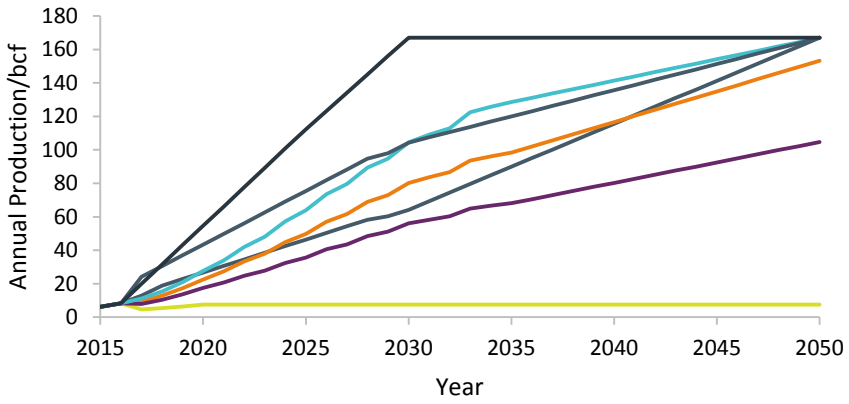
Research we have carried out

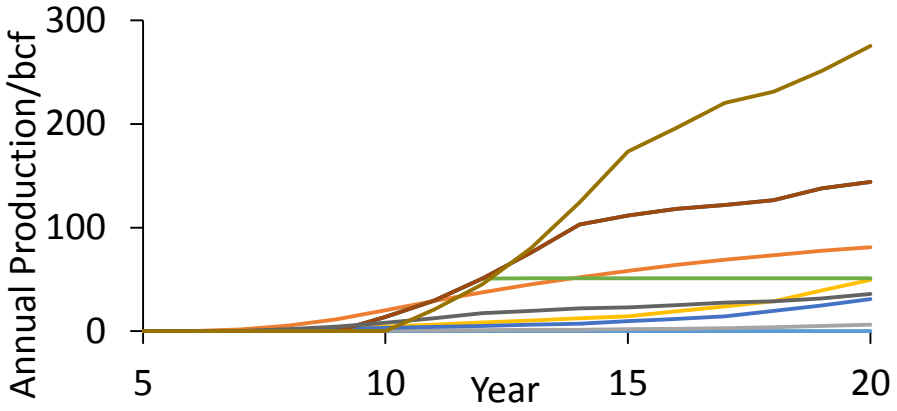
- "Impact of distributed gas sources on the GB gas network"
- Joint innovation project with SGN and National Grid Gas Distribution
- Outputs:
  - i) Projections of future distributed gas injection
  - ii) Challenges to connecting

Distributed gas projections

Biomethane Scenarios*



CBM Production profiles



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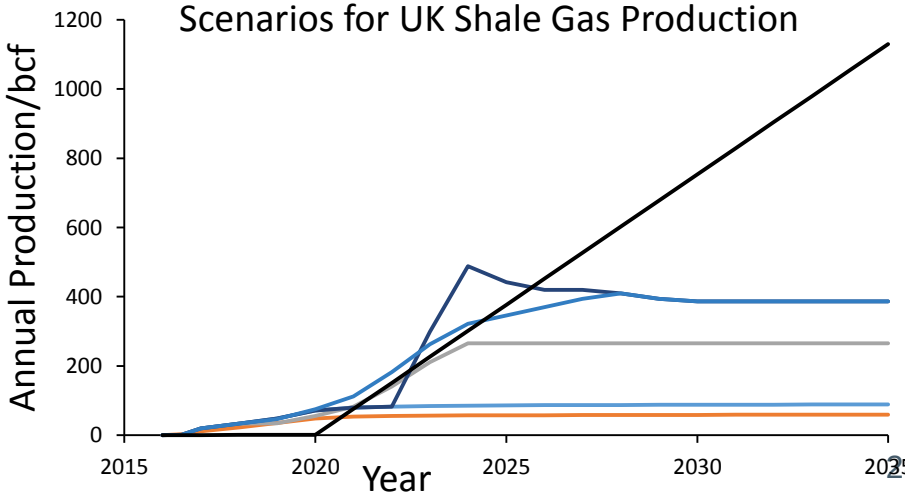
Scenarios for UK Shale Gas Production



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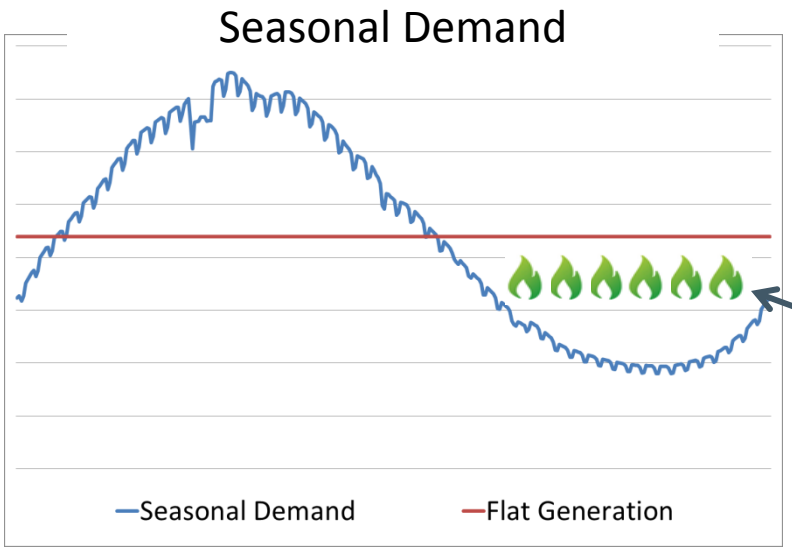
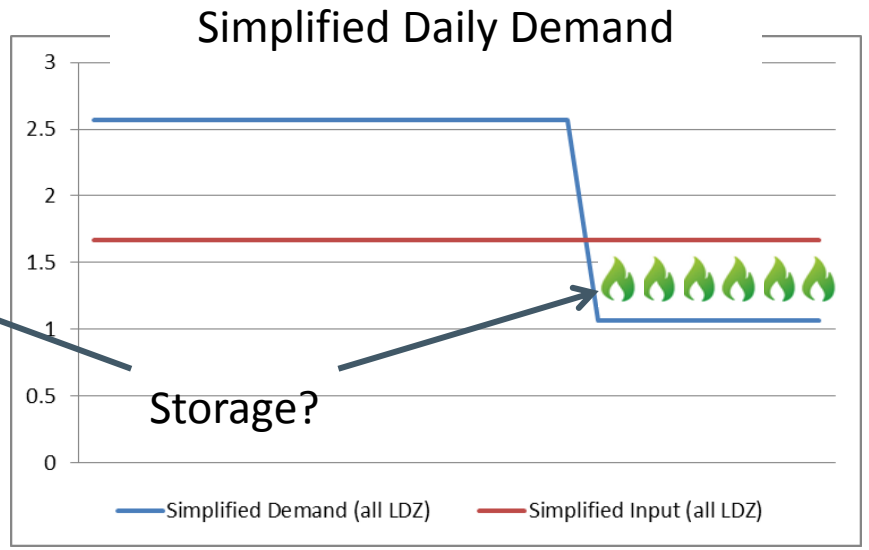
Challenges to connection

- Capacity constraints
- Minimum CV requirements and Gas Quality
- Connection costs
- Awareness and engagement with potential connectors
- Geographical constraints – Wales vs south west England

Key challenge - capacity

- Seasonal and daily demand variations
- Storage will be required
- Compression may also help injection





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Key challenge – gas quality

- Calorific value and shrinkage
  - Gas calculation of thermal energy regulations
  - High cost of propanation
- Gas Safety (Management) Regulations and Gas Quality
  - Wobbe and content considerations

Key challenge – awareness & engagement

- Raising awareness of the potential to connect to the gas network and engaging with potential connectors
- Raising wider awareness to policy makers of the benefits of alternative gas
- Policy
  - Some policies may need to change and make sure our policies to aid connections are kept up-to-date

Raising wider awareness of green gas and the potential benefits

Key challenge - Wales

- Our thoughts on potential Welsh challenges:
  - Lack of awareness in Wales – potential connector community
  - Relatively large footprint of Welsh agriculture versus the rest of the UK – larger number of smaller farms
  - Connection potential – geographical barriers to connection to grid

But what do you think?

Customers perspective

- We asked our current connectors to give their perspective on the experience, what advice they'd give new connectors – and what more we can do to help the process.

  - Customers suggested that others get in touch with us very early in their planning - and plan well ahead. This is a long, involved, complex and costly process

  - More detailed and clear information on the whole connection process was requested - including more detail on the whole process, not just the bit that involves us

  - Customers also suggested that we make more effort to promote connection opportunities, invest in innovation, and look at connection agreements for RHI projects

Customers perspective continued

- We asked our current connectors to give their perspective on the experience, what advice they'd give new connectors – and what more we can do to help the process.

Look at collaborating with other networks for innovation ideas

Connecting to the grid is a big responsibility, this can't be underestimated

Consider new RHI rules and what we need for pre-accreditation

WORKSHOP 2

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Questions

- These are what we think the challenges are – do you agree?
- What have we missed?
- What do you think we should do to overcome these challenges?

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SESSION 3 (PART ONE):
MOVING FORWARD

Sarah Williams
Business Improvement Manager

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Case studies

- Two external case studies that demonstrate innovation in this arena from:
  - **Lorna Millington**, Design Manager, National Grid Gas Distribution
  - **Professor Sandra Esteves**, Energy and Materials Director, Wales Centre of Excellence for Anaerobic Digestion, University of South Wales

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National Grid's Low Carbon Gas Vision
Delivering commercialisation projects

Lorna Millington

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Gas Distribution

Overview

- Role for renewable gas
- Delivering renewable gas at volume
- Pathway from germination to plant
- Deployment and the future

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ADVANCED PLASMA POWER

Progressive energy

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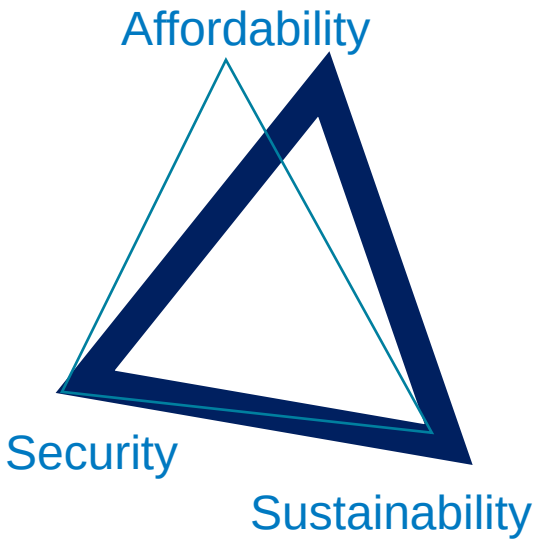
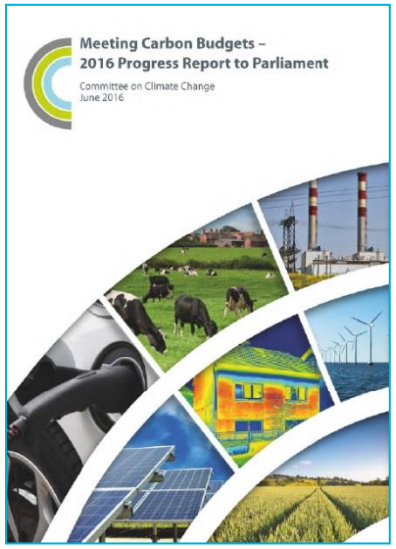
Decarbonising Heat and Transport



- We need low carbon, secure and affordable solutions for heat and transport
- In its recent report, the CCC acknowledged that the UK has made good progress decarbonising the power sector, but *'almost no progress in the rest of the economy*'
- Sustainable green gas provides the lowest cost pathway to decarbonised heat and transport using existing infrastructure



'2050 Energy Scenarios The UK Gas Networks role in a 2050 whole energy system' KPMG (2016)
'Too Hot to Handle? How to decarbonise domestic heating' Policy Exchange (2016)
'Future of Gas' National Grid (2016)

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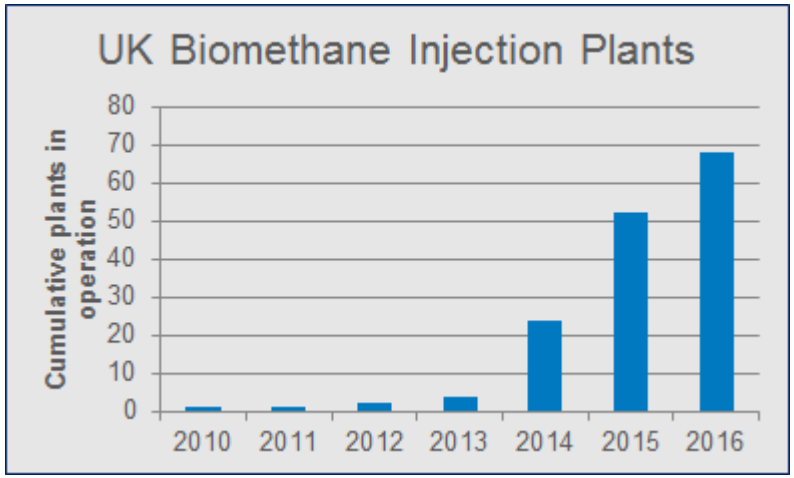
Delivering Renewable Gas



- Anaerobic Digestion: important role, but limited by feedstock type & availability
- BioSNG offers the potential to exploit a much wider range of feedstocks




Feedstock → Syngas Production & Conditioning → Methanation → Refining

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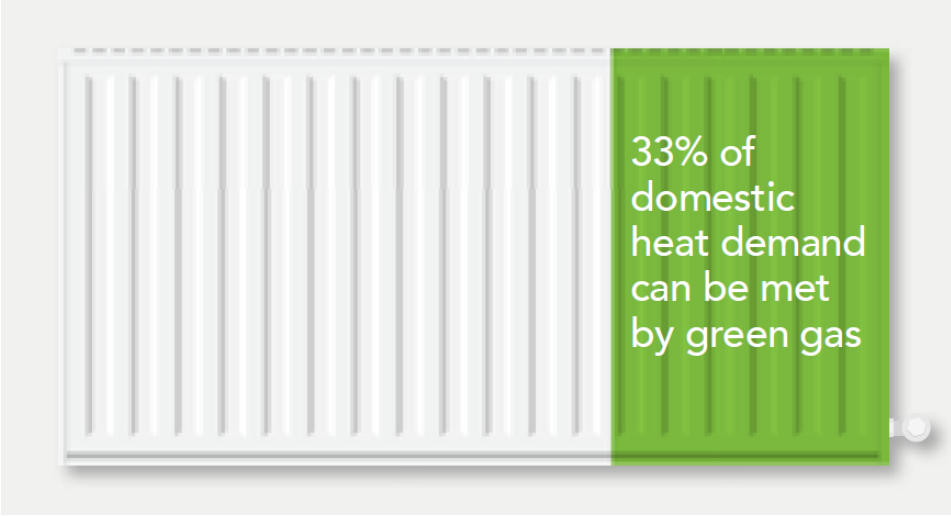
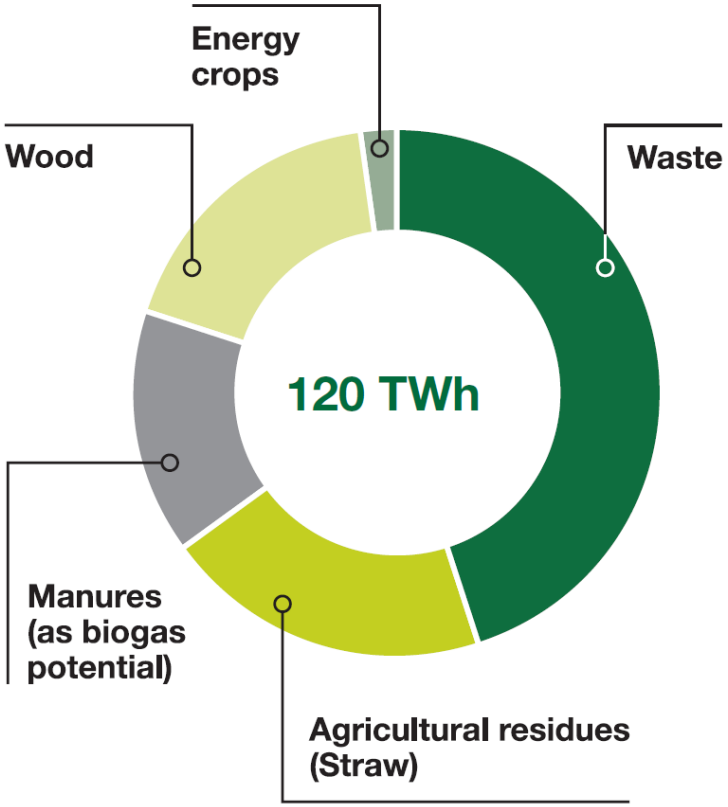
Feedstock in the UK

- UK: 244,000km^2, 64 million people
- Exporting ~4million te waste per annum
- Waste is a significant resource





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Pilot Plant

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Pilot Plant Delivery

BESTF ERANET European Funding £2.2M
One of 3 awards in first year funding round

BESTF

Network Innovation Competition £1.9M
One of 4 awards in first year funding round

RIIO NIC NETWORK INNOVATION COMPETITION

National Grid

nationalgrid THE POWER OF ACTION

Advanced Plasma Power

ADVANCED PLASMA POWER

Progressive Energy

Progressive energy

Carbotech

Carbotech
VIESMANN Group

3Year Pilot Plant Programme

- **Finalisation of design & safety review**
- **Procurement**
- **Construction and installation**
- **Testing & optimisation**
- **Dissemination**

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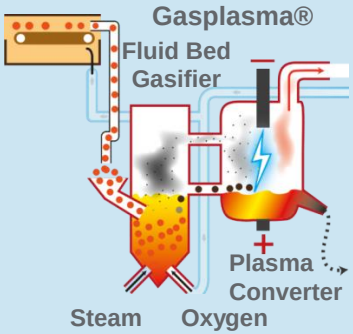
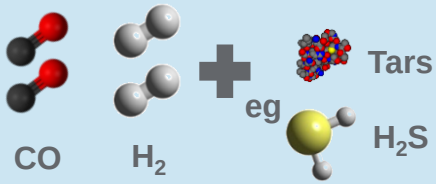
The Process & Key Requirements

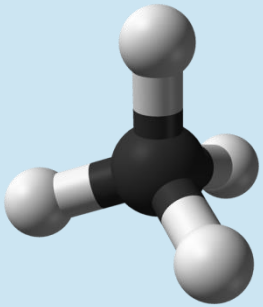


GASIFICATION & GAS PROCESSING

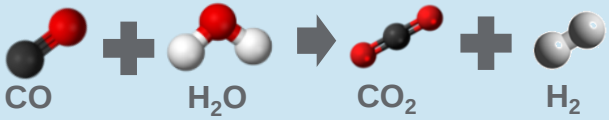


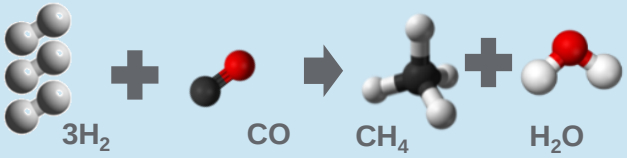
Ability to process waste as well as biomass

Ability to deliver high quality synthesis gas



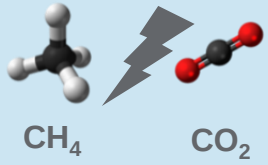
CONDITIONING & METHANATION





Ability to methanate at moderate scale

UPGRADING



Ability to separate biomethane effectively

Delivery to market

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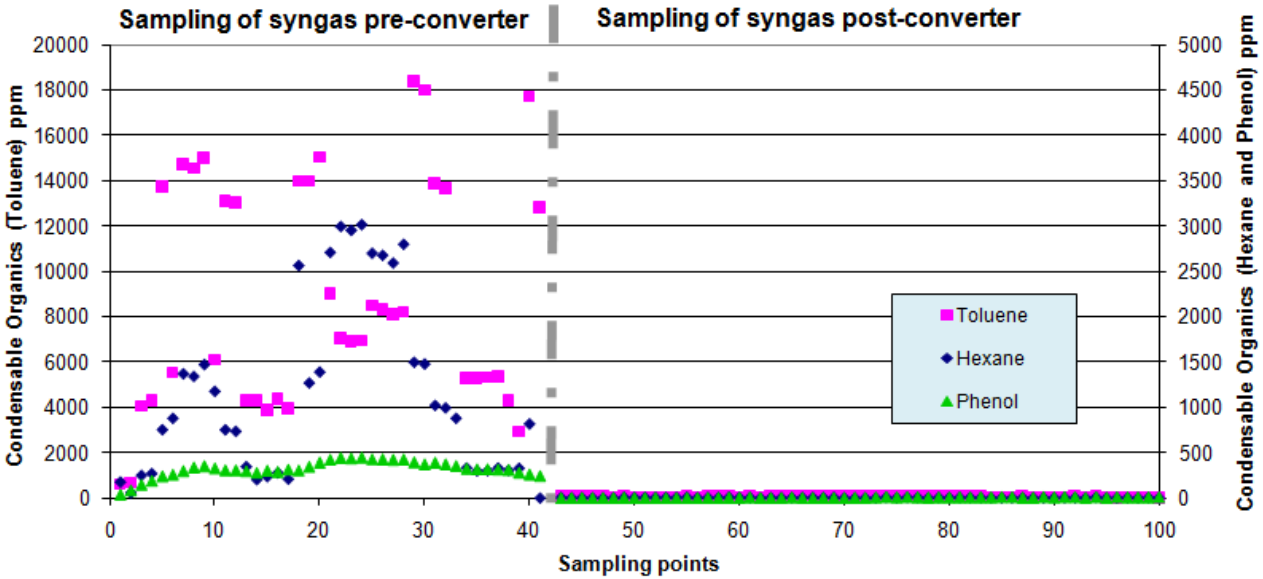
Delivering a clean syngas – Tar kills



- Conventional Fluidised bed gasification with down stream plasma treatment. Operational facility since 2008
- Plasma reforms/cracks the tars to simple gaseous products, which contribute to the energy of cleaned gas.
- Thiophenes & organic sulphur reformed to CO, H_2 & H_2S

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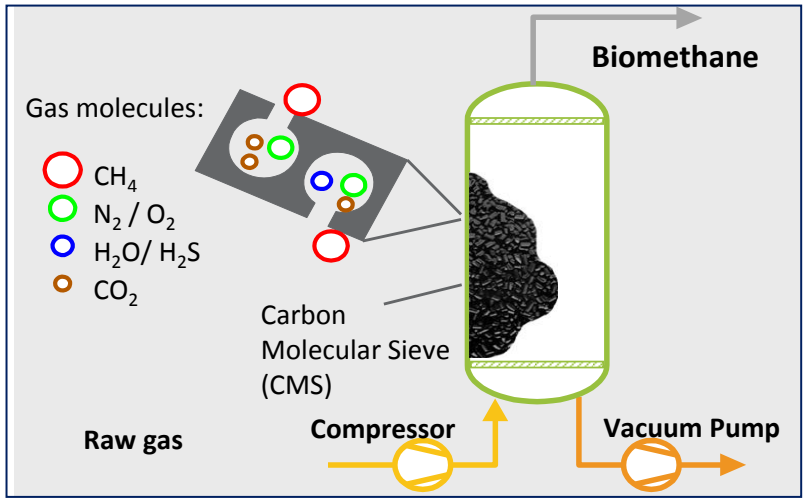
Methanation & Refinement

- Established commercial process with decades of experience at GWth scale.
- Challenge is to deploy at ‘biomass/waste’ scale
- Focused on simpler, lower cost ‘once through’ processes

- PSA has been designed to be flexible
- Removal of hydrogen is necessary on this pilot facility
- Different depressurisation configurations possible to optimise recovery and purity



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The Pilot Plant

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THE POWER OF ACTION

Advanced Plasma Power

Progressive energy

Carbotech
VIESMANN Group

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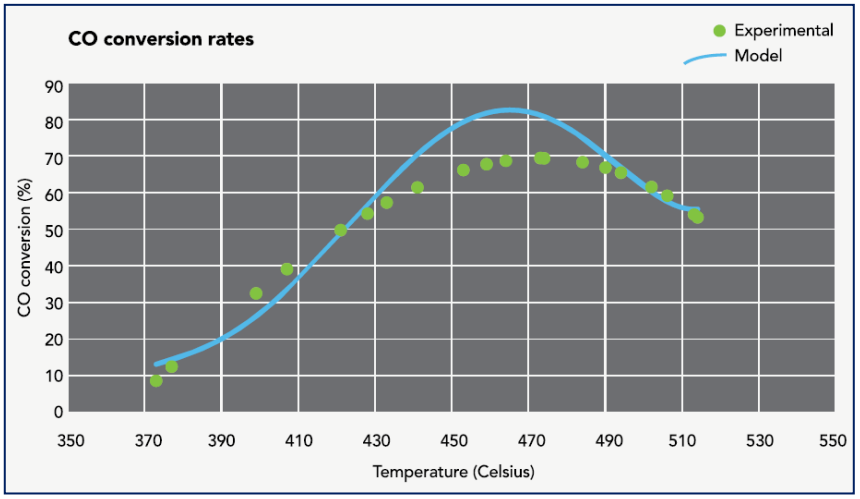
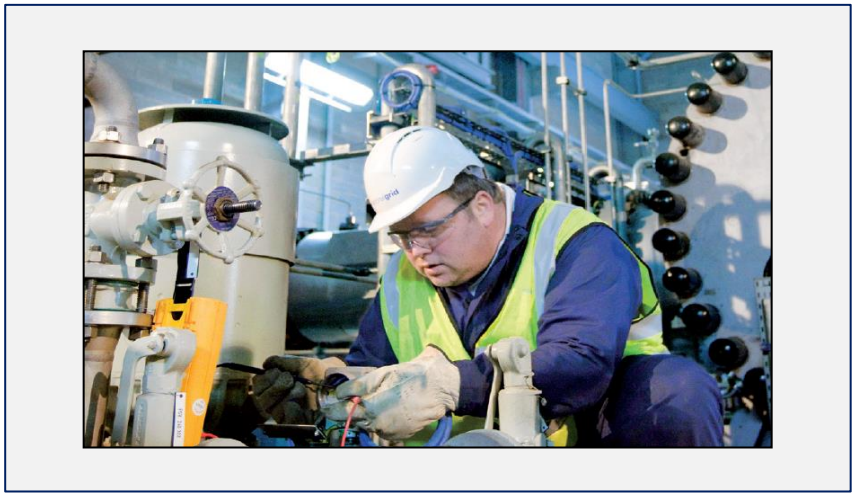
Key Lessons learned

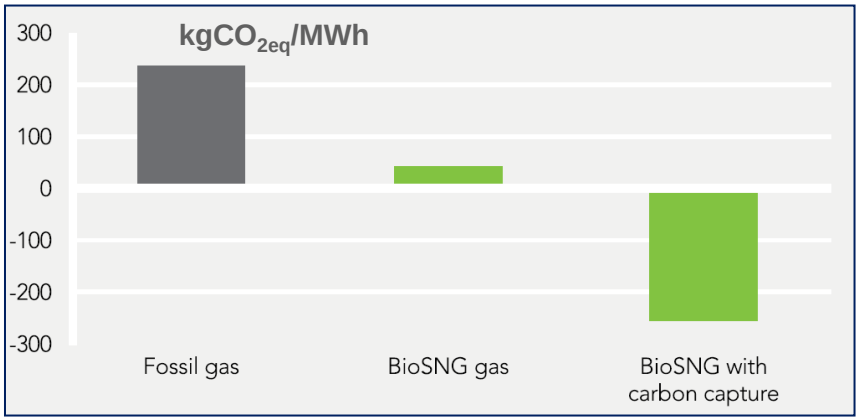
TECHNICAL



OPERATIONAL



ENVIRONMENTAL



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Commercial Demonstration Project

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Project Drivers

BioSNG Pilot (50kW)

Technical demonstrator & test bed for process improvements & optimisation, health and safety, operator training

£5m total investment

Commercial Risk too high

Deployment (40MWth)

Technical, construction, operational & commercial risk acceptable to funders

£90m investment with return to funders

Commercial Demonstrator (3MW)

Addresses construction, operational, & commercial risk

£25m total investment. Supported by Dft Advanced Biofuel Demonstrator & OFGEM Network Innovation Competition

Department for Transport

RIIO NIC NETWORK INNOVATION COMPETITION

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Full Chain £25M 'Small Commercial' Facility

SECURED, PROCESSED WASTE FEEDSTOCK

Swindon Borough Council

CONVERSION TO HIGH QUALITY SYNGAS

Advanced Plasma Power

Outotec

CONVERSION TO GRID & TRANSPORT QUALITY SNG

amec foster wheeler

CO_2 SALES

DELIVERY TO GAS NETWORK AND EXISTING HGV FLEET

WALES&WEST UTILITIES

SUFFICIENT FOR 1500 HOMES OR 75 HGVS

Howard Tenens

EXPLOITING INNOVATIVE TECHNOLOGY. THIS WILL BE THE WORLD'S FIRST GRID-CONNECTED, FULL CHAIN, WASTE TO SNG FACILITY OPERATING AT A COMMERCIALLY REPRESENTATIVE SCALE UNDER COMMERCIAL CONDITIONS.

Department for Transport | RIIO NIC Network Innovation Competition | Advanced Plasma Power | nationalgrid | Progressive energy | cng services ltd | WALES&WEST UTILITIES

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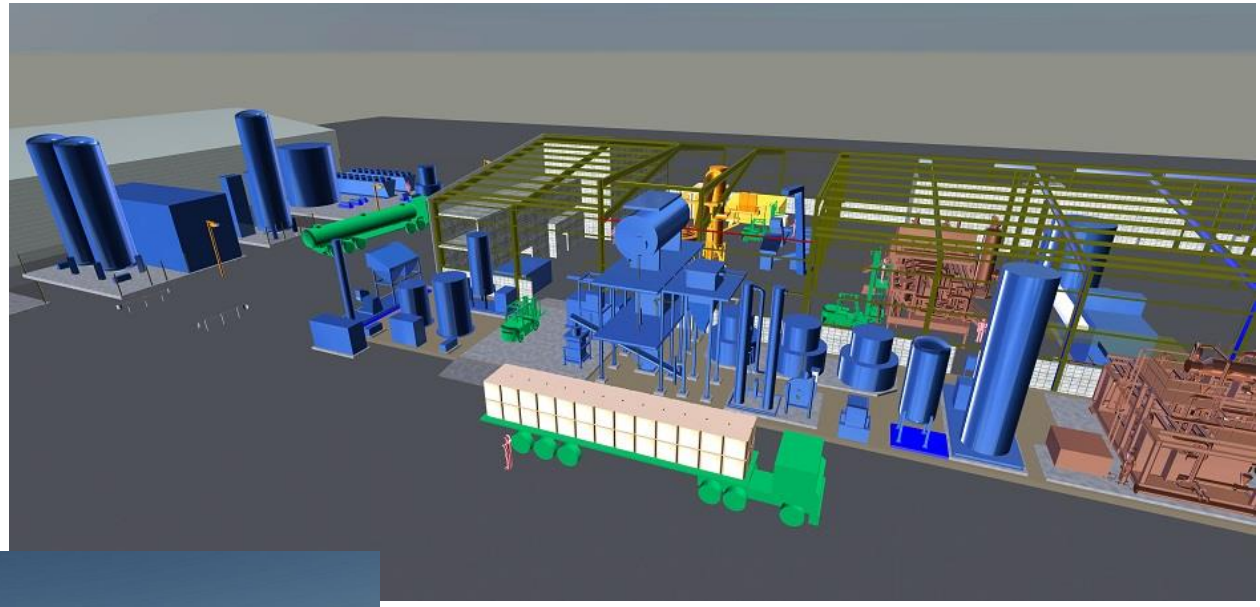
Project Progress

- Secured planning and permitting
- Agreed waste supply
- Agreed gas offtake
- Agreed CO_2 sales
- Developed detailed design
- Placed long lead orders



On track for delivery of 1 million kilogrammes of BioSNG in 2018

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COMMERCIALISATION

Demonstrator

- Grant supported project
- Produces 22GWh gas per annum.
- Enables further commercialisation.
- Operational 2018.

Full Scale Plant

- Enabled by commercial demonstrator.
- Produces 310GWh pa.
- Development underway
- Operational 2020.

Roll Out

- Target chemical, oil & gas and waste companies together with local authorities.
- First operational full scale plant will catalyse sales.
- Cost parity with fossil gas

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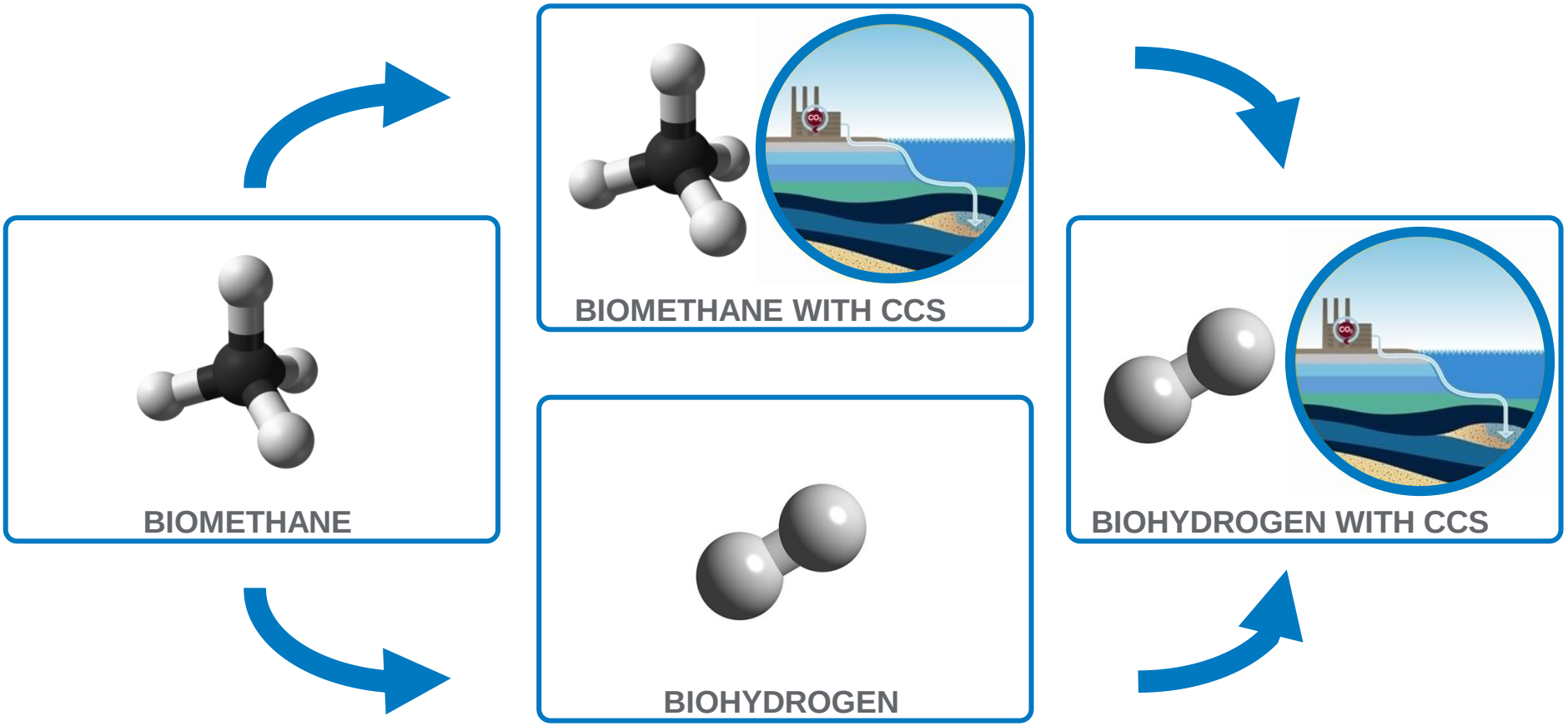
Pathways to Deeper Decarbonisation



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Summary

BIOSNG WILL CONVERT THE UK'S LARGEST SOURCE OF RENEWABLE CARBON TO NATURAL GAS FOR DELIVERY VIA A WORLD CLASS NETWORK TO MEET HEAT AND TRANSPORT DEMAND.




Low cost route to decarbonising heat and transport through use of:

- Underexploited waste resource
- Efficient technology
- Existing infrastructure

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Thank you

To find out more about this project please contact a member of the Project Team

David Pickering, BioSNG Project Manager, National Grid Gas Distribution
david.c.pickering@nationalgrid.com
07867 537360

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THE AD CENTRE

THE WALES CENTRE OF EXCELLENCE FOR ANAEROBIC DIGESTION

Redesigning Anaerobic Digestion Technology for Flexible Green Alkane Gases Production

Wales & West Utilities Stakeholder Workshop

Bristol County Cricket Ground, 27th March 2017

Prof. Sandra Esteves

sandra.esteves@southwales.ac.uk

SERC
SUSTAINABLE ENVIRONMENT RESEARCH CENTRE

THE AD CENTRE
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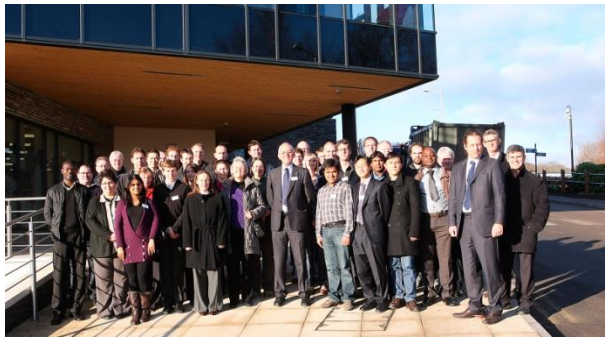
- Anaerobic Digestion
- Waste and Wastewater Treatment
- Bio Energy Systems
- Monitoring and Control
- Environmental Analysis
- Biohydrogen Systems
- Bioelectrochemical Devices
- Hydrogen Energy
- Advanced Nanomaterials
- Bioplastics Production
- P2G, Biogas upgrading and utilisation
- LCA and economic evaluations



H_2 The Hydrogen Centre

USW Team's Expertise & Facilities

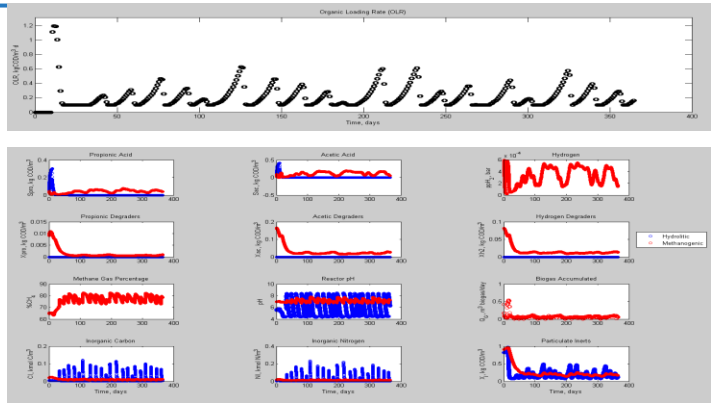
- Team has decades experience in bioreactor (anaerobic) design, integration, monitoring and control
- Novel process development in the lab (1-100 l), pilot (200 l -30 m^3) and full scale experience (50-7000 m^3)

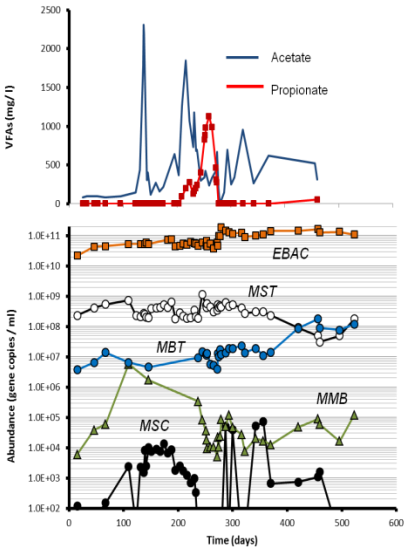


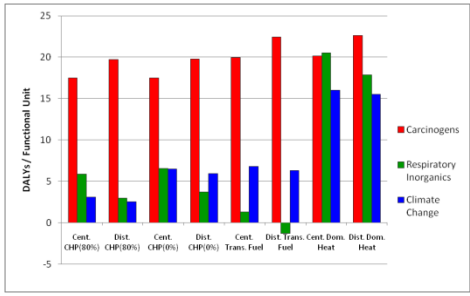


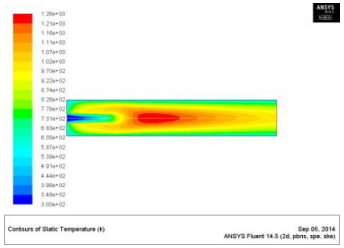
USW Team's Expertise & Facilities

- Expertise in bioreactors, biochemistry, biotechnology, microbiology, engineering, monitoring, modelling and control, economic and environmental appraisals
- 450m^2 lab space, 13 labs, an extensive suite of analytical equipment - headspace GC/FID, ion chromatography, ICP-AES, CHNSO, TOC, TKN analysers, GC/TCD, GC/FPD, GC/MS/MS, SEM, NMR, SFE, GC-MIS, on-line FT-NIR, rheometer, zeta potential analyser, particle sizer, Ion Torrent Sequencer, RT-PCR and DGGE
- ADM1 model, AI tools, LCA software/databases and CFD software









Anaerobic Digestion Process

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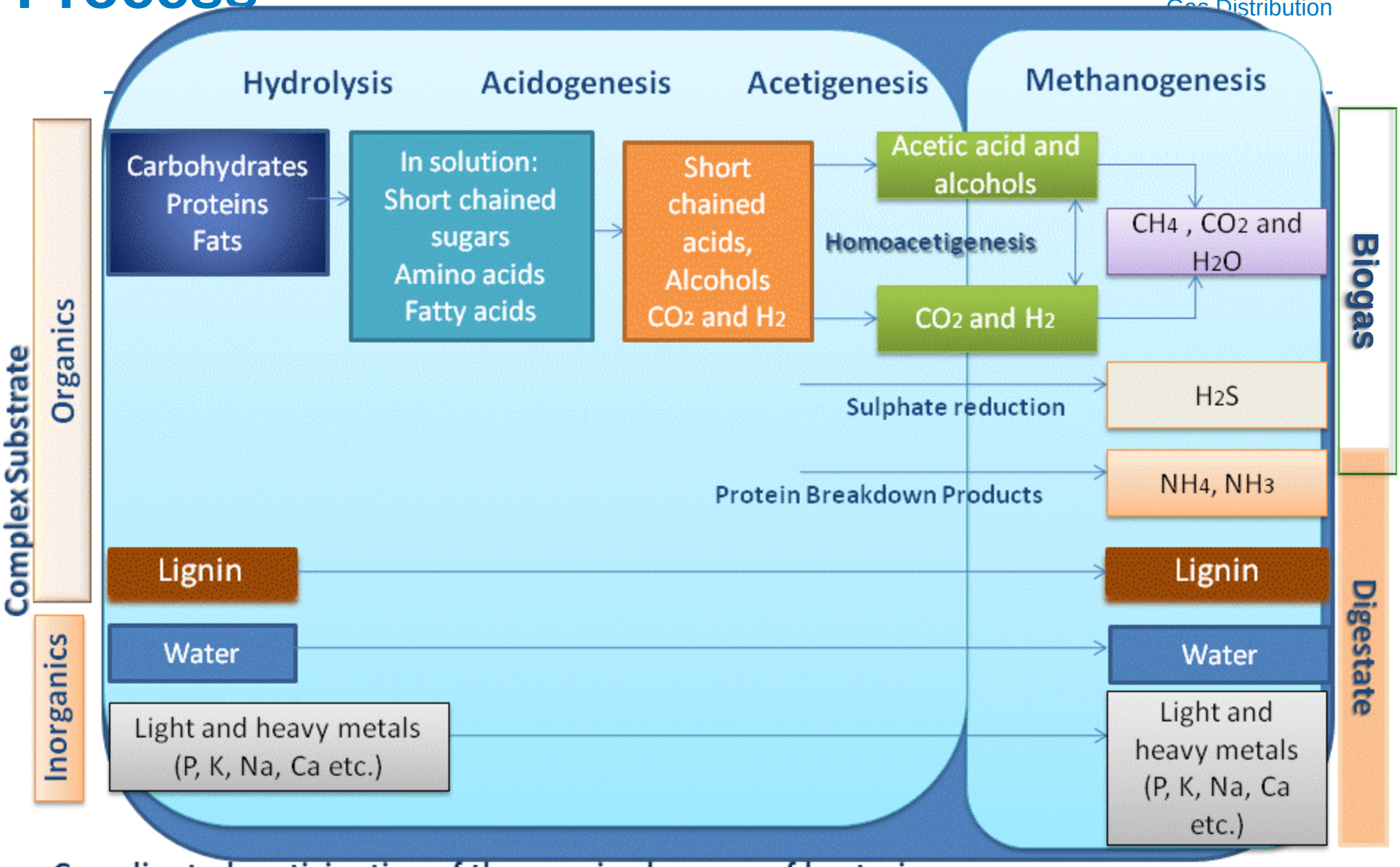
Gas Distribution



Coordinated participation of the required groups of bacteria
Process can take place in one or more stages (separate reactors)

Unlocking new potential with R&D

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ADBA 2025 "high" potential scenario		
Feedstock type	TWh useable energy (after 10% parasitic)	Useable energy after R&D (after 10% parasitic)
Household food waste	4	5
C&I food waste	5	6
Farm animal wastes and bedding	8	9
Crops	12	17
Sewage sludge	5	5
Other potential sources	2	
Nature conservation managed		0.4
Straw		3
Uncontaminated organic street sweepings (e.g. leaves) and park waste (e.g. grass cuttings and leaves). Pretreatment, dry AD.		3
Household garden waste (e.g. grass cuttings and leaves). Pretreatment, dry AD.		3
Orchard waste (e.g. apple pomace)		1
AD integrated into greenhouse horticulture with waste heat, co2 use		2
Glycerol - dependant on biodiesel industry		0.5
Fish processing waste - conventional sources		0.5
Higher value food production integration such as hydroponics, aquaponics and aquaculture (overlap with greenhouses)		2
Microalgae (e.g. using nutrients from sewage sludge, digestate etc. and waste heat, co2 and water from AD plants). Also potential to use excess grid electricity.		4
Macroalgae (e.g. seaweed etc.)		1
Power-to-gas via hydrogen with AD		31.8
Total	35.4	95.3
Domestic gas demand	300	270
Percent of domestic gas demand	12%	35%

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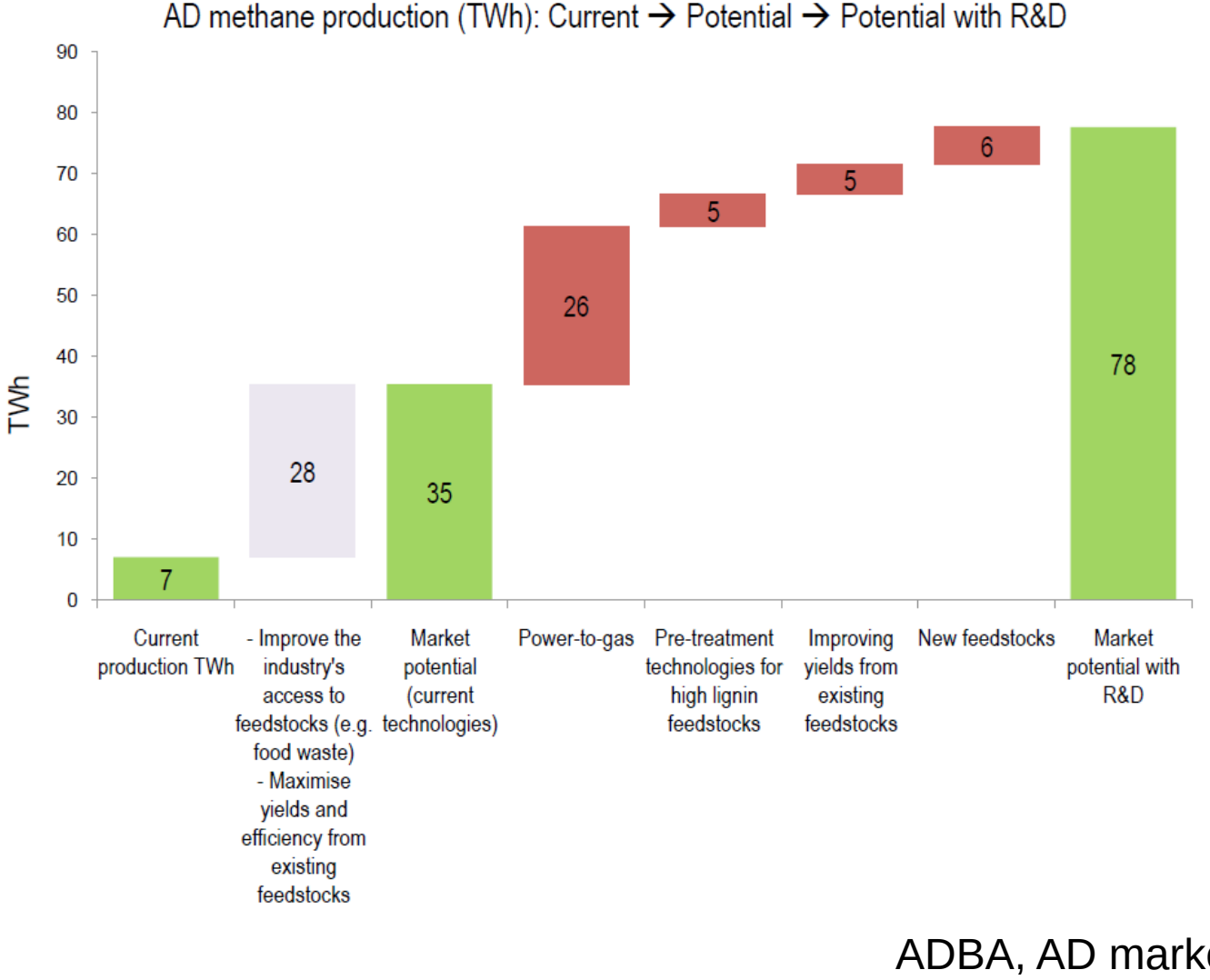
Gas Distribution

Unlocking new potential with R&D



ADBA, AD market report July 201

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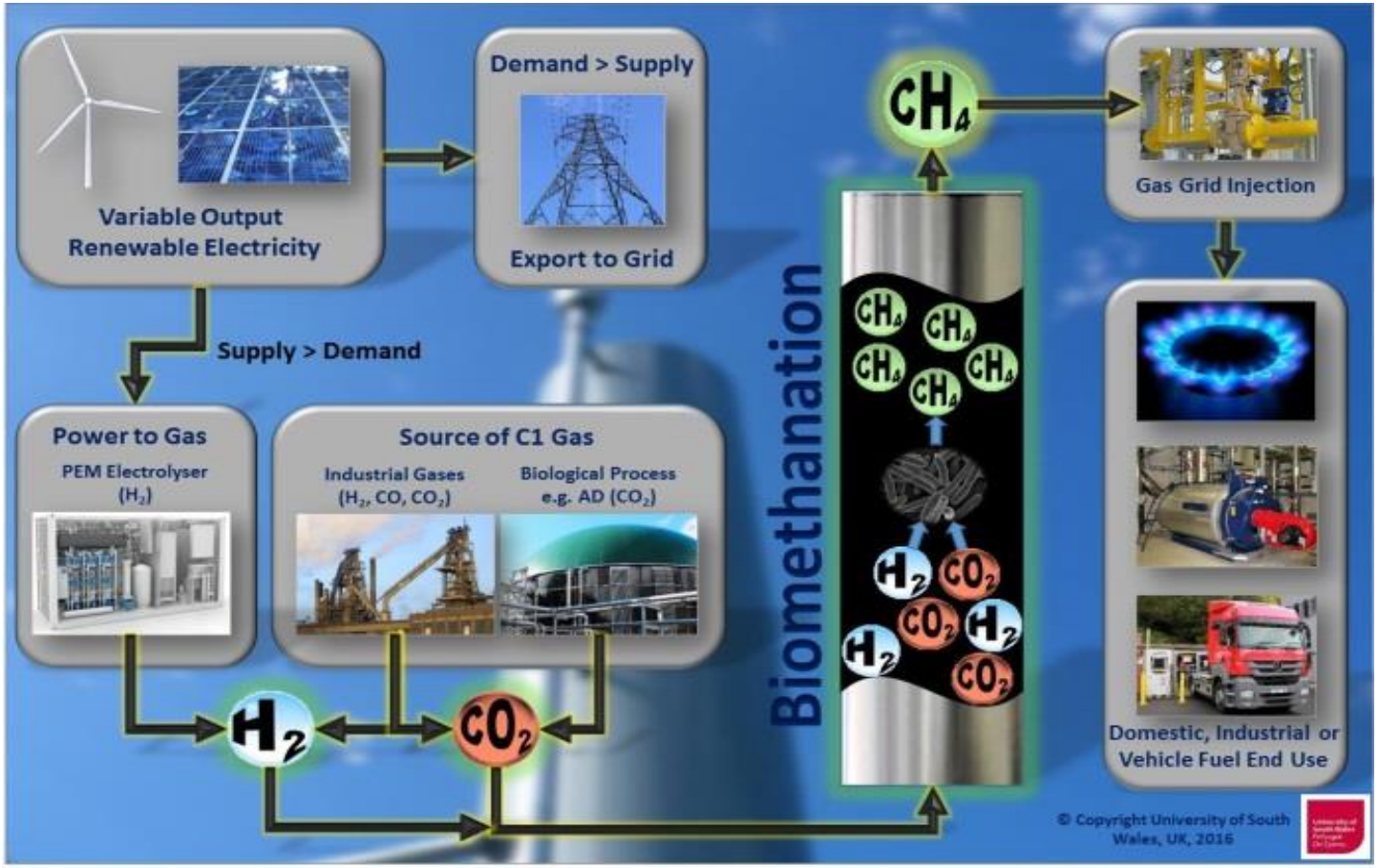
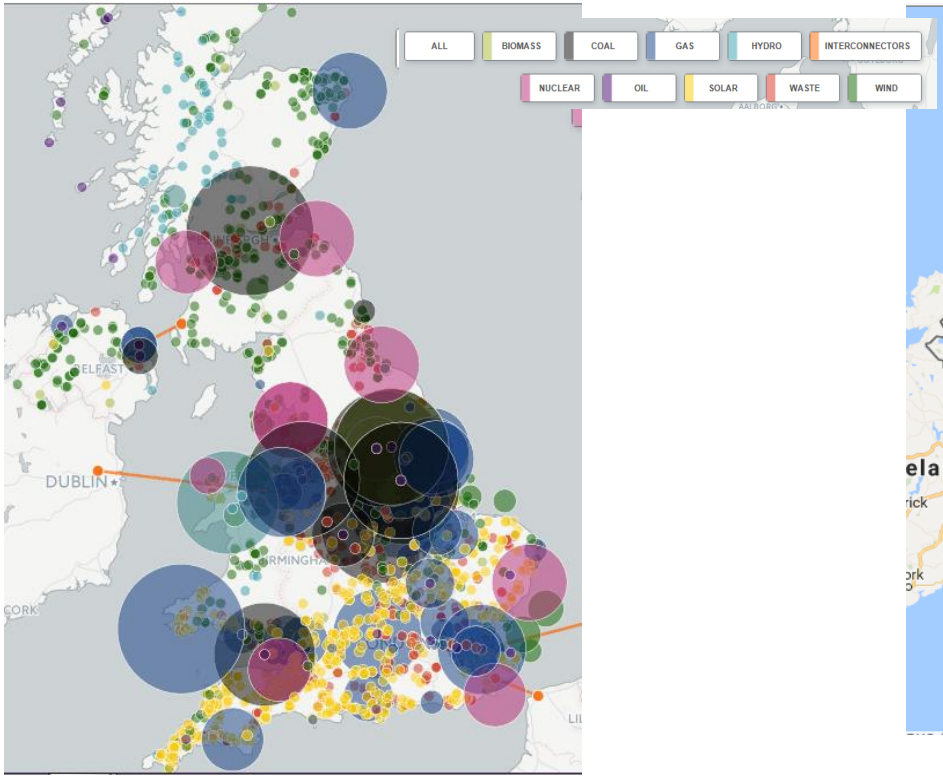
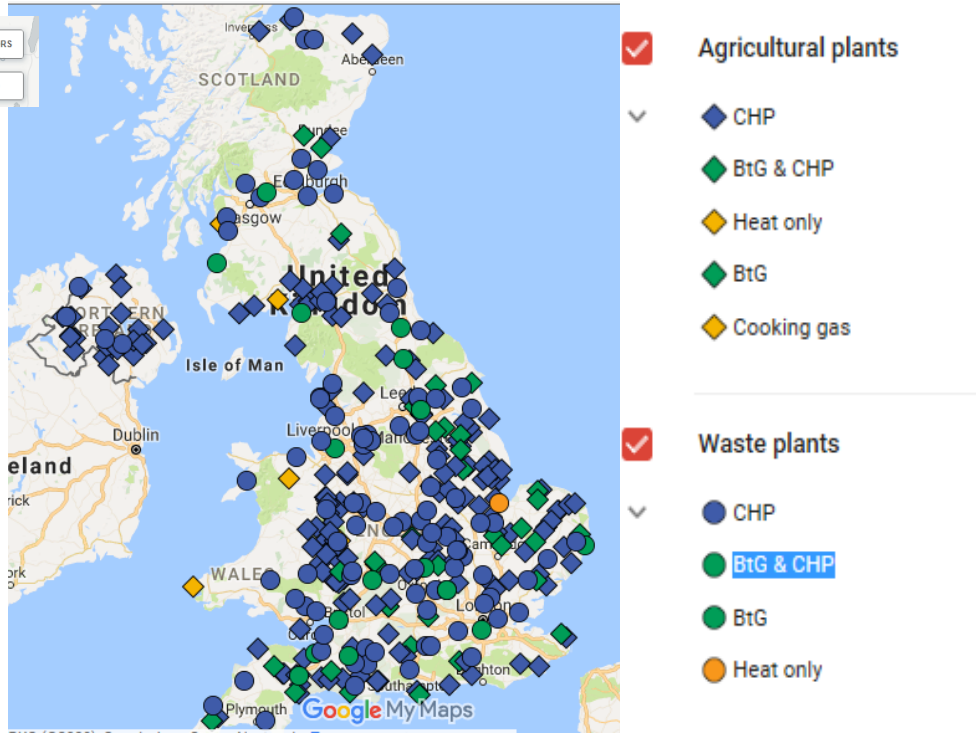
Power to Methane Concept



AD Technology Potential Integrations

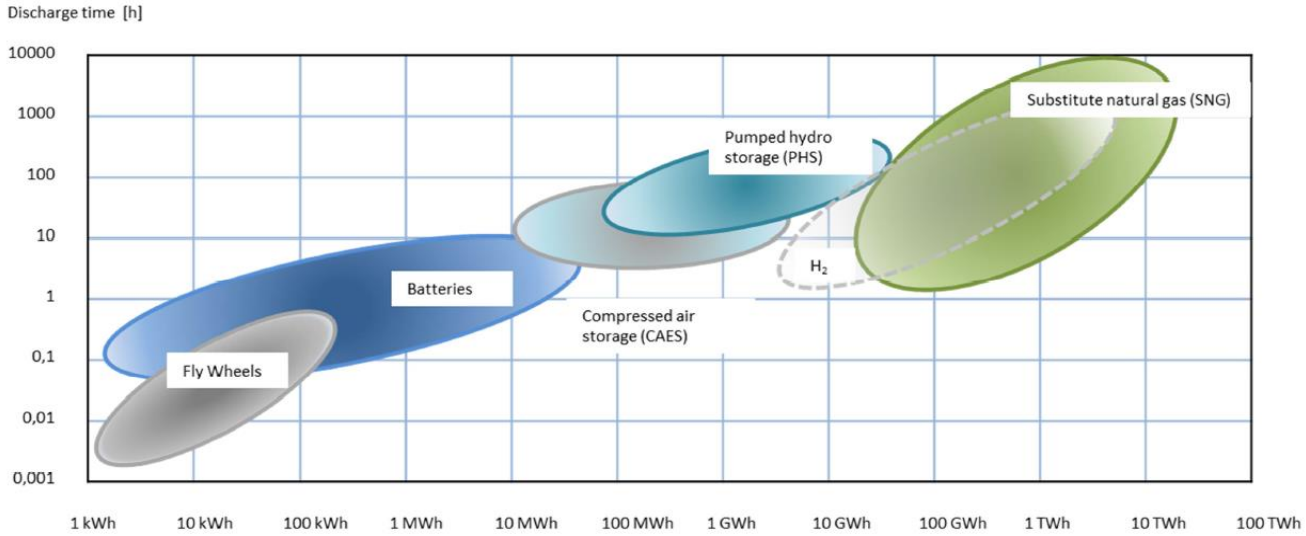


(Source: Carbon Brief Org website, March 2017)
Current distribution of energy generation in the UK (sources of CO_2 can be identified for coal, gas and biomass energy generation sites; renewable energy sites are also indicated)



AD infrastructure (outside Water sector); CO_2 is available at all these locations and can easily be used, in the BtG (biomethane to grid) plants in green colour the CO_2 has already been separated and is ready to use (Source: AD portal biogas map, March, 2017)

Storage of Renewable Electricity



Types of energy storage plotted against the amount of time they can be stored for and the quantity of energy that can be stored (Source: Specht et al . 2009)

- Batteries – expensive, not environ. friendly & short life
- Pumped hydro & underground compressed air storage are limited by geographical factors
- Super capacitors, superconducting coils & flywheels – short discharge period – suitable only as emergency UPS units

- Power to green gas – greatest capacity & the only option to store electricity in order of several TWh over a long period of time
  - Sabbatier conversion using metal catalysts – expensive, high temp requirement, low selectivity, low yields and deactivation
  - Biomethanation – low cost, low temp., high throughput & conversion efficiency and resistant to contaminants

Need to Match Electricity Supply and Demand

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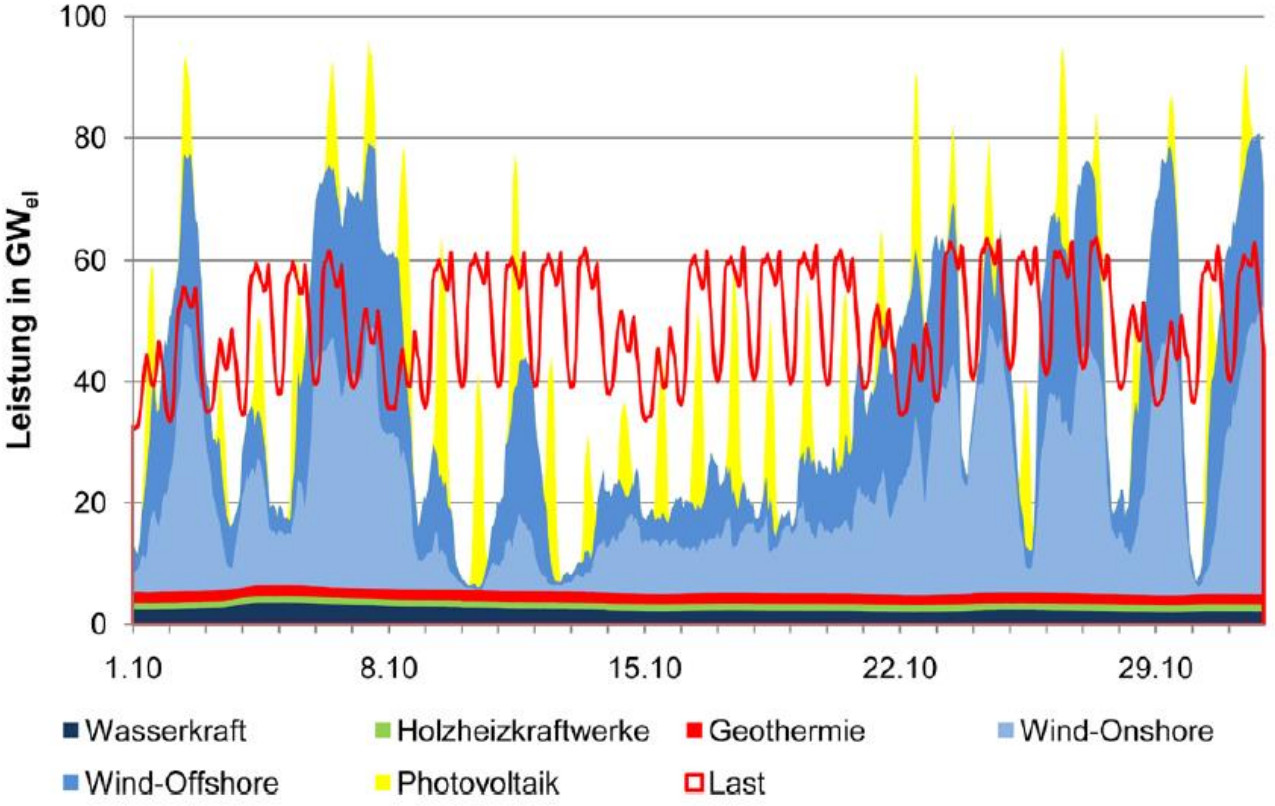
Gas Distribution



Simulated Power Demand and Renewable Electricity Supply in Germany in October 2050, Based on 2006 Weather

Source: Fraunhofer IWES, taken from Trost et al. (2012)

Need to Match Electricity Supply and Demand

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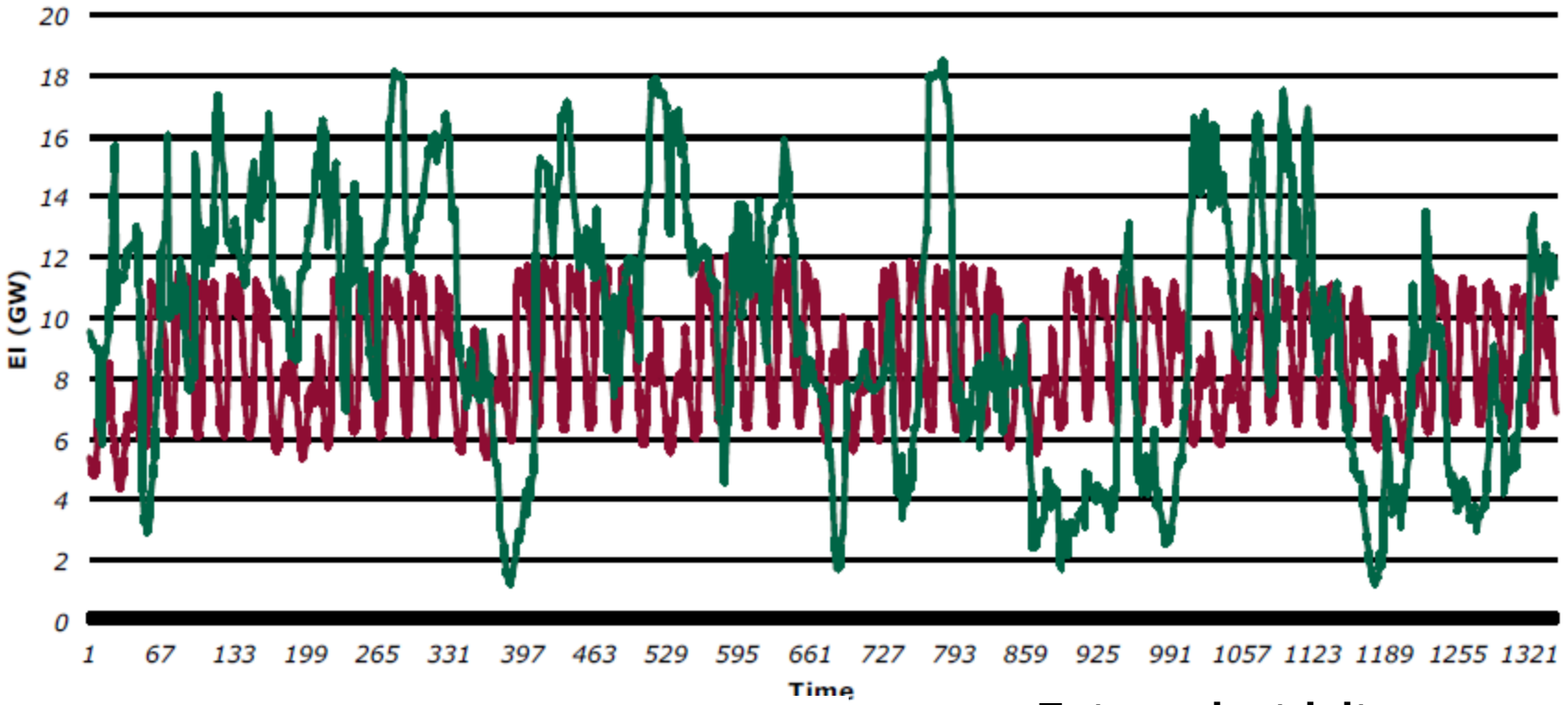
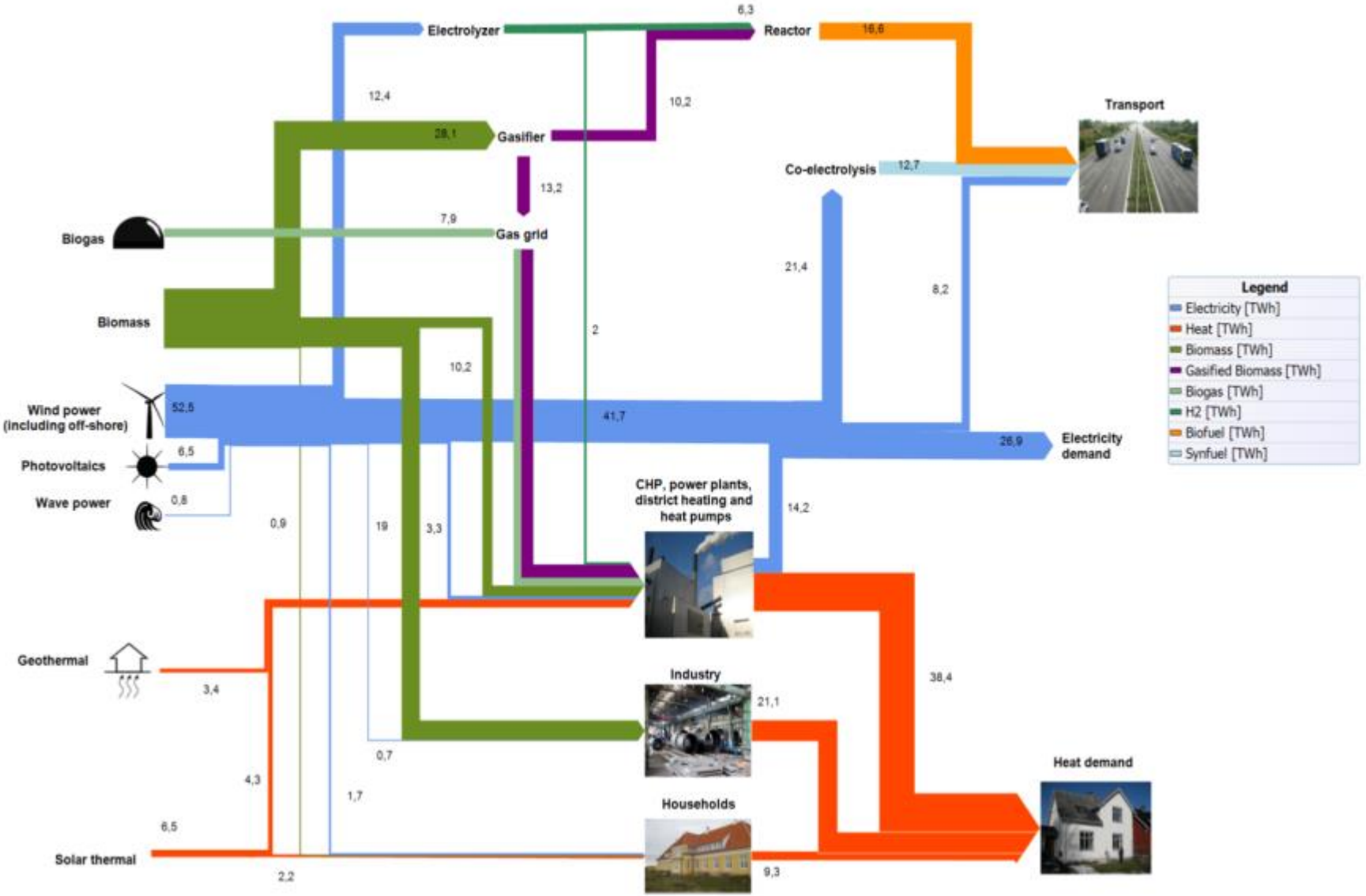


Electricity demand (current pattern)

Future electricity supply (wind-solar-biomass)

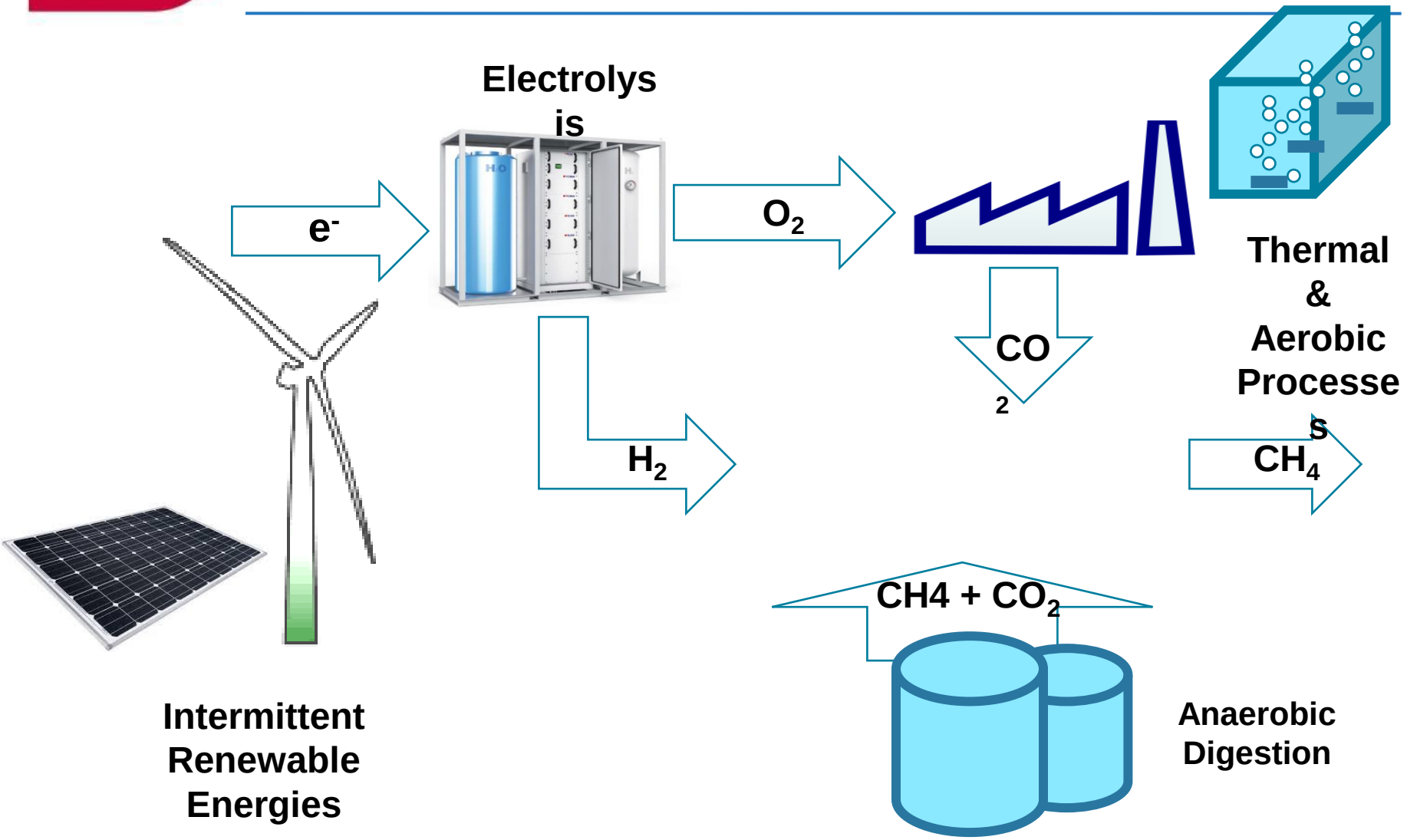
Source: Energinet.dk, *Energi 2050 – Vindsporet, January 2011*

Denmark's (100%) Renewable Energy Strategy for 2050

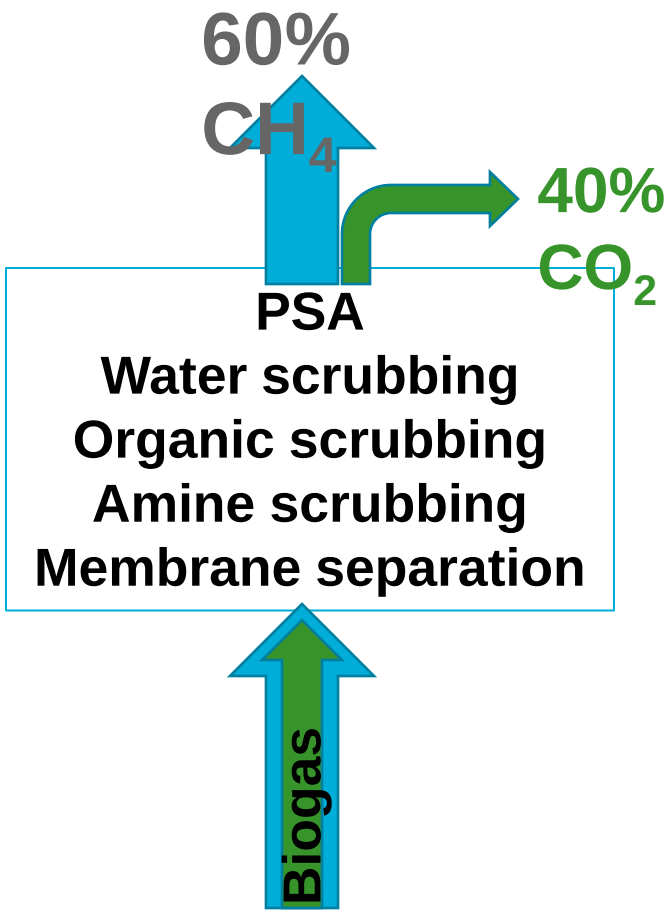


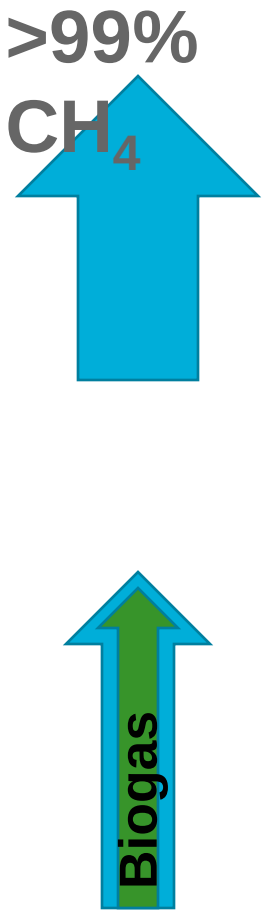
Source: www.ceesa.dk/Publications

Biomethanation
P2G & Biogas Upgrading



Existing Commercial Technologies for Biogas Upgrading vs. Biomethanation





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BIOMETHANATION

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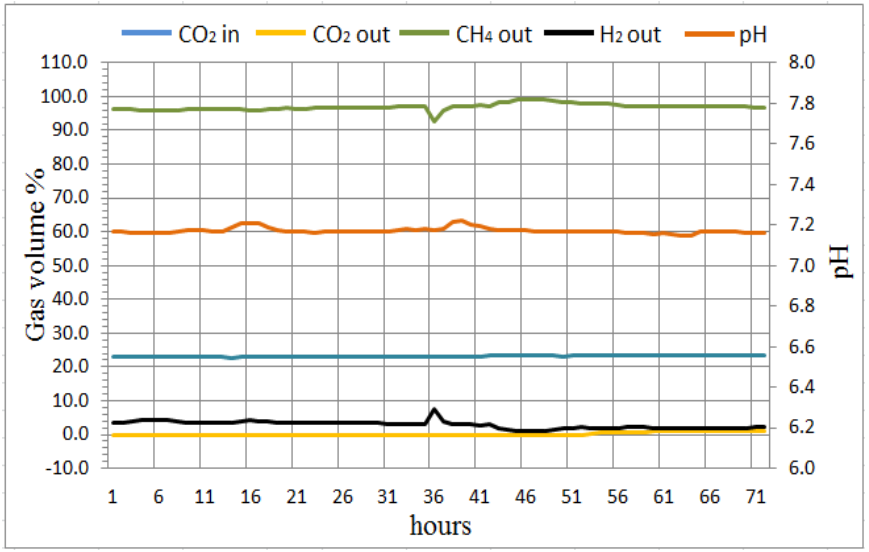
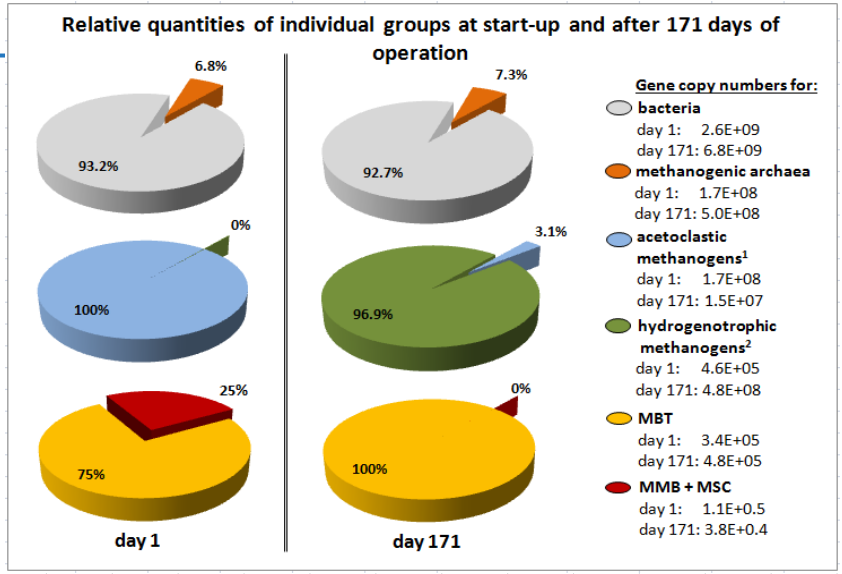
AERIOGEN® PCT filed P2G & Biogas upgrading

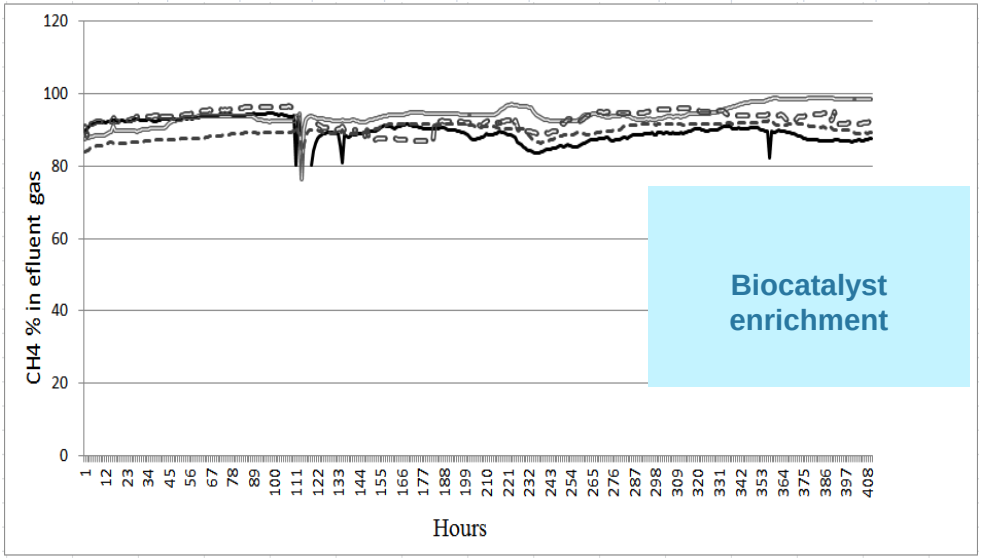
- AERIOGEN® has been developed through novel microbial community concepts, automation and control and multiple reactor designs evaluated for increased performance and reduced energy consumption and footprint
- Novel enriched, self sustaining and robust microbial culture
- Ex-situ process superior compared to in-situ since there are no conflicts with organics conversions
- Designed for high rate continuous and instantaneous conversion with a small footprint (>230 VVD and increasing) with 99.7% CH_4 output
- Low temperature mesophilic and low pressure operation
- Low maintenance; no nutrient addition after start-up and no pH buffers
- Automated gas throughputs for optimal efficiency
- Automated water removal; ability to maintain culture and nutrient levels
- Robust in terms of O_2 and intermittency in gas flows
- Low parasitic energy

AERIOGEN® High Methane Quality Output and Control Over Time





High input gases control allow a 99.7% quality output and help maintain appropriate pH



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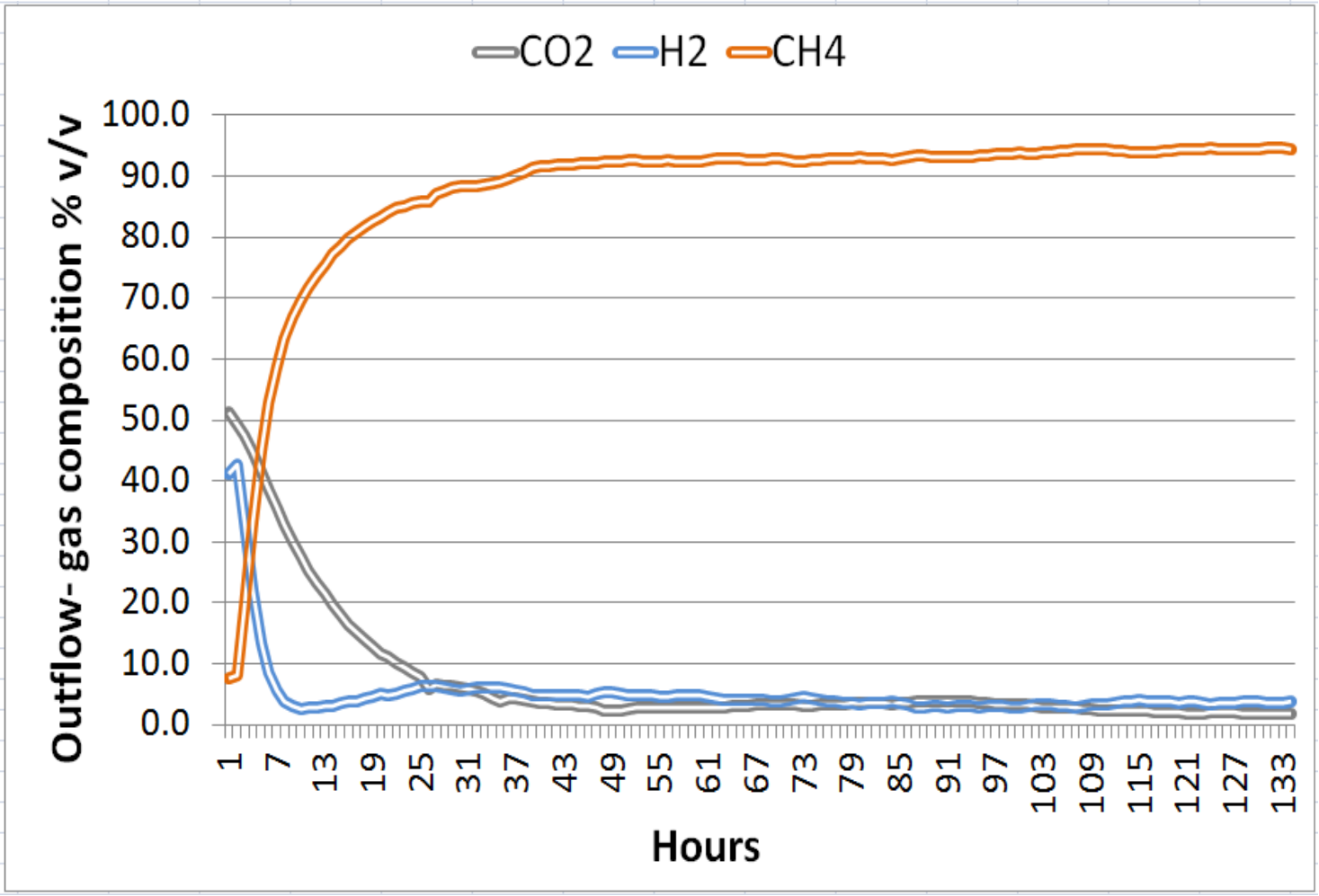
AERIOGEN® Process Recovery After Fasting for 45 days



Power-to-Green Methane in UK

Gas Distribution

- Feasibility study
- Production of ‘synthetic methane’ using biological methanation and electrolytic hydrogen
- CO_2 sourced from existing biogas to biomethane upgrade facility operating at waste water treatment plant
- H_2 from rapid-response PEM electrolysis providing grid-balancing services
- Biomethanation process **AERIOGEN®**
- Project commenced 1st June 15
- Funded by UK Government via Innovate UK
- Project partners: ITM Power, Wessex Water, Wales & West Utilities, University of South Wales, BPE Design & Support Ltd.

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Prifysgol De Cymru

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AERIOGEN® Technology Development

Innovate UK

IUK / BBSRC Industrial Biotechnology Catalyst

Feasibility of an Innovative reactor for enhanced 1C gas bioconversion for energy production and storage

Start Date: January 2016

Evaluate potential for improvement of gas / liquid transfer in novel reactor

- **Production of green methane**
- **Production of carboxylic acids**

BBSRC bioscience for the future

NiTech® SOLUTIONS

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Enhanced green CH_4 production with low cost energy storage through a real-time management strategy for AD plants to meet variable network gas demand

Flexible Methane Production

- Current configurations of AD/biomethane plants are not flexible in terms of gas output (over days/seasons), have long conversion periods and cannot vary output suddenly, leading to a mismatch between supply/demand
- Points of entry to the gas grid are limited by capacity on a daily basis as well as due to seasons e.g. summer 1/3 – 1/1000 of that in winter
  - **Leading to a number of AD plants not being able to connect to the gas grid**

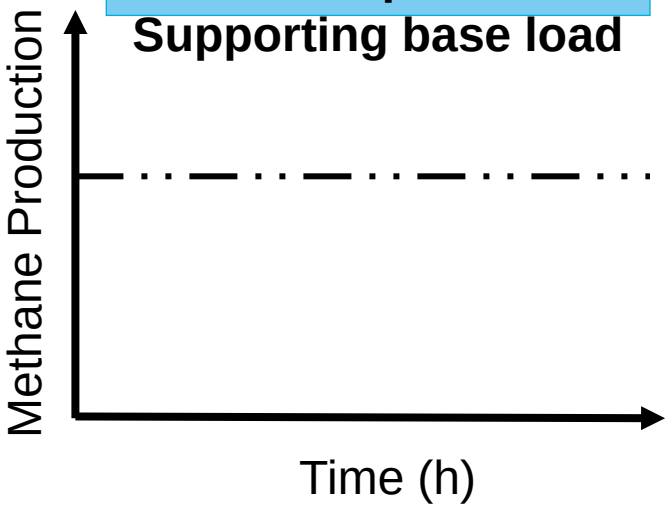
kess2
Ysgoloriaethau Sgiliau Economi Gwybodaeth
Knowledge Economy Skills Scholarships

WALES&WEST UTILITIES

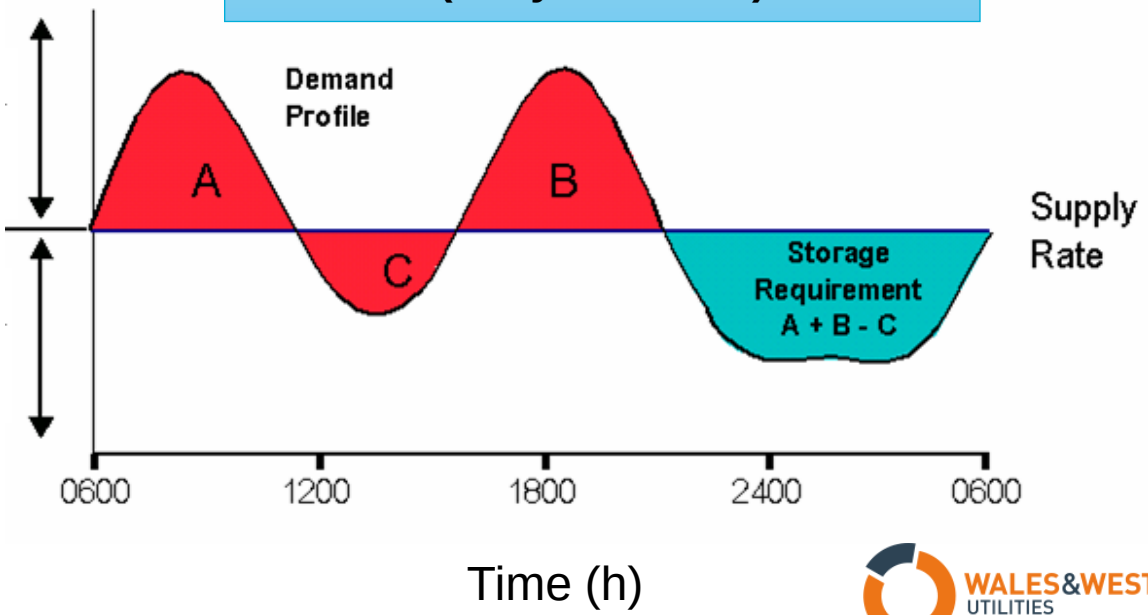
UNDEB EWROPEAIDD EUROPEAN UNION
Llywodraeth Cymru Welsh Government
Cronfa Gymdeithasol Ewrop European Social Fund

Varying Methane Production Profile

CURRENT
Fairly Constant Output
Supporting base load



FUTURE
Variable Output to Meet Gas Needs (Daily/Seasonal)



- AD Plant(s) as the only gas supplier(s) or part of a gas supply mix
- Production and supply of methane from organics and inorganic gases
- Production and supply based on predictive gas demand refined with gas grid feedback control (artificial intelligence based techniques) with less than 1 hr response

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Flexible Methane Production Project Objectives

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- Evaluate the range of spatial and temporal demands within gas networks
- Evaluate a selection of integrations between novel biotechnology reactors operating on a range of organics as well as inorganic gases
- Use ancillary technology to facilitate daily/weekly and inter-seasonal energy storage to enable rapid conversions to methane when necessary
- Evaluate a novel supervisory control system that links predictive modelling for gas network demand with novel control strategies for the biotech plant operation
- Establish the technical, economical and environmental feasibility for the implementation of this novel concept of energy storage

Bio-Alkane Production

- Possibility of addition of biopropane, produced via
  - hydrotreated vegetable oil (HVO) - restricted to oil availability
  - gasification & pyrolysis (cellulosic biomass)
  - hydrothermal fermentation (starch/sugars)
  - Conversion from biomethane
  - Some work has started on synthetic biology e.g. E. coli
  - Our work relates to ecosystem derived microbial cultures

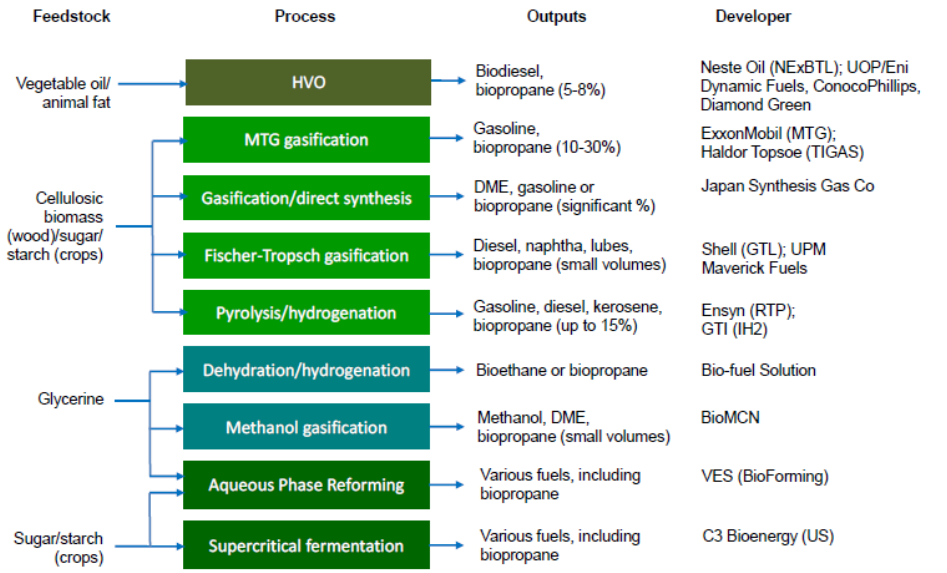

Figure 1: Principal process technologies that can produce biopropane

Source: Menecon Consulting/Atlantic Consulting analysis

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Production of high chain alkane gases (C2-C4) from anaerobic biological processes

- Production of C2-C4 bioalkanes gases for adjusting methane gas quality for natural gas grid injection (Wobbe index and CV)
- Reducing propane costs, additional installations and site footprint and even avoid planning refusal
- Reduce the H&S requirements and risks associated with large propane gas storage on sites by having production match demand
- Increase the gaseous stream sustainability by utilizing renewably produced alkane gases C2-C4, which would help further with the decarbonisation of the gas grid

kess2
Ysgoloriaethau Sgiliau Economi Gwybodaeth
Knowledge Economy Skills Scholarships

WALES&WEST UTILITIES

UNDEB EWROPEAIDD
EUROPEAN UNION

Llywodraeth Cymru
Welsh Government

Cronfa Gymdeithasol Ewrop
European Social Fund

Acknowledgments

Drs. Tim Patterson, Savvas Savvas, Alex Chong, Bing Tao, Phil Kumi, Prof. Richard Dinsdale and Joanne Donnelly

Prof. Sandra Esteves sandra.esteves@southwales.ac.uk

Panel Q&A

- Panel:
  - **Lorna Millington**, Design Manager, National Grid Gas Distribution
  - **Professor Sandra Esteves**, Energy and Materials Director, Wales Centre of Excellence for Anaerobic Digestion, University of South Wales
  - **Chris Clarke**, Director of Asset Management, Safety & Environment, Wales & West Utilities
  - **Bethan Winter**, System Operation Manager, Wales & West Utilities

SESSION 3 (PART TWO):
MOVING FORWARD

Ian Marshall
Green Gas Development Manager

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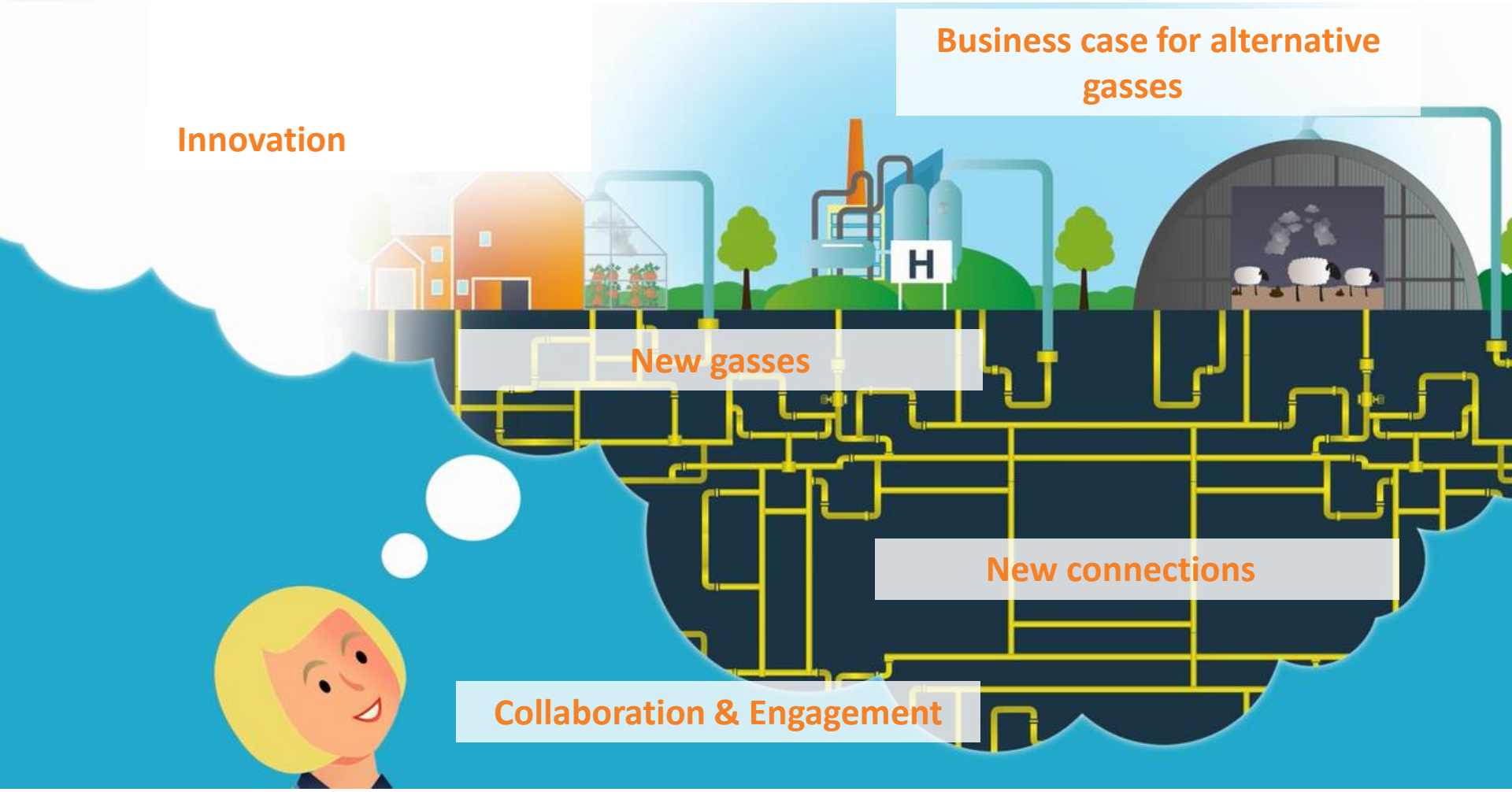
Designing our future

- Forward plan – what we want to do:
  - Develop a low cost investment pathway that will lead incrementally towards a low/zero carbon heat, power & transport future
  - Deliver domestic, commercial & industrial peak energy needs
  - Promote green and alternative gas sources
  - Enable renewable electricity by creating additional energy storage capability in our network – and balance supply and demand fluctuations
  - Reduce our carbon footprint, including reducing gas leaking from our network

The future from a Wales & West Utilities perspective



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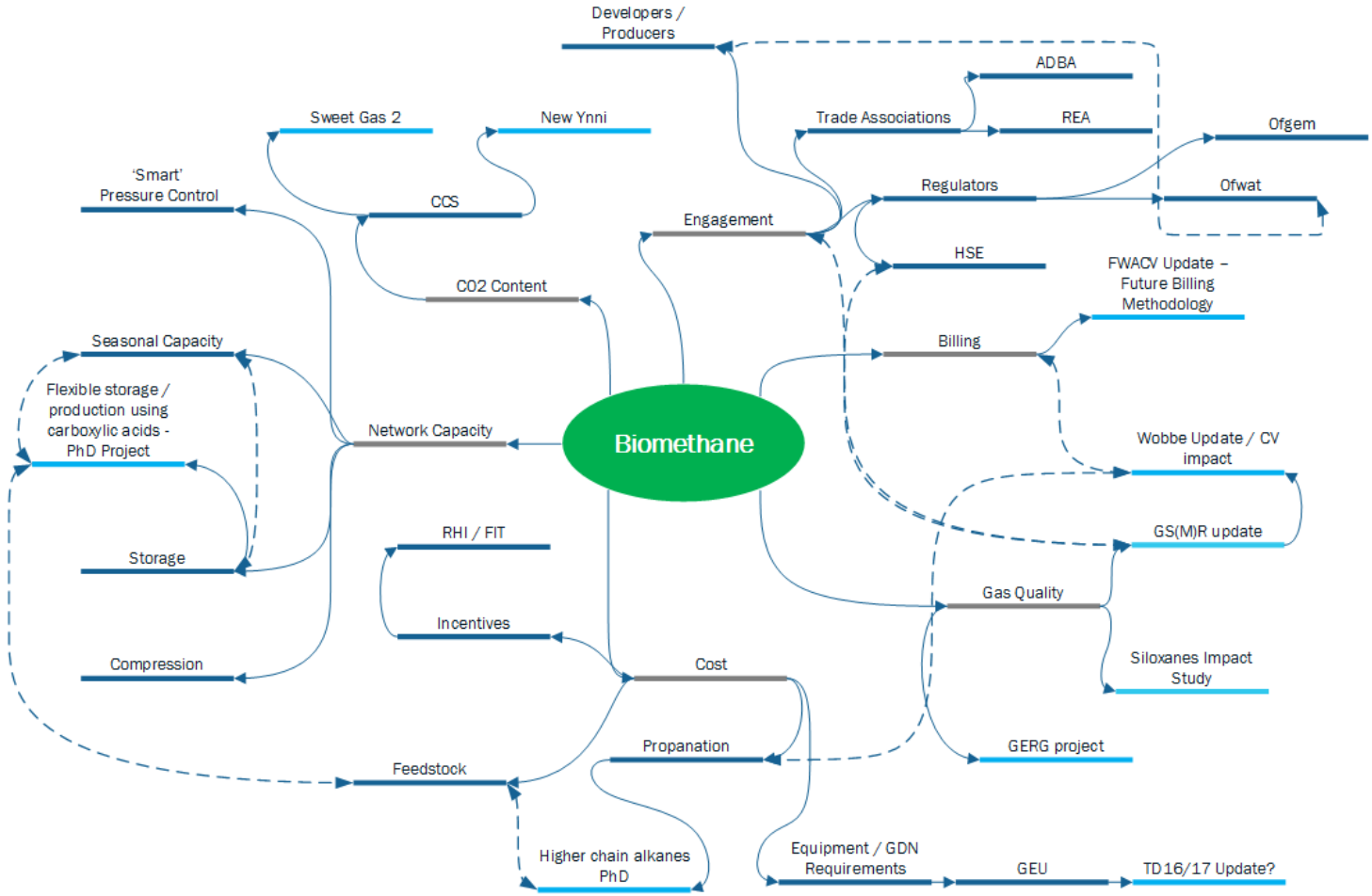
Collaboration & engagement

- Priorities for engagement
  - Meeting with stakeholders
    - Understanding future customer requirements is key to make sure our networks are fit for purpose
  - Workshops like today – frequency?
    - Today's workshop has come about as a direct result of feedback from stakeholder workshops last year
  - Connections Booklet
- Engaging with industry through industry groups
  - E.g. potential for natural gas vehicles
- Lobbying
  - Parliamentary
  - Regulatory
    - Further work with policy makers to make sure future energy pathways are based on robust evidence
    - Further work with BEIS / HSE to update GS(M)R

Innovation and challenges



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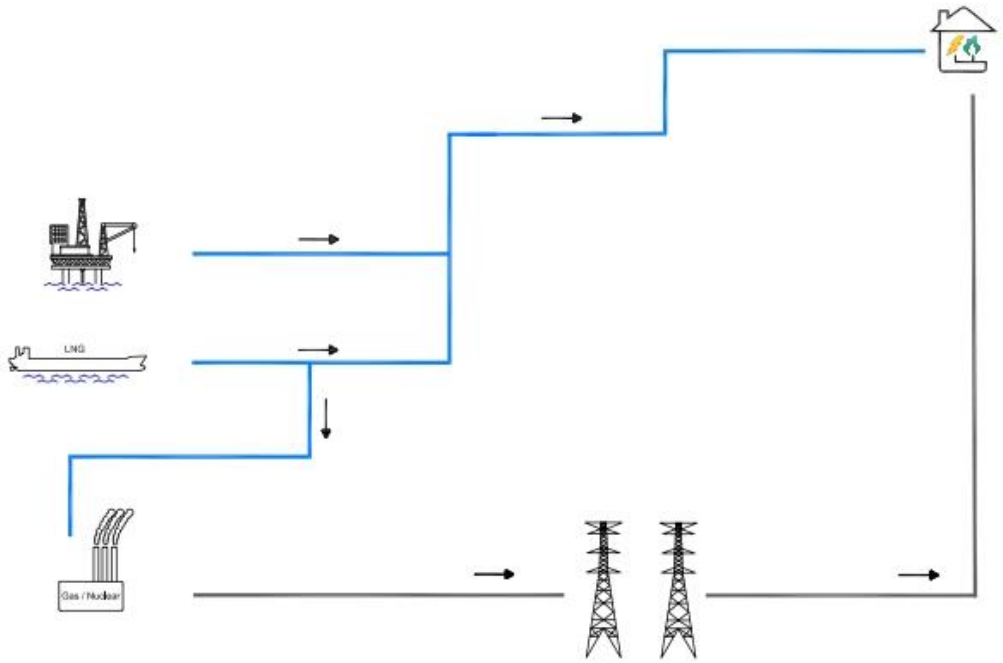
Development of energy networks



Key

Gas

Electricity

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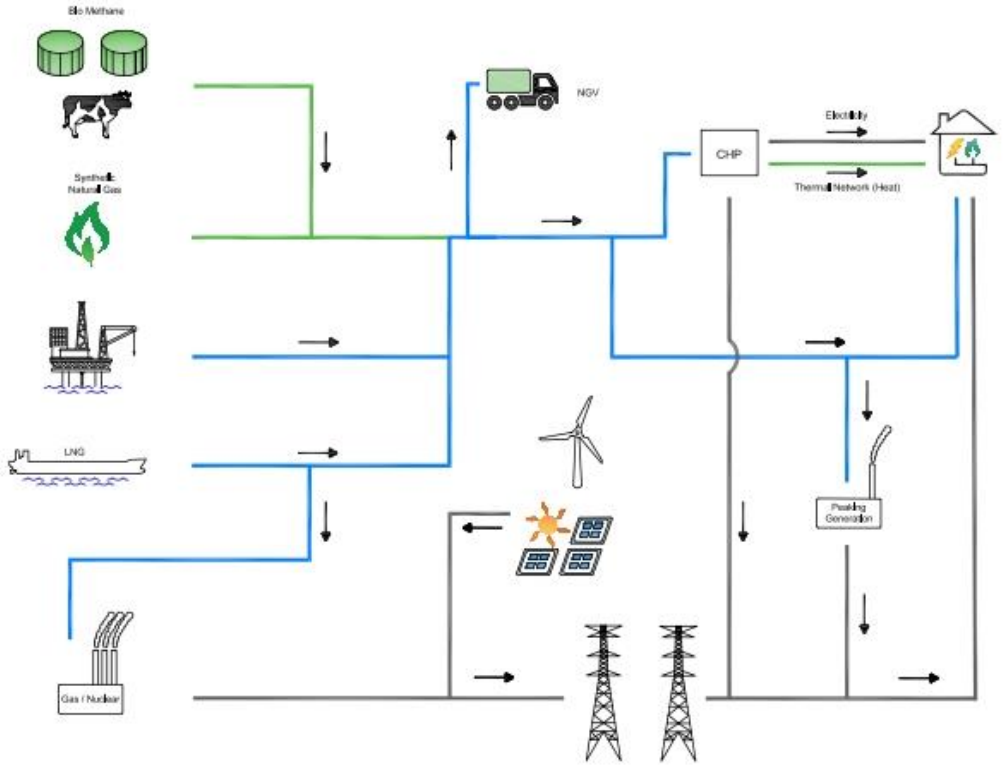
Development of energy networks



Key

- Gas
- Electricity
- Green Gas

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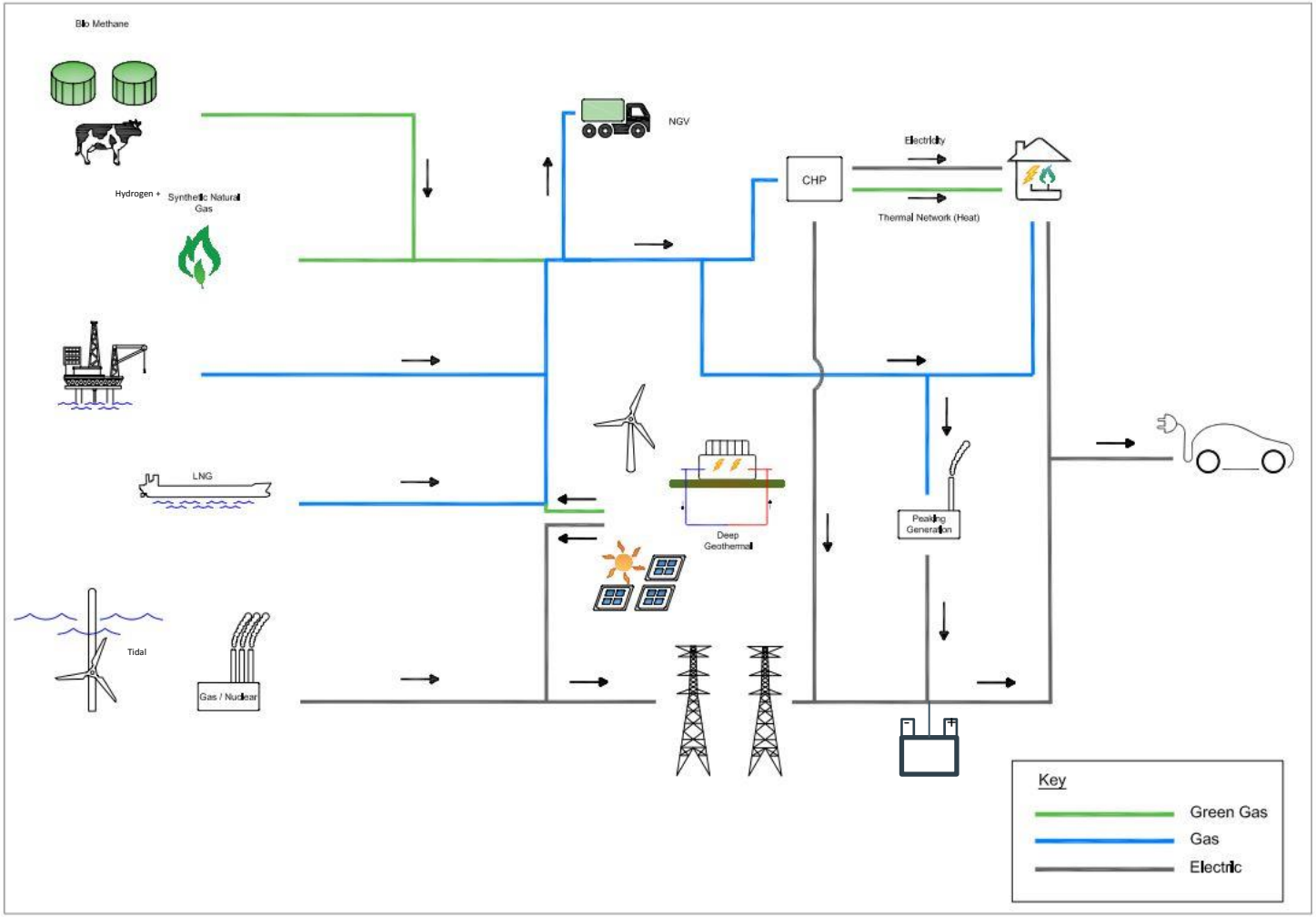
Future Energy Network



An integrated energy network enables the use of renewables

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WORKSHOP 3

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Questions

- Are we focusing on the right development areas of:
  - Gas quality
  - Network capacity
  - Alternative gases
  - Other innovations
- Do you think our ‘how to connect’ booklet is comprehensive?
- Anything else you would like to raise?

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THANK YOU FOR YOUR PARTICIPATION

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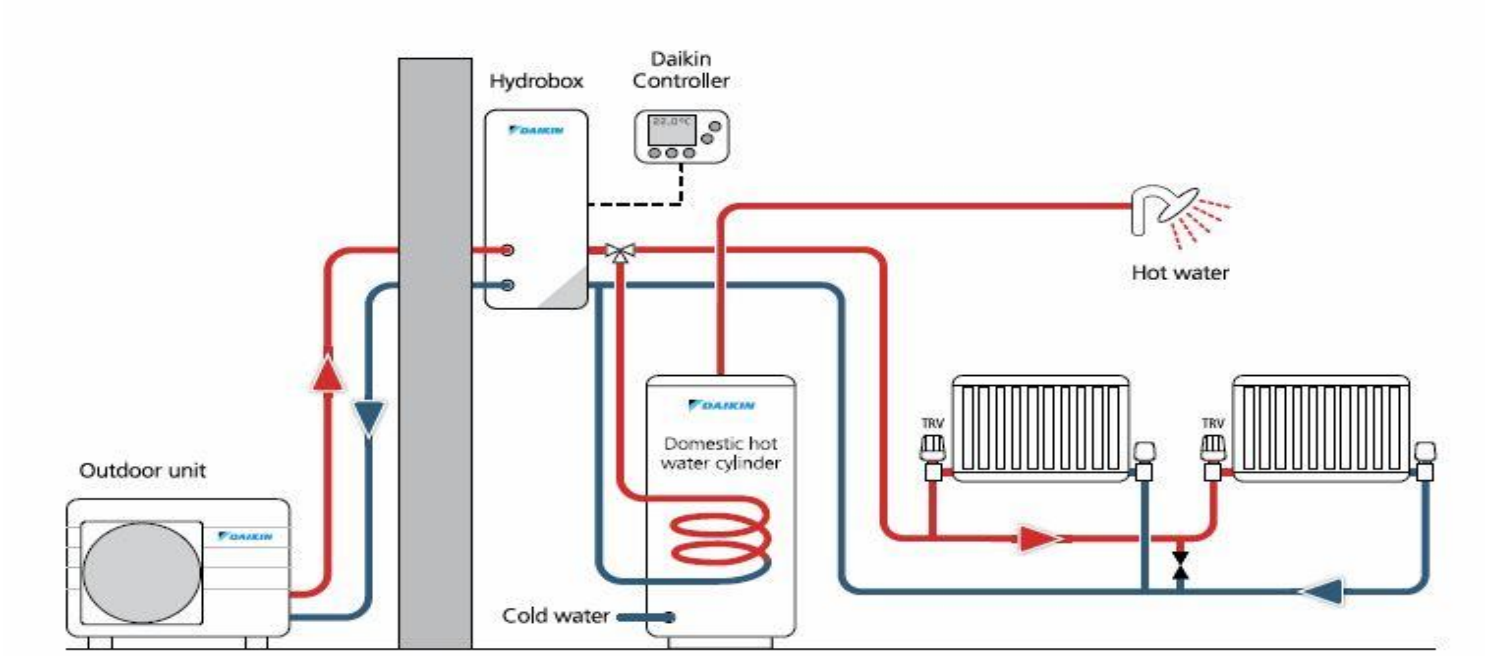
Project FREEDOM

- A £5m project to evaluate Hybrid Heat Pumps
- Install hybrid heating system into homes in 2017
- 75 systems to be installed in Bridgend



Small heat pump with gas boiler

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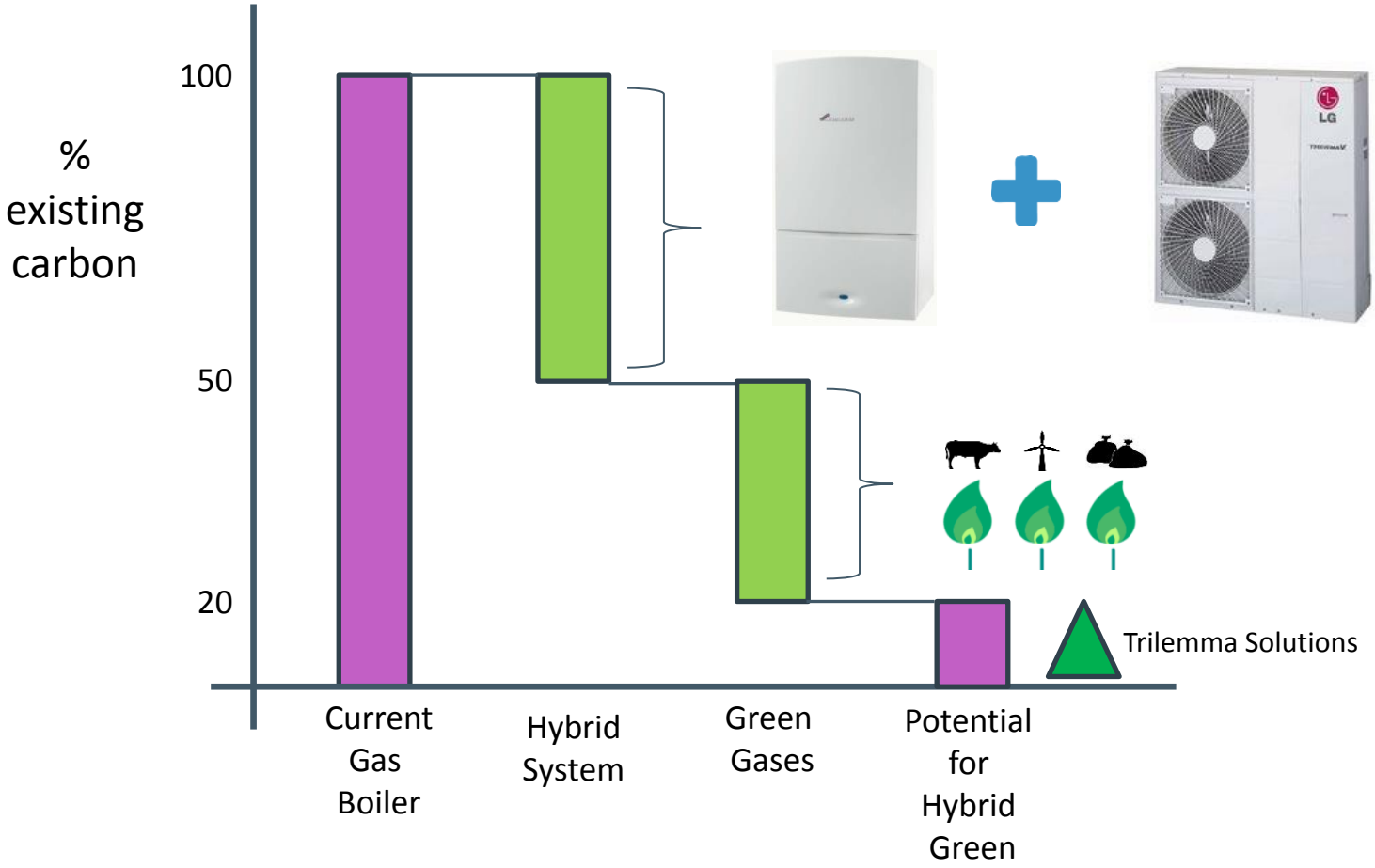
Waterfall – Hybrid Green Heating



Potential 80% carbon reduction

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Your energy
Our network

Using our gas network
for your alternative gas

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