Low Carbon Solutions
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Despite new technology, there has never been an energy transition in the past…

- Shifts in primary energy supply has taken decades in the past
- …but GROWTH in energy demand more than outweigh shift between supply sources
- To meet the 1.5 degree target, all energy use has to be carbon neutral by 2050!
- This cannot be solved by phasing in renewables only - it is currently a small fraction
- We need to use the entire toolbox to have the slightest chance of succeeding
The Challenge and the Tool-Box

- **Clean**
- **Reliable and Safe**
- **Affordable**

**Cost Efficiency EL : MOL**
- Energy Transport 1 : 10
- Long Term Storage 1 : 100

**European Energy-Mix 2018**
- MOLECULES
- EL
- Clean EL

**Green Hydrogen and Power to X**
- Electrolyser and Fuel Cell

**Blue Hydrogen**
- CCS
- Hard-to-Decarbonize Industry
- Permanent CO2 Storage (CCS)
- Gas Reformer w/CCS

**Renewable EL**
- Nuclear

**Zero Carbon EL**
- Hydrogen fired EL power

**Improve Carbon Efficiency**
- Switch from Coal ...
- ... to Natural Gas

**Energy Transport**
- 1 : 10

**Long Term Storage**
- 1 : 100
Four Main Strategies

**Transformational Blue Hydrogen**
Establish major hydrogen infrastructure supplemented by renewable

**Incremental Renewable**
Focus on semi-commercial solutions (limited market intervention)

**Transformational Renewable**
Electrification based fully on renewable solutions (including electrolyser and fuel-cell hydrogen solutions)

**Pragmatic Electrification**
Electrification based on renewable, but fossil based back-up and massive nuclear
Equinor Hydrogen Portfolio

**H2M - Magnum**
- Energy: 8-12 TWh
- Utilise existing gas power plants
- Switch fuel from natural gas to clean H2
- Clean electricity
- Clean back-up for solar and wind
- Launch large-scale H2 economy
- Partners: Nuon and Gasunie

**H21 North of England**
- Energy: 75-85 TWh
- Domestic heating in UK
- Utilise existing gas network
- Synergies with industry/power generation
- Enables H2 to transport later
- Partners: Northern Gas Network and Cadent

**New Projects**
- Maritime transport – Norway
- Clean Hydrogen Pilot - Norway
- Ammonia to Power – Japan (6-7 TWh)
- Power and Industry – France with GRT Gaz
- Heat and power – Germany with OGE
- Hydrogen CCU – UK (80-90 TWh)
- Power and Industry – NL (12-20 TWh)
H2M – Magnum, Netherlands

- Energy: 8-12 TWh
- CO₂ emissions reduction of 2 Mton/year
- Utilise existing gas power plants and gas infrastructure
- Switch fuel from natural gas to clean H₂
- Clean, flexible electricity as back-up for solar and wind
- Launch large-scale H₂ economy

- Partners:  
  [NUON]  
  [gasunie]
Perfect fit of Offshore Wind and Hydrogen

360 MW

440 Mw Unlimited, Clean Backup

20,000 x 20ft (2.5 days backup)

1 MWh Li-ion batteries 10 sec backup
Wind Intermittency Managed via Blue or Green Hydrogen

Simplified concepts

Perfect fit #1

100%

50%

Perfect fit #2

Excess, curtailed wind power converted to hydrogen

100%

50%

Perfect fit #1

Electricity from #2,3,4 via Green Hydrogen

Stable demand

One project enough to back-up 200 wind turbines (6MW)

Large portfolio required to back-up 200 wind turbines (6MW)

1 unit

1.200 MW Flexible Clean Power

3.600 MW Electrolysis

1.200 MW Fuel Cells

x 600 wind turbines (6MW)

Major Substations(s)
H21 North of England

- System approach to decarbonise residential heating and distributed gas use
- **Fuel switch from natural gas to hydrogen**
  - Large-Scale: 12.5% of UK population, ~85 TWh
  - 12.5 Million tons CO2 reduction per year
  - 12 GW hydrogen production
  - 8 TWh storage of hydrogen
  - CO2 footprint 14.5 g/KWh
  - Offshore CO2 storage in either UK or Norway
  - Facilitating unlimited system coupling between gas and electricity
  - CAPEX: £23 billion
H21 NoE Supply Concept

Greenfield Hydrogen Facility
- Location: Easington
- Capacity: 12 GW
- Configuration. Multi train, self-sufficient with power

Hydrogen Storage
- Location: Aldbrough
- Capacity: 8 TWh
- Configuration. 56 caverns at 300,000 m³

CO2 Storage
- Location: Bundter
- Capacity: +600 Million @ 17 mtpa
- Configuration. Saline aquifers
The Next Steps

- **2019**
  - Critical Safety Evidence

- **2020**
  - BEIS Led: £25m ‘Hy4Heat’
  - GDN Led: £10.3m H21 NIC
  - GDN led: £5m Field Trials (NOT YET FUNDED)

- **2021**
  - Live Trial (one winter)

- **2022**
  - The Critical Evidence Justifies the safety case for the live trial (NOT YET FUNDED).

- **2023**
  - H21 NoE: £250m FEED Study (NOT YET FUNDED)
  - Earliest Policy Decision
Understanding the Challenge

Natural Gas currently provides Europe with more than 1500 TWh of flexible energy.

What is 1500 TWh?

Vehicle
20,000,000,000 X

Battery park
11,600,000 X

Hydro
200 X

TESLA 75D Li-Batteries

World largest battery park in Australia (129 MWh)

Norways biggest hydro electrical storage - Blåsjø
Decarbonising Energy Systems

**Easy** complexity to decarbonise **Hard**

**Transport**
- Battery (mostly) plus Hydrogen for Heavy Duty
- Large Battery Systems for Daily Swing (night-to-day)
- Light Industry powered by Renewable

**Power**
- Hydrogen Fuel-Cell Trains
- Hydro-Power as Battery for Small Scale Intermittency
- Heavy Industry powered by Hydrogen from Natural Gas + CCS

**Industry**
- CCS for Industry without other Alternatives
- Hydrogen for Large Scale Seasonal Storage

**Heat**
- Heat Pumps For Efficient Use of Electricity in Homes
- Hydrogen for Efficient Transfer of Energy from Production to End-Users

**Multiple technologies to address the challenge**

Natural Gas Reforming to Hydrogen with CCS
Key Messages

• Decarbonizing Europe towards 2050 is a major challenge.

• Renewable solutions are perfect for the carbon-light sectors.

• Heavy industry, heat and flexible power generation require large-scale solutions on which we need to start working today.

• Hydrogen from natural gas with permanent offshore storage of CO2 offers:
  • **Low cost** – *Gas reforming is the most cost effective hydrogen pathway*
  • **Low technical risk** - Proven technology in H2 production and CO2 storage
  • **A clean value chain** – *The CO2 is returned to permanent offshore storage*
  • **Large scale** – *The industry has demonstrated a track-record of mega projects*

• Hydrogen from natural gas with CCS will establish a robust hydrogen infrastructure that green hydrogen can utilize.