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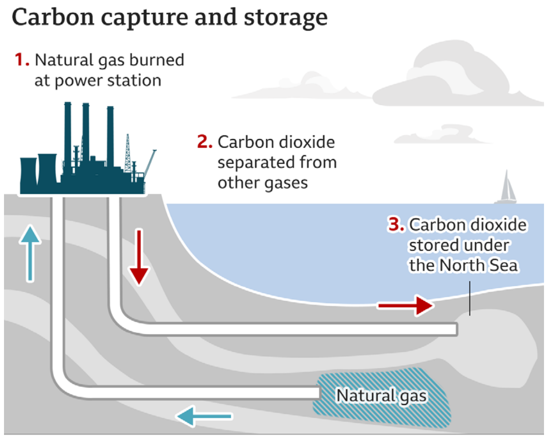
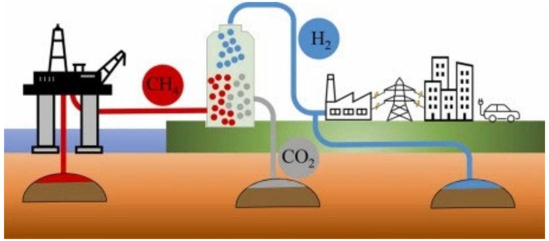
Sustainability at Great Yarmouth Power Station





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About Me

- Alfie Dellar
- Student at UTCN
- Maths, Physics, and Engineering A-levels
- Interested in engineering

What I’ve done/learnt

- 1 Week at Great Yarmouth Power Station
- 2 Days at RWE Swindon offices
- Multiple EEEGR workshops
- 3 Weeks at Orbis energy (for research)

My Project

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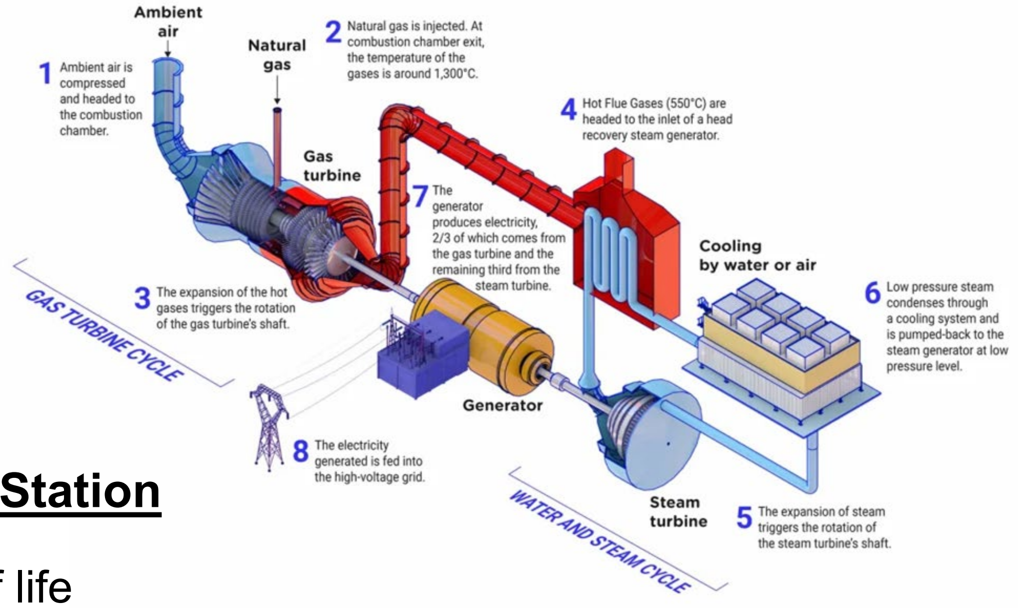
- ➔ Decarbonisation at Great Yarmouth Power Station
- ➔ Hydrogen fuel and Carbon Capture and Storage (CCS)
- ➔ Effects on Efficiency
- ➔ Analysis of what should be put in place

Great Yarmouth Power Station

Positives about the Power Station

- It has a strong, direct link with Bacton Energy Hub
- RWE owns a large plot of land around it (helpful for Carbon Capture)



CCGT: Combined Cycle Gas Turbine

Things to consider about the Power Station

- It is getting towards its planned end of life
- Requires regular maintenance

Bacton Energy Hub

What is it?

- 5 Gas terminals within 4 sites
- Processes and extracts gas for Great Yarmouth Power Station (and other sites e.g. Kings Lynn)
- Natural gas (Methane) from North Sea Gas Reserves

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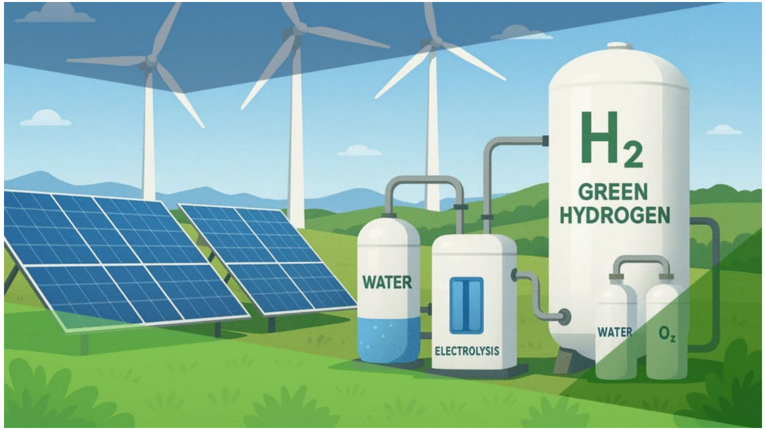
Hydrogen

Green

- ❖ Produced via electrolysis of water
- ❖ Electricity comes from renewables (e.g. wind, solar)
- ❖ Costs around £1 billion to establish the infrastructure



Blue

- ❖ Produced via steam methane reforming (use of steam)
- ❖ Steam from either an electric boiler or a CHP
- ❖ Costs around £1 billion to establish infrastructure

Hydrogen

Emissions

- No CO2 emissions from hydrogen combustion
- Increase in NOx emissions - not a direct greenhouse gas, but causes problems e.g. acid rain
- Hydrogen is also not a direct greenhouse gas, but if a pipe leaks, the H2 will react with other chemicals in the air to create things such as methane

Percentage

- **20%** - a mixture of 80% methane and 20% hydrogen by volume, which is the maximum percentage of H2 that can be put through pipes and flanges without substantial leaks
- **100%** - Pure hydrogen gas, flanges must be welded and massive changes would need to be made to the CCGT e.g. a new turbine

Carbon Capture

Non-Pipeline Transportation

- CO2 stored as a liquid
- Highly polluting
- Commitment to more employees
- Transfers CO2 to an offshore platform where it is injected into empty gas reserves

Pipes

- Very long pipeline required to be built underwater
- Difficult to do maintenance
- If the pipe leaks, it will be highly polluting
- Injects CO2 directly into empty gas reserves

Carbon Capture

Emissions

- Reduces CO2 emissions by 90-95%
- The Carbon Capture infrastructure will require energy, making the whole process less efficient
- Pollution from boats/ pipe leaks during transport

The Infrastructure

- Very large amount of space required on site
- Technology exists already
- £2+ billion pound project

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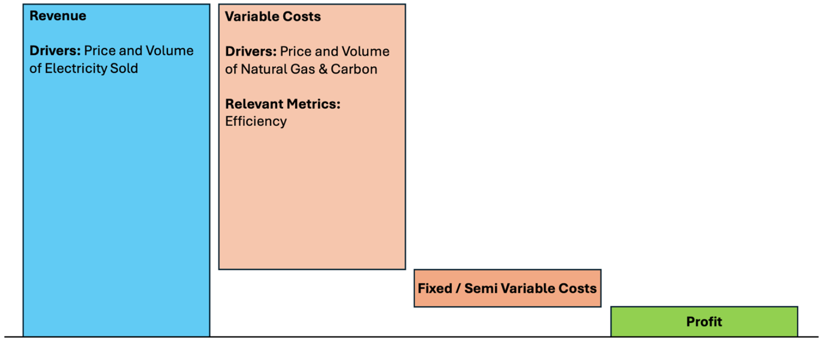
End to End Efficiencies

Why have I looked at efficiency?

- High efficiency = high profits
- Too much efficiency loss makes a solution unviable for use
- Have to be able to meet energy demands (maintain security of supply)

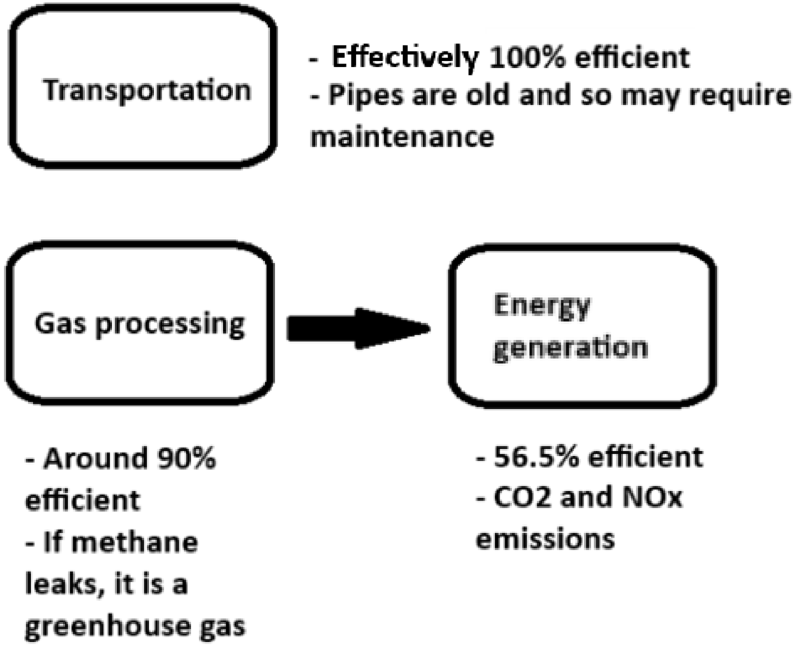


An illustration of the economics of a UK gas power plant – not to scale

I have ignored energy losses from:

- Power transmission from the power station
- Methane extraction

Current Great Yarmouth Power Station



Overall Efficiency: 50.9%

Green Hydrogen

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Transportation

- 90% efficient
- Pipes in Great Yarmouth would need to be modified (flanges welded)
- Hydrogen is not directly a greenhouse gas but can react with other gases to make some e.g. methane

Electrolyser → **Liquefaction + storage** → **Energy generation**

Electrolyser

- 75% efficient
- No direct emissions
- Requires electricity (from windfarms)

Liquefaction + storage

- 90% efficient
- Requires electricity for liquefaction

Energy generation

- 56.5% efficient (no change)
- Zero carbon emissions
- NOx emissions

Overall Energy Efficiency: 34.3%

Blue Hydrogen (Electric Boiler)

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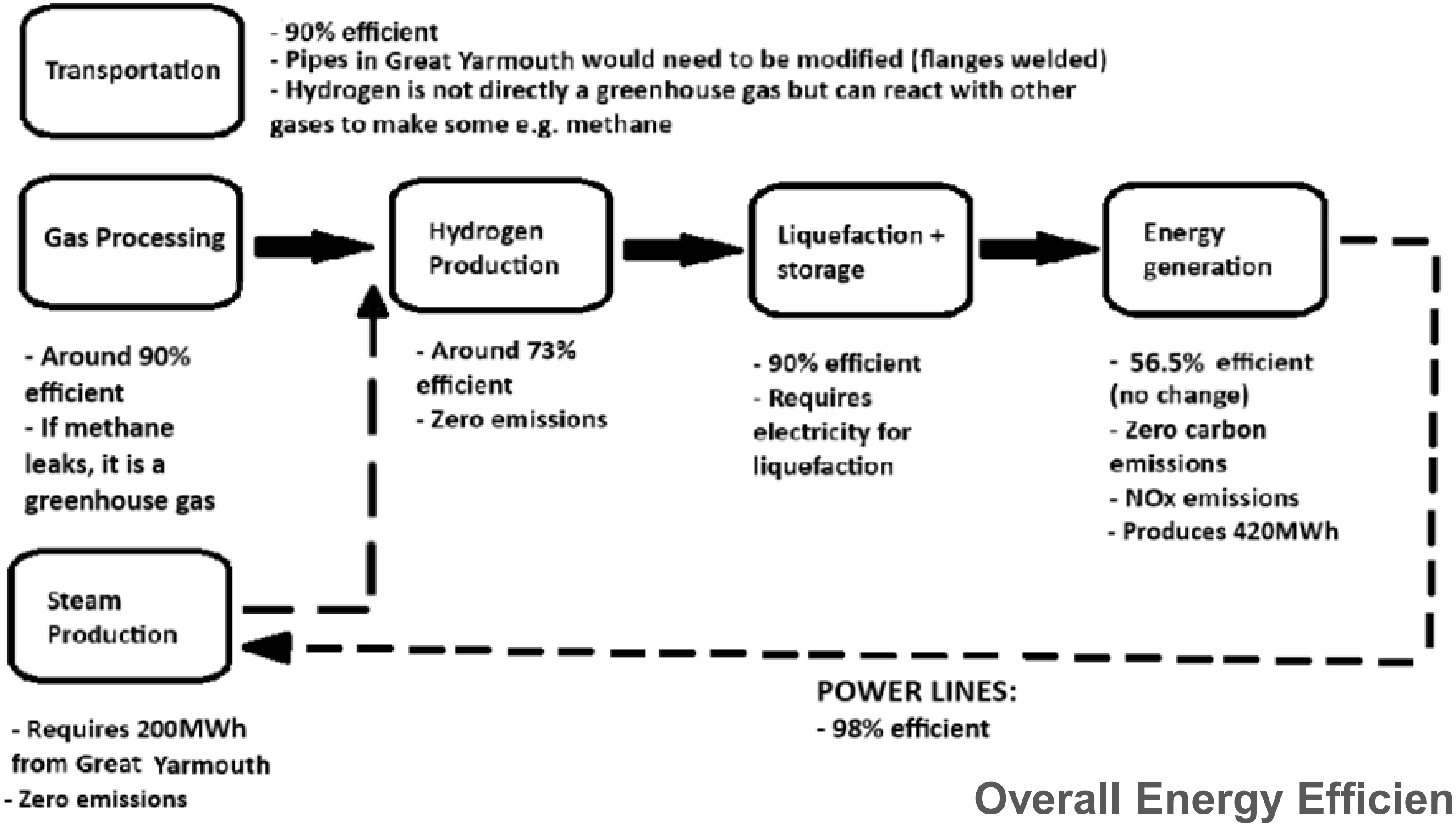
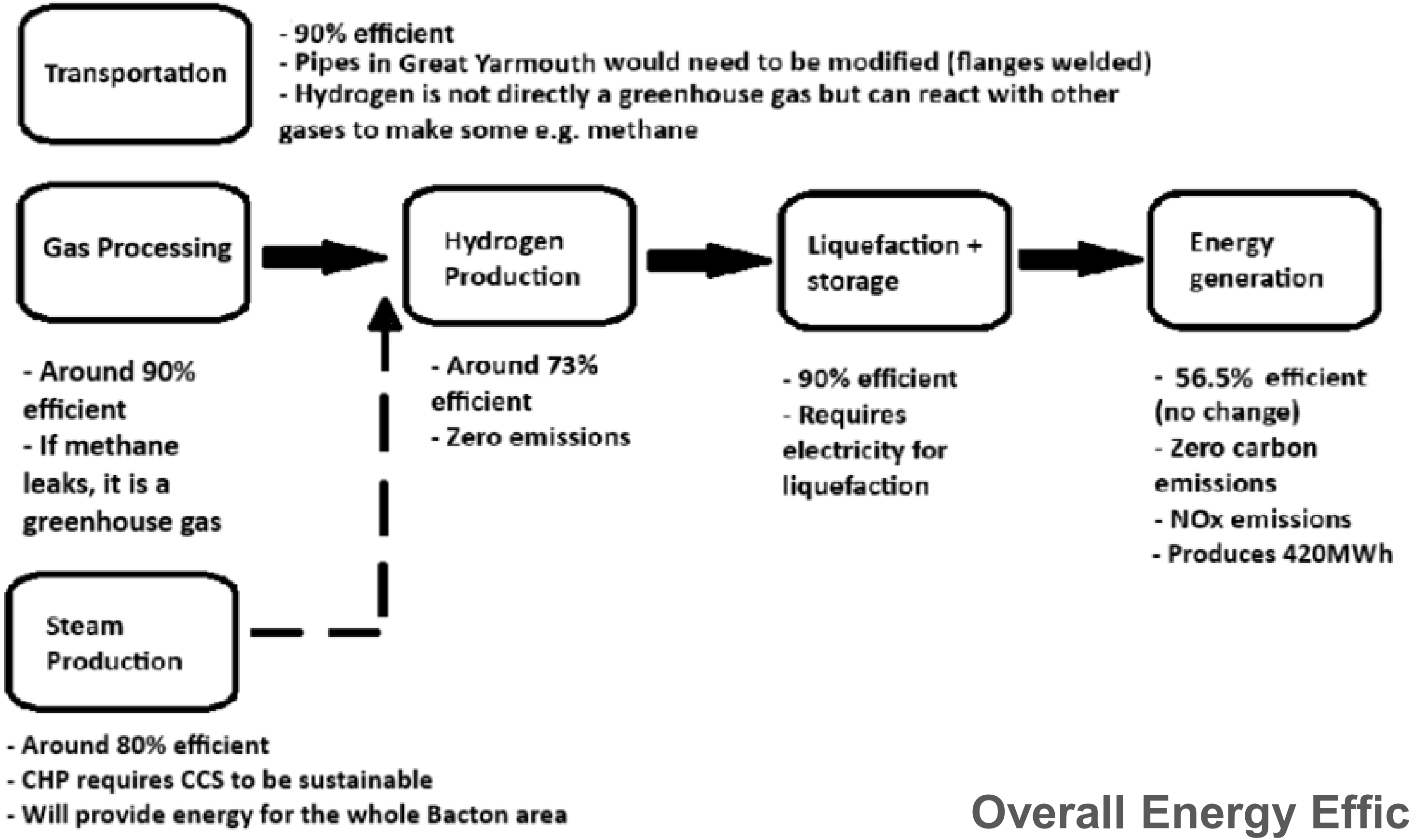


Overall Energy Efficiency: 14.0%

Blue Hydrogen (Combined Heat and Power plant)



Overall Energy Efficiency: 24.1%

Carbon Capture (Non-Pipeline Transportation)

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Transportation
- Effectively 100% efficient
- Pipes are old and so may require maintenance

57.7% total efficiency

Gas processing → **Energy generation** → **Carbon Capture** → **Liquefaction** → **Boat (transport)** → **Injection into the ground**

Gas processing
- Around 90% efficient
- If methane leaks, it is a greenhouse gas

Energy generation
- 56.5% efficient
- CO_2 and NOx emissions

Carbon Capture
- Around 80% efficient
- Around 90% of CO_2 removed
- Since it requires power, the power station will have to run for longer, decreasing CO_2 reduction to around 70%

Liquefaction
- Around 94% efficient
- Carbon must be stored as a liquid for overall efficiency
- Dangerous to store in tanks in town

Boat (transport)
- 100 metric tonnes of fuel per day
- 625MWh per day assuming it runs 1/4 of the time
- Highly polluting

Injection into the ground
- Around 250 MWh per day
- Use of empty gas resevoirs

Energy output of GY power station per day: 5GWh
Final energy: 2.885GWh

Overall Energy Efficiency: 29.3%

Carbon Capture (Pipes)

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Transportation

- Effectively 100% efficient
- Pipes are old and so may require maintenance

72.5% total efficiency

Gas processing → **Energy generation** → **Carbon Capture** → **Compression** → **Pipes** → **Injection into the ground**

Gas processing
- Around 90% efficient
- If methane leaks, it is a greenhouse gas

Energy generation
- 56.5% efficient
- CO_2 and NO_x emissions

Carbon Capture
- Around 80% efficient
- Around 90% of CO_2 removed
- Since it requires power, the power station will have to run for longer, decreasing CO_2 reduction to around 70%

Compression
- Around 125 MWh used per day
- compressed to a supercritical state (not liquid)

Pipes
- 100% efficient
- Polluting if it leaks
- Very long pipe required

Injection into the ground
- Around 250 MWh per day
- Use of empty gas resevoirs

Overall Energy Efficiency: 36.9%

Summary Table

	Efficiency	Project Cost	Pollution	Maturity
Current Great Yarmouth (unchanged)	50.9%	£0 extra cost	Substantial CO_2 emissions, some NOx emissions	Towards its planned end of life
Green Hydrogen	34.3%	£1 billion	Zero CO_2 emissions, more NOx emissions	Very new technology, untested
Blue Hydrogen (electric boiler)	14.0%	£1 billion	Zero CO_2 emissions, more NOx emissions	Tested and proven technology
Blue Hydrogen (CHP)	24.1%	£2 billion	Minimal CO_2 emissions, more NOx emissions	Tested and proven technology
Carbon Capture (Non-Pipeline Transportation)	29.3%	£2+ billion	Boat is likely highly polluting, 90-95% CO_2 reductions	Currently used and tested technology
Carbon Capture (Pipes)	36.9%	£2+ billion	90-95% CO_2 reductions	Widely used and tested technology

PESTLE analysis

——————	P - Political	E - Economic	S - Social	T - Technical	L - Legal	E - Environmental
Green Hydrogen	**Capital Grants**- (£240 million net Zero Hydrogen Fund), Most government funds are used elsewhere (e.g. HyNet)	Around **£1 billion** just to supply Great Yarmouth Power Station	**Creates jobs** within the Bacton area	Alkaline **electrolysis** using electricity from wind farms, Very **new** and untested technology.	**Environmental impact** assessments, **water access** permissions, possibly requires **more land**	Highly sustainable with **Zero CO2 emissions**, although may lead to **increased NOx emissions**
Blue Hydrogen (Combined Heat and Power Plant)	**Most government funds are used elsewhere** (e.g. HyNet) so would need to try and reach out to secure it	Around **£1 billion** just to supply Great Yarmouth Power Station, can profit from electricity produced	**Creates jobs** within the Bacton area	**Widely used technology**, steam used to separate out hydrogen from methane.	Will require **more land** at Bacton, **Environmental impact** studies	Overall provides **low CO2 emissions** due to the efficiency despite the CO2 output from the CHP (which is mostly captured with CCS)
Carbon Capture (Pipes)	**NSTA licensing** for use of empty gas reserves, need to try to get funding from the government.	**Multi-billion** pound project, More employees permanently, **most efficient** and so will **make the most money**	**Creates jobs** within the Great Yarmouth area	Lots of **piping** to be places under the water, large structure on power station site to capture carbon, already **existing and tested technology**	Possibly requires **more land**, should capture at least **95% of CO2** from the power station, but **aiming for at least 90%**	**Not all CO2 captured**, if pipes leak the ocean and atmosphere will be polluted

My Conclusion

Overall, **blue hydrogen using a CHP plant** is the **best option** for Great Yarmouth Power Station from my research, and **CCS using pipes** is the **second best,** and should be used for the CHP plant.

I have chosen this option because:

- ★ The technology is already there and widely used
- ★ Low CO2 emissions (only from CHP plant)
- ★ Energy from the CHP plant can be used for more development within Bacton
- ★ High efficiency and so high profits

Although, some of the drawbacks include:

- NOx emissions increase
- High cost

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Any Questions

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