MECH433 Energy and the Environment Assessment Part 1 - Population 300k

Name : Swaraj Patra
Student Number :201596665

Location Info:

Offshore windmills – They are placed on shallow sandbanks of *Kish and Bray* which is about 10km away from *Dublin coastline*.
On shore windmills- Suitable spots are *Galway wind farm, Sliabh Bawn, Carrigdangan, Boggeragh, Lisheen,* etc.]
Natural gas with CCS (NGCC)- *Aghada AD1,AD2natural gas plant* which close to the nearly empty *Kinsale Head gas field* which is a suitable spot to store Carbon.[3]
Hydroelectricity – locations *Ardnacrusha, Erne - Cathleen's Falls, Liffey – Pollaphuca, Erne – Cliff, Lee – Inniscara, Lee – Carrigadrohid*. [1]
Tidal Barrage- Sites where Tidal energy can be implemented are *Galway Bay, Mayo Cost, Dublin Bay, Cork Harbor*[5] and some spots in *St. George's Channel and the North Channel*.
Nuclear- Nuclear plant should be near the cost or a large water body like a reservoir. The spot selected is in *Wexford region*.
Geothermal DH – Project spot suitable is in the *South of Dublin* as there is very low heat under the main city so networks could be built for heat transfer.
Battery – The charging stations are built in the city of *Dublin*.
Pumped storage- Existing pumped storage is used located in *Turlough hill*.

Assumptions Made

Total energy requirement-

Total number of households= 187500: 120000 (singles), 45000(couples), 22500(family)

Singles are not grouped to get max possible requirement.

- No. of fridges= 187500 households
- Light per day= June-July:3hrs, April-May & August:4hrs, March & Sept:5hrs, Feb & Oct:6hrs, Nov-Jan:7hrs.
- Average hours of **heating** per day= Sept-April:6hrs, May-August:2hrs.
- Transports taken into consideration

  BMW i3

  Watt per km: 0.19kwh/ km
  Daily use: 100km - 19 kWh

  Tesla model S

  Watt per km: 0.193kwh/ km
  Daily use: 100km - 19.3 kWh

MG ZS EV

Watt per km: 0.22kwh/ km
Daily use: 100km - 22 kWh

- Average of charge needed to travel 100 for 3 cars is taken which is 20.1KWh. Assuming households use any of the mentioned cars.
- Cooking equipment

  Oven-Bosch Serie 4 HBS573BS0B=1.3hrs:3000w

  Microwave-Bosch BFL553MS0B =20min:900W

  Toaster- BOSCH TAT7203GB = family:30min:1000w, couples:15min:1000w, single:8min:1000w.

  Kettle- Bosch TWK7503GB= family:10min:3000w, couples:10min:3000w, single:5min:3000w.

  Induction cooktop-BOSCH Serie 4 PKE611D17E = family:1.45hrs:7200w, couples:1hrs:3800w, single:45min:3600w.

Wind energy- Average wind speed in the area is considered using wind speed map- Offshore 8-10.4m/s, On shore 7- 9.5m/s. [4]

NGCC – losses other than CCS capture are 2.9MWh**,** Energy needed for CCS to capture 1tonn of CO2=4MW.

Hydro – Head is increased by 5m, and flow is increased by increasing the area of the reservoir.

Tidal- Average speeds are taken into consideration which is 2m/s, and max range 4.

Geothermal- Comparing values from a similar project made in Ile-de-France region. [9]

Not more than 10% of energy is lost in the generation process and the grid.

Storage capacity is determining the excess amount of energy that needs to be stored from sources like Wind, Tidal and Hydro as they cannot always be generated on demand like Nuclear and NGCC.

Possible excess amount that can be generated = 455.5MW

Max time without enough wind or tides = 42 hrs

Storage capacity needed = 19.1GWh

City of Dublin is divided into 5 major residential areas.

Energy Mix (add columns where needed)

Generation	Energy 1	Energy 2	Energy 3	Energy 4	Energy 5	Energy 6	Energy7
Type	Offshore wind turbines	On shore wind turbines	NGCC Natural gas-CCS	Hydro electric	Tidal Barrage	Nuclear	Geothermal District Heating
Total Output Capacity	351 MW	409 MW	681 MW	148 MW	353 MW	1300 MW	134 MWth
Normal Output Rate	172.5 MW	241.5 MW	115 MW	103.5 MW	288 MW	195.5 MW	92 MWth
% Of Total	15%	21%	10%	9%	20%	17%	8%
Standard cost (MWh^{-1})	75	63	125	80	90	92.5	140
Weighted cost (MWh^{-1})	11.25	13.23	12.5	7.2	18	15.725	11.2

Average Cost per MWh: £89.105

The mix currently consists of 15% Offshore wind, 21% On shore wind, 10% NGCC, 9% Hydroelectric, 20% Tidal, 17% Nuclear, 8%District Heating Through Geothermal. In the mix wind and tidal are dependent on natural factors hence during summer they might have a drop in production. Hence NGCC and Nuclear could be used to compensate for drastic drop in energy in the grid. The total possible output from all the production methods is higher than required to also compensate for energy loses in grid and storage.

Specific Information Required for Different Technologies

Offshore Wind Energy- For offshore windmills **Haliade-X** is considered.

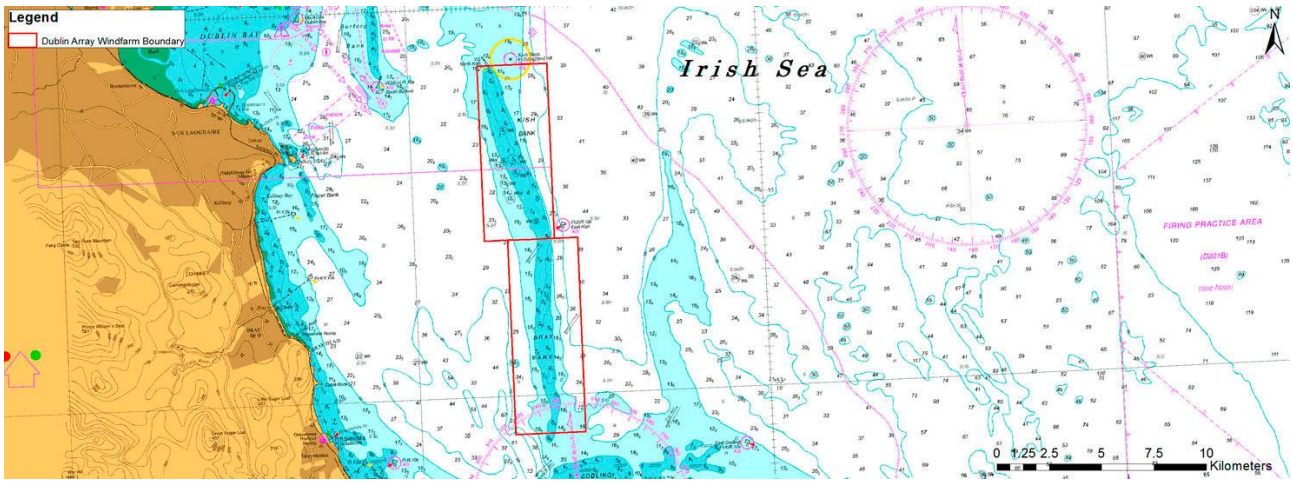
Height of 240m and diameter of 220m [8].

Speed=8-10.4m/s. [4]

No. windmills =45

Power Efficiency = 7.8 MW

Location is Suitable due to naturally formed shallow sandbanks that can hold up to 60 windmills.



On Shore Wind Energy- For on shore windmills **EnVentus** by Vestas is considered

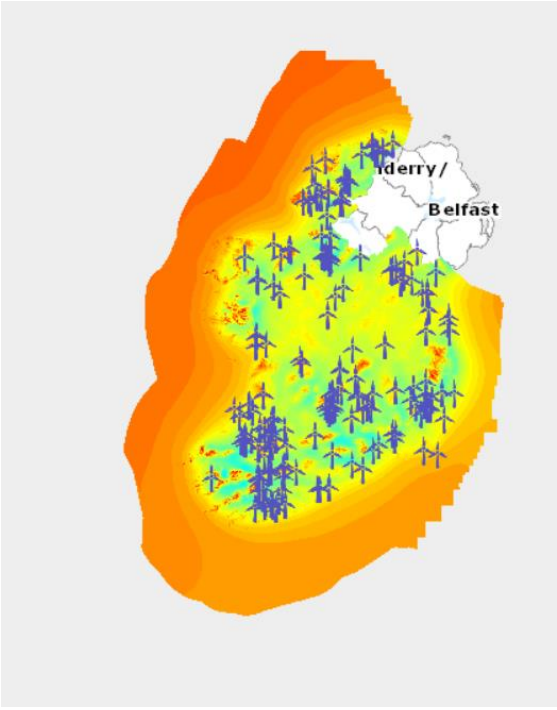
Height of 166m and Diameter of 165m [7].

No. of windmills = 130

Speed ranges from 7- 9.5m/s. [4]

Power Efficiency = 3.14 MW

All windmills are to be distributed among the locations mentioned above since they are currently functional and receive good winds.



NGCC- Location is are 2 existing 681MW natural gas plant that is to be integrated with CCS.

The captured carbon can be stored in the ***Kinsale Head gas field*** which is an almost depleted natural gas field. It suitable since it was able to store natural gas for millions of years and is very close to the Aghada natural gas plant.

Example for similar technology is the New $96 million CCS project for Natural Gas and industries announced on 10th Feb 2022

https://www.energy.gov/fecm/articles/us-department-energy-announces-96-million-advance-carbon-capture-technologies-natural.

Hydroelectric-

Locations are the most power generating hydro plants in Ireland. They are modified to increase the annual output.

Generator	f	h	no. turbine	improved GWhr
Ardnacrusha	250	35	3	509.5
Erne - Cathleen's Falls	200	35	3	370.8
Liffey - Pollaphuca	150	25,25,47	3	82.5
Erne - Cliff	200	35	4	175.5
Lee - Inniscara	70	35		117.89
Lee - Carrigadrohid	200	25		41.107
			total=	1297.297

The head is increased by increasing the height of the fall by increasing the reservoir height.

The flow rate is increased by increasing the capacity of the Dam. Which is done by excavating the area.
The calculation to increased flow rate and generator capacity following formulas are used.

$$P = \eta * \rho * g * h * Q$$

P is the power output Watts

η is the efficiency of the turbine 0.4

ρ is the density of water, taken as 998 kg/m³

g is the acceleration of gravity, equal to 9.81 m/s²

h is the head, or the usable fall height.

Q is the discharge

$$Q = A * v$$

A is the cross-sectional area of the channel

v is the flow velocity

Annual operation time is = old annual capacity GWhr/old production capacity MV

The improved capacity is determined only for time the older generators were used. Hence there is possibility to produce more than projected amount.

Tidal

For the provided location:
Min wave heigh=2m
Max wave heigh =4m
Area of the cost used for building tidal barrages= 7000Km^2
No. of turbine= 31

Energy generated per cycle at high tide =156.57MWh
Energy generated per cycle at low tide = 117.31MWh

Nuclear

Reactor type= Advanced PWR
Manufacturer= Westinghouse
Power output =1.3GW
Refueling time = 4 weeks (December)

During refueling dependency could be shifted to wind, NGCC, Tidal and Geothermal

Wind speeds are higher and more constant in winter so can generate enough to completely replace nuclear dependency. In case of wind energy drops NGCC could be used to compensate the demand and geothermal helps in reducing dependency on electricity for heating.

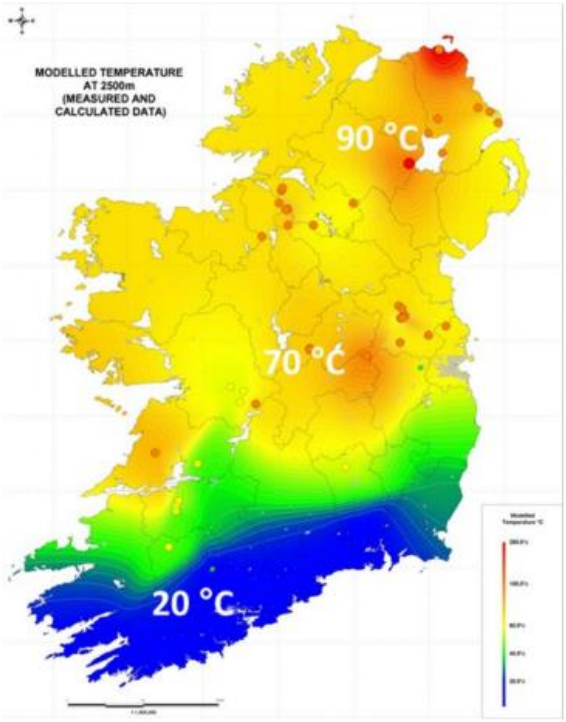
Geothermal District Heating-

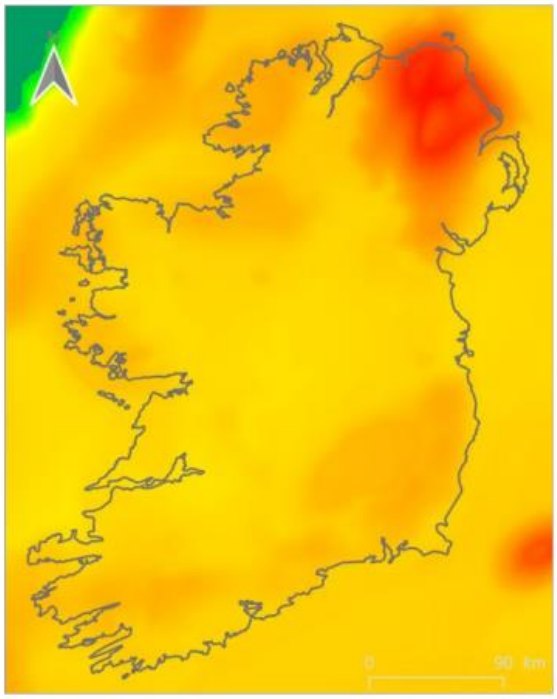
It is used to generate heat that could help reduce the dependency on electricity for heating. The heating capacity is determined from similar projects.

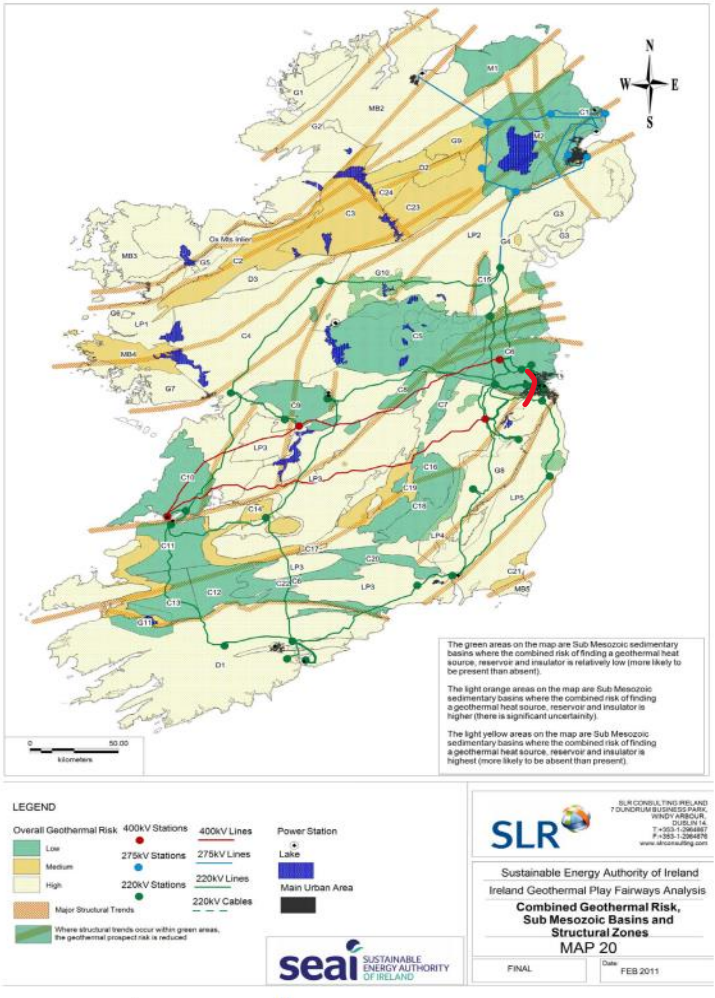
The project it is compared to is geothermal system installed in Orly Airport in the Ile-de-France. This was able to generate around 135MW heat though a 35 km spread pipeline.

Liquid used for heat transfer= water
Depth of geo hole = 1km
Location = South of Dublin
Similar expected projects in Tallaght Town Centre.

The Power Storage for the Grid is designed with a mixture of battery and Pumped storage. This is done in a ratio of 40% and 60%.







Battery Storage-

Container type Lithium-Ion battery storage.

Charging capacity 1MW in 2 hours

Storage density: 1-5 MWh per container.[23]

No. of containers needed = 1600 units.

The 1600 units can be dividing among the 5 residential areas and commercial areas.

This would help immediately supply any sudden demand in a localized area hence reducing the sudden load.

Battery storage also has the added advantage of increasing the unit size if needed.

Pumped Hydro –

Location is an existing structure Turlough hill

Storage density: 24.2GWh

Production capacity:292MW

Mean Flow of pumping – 22.1m^3/sec.

Time for operation 70 sec.

Expected production rate – 290MW.

Added advantage of excess of storage capacity in case overall demand increase without many modifications.[33]

Storage

Storage	Storage 1	Storage 2	Storage 3
Type	Battery storage	Pumped Hydro	
Energy Capacity	8GWh	12GWh	
Output / Discharge Rate	140MW	290MW	
Lifetime	58 hrs	42hrs	
% of Total	40%	60%	
Standard cost (MWh^{-1})	100	148	
Weighted cost (MWh^{-1})	40	88.8	

Average Cost per MWh : £128

The Power Storage for the Grid is designed with a mixture of battery and Pumped storage. This is done in a ratio of 40% and 60%. This is done to reduce the overall cost for energy storage and provide localized storage solutions for grids.

Reasons for Choosing Energy Generation Types

Onshore Wind –

- Existing infrastructure and commercial successful.
- Largest net zero contribution in Irelands current infrastructure.
- Largest contributor in current energy mix for Ireland.

Offshore Wind-

- Better performance than on shore windmills
- Higher wind speeds off the shore.
- Large amount of Shore area for the windmills to be constructed.

NGCC-

- Ireland can meet 60% of its demand using domestic Natural gas supply.
- Able to satisfy high demand when needed making it a good backup.
- Natural gas is more eco-friendly than other fossil fuels.
- Natural gas with CCS can reduce the carbon emission up to 90%.

Hydro-electricity-

- One of the most consistent sources of energy.
- Can be stopped when needed and be used according to the demand.

Nuclear-

- Most advanced forms of energy.
- Can instantly provide with large surge of energy when required.
- Could easily adapt to growing population.
- Ample amount of water bodies for nuclear plant.

Tidal-

- Is cyclic in nature.
- Dependent on lunar cycle.

- More area to implement.
- Well researched technology and potential in Ireland.

Geothermal –

- Capable to satisfy more than 40% of heating requirements.
- Can be incorporated into existing industries and infrastructures.
- Help in reducing the demand of electricity for heating application

Response to generation failure for 24 hours

Wind- in case of generation failure of Offshore turbine it is very likely that there might be failure in some on shore turbines as well. So, the power generation in the mix might drop around by 350MW or in case where there is failure of both the on shore and Offshore turbines there might be an energy drop of 410MW.

Response-

- Battery and pumped storage combined can give upto 430MW of output for 48 hrs.
- Energy from nuclear, tidal and NGCC can easily compensate if battery doesn't have enough backup.

Tidal- failure in case of maintenance or other issue for 24hrs would reduce the input by 288MW.

Response

- Using hydro pumped storage with battery can support it for more than 48hrs.
- if the failure is not in winter then Energy from nuclear and NGCC can produce on demand energy to compensate for excess demand.

Nuclear- Failure for 24 hours would reduce the total input by 195MVfor 24hrs.

Response-

- Increasing output of NGCC and with some additional energy from pumped storage the demand can be satisfied.
- In case the failure is in winter the wind alone is capable to compensate for nuclear completely.

Hydro- Failure for 24 hours would reduce the total input by 103.5MVfor 24hrs.

Response-

- Hydro power can be replaced easily using Battery storage.
- In case the battery doesn't have enough backup it can be replaced by nuclear or NGCC .

NGCC- Failure for 24 hours would reduce the total input by 115MVfor 24hrs.

Response-

- It can be compensated using battery
- Can be compensated using nuclear, wind and tidal.

If any of the scenarios take place in December where nuclear power is shutdown managing battery is important. in case of tidal failure have to depend upon NGCC

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