LPMS consulting

REDUCING CARBON DIOXIDE EMISSIONS

EPOWER

LPMS CONSULTING:

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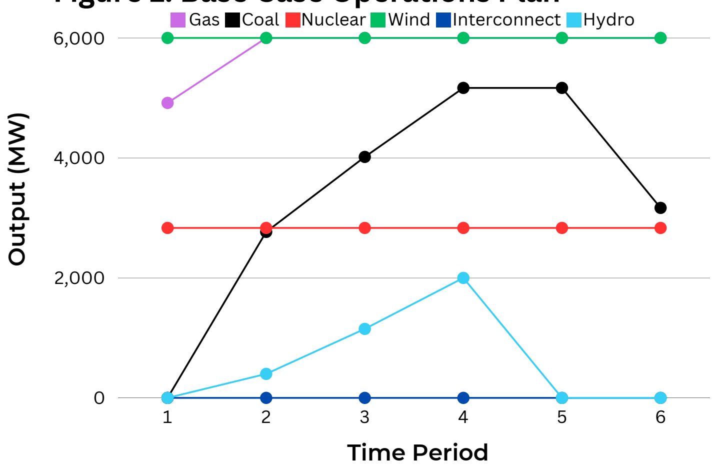
EXECUTIVE SUMMARY

This report intends to develop an operations plan for the client, EPower, which generates the maximal profit. The operations plan specified the output from each of the six sources of power: gas, coal, interconnect, hydro, nuclear and wind during each of the six time periods specified by EPower. The total output must satisfy the power demand at any given time, with surplus power being directed to the hydro pump to store additional energy for use in times of higher demand.

Our analysis was divided into three stages. Stage one addressed the current operations conducted by EPower to guarantee the validity of our model for further applications, as well as explore the impact of the proposed reduction in carbon dioxide emissions by 50%. In stage two, we considered introducing solar power as an additional power source to mitigate the impact of the new carbon dioxide regulations. Finally, in stage three, we reduced the power output of coal, gas and nuclear, in turn, to further reduce the number of carbon emissions being produced. We will conclude with our recommendations to the client based on our analysis.

STAGE ONE

Figure 1: Base Case Operations Plan



The current daily power generation schedule was modelled using Xpress, for which the table of values is shown in Appendix A. For this, we considered the power demand per period in the day as provided by EPower, along with information about the maximum current outputs for each source. This ensured that the model we built replicated the current generation schedule at EPower. Figure 1 illustrates the current generation schedule at EPower. This yields a daily profit of approximately £1.81 million. The current daily income is £13.82 million, with total daily costs of £12.02 million (including running and increased costs). Of note is that there is no power output from interconnect due to its high running costs, while the nuclear output is constant due to this energy source's high increased costs.

We then investigated the generation policy if EPower decided to reduce CO2 emissions by 50%, giving an emissions limit of 100,000 units daily. Under this policy, the generation schedule is shown in Figure 2, yielding a daily loss of £1.46 million. Since the daily demand remains unchanged, the income stays the same, but there is an increase in total daily costs to £15.29 million. The increase costs have risen from £65,000 to £190,000 for gas and from £0 to £150,000 for the interconnect. On the contrary, the increased costs have diminished from £413,000 to £0 for coal since it is no longer generating power. The increased costs for power generated by the hydro-power plant remain unchanged.

The significant changes in the schedule include the following:

- Power generated by nuclear had increased to nearly double the maximum output from before CO2 emission limits were reduced and is now maximized.
- Coal is not used to generate power anymore due to its high CO2 emission levels (1.2 units/MWh), which leads to energy being purchased from the interconnect now, with approximately 35.6 Gigawatts (GW) being purchased daily at a total cost of £3.71 million.
- The energy at the hydro pump reservoir reduced immensely at the end of each period compared to the current scenario.

On the contrary, using wind as a power source is still being maximized throughout.

We also found that reducing the CO_2 emissions to approximately 63% and below causes EPower to incur daily losses instead of profits. Figure 2 illustrates this trend as the CO_2 limits are reduced from 100% to 50% gradually.

Figure 2: Impact of reducing Carbon Dioxide emissions

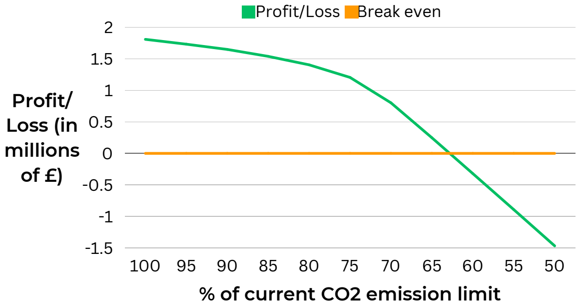
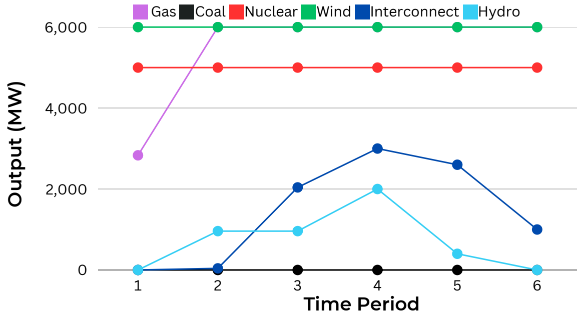


Figure 3: Operations with 50% reduction in carbon dioxide emissions

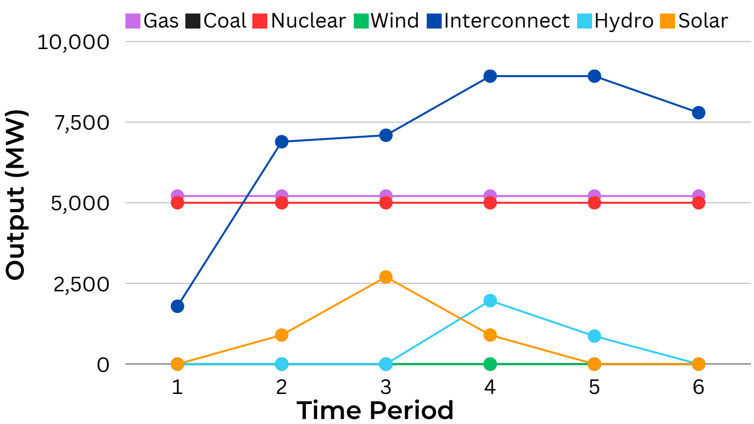


STAGE TWO

In stage two, EPower wishes to introduce Solar Panels as an additional source to generate power. Despite such a power source being season-dependent, it can be quite beneficial since no running or increased costs are associated with it after installing the panels. Our team considered the power generation schedule on a day in the spring with zero wind output. The maximum output EPower can expect from the solar source for each time period in spring is given in Appendix B. Note that this schedule has been modelled under the reduced (by 50%) CO_2 emission policy.

Under the reduced CO_2 policy and including solar energy as a power source, the daily loss is £12.63 million. Again, due to no change in demand, the income is still £13.82 million. However, the daily costs have now increased to £26.45 million. This is primarily because the wind is no longer a power source, which was earlier used to the maximum and is currently one of the cheapest sources available to EPower. This caused a substantial increase in power purchased from the interconnect, resulting in costs of £15.4 million daily attributed to the interconnect alone. The generation schedule in this scenario is given in Figure 3. In this case, the power generated by the gas and hydro-power plants was reduced. Unfortunately, no excess power was being sent to the hydro pump storage. Hence, the amount of reserve energy at the end of each time period was lower on average than when the solar panels were not used.

Figure 4: Operations with the addition of Solar Power



In the given conditions, EPower should prepare for losses. However, they are not a result of the introduction of solar panels but rather the absence of wind as a power source. The power generated from the solar panels would be maximized at every period it can be used.

STAGE THREE

In stage three, EPower decided to eliminate each of the "dirty" fuels (coal, gas and nuclear) in turn to explore the impact on the operations plan. As in stage two, the absence of wind was assumed. The solar outputs were the same as in stage two, and carbon emissions were reduced by 50%.

When first considering the elimination of coal, the daily loss was £12.6 million, thereby providing the same loss as when coal was included as a power source. This is because there was no coal being used in stage two either. Hence, the results shown in Figure 4 also apply in this case.

When considering eliminating gas as a power source, the daily loss was £14.8 million. This is because while total income is the same (due to no change in demand), the daily costs have increased to £28.7 million. Without gas or wind as a power source, more energy was bought via interconnect. The total costs for interconnect were £22.36 million daily. The generation schedule for this scenario is given in Figure 5. The figure shows how the power generated by coal is now non-zero due to the absence of gas, with a constant output of 3,125 MW. The nuclear and hydro-power plant output remains the same as in stage two.

When finally considering the elimination of nuclear as a power source, the daily loss was increased substantially to £18.6 million. This is because while the demand and, therefore, total income do not change, the daily costs increase to £32.45 million. Without nuclear and wind as power sources, more energy is bought from interconnect. The daily total costs for interconnect are £27.4 million. The generation schedule for this scenario is given in Figure 5. The figure shows how the power generated by gas, coal and the hydropower plant output remains the same as in stage two.

Hence, the three scenarios here show that eliminating nuclear or gas as a power source leads to even further losses for EPower.

Figure 5: Operations without gas

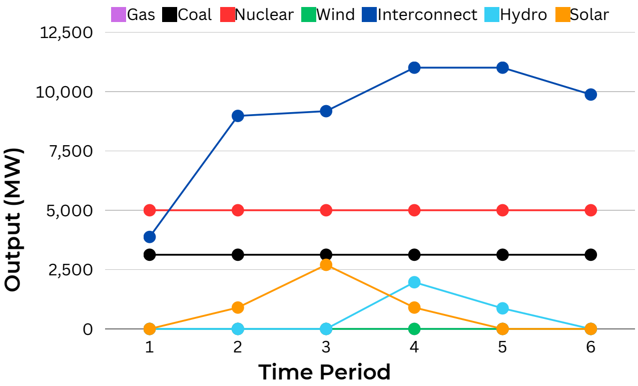
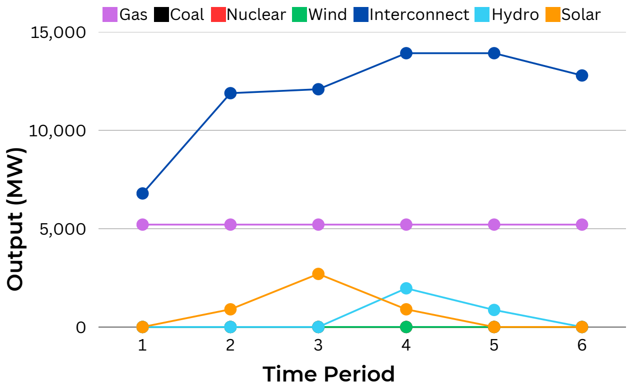


Figure 6: Operations without nuclear



FURTHER RECOMMENDATIONS

Based on our results, the proposed reduction in carbon dioxide emissions by 50% will lead to considerable losses for EPower. Therefore, the company must take action to mitigate the impact this has on its operations to remain profitable. LPMS Consulting proposes the following recommendations to maximize profits.

Recommendations:

Increase the maximum output of the wind power plant

One potential strategy to mitigate the impact of reducing carbon dioxide emissions is to expand the wind power plant and increase its maximum output. This would require substantial initial investment, however, increasing the number of wind turbines could lead to long-term profits for EPower. From our initial model, it is evident that wind is an attractive power source for EPower as the wind output is operating at a maximum of 6,000 MW throughout the day. This is likely due to the low running costs associated with wind power and its eco-friendly nature.

To explore the potential of expanding the wind power plant, we modelled how the daily profit varies as a result of increasing the maximum output of wind power from the original 12,000 MW to 18,000 MW. We considered a day with moderate wind conditions.

Figure 7: On a day in spring where the wind generates 35% of the maximum output

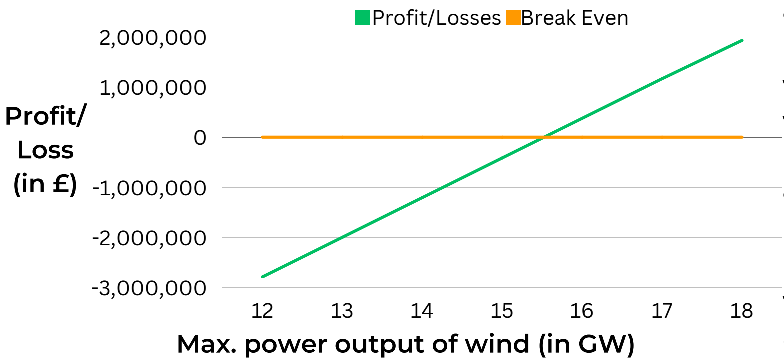


Figure 7 illustrates the results of our investigation. We see that increasing the total capacity of the wind power plant by around 33% would enable the company to break even, given that the wind conditions were sufficient to produce an output of 35% of the maximum. Hence, expanding the wind capacity could be a feasible strategy for EPower to maximise its profits.

Further Analysis:

Potential alternative renewable energy sources

We suggest considering other potential power sources which could be added to EPower's current operations. Many renewable energy sources, such as wind and hydro, rely heavily on the weather. Therefore, diversifying the power sources employed by EPower will mitigate the impact of poor weather conditions on operations.

Potential sources the company could consider include geothermal or biopower. Geothermal power plants produce energy using heat from the earth. Consequently, this source is wholly independent of weather conditions and delivers a consistent baseload of energy (Office of energy, efficiency & Renewable energy, 2011). Biopower is produced by converting plant-based biofuels into power using similar processes to fossil fuels. Although this process does not eliminate carbon dioxide emissions entirely, it does reduce them. It is also unaffected by the weather, which reduces risk and makes it favourable over fossil fuels.

Environmental impact associated with interconnect

Based on our results, the optimal operations plan after the 50% reduction in carbon dioxide emissions includes the use of interconnect. EPower needs to determine the source of this energy to ensure they are achieving their emissions targets and not producing carbon dioxide by proxy. The UK has interconnector links with France, Belgium, Norway and the Netherlands. In 2022, approximately 70% of energy sourced via interconnect was produced using zero-carbon sources, and the National Grid has outlined goals to increase this to 90% by 2030 (National Grid, 2022). However, this means that some emissions are associated with interconnect. There could be similar issues present for Epower, so this needs to be considered in the current model.

Consideration of seasonal weather variation and the impact on operations

The current renewable energy sources offered by EPower (hydro, wind and solar) depend highly on weather conditions or seasons. Therefore, EPower needs to understand how its output varies due to changes in the weather and seasons and the impact this has on its operations plan. As a potential for further analysis, we suggest incorporating seasonal weather data into the current model. This would allow EPower to build a comprehensive annual operations plan considering seasonal weather variations and thus mitigate risk as they could incorporate additional strategies to accommodate periods of unfavourable weather.

Impact of further emissions restrictions

Finally, the government will likely impose further emissions regulations due to the increasing concerns regarding the global climate crisis. Hence, we suggest EPower undertake further scenario analysis to explore the consequences of reducing emissions on their operations plans. This would facilitate a greater understanding of the most appropriate strategy for EPower moving forward.

REFERENCES

National Grid. (2022) *What are electricity interconnectors?* [online]. Available at: [What are electricity connectors?]() [Accessed: 5th April 2023].

Office of Energy Efficiency & Renewable Energy. (January 2011). *Geothermal Basics.* [online]. Available at: [Geothermal Basics]() [Accessed: 5th April 2023].

APPENDICES

APPENDIX A - Demand for energy over different time period periods

TIME PERIOD	00-06	06-08	08-16	16-20	20-22	22-00
DEMAND (MW)	12000	18000	20000	22000	20000	18000

APPENDIX B - Solar output over different time periods (introduced in Stage 2)

TIME PERIOD	00-06	06-08	08-16	16-20	20-22	22-00
SOLAR OUTPUT (MW)	0	900	2700	900	0	0

APPENDIX C - Current generation schedule

Time Period	Gas	Coal	Nuclear	Wind	Interconnect	Hydro
1	4917	0	2833	6000	0	0
2	6000	2767	2833	6000	0	400
3	6000	4017	2833	6000	0	1150
4	6000	5167	2833	6000	0	2000
5	6000	5167	2833	6000	0	0
6	6000	3167	2833	6000	0	0

APPENDIX D - Generation schedule under reduced CO2 limits (by 50%)

Time Period	Gas	Coal	Nuclear	Wind	Interconnect	Hydro
1	2833	0	5000	6000	0	0
2	6000	0	5000	6000	40	960
3	6000	0	5000	6000	2040	960
4	6000	0	5000	6000	3000	2000
5	6000	0	5000	6000	2600	400
6	6000	0	5000	6000	1000	0

APPENDIX E - Generation schedule under reduced CO2 limits (by 50%) with Solar panel on a spring day when there is no wind available to harness power

Time Period	Gas	Coal	Nuclear	Wind	Interconnect	Hydro	Solar
1	5208	0	5000	0	1792	0	0
2	5208	0	5000	0	6892	0	900
3	5208	0	5000	0	7092	0	2700
4	5208	0	5000	0	8925	1967	900
5	5208	0	5000	0	8925	867	0
6	5208	0	5000	0	7792	0	0

APPENDIX F - Generation schedule when gas is eliminated as a power source.

Time Period	Gas	Coal	Nuclear	Wind	Interconnect	Hydro	Solar
1	0	3125	5000	0	3875	0	0
2	0	3125	5000	0	8975	0	900
3	0	3125	5000	0	9175	0	2700
4	0	3125	5000	0	11008	1967	900
5	0	3125	5000	0	11008	867	0
6	0	3125	5000	0	9875	0	0

APPENDIX G - Generation schedule when nuclear energy is eliminated as a power source.

Time Period	Gas	Coal	Nuclear	Wind	Interconnect	Hydro	Solar
1	5208	0	0	0	6792	0	0
2	5208	0	0	0	11892	0	900
3	5208	0	0	0	12092	0	2700
4	5208	0	0	0	13925	1967	900
5	5208	0	0	0	13925	867	0
6	5208	0	0	0	12792	0	0