OEC 2020 Programming

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1 Problem Description

Balancing the power grid for the province of Ontario involves trading off safety, monetary, environmental, and public welfare concerns. Major stakeholders include the Ontario provincial government and power regulatory bodies (primarily the Independent Electricity System Operator, or IESO), Ontarian consumers of power, neighbouring jurisdictions to which Ontario can export power or from which it can import (such as Quebec, New York, Michigan, and Minnesota), and the public in the vicinity of power generation stations. Power generation authorities in Ontario and in partnered regions are concerned with accurately and efficiently allocating generated power without incurring too much cost or oversupplying to the point of damaging equipment. Consumers have been promised a fixed cost for power so are less invested in minimizing the cost of generation, but are strongly affected by blackouts and brownouts. All stakeholders have some motivation to reduce environmental impacts, be it regulatory, a sense of social responsibility, or impact on personal wellness.

We have constructed a power grid allocation simulator that is meant to be used by Ontario power generation authorities, that balances the needs of the user with the needs of the other stakeholders.

1.1 Assumptions

Electricity rates changed to Ontario customers are fixed, but depend on the season. Since the season is not known at runtime, and only a single line of input can be read before the program must output selling cost, we average the 5-hour forecast temperature in the first hour of input, and charge summer rates if the average temperature is above 10 °C, a rough estimate based on the provided average monthly temperatures in 2018 and 2019.

2 Strategy

We saw two mostly independent technical challenges, which we solved with different mechanisms.

1. Managing long-term nuclear rates to maximize hydro use. Where possible, it is always optimal to supply as much of the demand as possible using hydro power, since it is green, has the lowest cost, and has the lowest emissions rate. Nuclear is also cheap and low-emission and can make up the remainder. However, it is risky to commit to generating a lot of nuclear power since it is very slow to ramp down and a sudden drop in demand might result in a damaging oversupply.

2. For short-term power generation, balancing between minimizing CO_2, maximizing green power generation, and not losing excessive amounts of money.

To manage long-term nuclear rates, we use a simple control system. We estimate future power needs, estimate future hydro supply, and move nuclear production up or down in the direction of the difference. We estimate future power needs by combining last week's next-five-hour-average, and expect future hydro supply to remain approximately constant.

After we have picked a target nuclear rate, we use a **linear programming solver** to select how to satisfy our power need. For all of the power sources other than nuclear, we have a provided capacity and may choose to use anywhere from 0 to all of it. This gives us a set of linear constraints, for example: the sum of the drawn capacity is equal to the demand. We then pick a utility function to maximize, based on the amount of CO_2 emitted by each source and the cost per MW for that source. The Simplex algorithm is then used to maximize the utility function under the constraints.[2]

This linear solver abstracts a lot of otherwise complicated logic in a customisable and extensible way - for example, the solver independently decides when to intentionally generate power to sell to nearby cities, based on its provided tradeoff between CO_2 emissions and dollars.

Our solution is robust to missing values in the provided CSV input - it will assume any missing power type is unavailable, and will attempt to avoid oversupply by ramping down power if the requested total power is missing.

2.1 Open-Source Code

We used two popular Python packages: `csv`, for parsing CSV files, and `numpy`, for a high-performance matrix implementation. Our linear maximizer was previously written by one of our teammates for the ICPC programming competition. If this solver had not been available, we would have used the `scipy` library for this functionality.

3 Applied Principles of Technological Stewardship

3.1 Deliberate Values

At first, we were concerned about the environmental impact of deliberately overproducing green energy to sell at a profit to neighbouring power grids. Meeting neighbours' power demands helps us keep power costs as low as possible and increases the amount of green energy produced in Ontario, but does release some CO_2; is the "green energy" metric then effectively artificially inflated? After researching Ontario's actual power imports and exports, we found that Ontario is only a net exporter to New York, Minnesota, and Michigan, due in part "to the higher prices and the higher carbon footprint of the supply mix used in those jurisdictions.[3]" These jurisdictions are stakeholders with different priorities than those of Ontario power generation authorities and we can use that knowledge to find a symbiotic balance between the two: Ontario can optimize its grid to produce extra renewable energy to sell to its neighbours and reduce the overall cost of its own power generation, which results in a small emissions increase in Ontario but a net emissions decrease in the market area (which would otherwise be using non-renewable sources).

While this demonstrates that a certain amount of prioritizing lowering costs over emissions can be a win-win, at what point is it better to reduce emissions even if it costs more money? We initially tried to reduce CO_2 as much as possible as long as we break even. During off-peak hours, it is hard to make a profit at all, and so we ended up producing a lot of CO_2 at off-peak hours, when we could have just taken a loss. We instead went with a simple linear combination of priorities, valuing reducing one tonne of carbon as worth $2000. This seems to be a good tradeoff, producing mostly optimally low amounts of carbon while still obtaining good profits. A recent study has detailed a carbon capture plant that could capture an imperial ton of CO_2 for $94-$232 USD, or a metric tonne for $135-$333 CAD.[1] This is significantly less than we are valuing a tonne of carbon at, however since the total capacity for carbon capture technology is still limited, we believe it is worth it to be conservative.

3.2 Realise Diversity

The principle of realising diversity entails recognising all users and stakeholders and ensuring that their needs are met. This has been a recurring theme throughout this report. To summarize: between power generation authorities both within and outside of Ontario, power consumers, and anyone else impacted by non-renewable energy or carbon emissions, we considered multiple strategies to balance accuracy, cost, and environmental impact. We are aware that these stakeholders may have other concerns that we did not consider; for instance, wind power can be detrimental to the quality of life of the nearby public even while reducing carbon emissions. We believe we have constructed an extensible piece of software so that future developers could build these additional stakeholder conditions in.

References

[1] David W. Keith et al. "A Process for Capturing CO2 from the Atmosphere". In: *Joule* 2.8 (Aug. 2018), pp. 1573–1594. DOI: 10.1016/j.joule.2018.05.006. URL: https://doi.org/10.1016/j.joule.2018.05.006.

[2] J.C. Nash. "The (Dantzig) simplex method for linear programming". In: *Computing in Science & Engineering* 2.1 (2000), pp. 29–31. DOI: 10.1109/5992.814654. URL: https://doi.org/10.1109/5992.814654.

[3] Independent Electricity System Operator and the Ontario Power Authority. "Review of Ontario Interties". In: (2014). URL: http://ieso.ca/-/media/Files/IESO/Document-Library/power-data/supply/IntertieReport-20141014.pdf?la=en.