MIT Energy & Climate Hackathon - Designing the Most Climate-aligned and Cost-effective Compute Infrastructure

Background

At Crusoe, our north star is our environmental impact. Crusoe's mission is to align the future of computing with the future of the climate. In practical terms, that means we deploy advanced digital computing infrastructure in ways that help solve climate challenges by reducing flaring from oil sites, greenhouse gas emissions, or incentivizing the deployment of renewable power sources.

Clean Energy and Cloud Computing

Primary Power Source

In the USA, Cloud hyperscalers tend to connect directly to the grid in states such as Virginia, or Ohio, where the electricity mix is still majority fossil fuels.

Other states offer renewable energy (wind and solar) in large quantities. However, the production is intermittent, leading to large variations in price and unpredictable supply. herefore, it is challenging for renewables alone to provide reliable compute uptime. There is an opportunity to access cheap and clean energy when renewables are negatively priced due to supply and demand imbalances (link). Taking advantage of these imbalances are key.

Back-up Power Sources

Back-up power sources allow data centers to remain online in the event of a power outage. Most back-up power sources today have two problems: (1) They emit carbon in most cases and (2) They require a large capital investment that goes unused.

- Batteries can be charged with renewable energy (in the best case scenario), they are cost prohibitive, and limited in capacity

- Diesel generators can last longer, but emit greenhouse gas emissions (i.e. carbon dioxide) and require refueling

Here are some available resources for considering energy sources, but not limited to below:

- Grid Emissions Factors that are readily available for each of the major data center areas – https://www.epa.gov/egrid/download-data .
- https://sustainablereview.com/challenges-in-renewable-energy/
- https://www.energy.gov/eere/articles/nrel-study-identifies-opportunities-and-challenges-achieving-us-transformational-goal
- https://www.energy.gov/eere/renewable-energy
- https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
- Crusoe: Case Study : https://openknowledge.worldbank.org/server/api/core/bitstreams/27e9b31f-c8bf-5fa4-aee3-3576d60e1a48/content (pages 98-102)
- 2023 World Bank Global Gas Flaring Tracker Report: https://thedocs.worldbank.org/en/doc/5d5c5c8b0f451b472e858ceb97624a18-0400072023/original/2023-Global-Gas-Flaring-Tracker-Report.pdf

Cloud Compute Instance Types

Instead of focusing on maximizing data center uptime at all costs (financial and environmental), a cloud computing platform can target specific workloads.

Cloud computing can take different forms:

- **On-Demand Instances**: customers can spin up a cloud instance at any time (and at the highest price) and are guaranteed availability. This is particularly useful for web servers experiencing high traffic.
- **Reserved Instances**: customers pay in advance for a cloud instance at a fixed price and is guaranteed a certain availability
- **Spot Instances**: the price of the instance varies depending on supply. The cloud provider reserves the right to terminate or preempt an instance at any time.

Problem Statement

Create a presentation for the most clean and cost effective cloud computation data center infrastructure. Your design is not required to be limited to a single location. State any assumptions you make regarding the type of cloud services you will provide, which locations you will pick, the energy mix you will use, and the back-up power sources (if any) deployed.

You should aim to:

1. Minimize carbon emission overall (primary and backup power source)
2. Minimize capital investment (backup power source CapEx, cooling infrastructure, etc.)
3. Maximize cloud revenue

What to include:

- Please include any resources you are using to make claims
- Please provide justification for the decision making process and backup with data and examples if possible
- Provide alternative solutions and pitfalls for the current implementation

What you should consider

- Please evaluate different energy sources and locations
    - Geographical benefits and limitations
    - Availability, ease of access
    - Pricing and setup cost
    - Benefits such as rebates, carbon credits
- Potential climate change impact
- Different parameters and COGS for setting up an infrastructure
- Apart from setup, operation cost for running a data center

What you don't have to consider:

- Government regulations

Additional Material

From a Digital Flare Mitigation perspective - we could expect that 90% of the gas that we consume would have otherwise been flared, 9% can be attributed to a local Grid Emissions Factor and 1% can be attributed to diesels. These will typically be smaller scale or modular deployments that won't require massive electrical infrastructure upgrades for grid interconnection. We are able to generate power at $0.025-$0.03/kWh conservatively, would pay $0.07/kWh for the grid and then diesels have equivalent CapEx/OpEx burden as traditional data centers.

From a Digital Renewable Optimization perspective (depends on data center load or nameplate capacity of wind farm) - At a wind farm we should make the assumption that 20% of the time we are pulling power that is negatively priced that would be curtailed upon completion of the production tax credit. The other ~50% of our power comes directly from the wind farm and the remaining 29% comes from the grid using the Grid Emissions Factor in West Texas and 1% from diesels. Regarding the economics, we avoid significant investment in the electrical infrastructure by tapping into the wind farm substation that has already been built. We are basically buying power at a $5 price floor and we expect our weighted power price to be in the $0.035-$0.04/kWh range. We would need to build out the data center infrastructure in a modular or traditional data center CapEx range which we estimate around $7mm/MW on land that is very inexpensive to procure for a cost reduction of 10-20%.

Natural gas backup is not as feasible because you can't connect to a natural gas pipeline and expect there to be gas the 1% of the time you might need it. You need to have a firm gas delivery contract (which is what led me to the design which adds BTC load to the gensets with CCS to allow for consistent gas delivery and genset operation). Natural Gas storage options are prohibitively expensive but we are trying to find creative approaches to drive down the cost.