Carbon Negative Computing?

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NORDIC E-INFRASTRUCTURE COLLABORATION

Overview

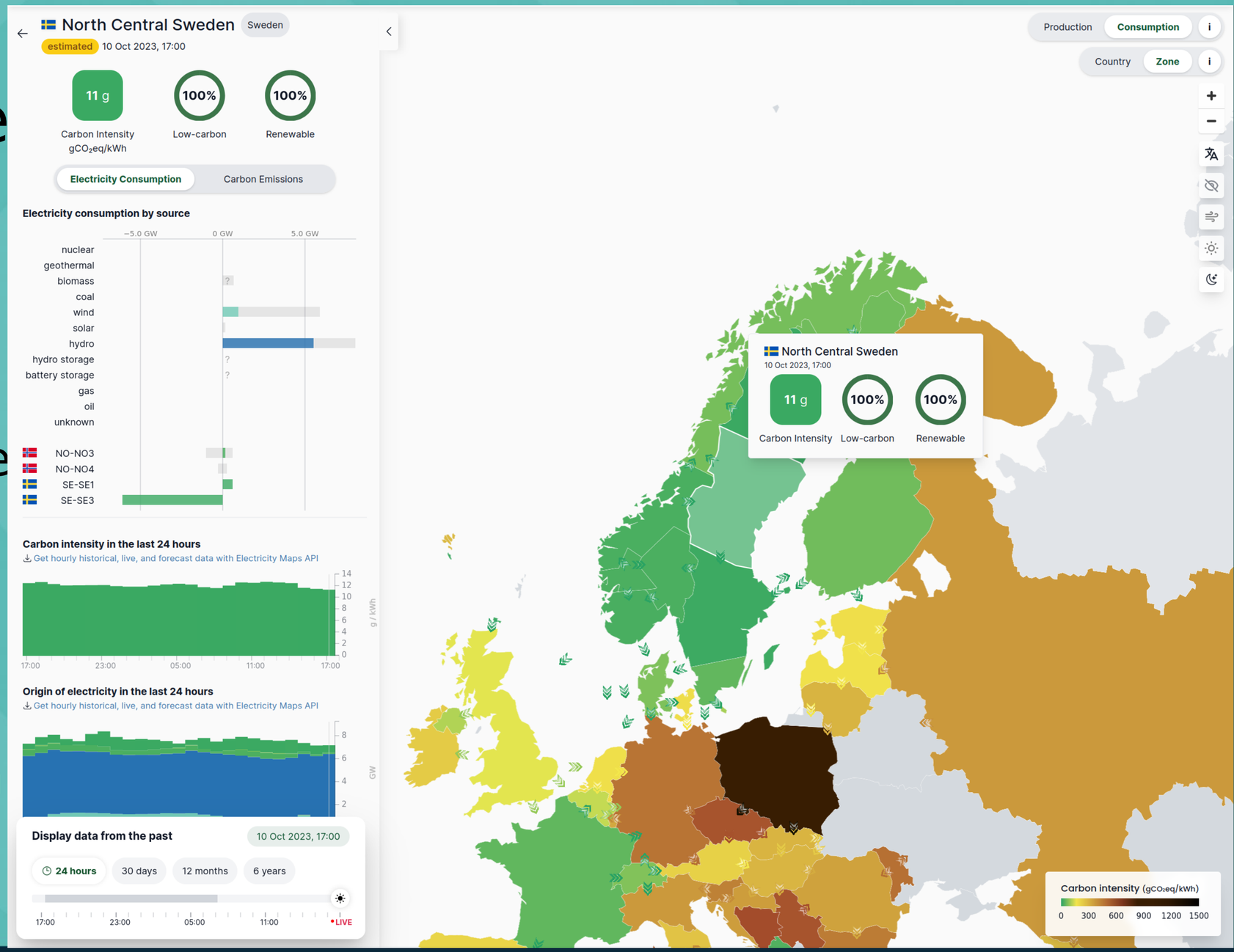
- Question
- Assumptions
- Calculations
- Conclusions

Question

- Net carbon emissions from HPC2N’s computing at Umeå University – positive or negative?
  - Located in Northern Sweden with very low CO2e per kWh
  - The heat is reused for campus heating which offsets district heating with higher emissions
- There is more than one way to calculate this
  - Under which assumptions is it negative?
  - What is the span?
  - Which calculations are reasonable?
  - Which assumptions are honest?
- Simplified question: Net effect of adding 100 kHS

Local power generation

- Power mix CO2e
- Power area SE2
  - Hydro and wind
    - CO2e here includes land use effects
  - Tiny share bio/waste (CHP)
  - Net exporter
  - ~15 g CO2e/kWh (long term avg)
  - electricitymaps.com



Marginal power consumption

- If we draw one kWh more, what's the impact?
  - 1 kWh more generated in the same power mix
  - 1 kWh more generated with different power mix
  - 1 kWh less exported to other power areas
- Range:
  - 1 g/kWh (non-fossil production, as per contract)
  - 11 g/kWh (margin power likely hydro, CO2e mostly land use effect)
  - 460 g/kWh (more gas burned in Denmark)
  - 1100 g/kWh (more coal burned in Poland)

Facility cooling

- Highly efficient air cooled compute room
  - No UPS, optimized airflow, cooled by the house/campus cooling
  - As described in previous HEPiXes
- Cooling comes from district cooling, free cooling (rootftop heat exchangers to air), heat pumps, etc
  - Depends on lots of factors:
  - Net cooling or heating need on campus (roughly 50/50)
  - Current electricity and district cooling costs
  - Generation limits
  - Outages and other operational constraints

Facility numbers

- From the audited annual financial and sustainability report of 2022 of Akademiska Hus
  - The public company that owns all the public university facilities
- Electricity: 0 or 1 g/kWh as per green energy contracts
  - 0 per contract, 1 “realistic adjustment”
- Heating: 65g/kWh for district heating
- Cooling:
  - District cooling: 3.6g kWh
  - Local compressor cooling: Assuming COP 2/3 (1 kWh power makes 2 kWh cooling, but also 3 kWh heating)

Computing impact

- Purchasing new servers, roughly 2 tons/server
  - Can vary by a factor 2-4 depending on model etc
- Power usage of WLCG computing
  - Old hardware: 110 MWh/year for 45 kHS, or 280 W/kHS
    - Due for replacement this year
  - New hardware (D. Britton, AMD Bergamo): 160 W/kHS
  - 200 W/HS seems reasonable, within a factor of 2
- Facilities
  - Apart from cooling water supply (ranging from district cooling to heat reuse), PUE is 1.03 in the HPC2N compute room (fans, pumps)

100 kHS impact, manufacturing

- 14 modern servers
  - 96 cores EPYC 9754 HT, 7497 HS/node (D. Britton)
  - Manufacturing emissions (rounded estimate): 40 tons CO2e
  - 8 tons/year assuming 5 years lifetime (case “new”)
- 210 old servers
  - 28 cores Intel E5-2690 v4 @ 2600 MHz, 276 HS/node (HPC2N prod)
  - Manufacturing emissions (rounded estimate): 600 tons CO2e
  - 75 tons/year for a 8-year lifetime (case “old”)
  - Or, arguably, 0 tons/year for old HPC cluster nodes re-used for HT in year 6-8 instead of buying new (case “reuse”)

100 kHS impact, power

- Assuming 100% load to make up for storage and systems server
- New: 100*180 = 18kW, 157 MWh/year
- Old: 100*280 = 28kW, 245 MWh/year

kg/year	New	Old
1 g/kWh	157	245
15 g/kWh	2355	3675

100 kHS impact, cooling

- Approximate numbers with some estimates
  - District cooling
    - 3.6 g/kWh
  - Heat pumps
    - COP 2/3: 1kW power cools 2kW and generates 3kW heat
    - 50% extra electricity, offsets 150% of cooling effect in campus heating
    - 50% extra electricity is more expensive than 100% district heating, generally
    - A new building with ultra low temperature heaters could be (much) more efficient
- Total cooling load: 120% of compute power use
  - Cooling measured in water temperature going into the room
  - Some inefficiences in heat transfer etc

100 kHS impact

- Two (relevant) scenarios
  - Realistic today: 95% of the time district cooling, 5% heat pump
  - Maximal heat pump: 50% district cooling, 50% heat pump
    - Net campus heating needed only in the cold part of the year
    - Financially worse than district heating at current prices
    - Old hardware manufacturing emissions high
  - Only “reuse” case relevant here, otherwise the manufacturing emissions divided by 8 years dominate over local power
- Any gas/coal scenario has large net emissions in all cases – no green checkboxes possible

Totals

CO2e tons/year	Realistic scenario New hardware	Realistic scenario Reused hardware	Maximal scenario New hardware	Maximal scenario Reused hardware
Contracted: Fossil-free	7.9	-0.16	-0.64	-13.5
Local mix: Long-term avg	10.2	3.5	2.3	-8.9
Export: gas displacement	84.6	119.5	94.3	134.7

Comments

- “Carbon negative computing” is possible for us
- Sensitivity analysis:
  - More efficient heat pump doesn’t change the CO2 emissions much but might make running it more of the time financially sound
  - Manufacturing emissions much larger than power+cooling
- District cooling might be better globally
  - Peak electricity usage during the coldest days strains grid
  - District heating is the cooling loop for the local CHP plant

Questions?

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