

Towards a Free Finer-Grain Carbon Map

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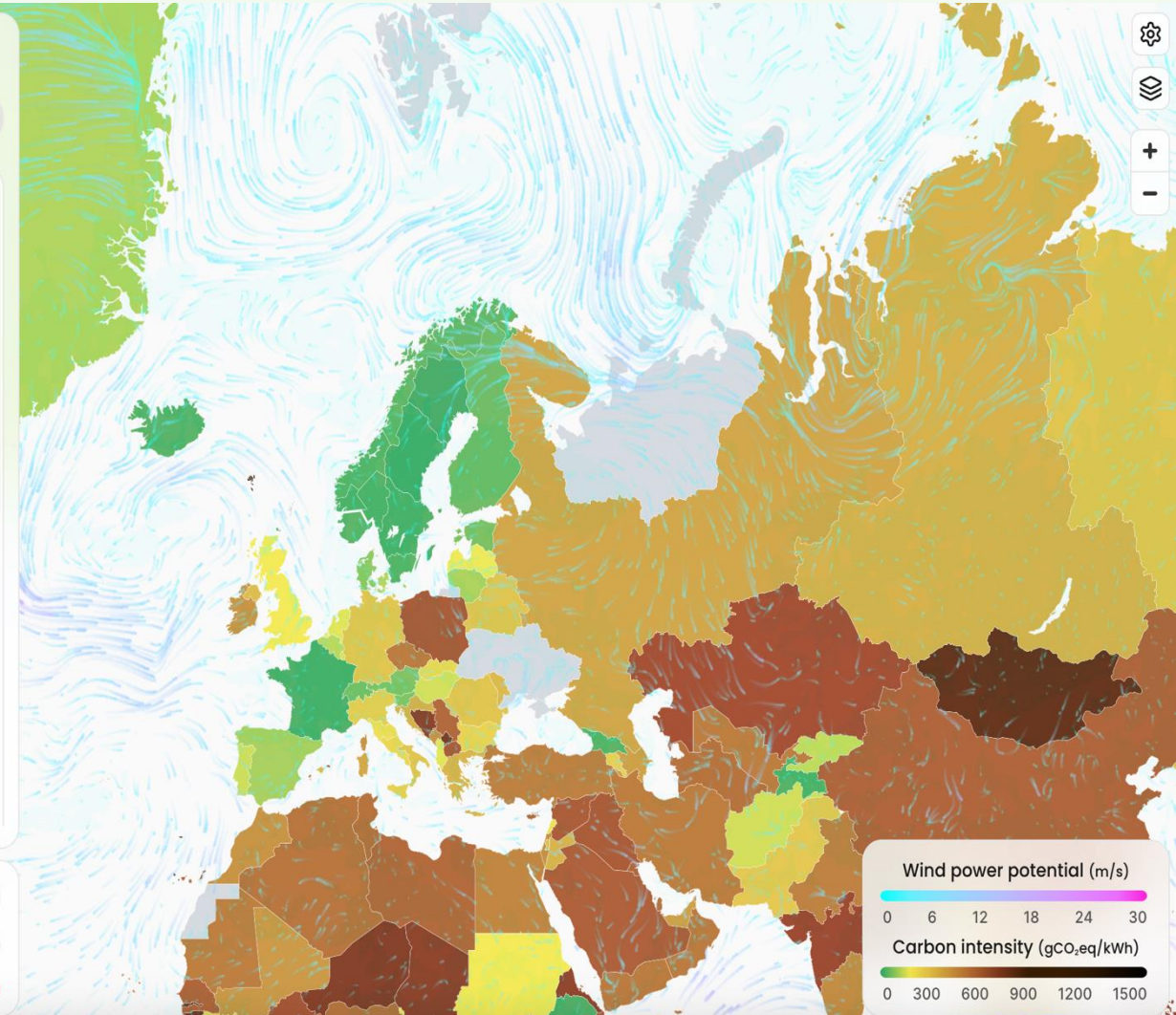
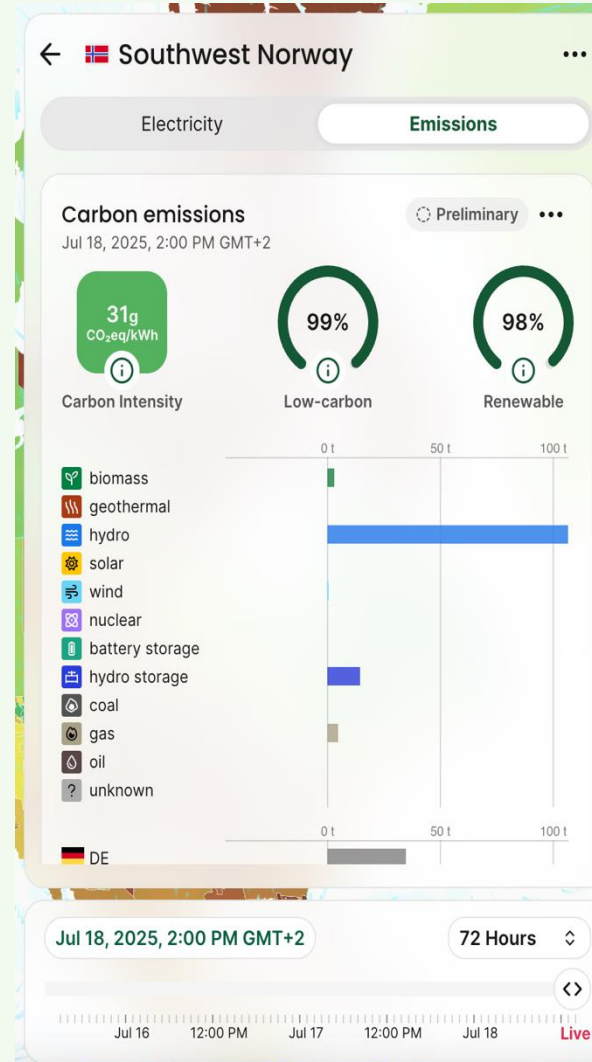
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Background

ElectricityMaps
(via <https://app.electricitymaps.com/>)

Drawbacks:

- Energy breakdown only available at zone or national level; zone areas too large for local users.
- Flow tracing assumes proportional sharing within the entire zone, which may not reflect actual practice.



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Freely Available Databases



Energy utility location information

- *OpenInfraMap* (via <https://app.electricitymaps.com/>)

Energy generation, demand, and trade data

- *ENTOS-E* (<https://transparency.entsoe.eu/>)

Location information

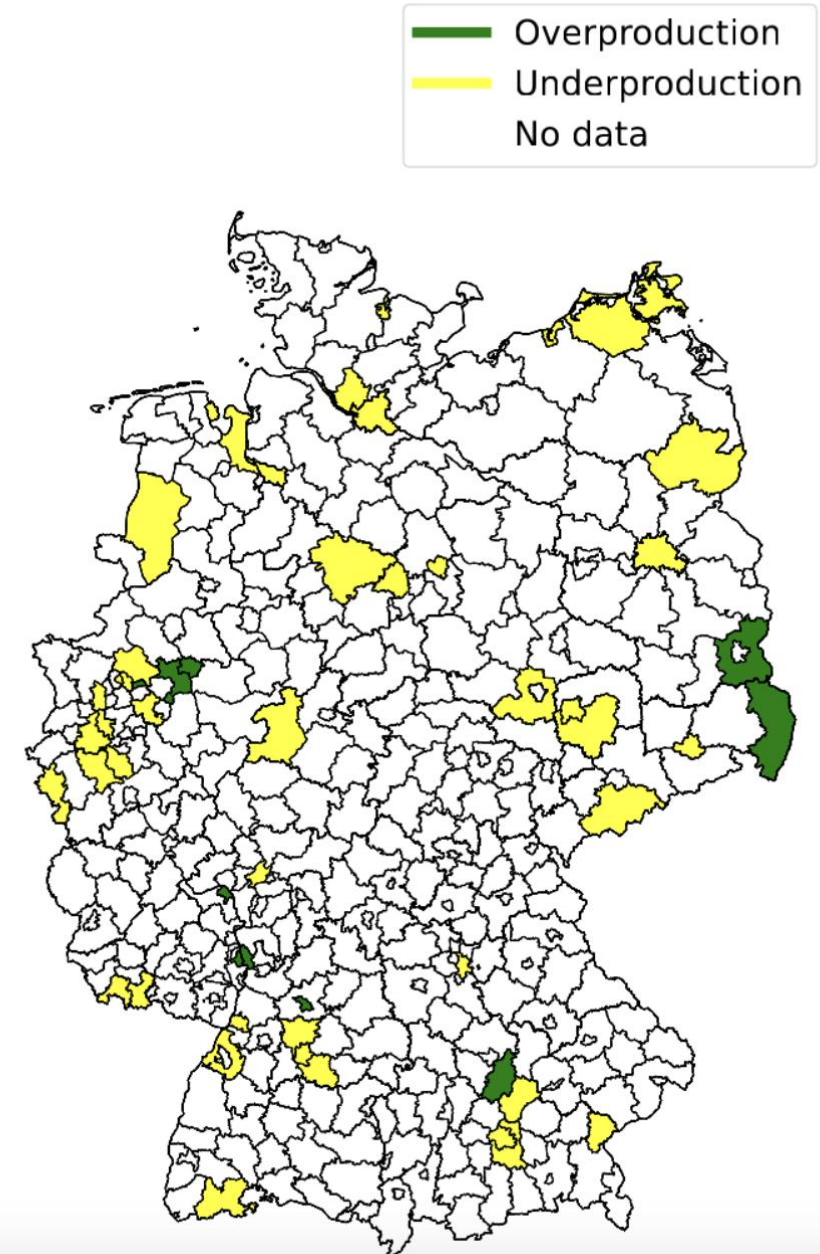
- *Google Maps* (<https://www.google.com/maps>)

Power plant information

- *transmission system operator (TSO) from countries such as Red Eléctrica de España (REE) , 50Hertz, Amprion, etc.*

Sub-regional Carbon Intensity

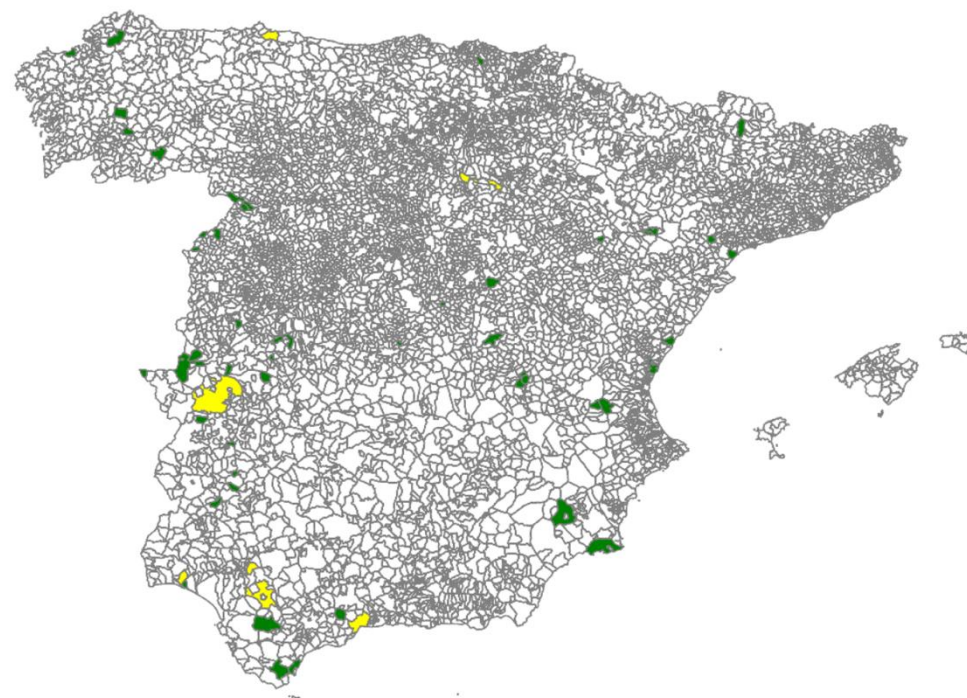
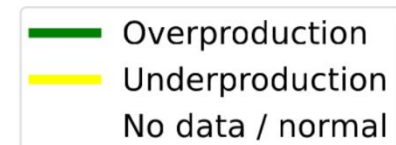
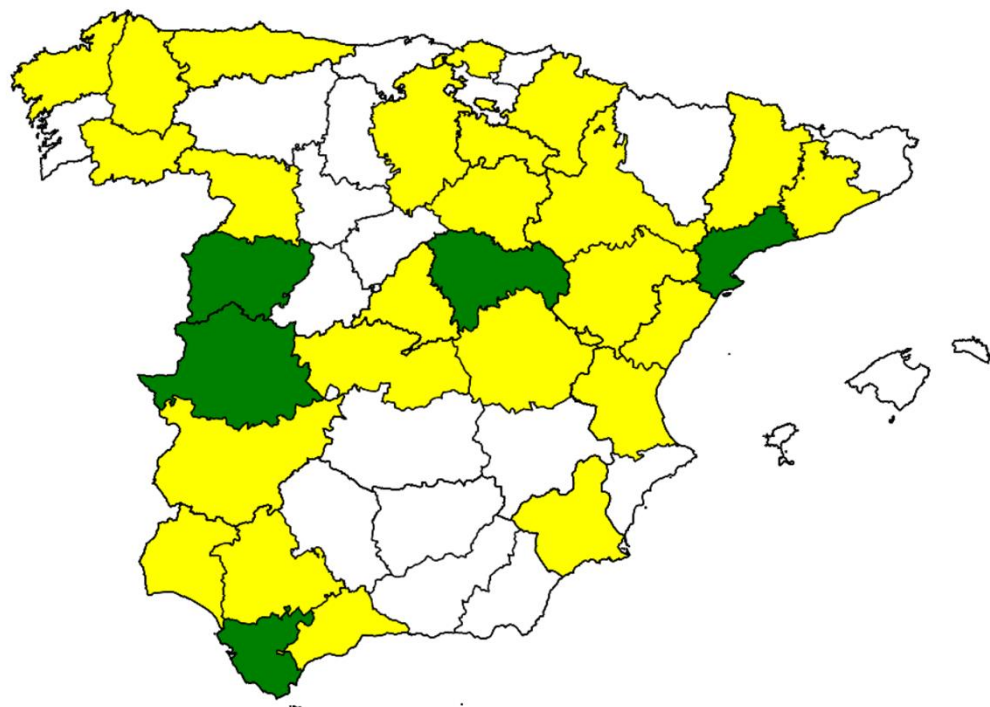
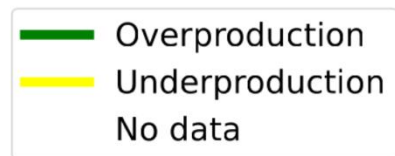
- We have local hourly energy production and consumption data for regional (NUTS3) and sub-regional (LAU) areas
- It's more reasonable to calculate local Carbon Intensity with local energy data rather than being represented by a national number
- CI calculated differently for self-sustained regions and not self-sustained regions



Sub-regional Carbon Intensity

- NUTS3 level

LAU level



Methodology:

The two parts : locally produced and imported from parent level:

1. NUTS3 imports from the national grid
 - NUTS3 production > NUTS3 consumption: use NUTS3 intensity mix
 - else: NUTS3 production + imports from national CI mix

$$CI_{NUTS3} = p * CI_{NUTS3_local} + (1 - p) * CI_{country}$$

2. LAU imports from its parent NUTS3
 - LAU production > LAU consumption: use LAU intensity mix
 - else: LAU production + imports from NUTS3 CI mix

$$CI_{LAU} = q * CI_{LAU_local} + (1 - q) * CI_{NUTS3}$$

More info to provide than EM

- Hourly regional CI for mainland Spain
- A more detailed regional carbon map allows users to navigate their routing path accordingly
- Real-time updating each regional Carbon Intensity gives users more freedom to choose between regional and national carbon information

2:00 AM



9:00 AM



19:00 PM



23:00 PM



Carbon Intensity maps for NUTS3 regions in mainland Spain at four different times on Jan. 1st, 2024.

March 1st, 2024



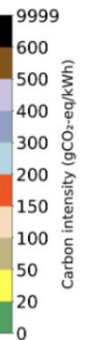
September 1st, 2024



November 1st, 2024



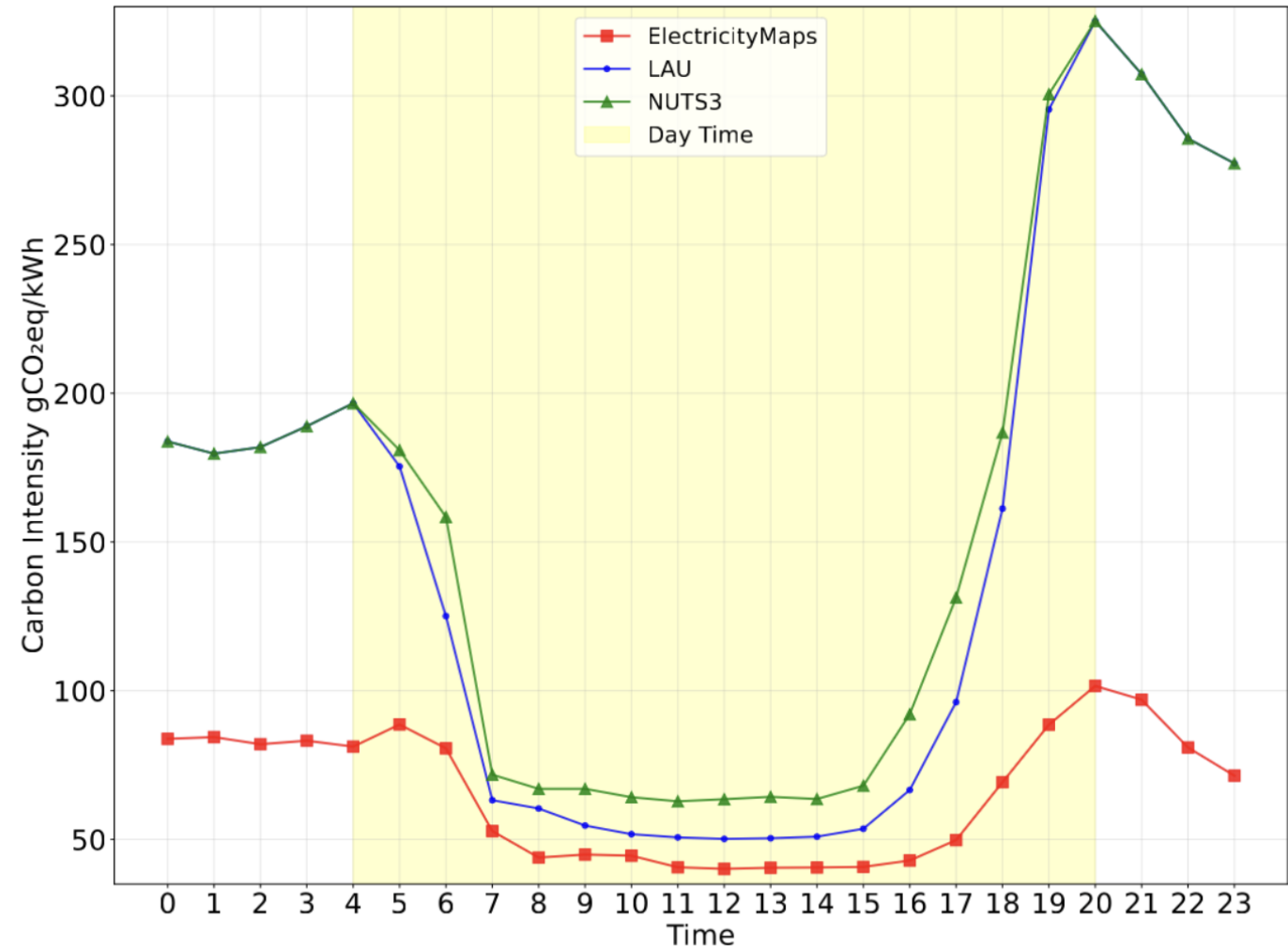
December 1st, 2024



Carbon Intensity maps for NUTS3 regions in mainland Spain at 15:00 on four different days.

More info

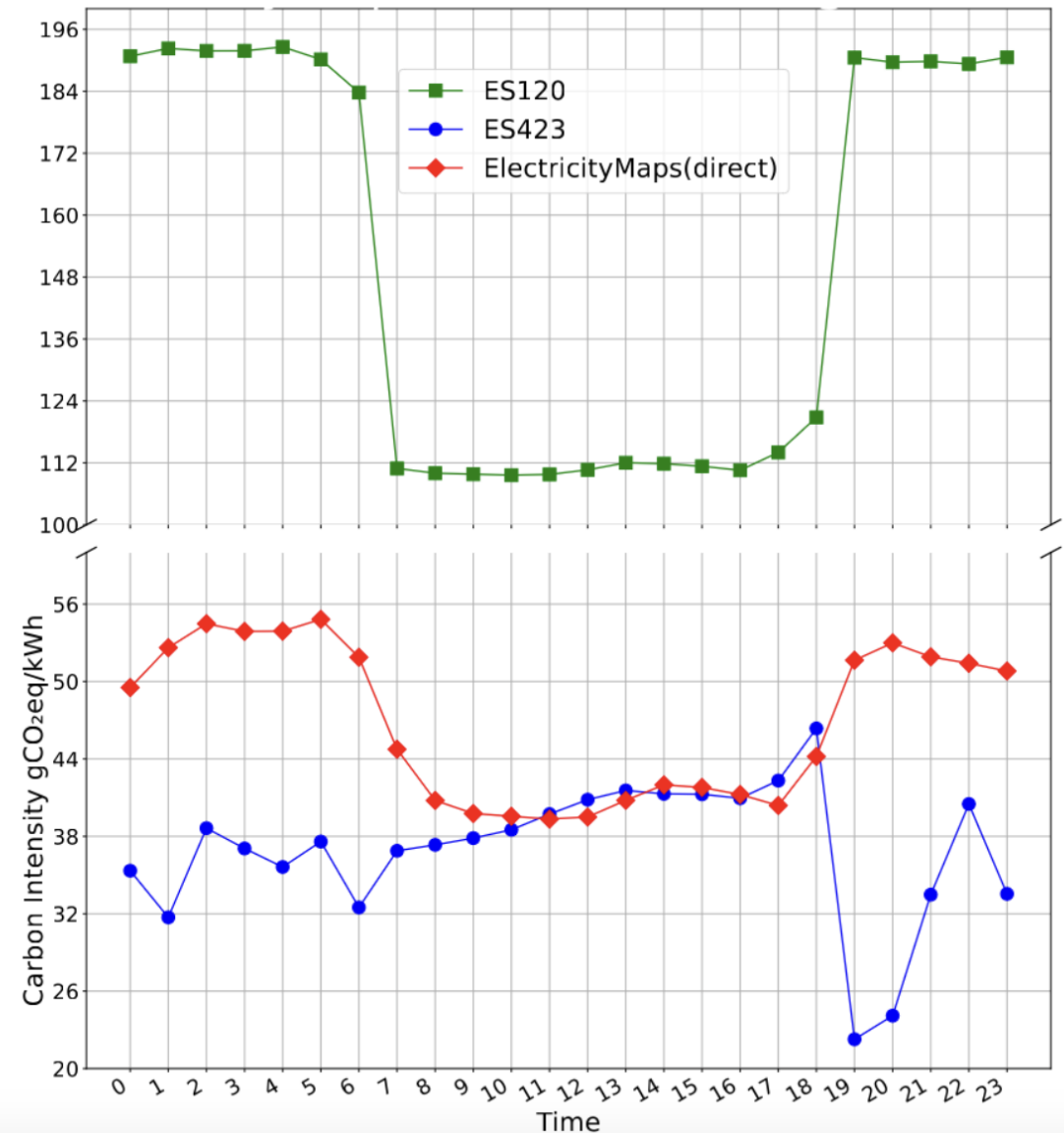
- At any time of a day, a regional Carbon Intensity can be mis-represented if we just look at the EM data;
- Each level of region will behave differently based on regional energy production/consumption
- From the record of entso-e, NUTS3 ES612 has all coal and gas power plants with one solar park in LAU ES612_11012. Thus when daytime starts, the LAU carbon intensity deviates from NUTS3 line



Carbon Intensity in the Cádiz Municipality (LAU ES612_11012), Cádiz Province (NUTS3 ES612) and ElectricityMaps data on July 1st, 2024.

More info

- For each hour, difference NUTS3 regions have completely different characteristics.
- The national Carbon Intensity only shows the sum of all observable regions and sub-regions.
- Regions may be canceling each others if only national Carbon Intensity is calculated.
- A path to a greener country could lead to a higher carbon emission



Problems that can be solved :

- Carbon-awareness for both intra-domain and inter-domain routing
- Domestic load-shifting for energy-consuming tasks with greener energy options, and avoiding legal or tax issues
- (different CDN source without legal problems for streaming)
- Help identifying the actual “greenness” of CDN nodes/data centers

Future Challenges

- **Electricity price and Power efficiency:** ICT carbon emissions also emphasize on electricity price and power efficiency, together with the greenness of energy.
- **Missing data and map beyond EU:** We currently use ENTSO-E for EU data. A global finer-grain map will require more source data on energy production and consumption
- **Market:** The diversity of the energy market influence both energy production and consumption. Public records can be difficult to trace PPAs (power purchase agreements).
- **Validation:** Our results derive from existing public data. Validating the results against other existing carbon data is difficult: almost other carbon databases only present data at the country level and most of them use same source data for EU.

Q&A