# WP6

## Self-Consumption:
## A core Lever for Carbon Footprint reduction

### *Milestone 6.2*

05/02/2026

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# Milestone 6.2 – initial formulation

Distributed Landmarks RIs = effective communities linked by:

- scientific skills and objectives
- technical management of their research facilities

**Self-consumption for multi-sited communities?**

*Promoting the emergence of a model of multi-sited energy communities for RIs, managed by a coordinated level of flexibilities; thus joining the movement of REC (Renewable Energy Communities) or CEC (Citizen Energy Communities) promoted by the European Commission.*

To be done:

- Applicability in ELI-ERIC
- Following up regulation
- Survey in the ESFRI?

# Milestone 6.2 – objectives

- Sharing scientific literacy & knowledge about self-consumption

- Interests of self-consumption for carbon neutrality (FlexRICAN)
  → GHG assessment of self-consumption for the FlexRICAN RIs

Applicability of self-consumption in RIs, collecting data & feedbacks

# Milestone 6.2 - presentation agenda

- **Self-consumption**
- Definition & indicators
- Interests & issues of self-consumption

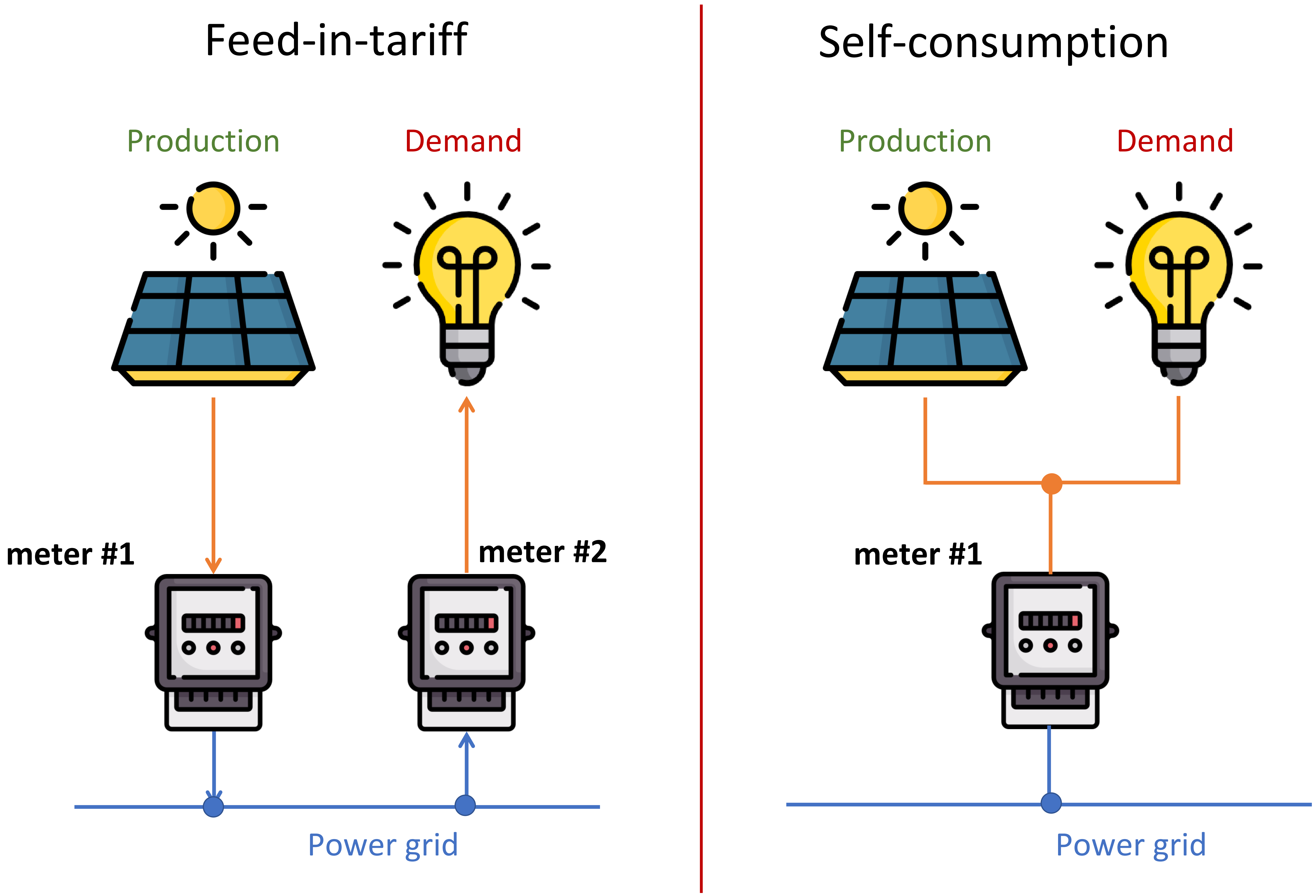
- **Case studies**: GHG assessment of self-consumption for the FlexRICAN RIs

- **ESFRI survey**

- **Open discussion**

# What is self-consumption

## Feed-in-tariffs / Self-consumption

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Reference: *Energy Communities: Sharing Resources on the Distribution Grid*, J. Coignard, 2022

# What is self-consumption

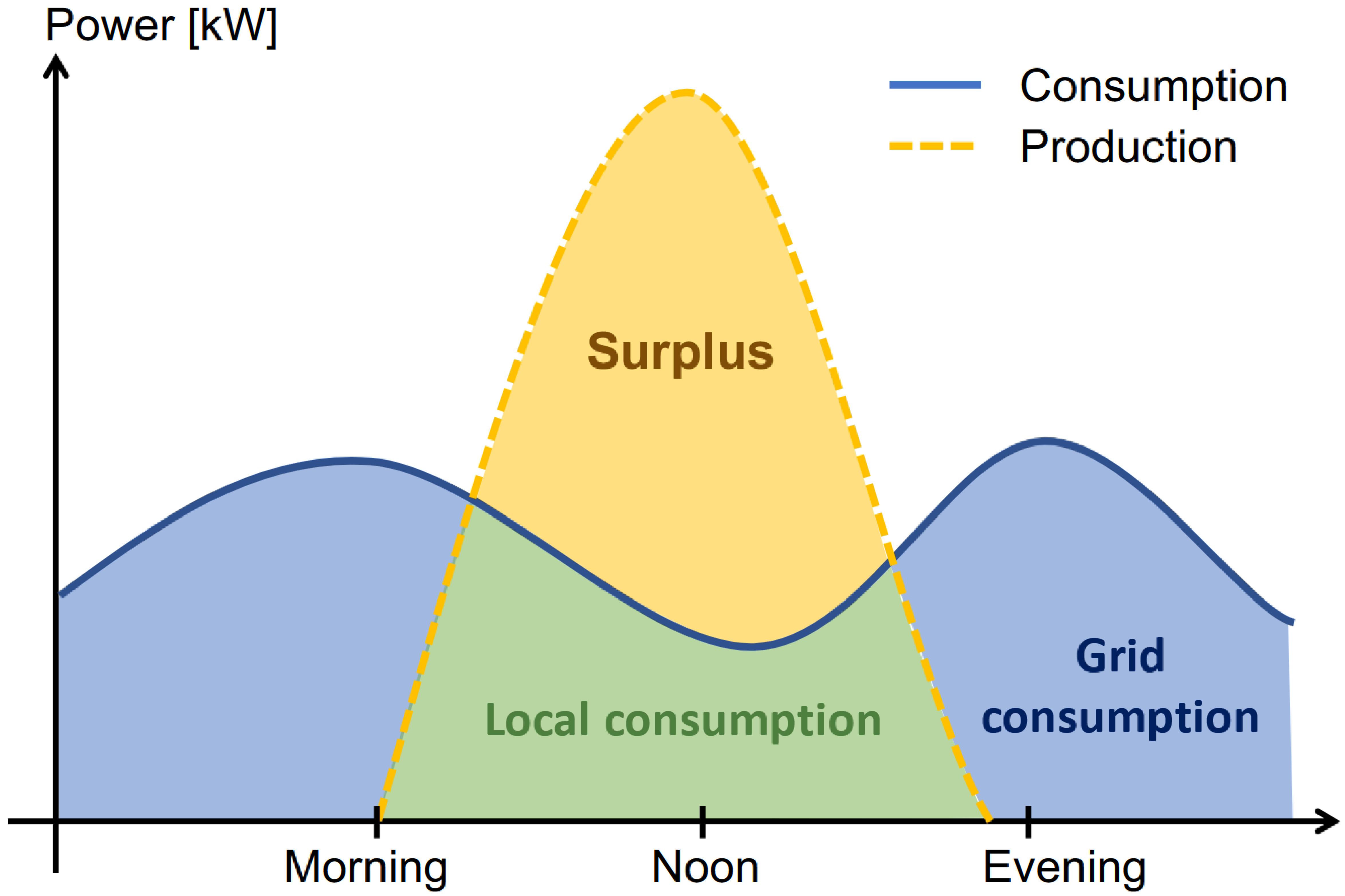
## Indicators

***Self-consumption*** refers to the share of locally generated energy—*typically photovoltaic (PV) systems*—that is directly consumed on-site.

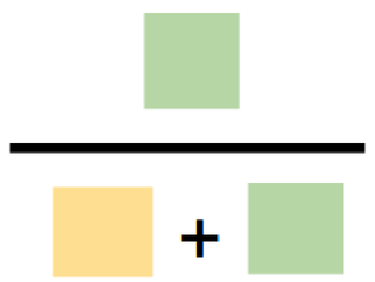
***Self-sufficiency*** refers to the degree to which an energy consumer or system meets its total energy demand through local energy generation.

# What is self-consumption

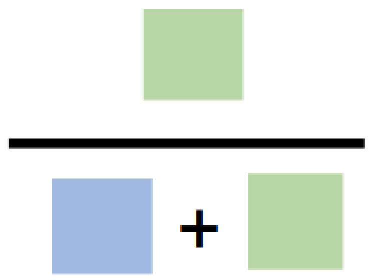
## Indicators




**Self-consumption =**



**Self-sufficiency =**



$$\text{self-consumption} = \frac{\sum_{t=1}^{T} \min\Big(\text{load}(t),\ \text{prod}(t)\Big)}{\sum_{t=1}^{T} \text{prod}(t)}$$

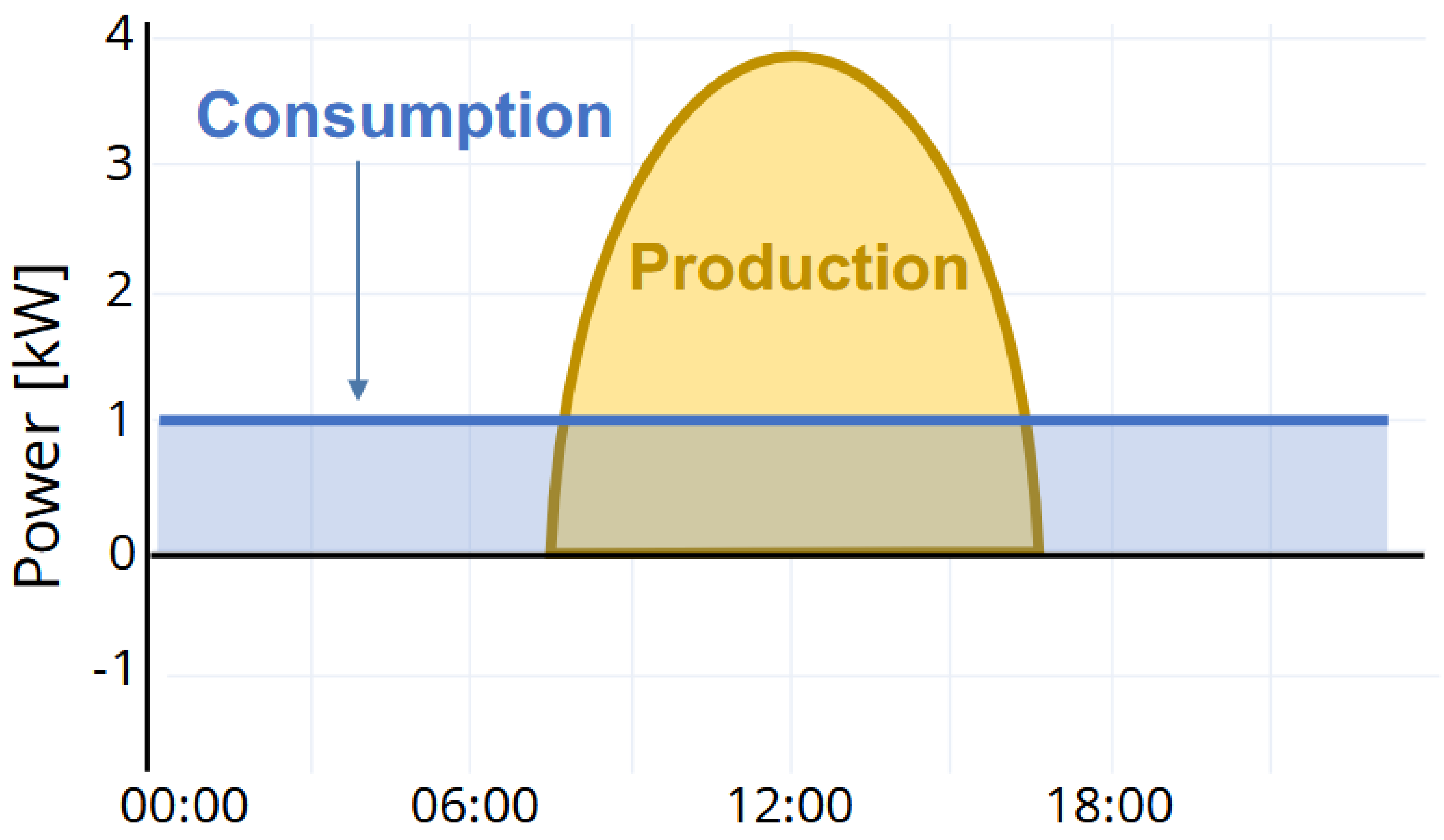
$$\text{self-sufficiency} = \frac{\sum_{t=1}^{T} \min\Big(\text{load}(t),\ \text{prod}(t)\Big)}{\sum_{t=1}^{T} \text{load}(t)}$$

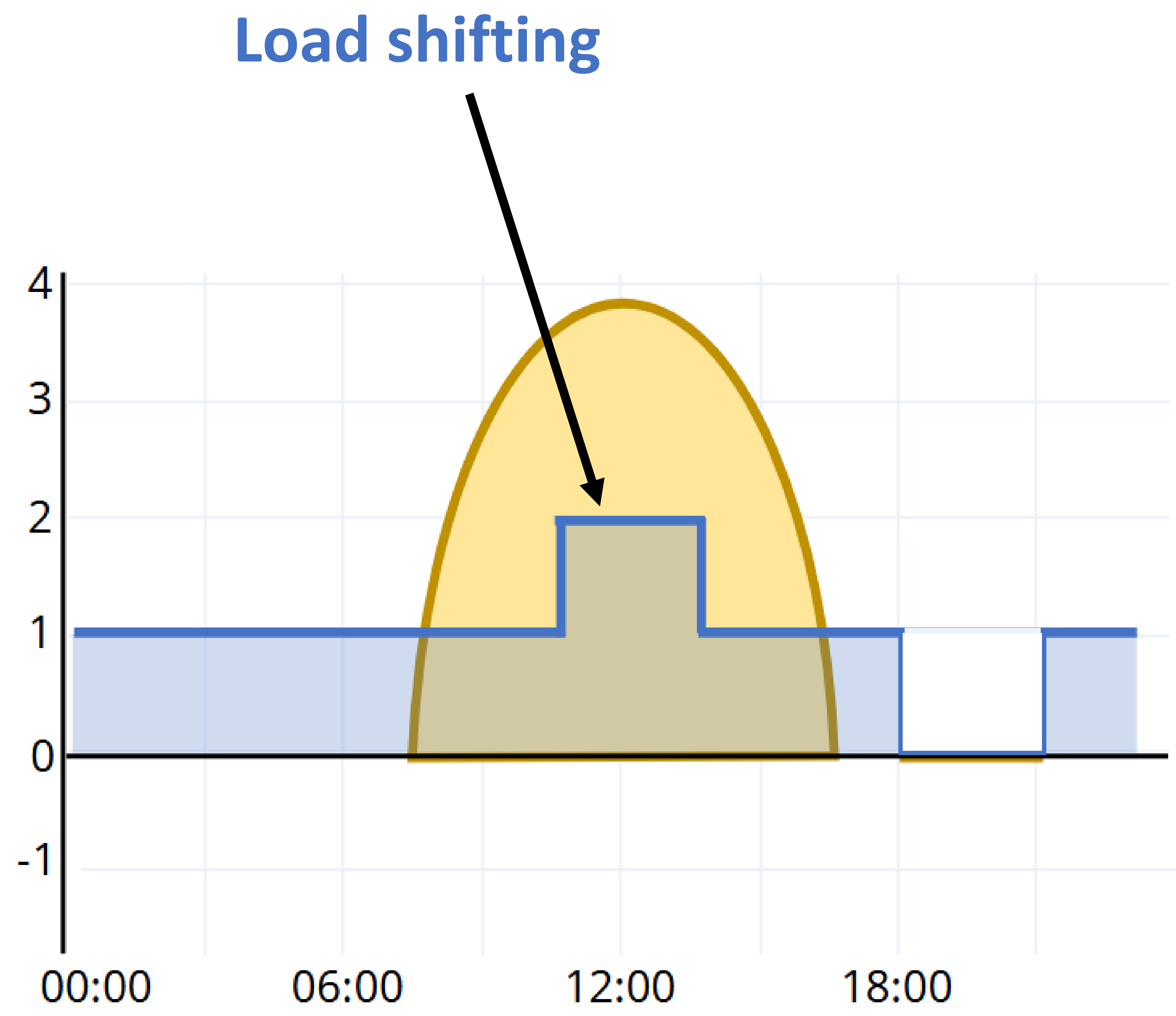


Reference: *Energy Communities: Sharing Resources on the Distribution Grid*, J. Coignard, 2022

# What is self-consumption

## Flexibility and storage



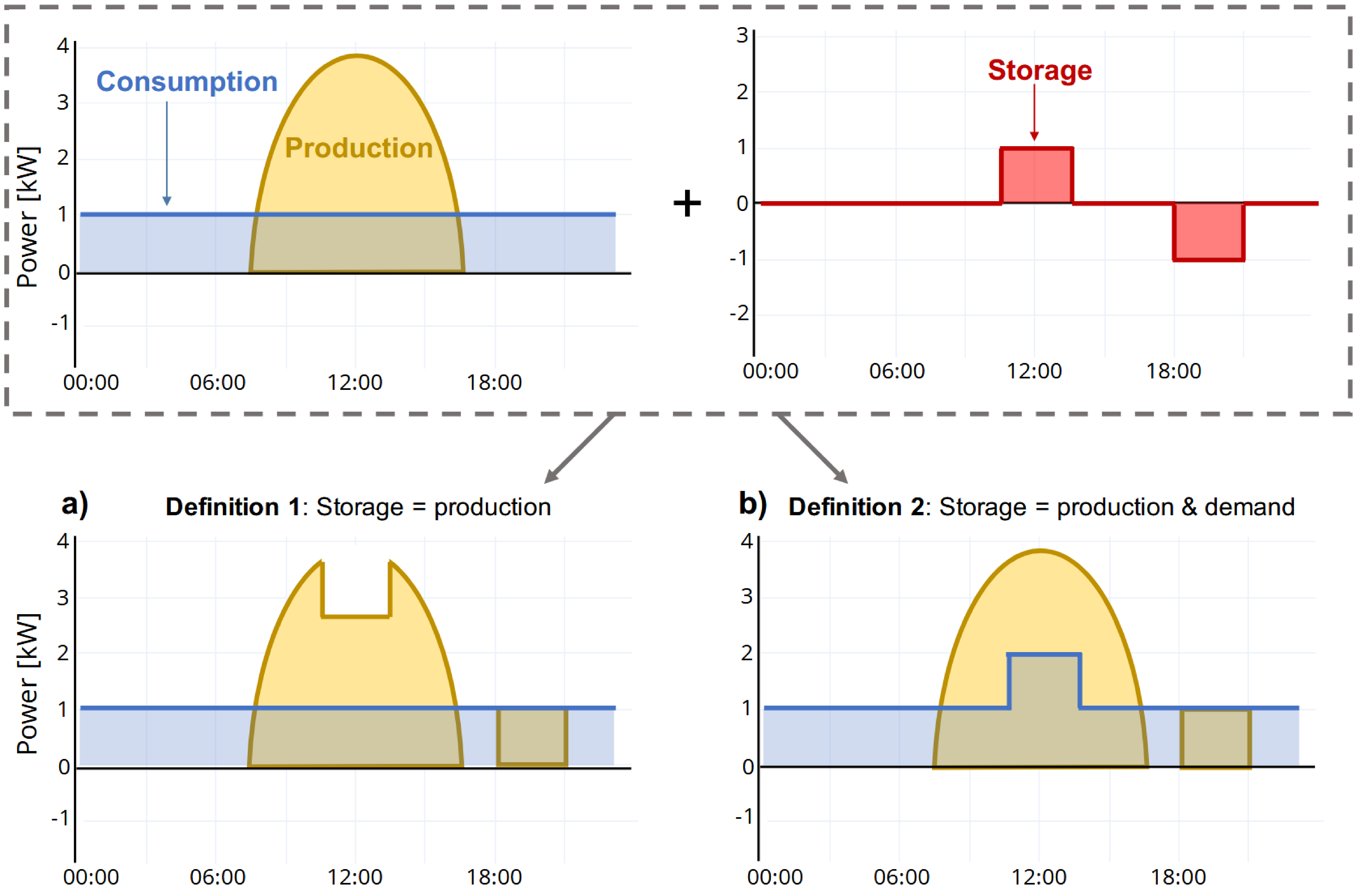






Reference: *Energy Communities: Sharing Resources on the Distribution Grid*, J. Coignard, 2022

# What is self-consumption

## Flexibility and storage




Self-sufficiency $= \frac{12}{24} = 50\%$

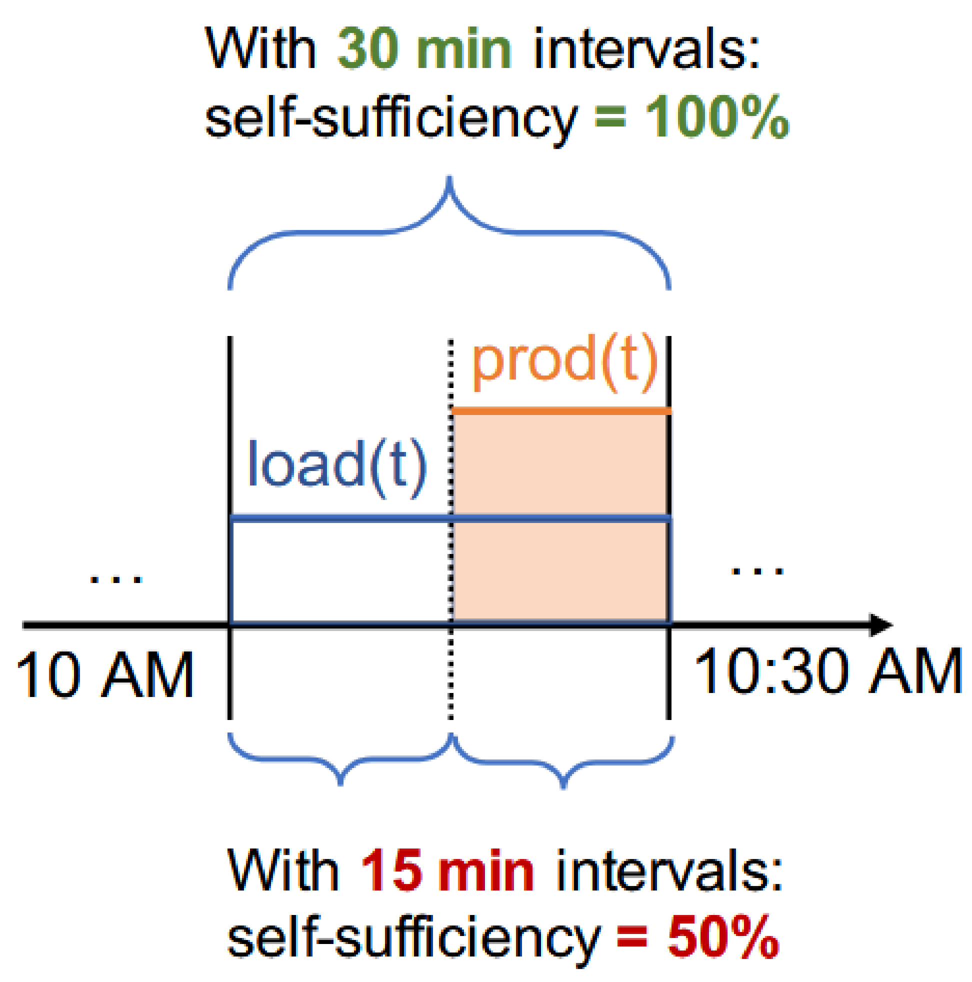
Self-sufficiency $= \frac{15}{27} = 55.5\%$

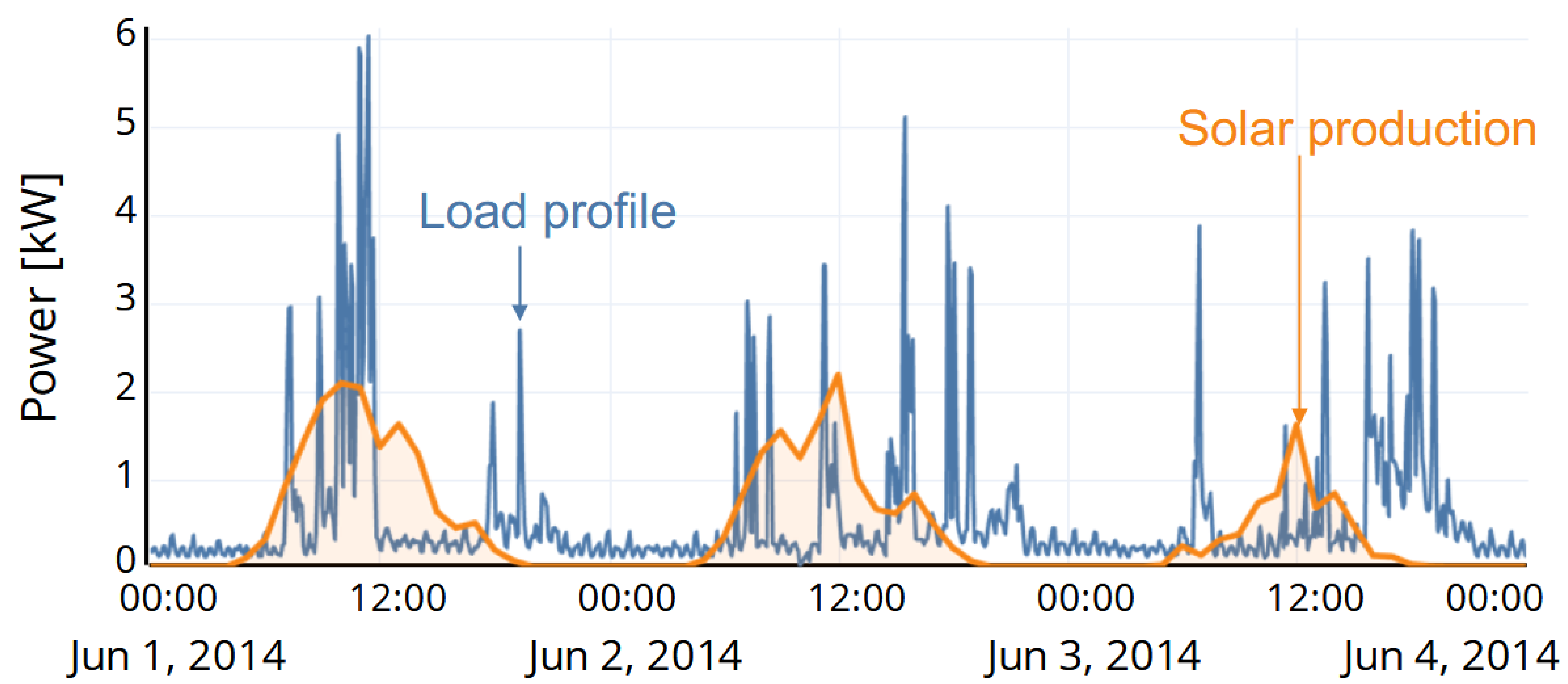


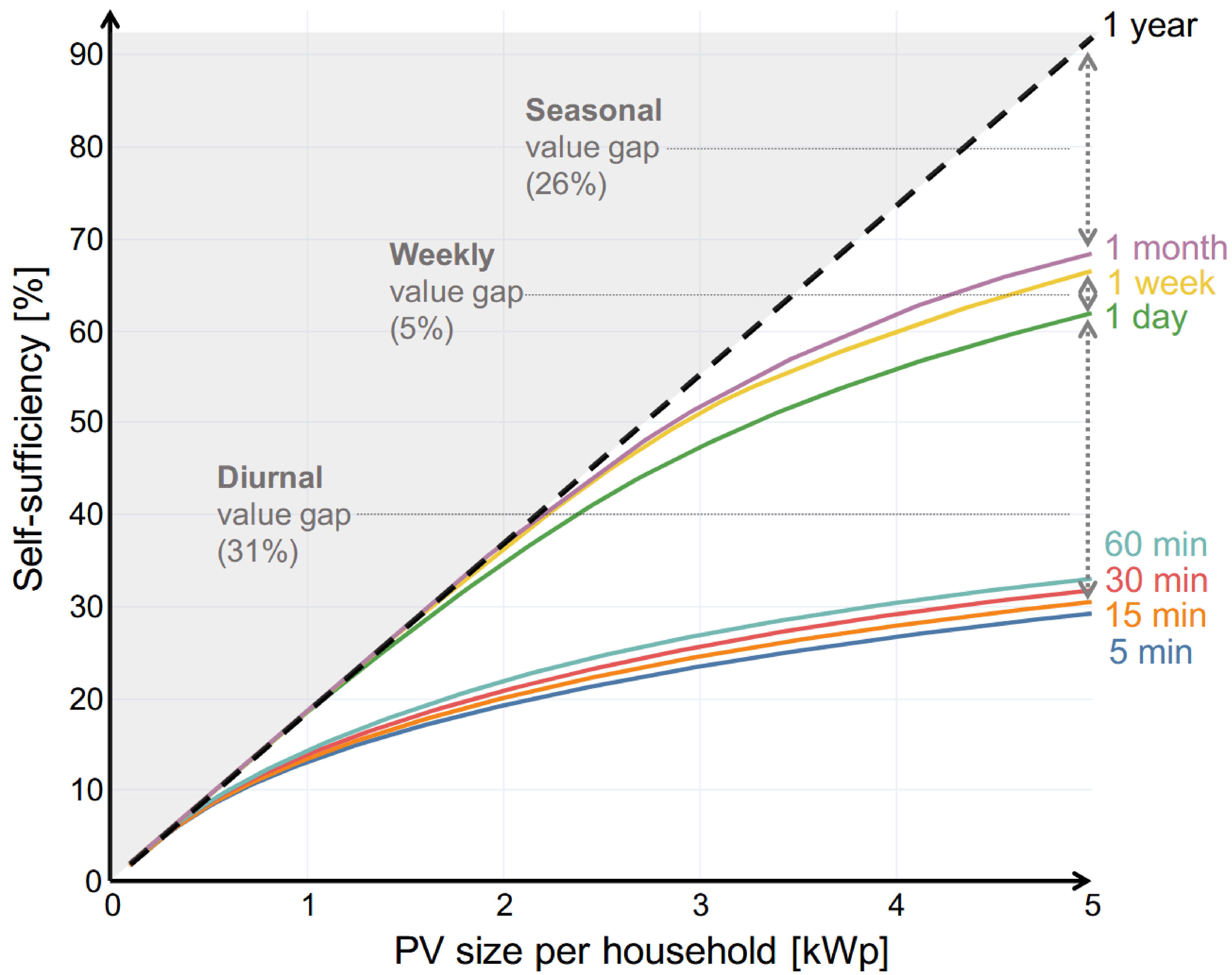
Reference: *Energy Communities: Sharing Resources on the Distribution Grid*, J. Coignard, 2022

# What is self-consumption

## The importance of temporal scope




Data:
- Consumption: residential, REFIT open data set (5min)
- PV : PV-GIS, (60min, interpolated 5min)



Reference: *Energy Communities: Sharing Resources on the Distribution Grid*, J. Coignard, 2022

# Energy sharing: types and scales

*Intelligent report 2024, Energy Pool resources*

- **Energy sharing** (also referred as **collective self-consumption**): It allows participants to share self-generated electricity free of charge or for a price, reducing reliance on the traditional energy market by using locally produced energy before drawing from the grid.
  - “ [...] the size of the installed capacity of the generation facility[...] is to be a maximum of **6 MW** [...] within a local or limited geographical area.“ *Art. 15a,* Directive 2024/1711 improving the European Union’s Electricity Market Design Directive (where CEC are detailed)
  - Energy sharing key: static, pro-rata, hybrid, hierarchical, dynamic

- **Peer-to-peer trading of renewable energy**: the direct energy transactions between individual consumers and producers, either through a direct contract or through a third-party market participant like an energy community manager or aggregator. This allows individuals to buy and sell surplus electricity without the need for an intermediary energy supplier.

- **Energy communities** (Renewable (REC) or Citizen (CEC) Energy Communities): A legal entity that allows citizens, Small and Medium-sized Enterprises (SMEs), and local authorities to collectively engage in the provision of energy exchange and storage services based on <u>open and voluntary participation</u>. They must be <u>controlled by their members</u> and <u>prioritize social and environmental benefits over monetary profit</u>.

# Energy sharing: types and scales

*Intelligent report 2024, Energy Pool resources*

**Renewable Energy Community(REC)**

- Allows SME
- **Geographical restriction**
- Can install assets for the generation of REn
- Activity centered on REn: generation, consumption, storage, sale

**Citizen Energy Community (CEC)**

- Allows small enterprises alone
- No geographical restriction
- Only install assets for electricity generation (REn or not)
- **Broader activity: distribution, aggregation, energy storage, energy efficiency, ...**

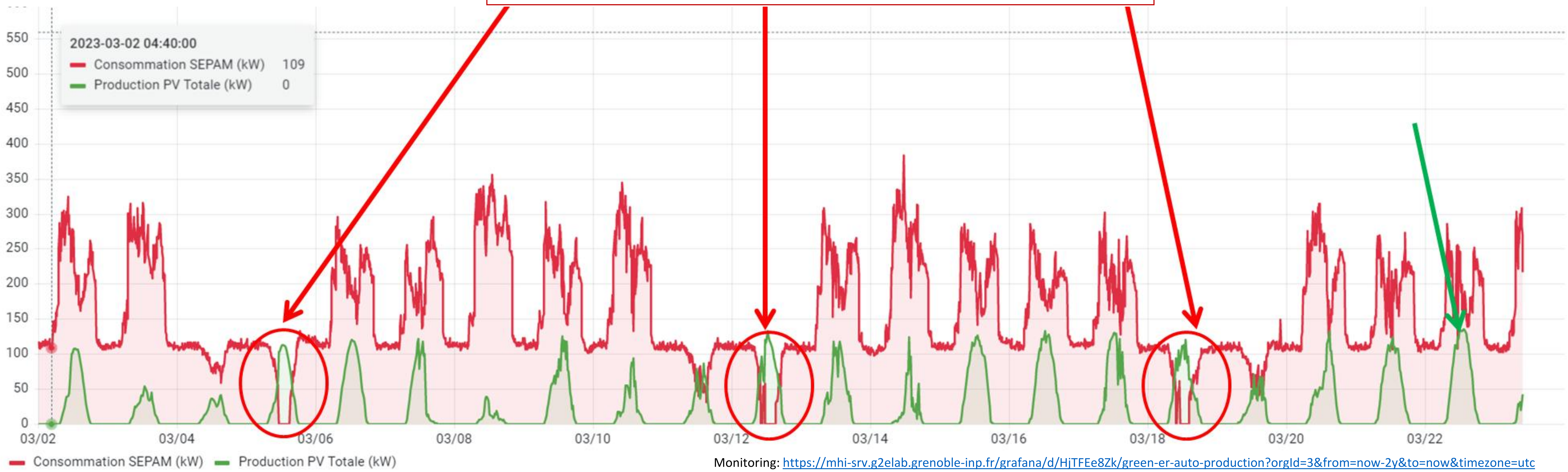
## Recent and moving domain

- Geographic boundaries,
- Types of legal person,
- Local interpretations of terms (autonomous, open, ...)

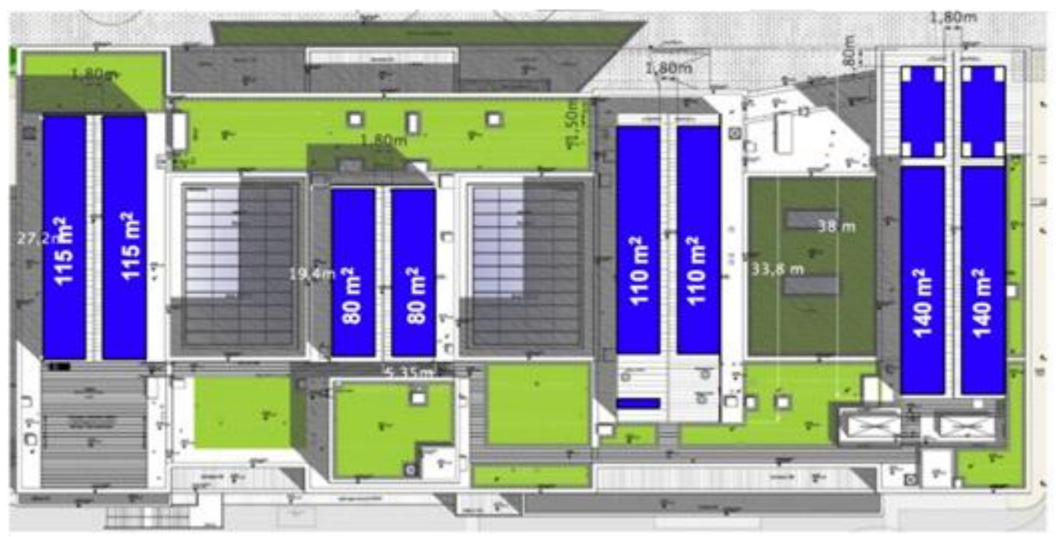
# An example: collective self-consumption in a university building (GrEn-ER)

- **Production:**
  - 195 kWp - 890m²
  - 250 MWh/year
  - 10% of GreEn-ER consumption (2000 occupants)
- **Costs: 300k€**
- **Savings: 42k€/year**

**Hours of self-sufficiency**




Monitoring: https://mhi-srv.g2elab.grenoble-inp.fr/grafana/d/HjTFEe8Zk/green-er-auto-production?orgId=3&from=now-2y&to=now&timezone=utc




# Interests and issues of self-consumption

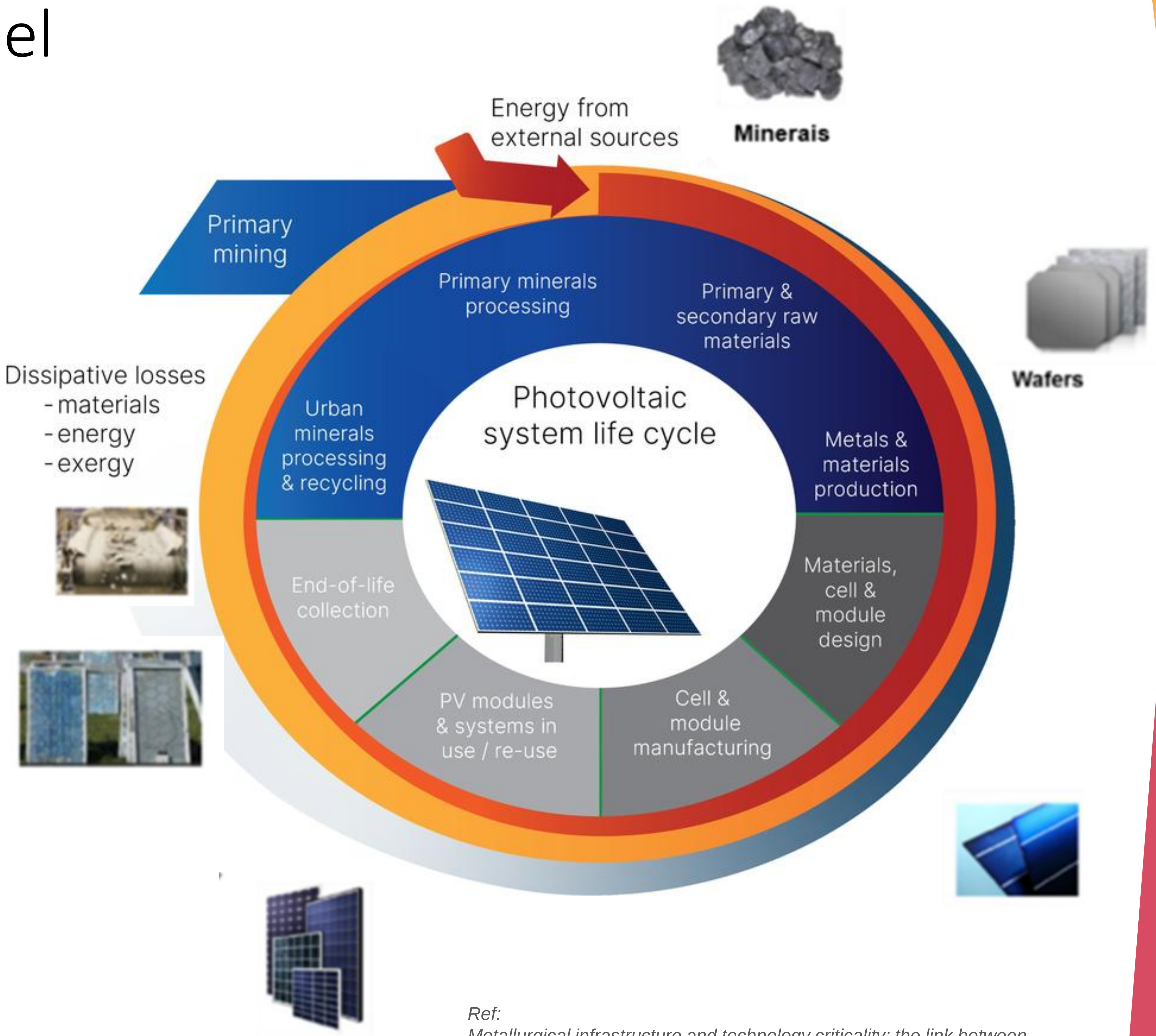
**Interests of self-consumption:**

- Integration of renewable energy
  - Energy transition: consistency, efficiency, sufficiency
  - Gaining autonomy from market prices
- Grid losses & constraint decrease
- Complementary earnings

**Challenge**: potential conflict between lowering overall GHG emissions and increasing self-sufficiency rates

# Environmental impacts

Lifecycle of a solar PV pannel

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*Ref:*
*Metallurgical infrastructure and technology criticality: the link between photovoltaics, sustainability, and the metals industry, Bartie et al. 2022*
*pictures:Nouha Gazbour, all rights reserved*

# GHG assessment

$$\text{GHG emissions} = \text{GHG for manufacturing \& end of life} + \sum_{n=1}^{\text{end of life}} \text{GHG in operation}$$

~investment (CAPEX)
Global warming potential (GWP) indicator

~operation (OPEX)

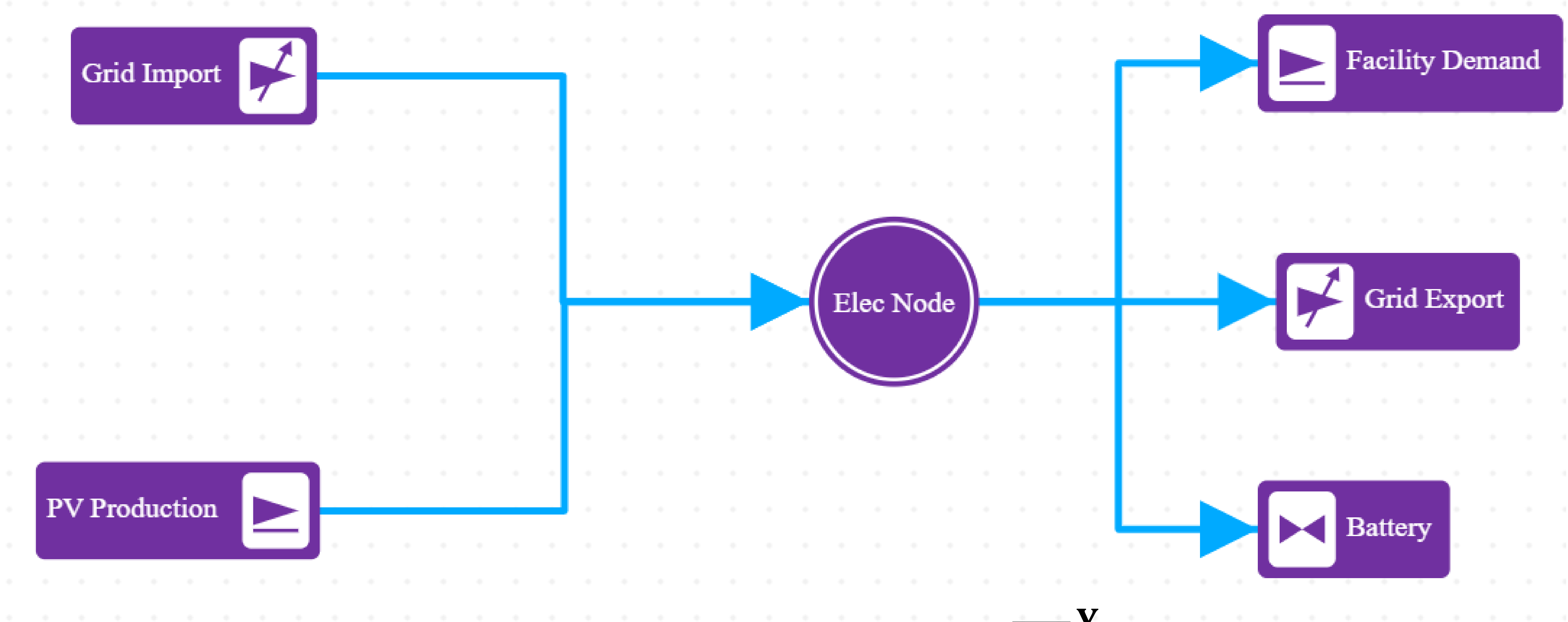
# GHG assessment

What is the combination of PV pannels and batteries that minimize the GHG emissions of RIs for self-sufficiency?

## Case studies:

# GHG assessment of self-consumption operations for the FlexRICAN RIs

# Case study




$$\textbf{Objective} = \textbf{Min. CAPEX} + \sum_{y}^{Y} \textbf{OPEX(y)}$$

$$\text{CAPEX} = \text{PV}_{\text{GWP}} \times \text{PV}_{\text{capacity}} + \text{Battery}_{\text{GWP}} \times \sum_{b}^{B} \left( \text{Battery}_{\text{capacity}}(b) \times \frac{\text{Battery}_{\text{usage}}(b)}{\text{Battery}_{\text{lifetime}}} \right)$$

$$\text{OPEX}(y) = \sum_{p}^{P} \lambda(p) \sum_{m}^{M} \left( \text{grid}_{\text{import}}(y,p,m) \times \text{grid}_{\text{emissions}}(y,p,m) \right)$$

Where $\lambda(p)$ is the coefficient representing the weight of the period $p$ within year $y$

We assume that energy exported to the grid does not represent a gain in CO2 reduction



*Hodencq, S.; Coignard, J.; Twum-Duah, N.K.; Mosquini, L.H.N. Including greenhouse gas emissions and behavioural responses in the optimal design of PV self-sufficient energy communities. COMPEL-Int. J. Comput. Math. Electr. Electron*

# Case study

## Key Assumptions :

1. Study Period is 20 years
2. Energy exported to the grid does not offset its equivalent in grid CO2 (no benefit in exporting to the grid).
3. Batteries are changed after 10 years
4. global warming potentials (GWP) used in the study:
   I. PV Modules : 858, 1040 and 1240 kg CO2eq/kWp
   II. Battery : 65kgCO2eq/kWh
5. Minimize the objective such that a target self-sufficiency rate is achieved

# Case study

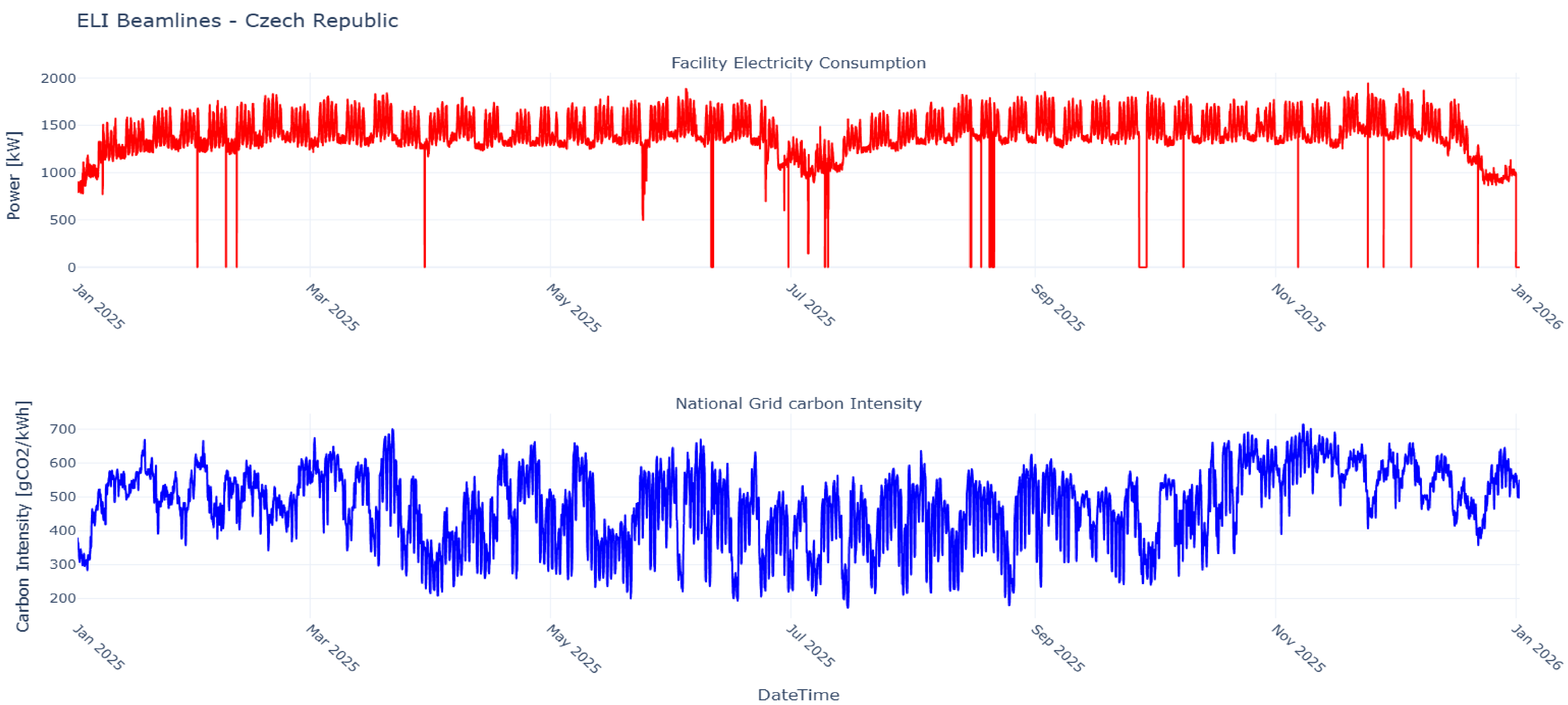
**Long terms dynamics** :

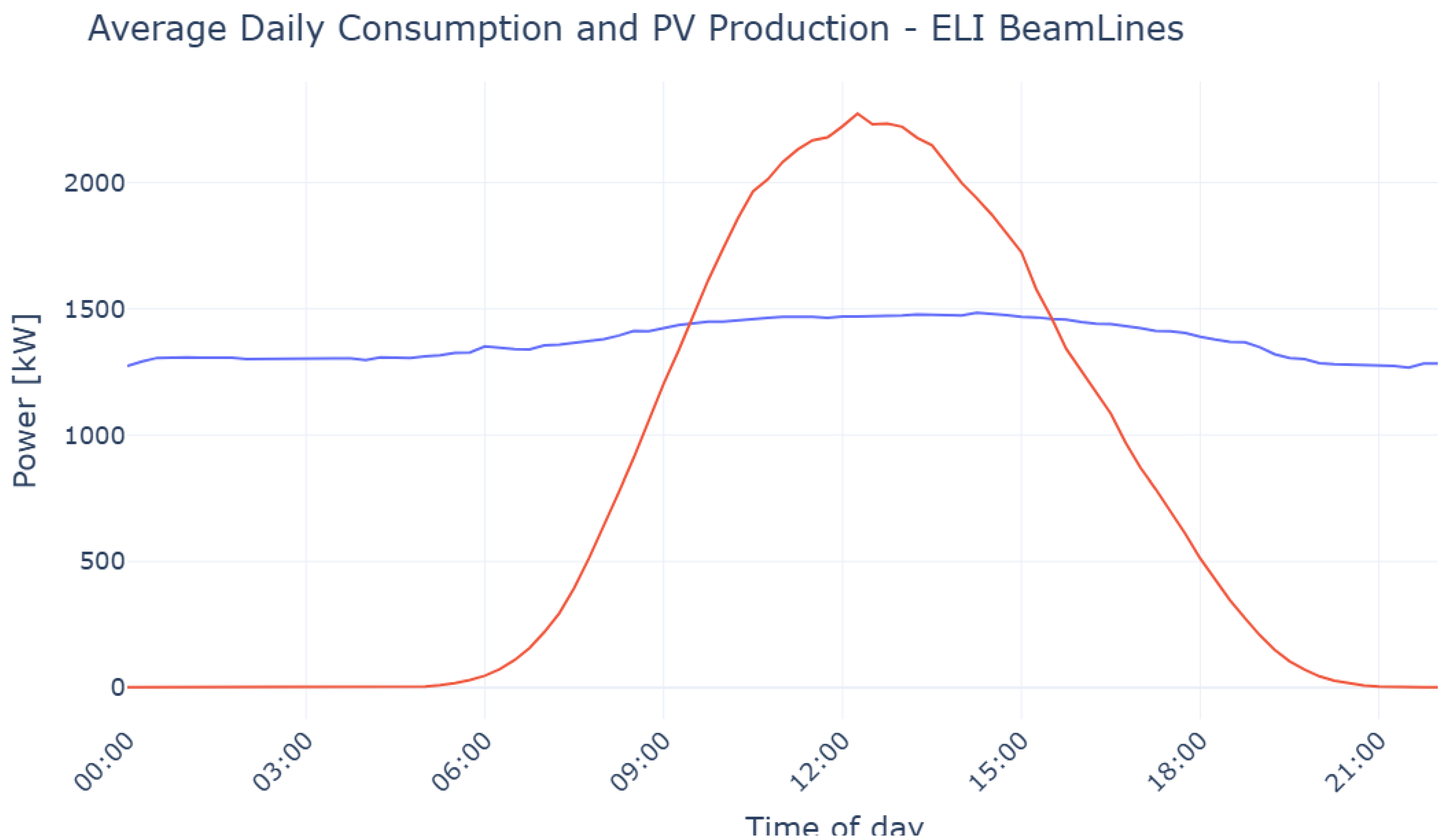
- battery aging
- solar panel aging
- battery investment decisions taken throughout the optimization at year 0, 10
- self-sufficiency target over the optimization horizon (20 Years).

**Short terms dynamics:**

- energy balance at the community level
- sub-hourly greenhouse gas emissions from the grid
- battery constraints and scheduling.

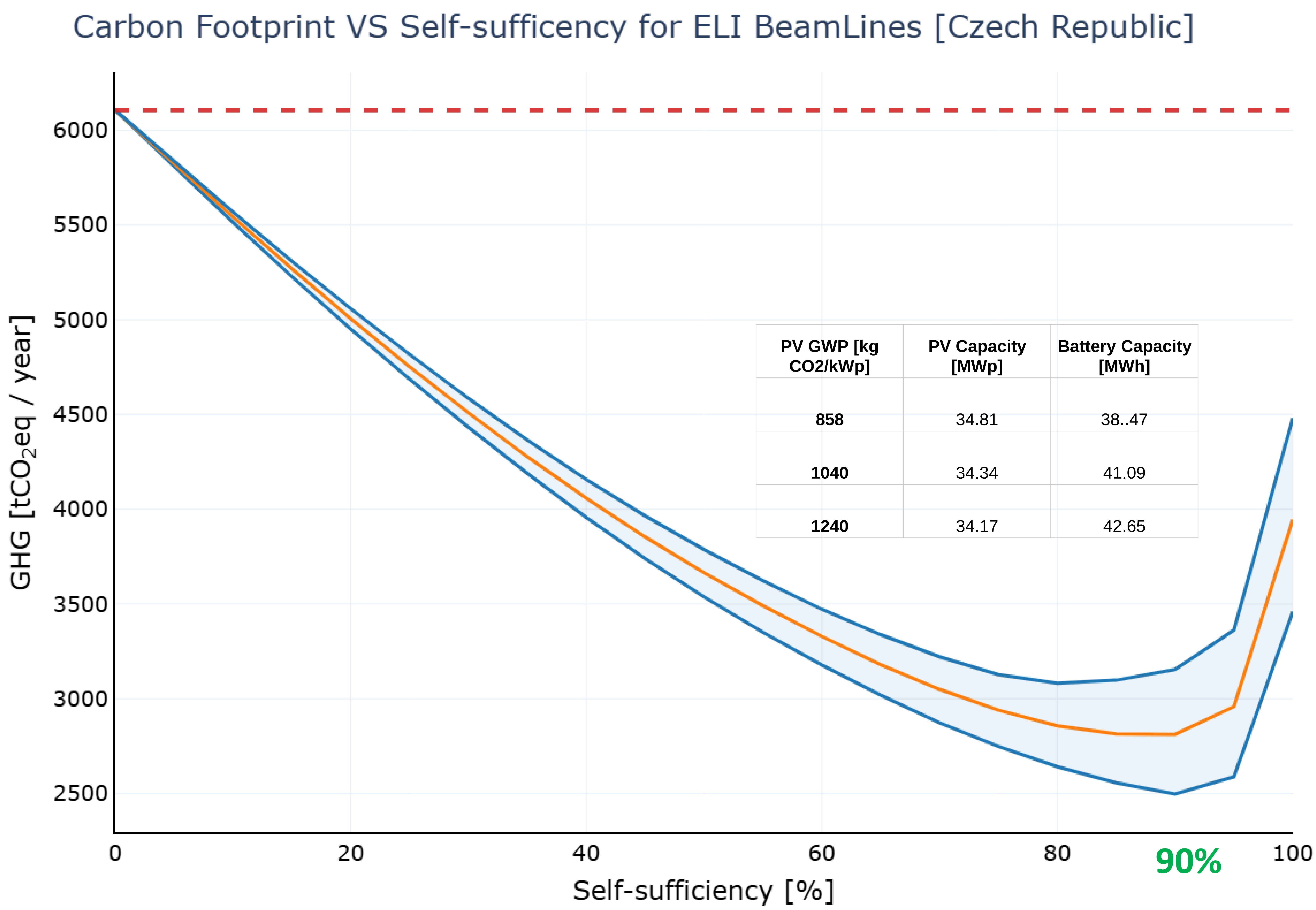
# ELI BeamLines - Data



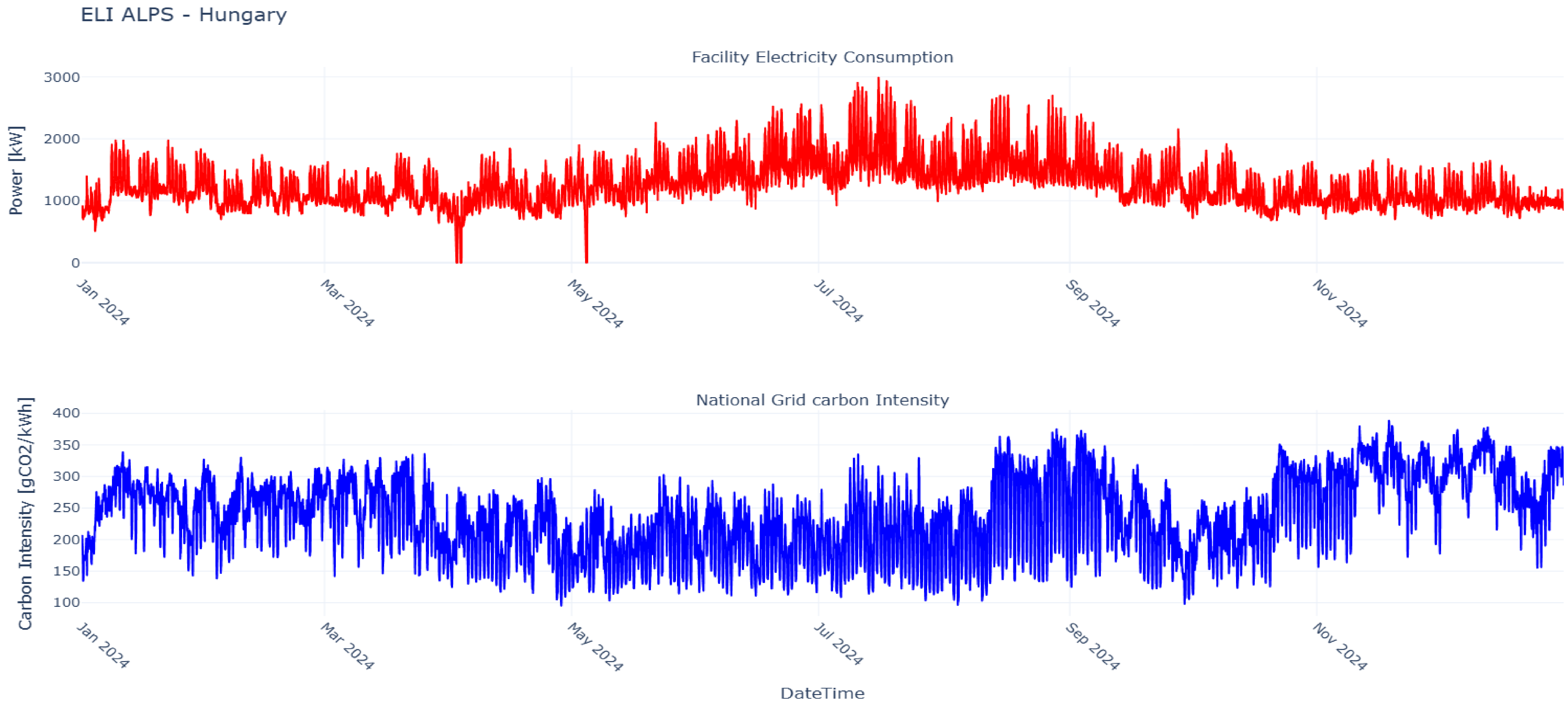

- **Main Activity**: High Power Laser Experiments
- **Annual Energy Consumption** : 11 GWh
- **Installed PV** : 350kWp
- Archetype: Maintenance of Indoor Environment

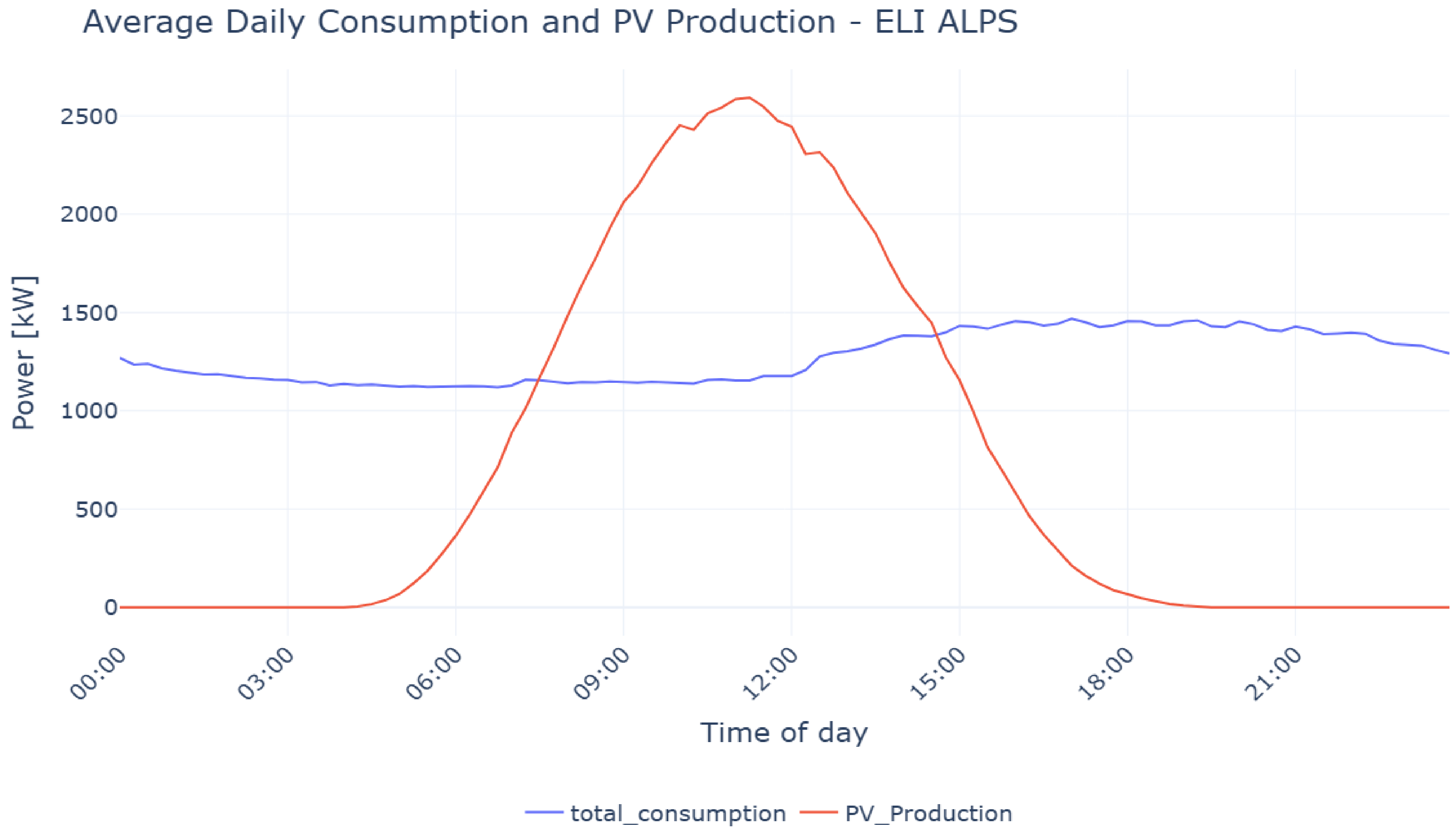
# ELI BeamLines - Results




| PV GWP [kg CO2/kWp] | PV Capacity [MWp] | Battery Capacity [MWh] |
|---|---|---|
| **858** | 34.81 | 38..47 |
| **1040** | 34.34 | 41.09 |
| **1240** | 34.17 | 42.65 |

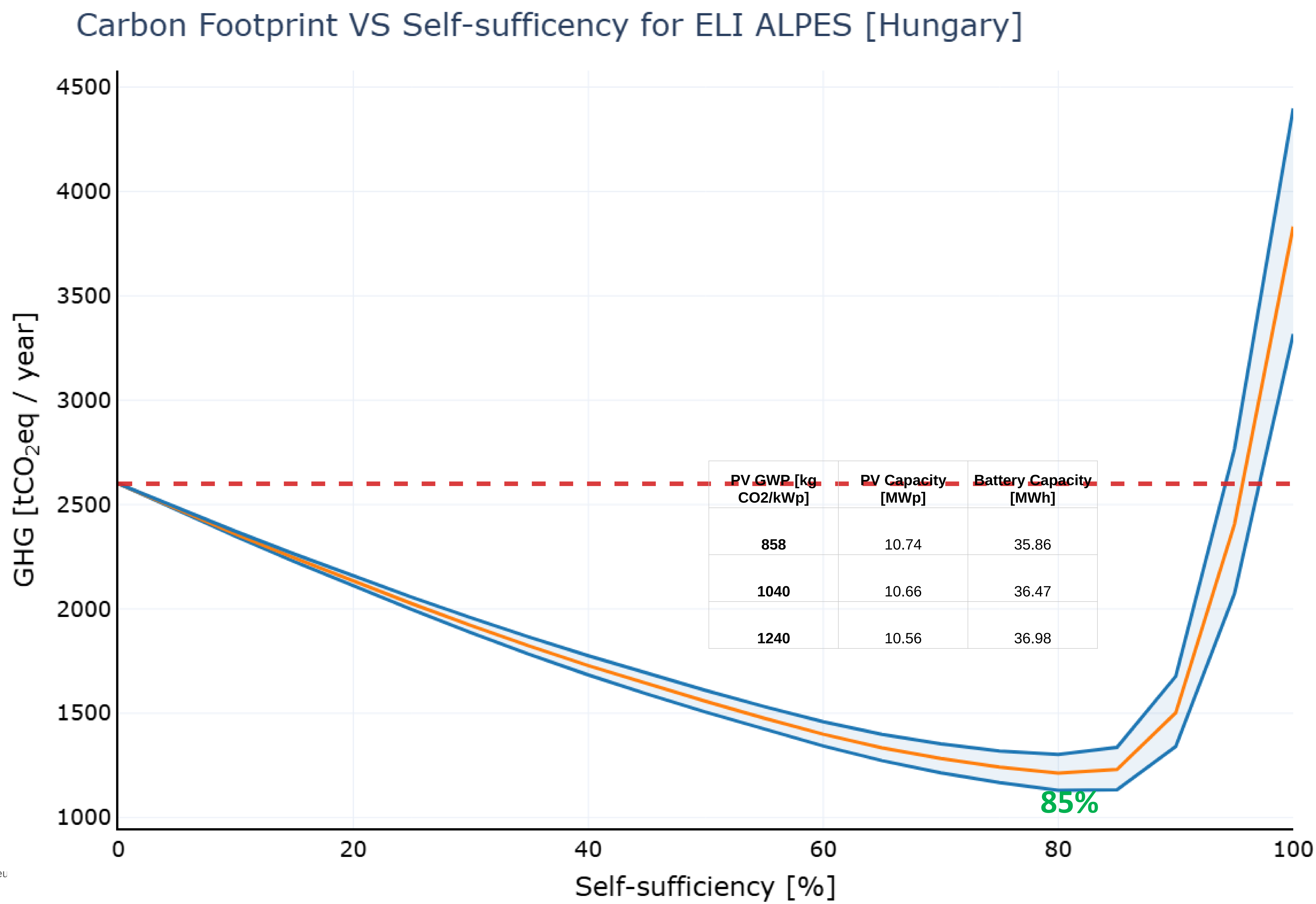
# ELI ALPS - Data



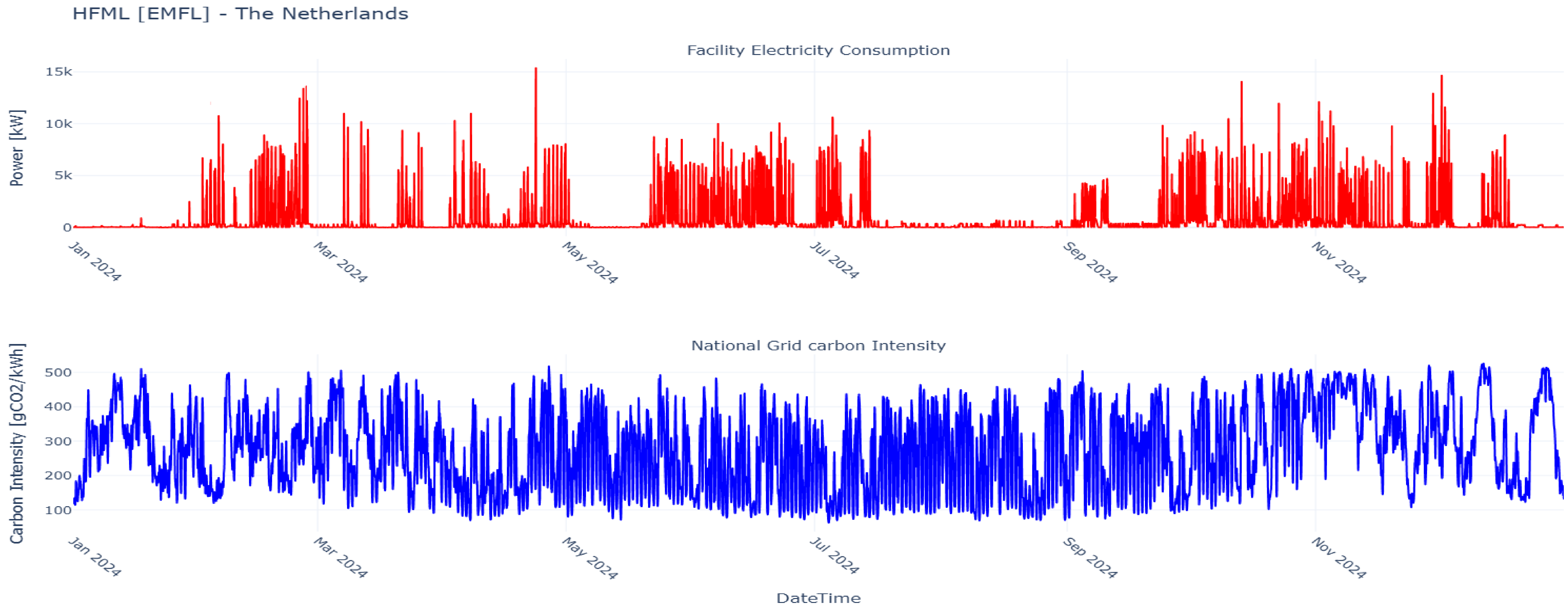

- **Main Activity**: High Power Laser Experiments
- **Annual Energy Consumption** : ~ 10 - 11 GWh
- **Installed PV** : ~5MWp
- **Archetype** : Maintenance of Indoor Environment

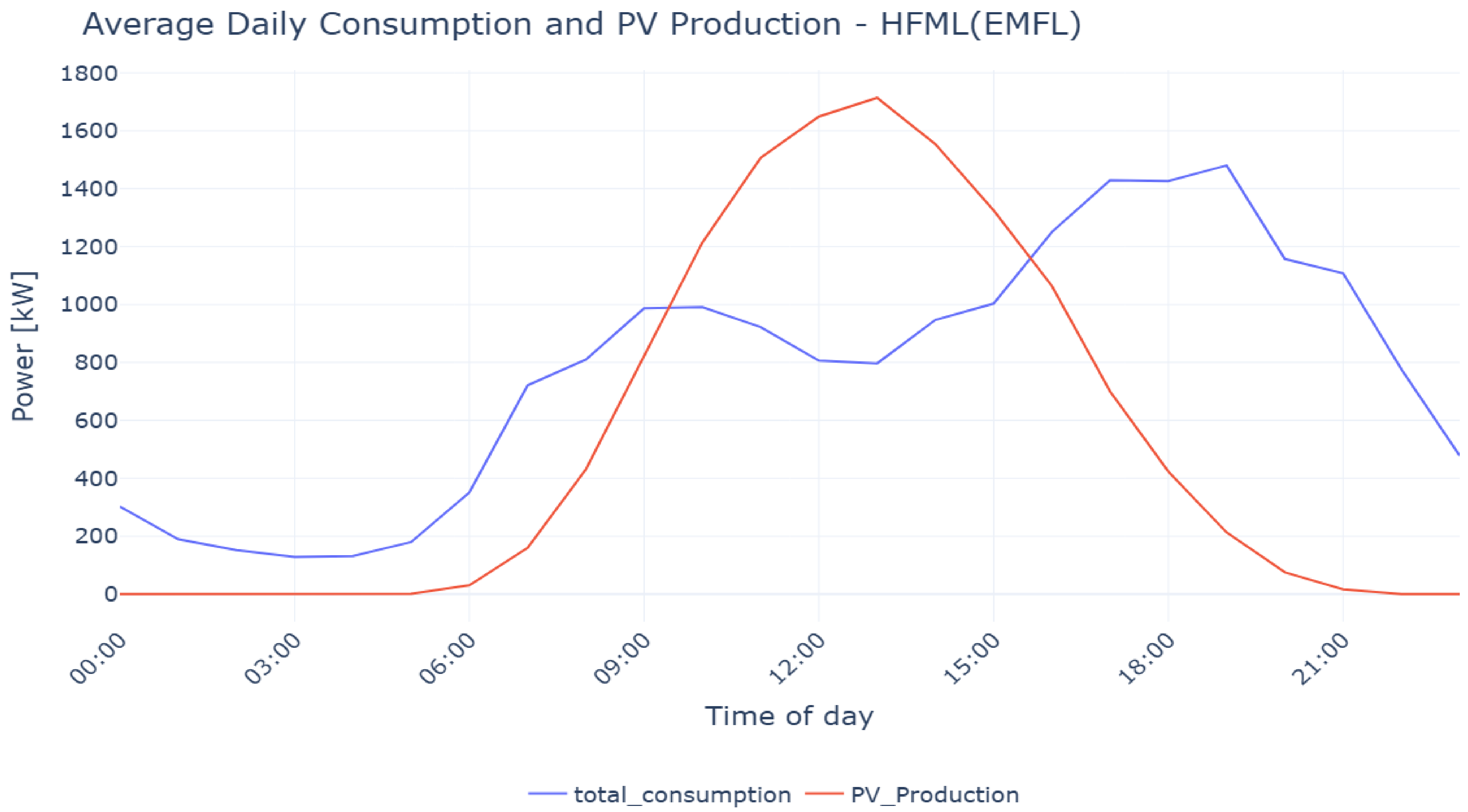
# ELI ALPS - Results




| PV GWP [kg CO2/kWp] | PV Capacity [MWp] | Battery Capacity [MWh] |
|---|---|---|
| **858** | 10.74 | 35.86 |
| **1040** | 10.66 | 36.47 |
| **1240** | 10.56 | 36.98 |

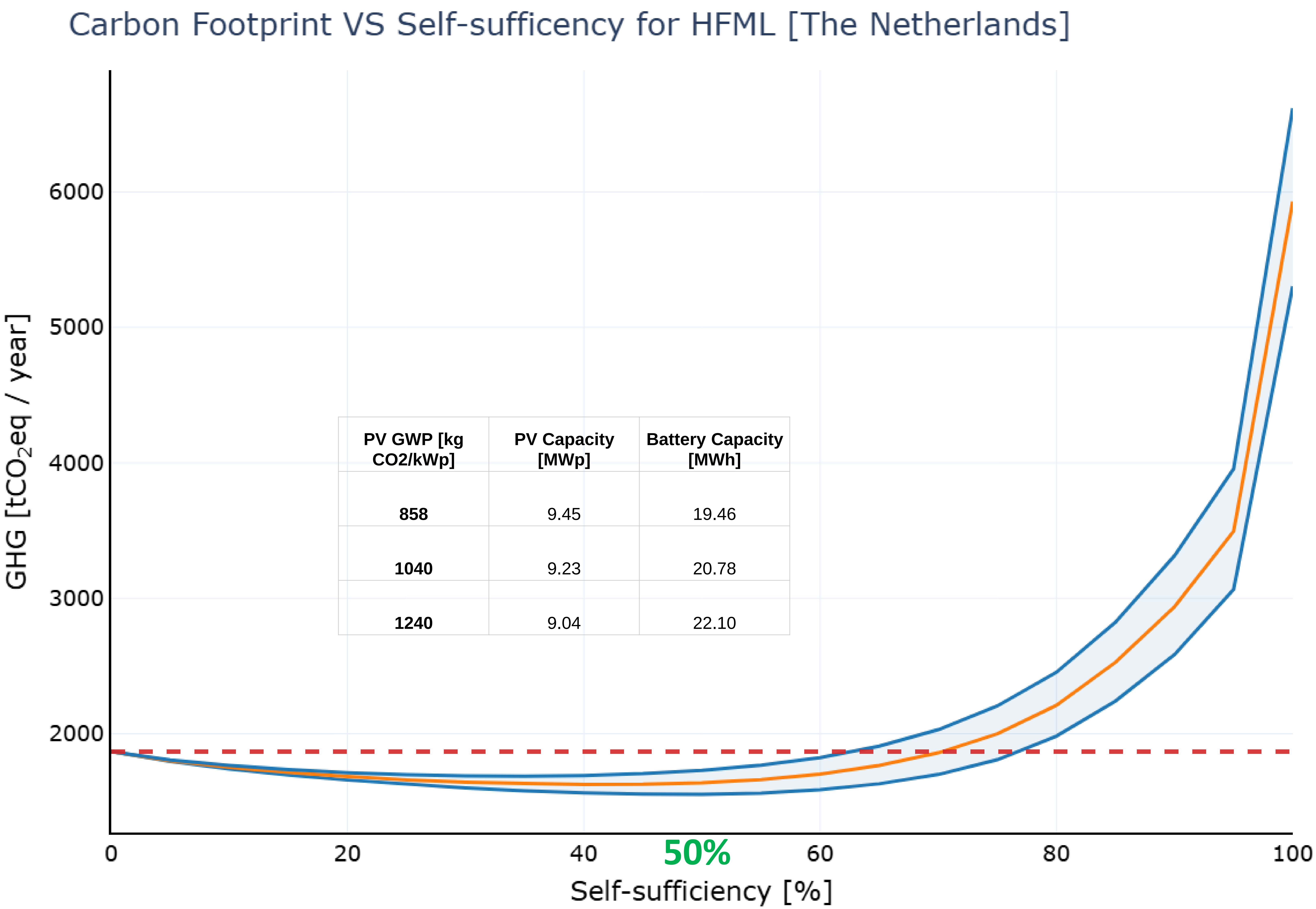
# HFML - Data



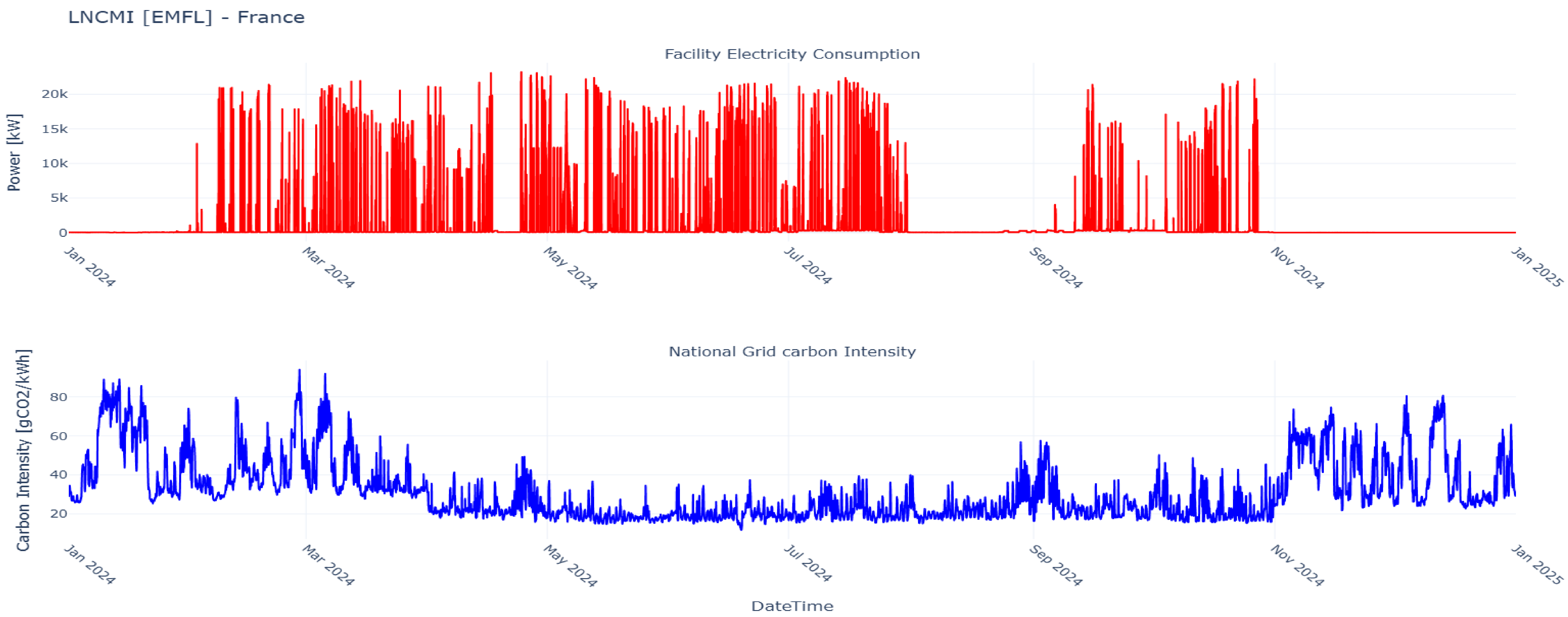

- **Main Activity**: High Magnetic Field Experiments
- **Annual Energy Consumption** : ~ 10 - 11 GWh
- **Installed PV** : ~123kWp
- **Archetype** : Powering Magnets for experiments

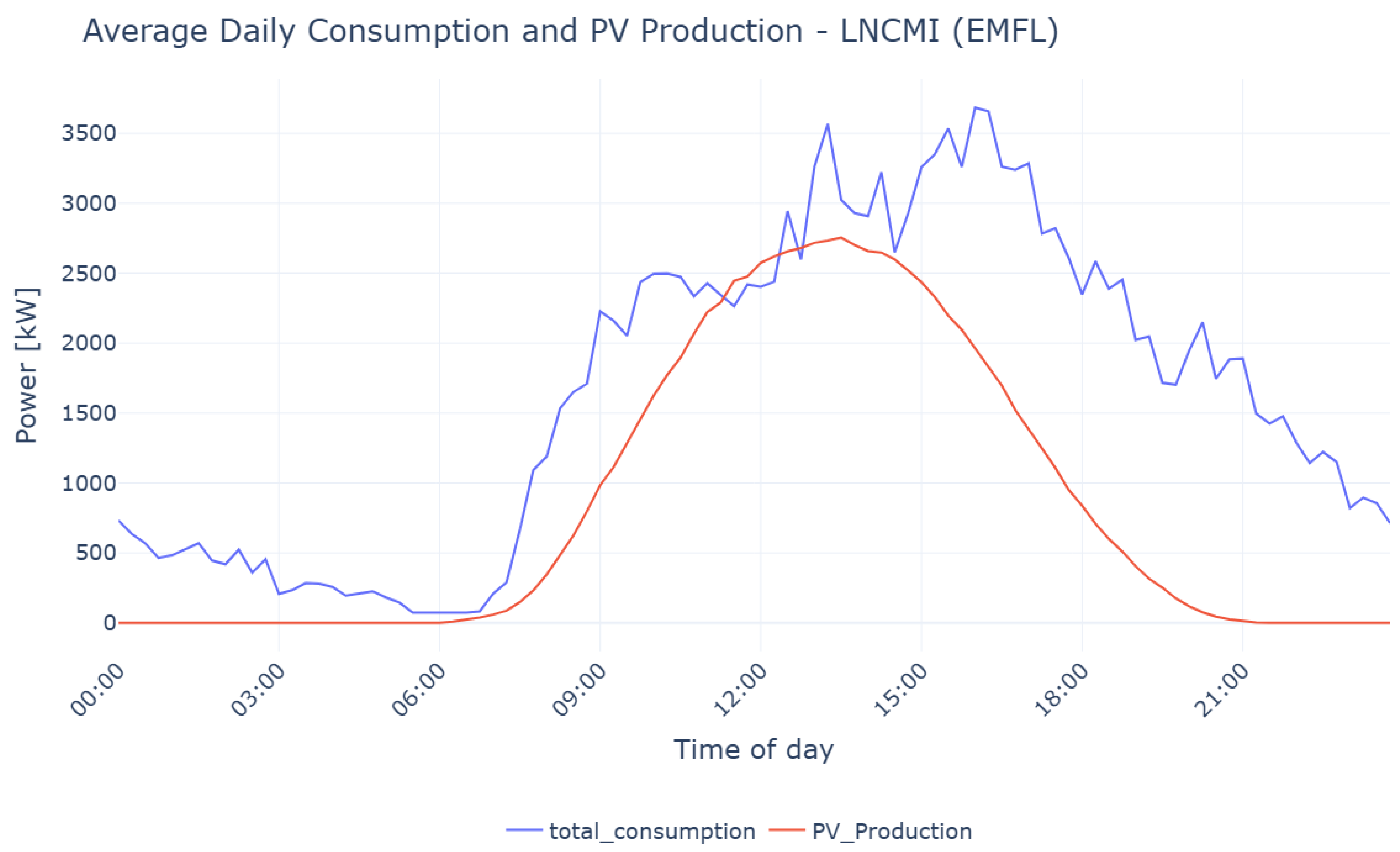
# HFML - Results




| PV GWP [kg CO2/kWp] | PV Capacity [MWp] | Battery Capacity [MWh] |
|---|---|---|
| **858** | 9.45 | 19.46 |
| **1040** | 9.23 | 20.78 |
| **1240** | 9.04 | 22.10 |

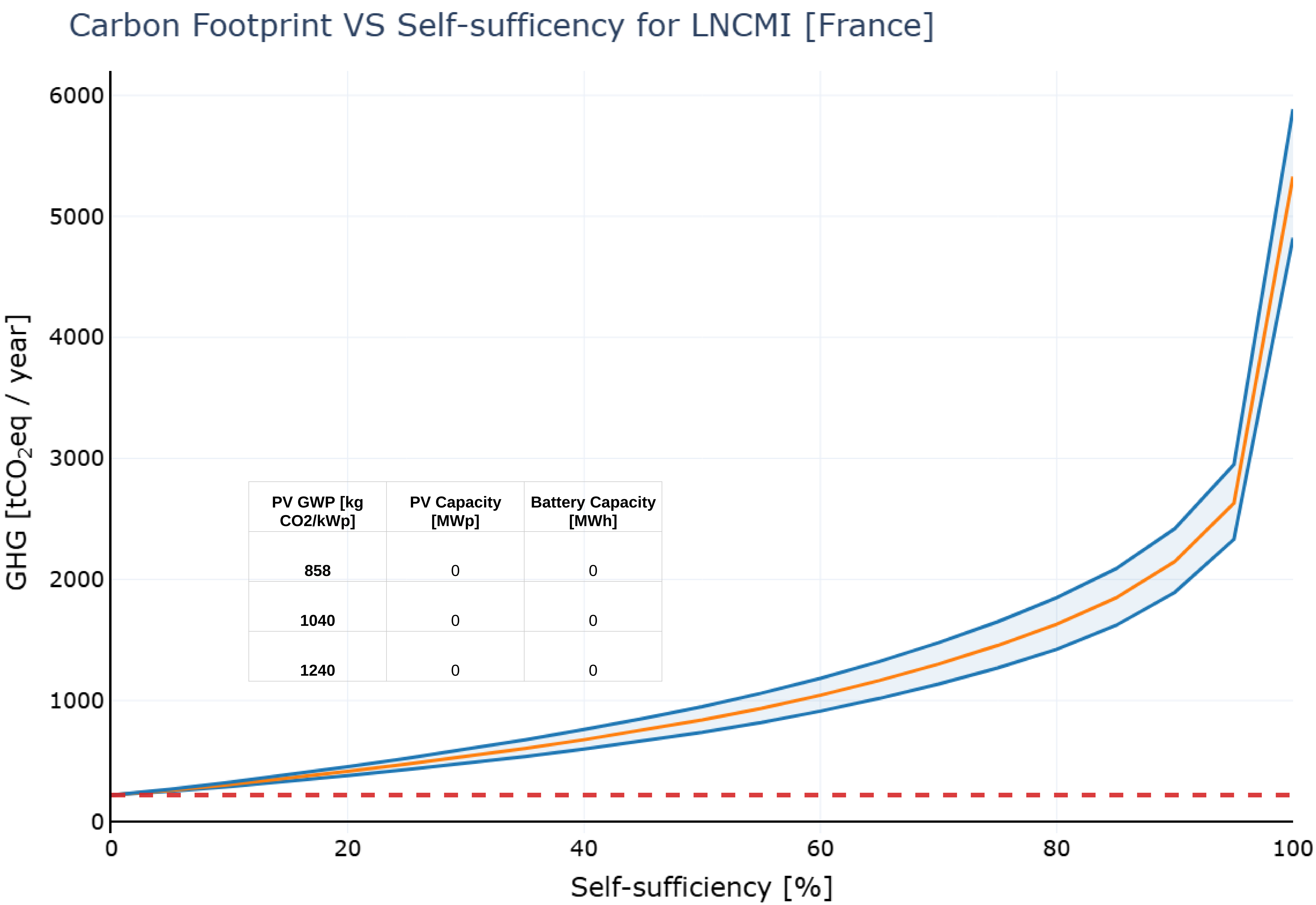
# LNCMI - Data




- **Main Activity**: High Magnetic Field Experiments
- **Annual Energy Consumption** : ~ 10 - 11 GWh
- **Installed PV** : N/A
- **Archetype** : Powering Magnets for experiments

# LNCMI - Results




| PV GWP [kg CO2/kWp] | PV Capacity [MWp] | Battery Capacity [MWh] |
|---|---|---|
| **858** | 0 | 0 |
| **1040** | 0 | 0 |
| **1240** | 0 | 0 |

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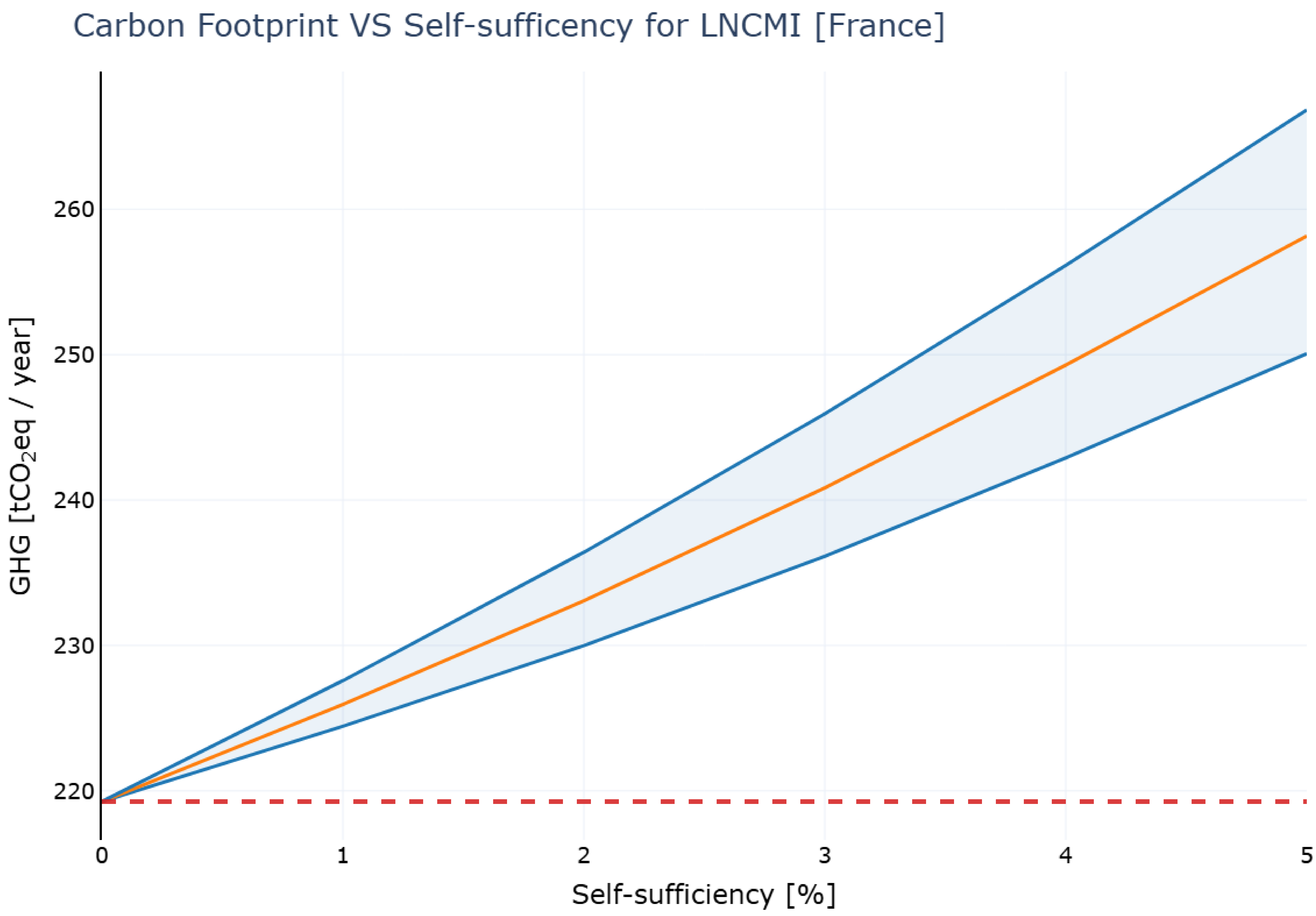
# LNCMI - Results Zoomed



# ESFRI survey

Applicability of self-consumption in RIs, collecting data & feedbacks

*The importance of addressing the **long-term sustainability issue of research infrastructures** was highlighted, which has become a **key agenda** item particularly for **distributed research infrastructures**: as national nodes rely on national-sustainability and pan-European hubs rely on the sustainability of the European agreements (or ERICs).*

Elena Hoffert (ESFRI EB),
Sustainability of the Research Infrastructures Ecosystem

- What is needed:
  - technically : national grid GHG emissions (electricity map), PV production (PV-GIS, PVlib), consumption profiles (local metering OR daily / seasonal consumption)
  - governance: local regulation

- Feedbacks of existing operations ?

# ESFRI survey

Applicability of self-consumption in RIs, collecting data & feedbacks

- Based on RI-SPOND *energy questionnaires* ?
  (completed by FlexRICAN ELIs, ESS, HFML, LNCMI + ESRF, GANIL, IRFM)

| **Name of organization, contact person** |
|---|
| Type of research being conducted |
| Number of sites (separate electricity delivery points) |
| Total annual consumption of energy (MWh) |
| Total annual consumption of energy (€) |
| Peak power requirement (kW) |
| List of all the classes of equipment that consume over 10MWh per year) |
| List all sources of power, including renewables |
| Amount of renewable energy generated (MWh per year) |
| Total amount of renewable power installed (kW) |
| Can the infrastructure operate all year, 24/7? Or does it depend on power availability from the grid? |
| Are the largest loads independent? (can they operate independently from each other, or do they have to work in correlation?) |
| How flexibile is the time operation of the infrastructure? Is it possible to program the operation of the infrastructure around the availability of power from the grid and from the renewable sources (on a scale of 1-10) |
| What is the percentage of energy being consumed by HVAC? |
| Is there an Energy Management System (EMS) in place? |
| What is the percentage of energy being consumed by IT (excluding datacentre HVAC) |
| Is there a significant energy consumption related to AI? (Estimate) |
| Do you control the sourcing of energy of your infrastructure (number and types of utilities, energy tendering processes) or do you depend on a parent institution (e.g. a University Campus)? |
| Annual distibution of Helium through  liquefier  and associated electrical consumption |
| General comments. |

# ESFRI survey (v0)

| | Name of organization, address, country, contact person |
|---|---|
| | Type of research being conducted |
| | Number of sites (separate electricity delivery points) |
| Consumption | Total annual consumption of energy (MWh) |
| | Total annual consumption of energy (€) |
| | Peak power requirement (kW) |
| | List of all the classes of equipment that consume over 10MWh per year) |
| | ***Can you provide your annual energy consumption profile?***<br>***If not, does the infrastructure consume energy:***<br>☐ at a rather constant level ☐ with variations from low to peak consumption<br>☐ mainly during daytime ☐ mainly during night time<br>Less operation in ☐ winter ☐ spring ☐ summer ☐ autumn (scale 1-10)<br>More operation in ☐ winter ☐ spring ☐ summer ☐ autumn (scale 1-10) |
| Production | List all sources of power, including renewables. |
| | Amount of renewable energy generated (MWh per year) |
| | Total amount of renewable power installed (kW) |
| | ***Is the production self-consumed? Shared with other infrastructures?***<br>If not, are there other energy intensive facility in the vicinity of the RI? |
| Flexibility | Can the infrastructure operate all year, 24/7? Or does it depend on power availability from the grid? |
| | Are the largest loads independent? (can they operate independently from each other, or do they have to work in correlation?) |
| | How flexible is the time operation of the infrastructure? Is it possible to program the operation of the infrastructure around the availability of power from the grid and from the renewable sources (on a scale of 1-10) |
| Governance | Do you control the sourcing of energy of your infrastructure (number and types of utilities, energy tendering processes) or do you depend on a parent institution (e.g. a University Campus)? |
| | General comments. |

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https://cloud.univ-grenoble-alpes.fr/s/fjDKce6TYp22bmE

# Open discussion

- Self-consumption in FlexRICAN?
  - Relevance in terms of GHG?
  - Energy communities in your surroundings?

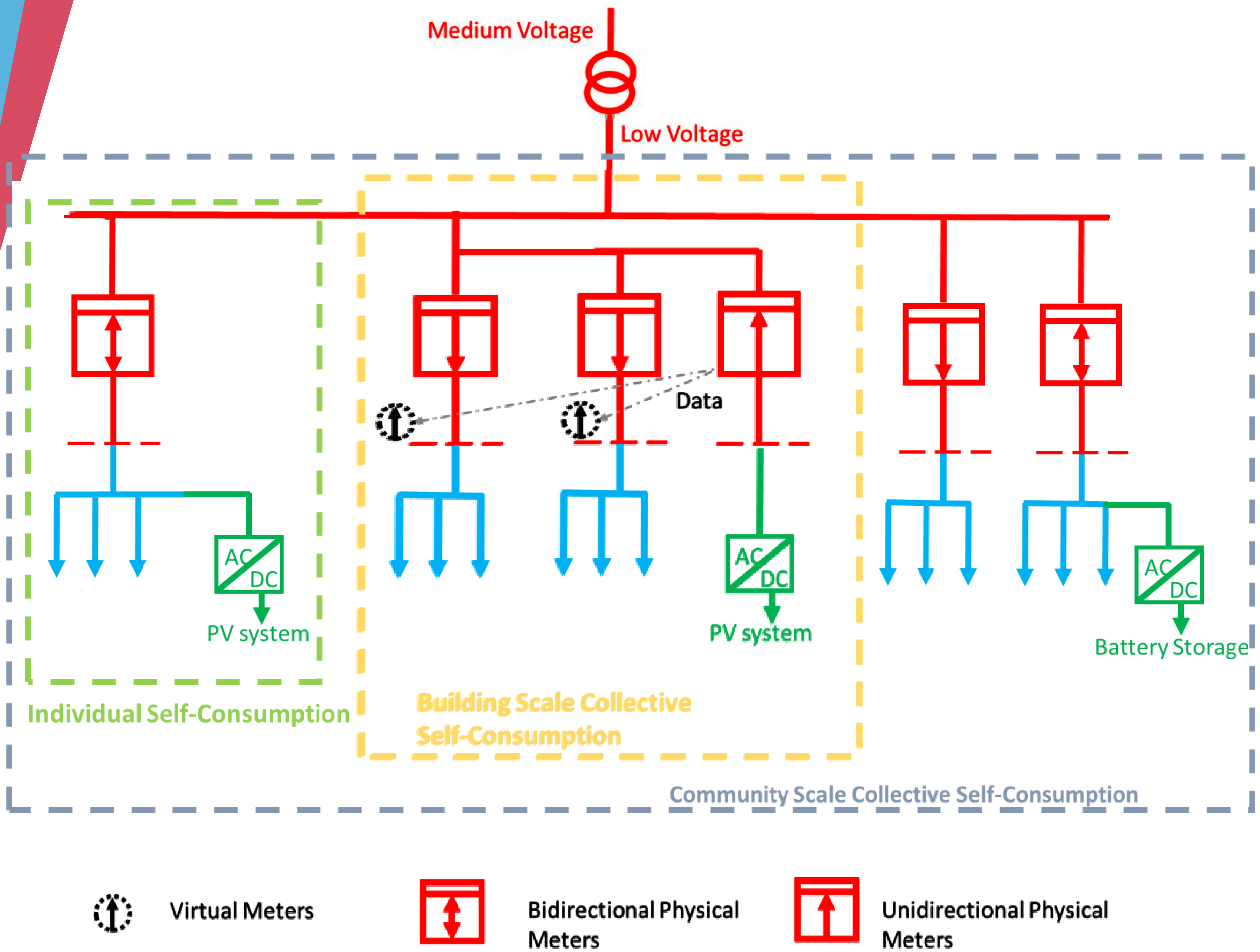
- Adressing self-consumption & sustainability in ESFRI:
  - Communicating,
  - Surveying (existing and potential),
  - Letter to the comittee,
  - Charter?

***UPDATE February 2026**: calculations taking into account the evolution of GHG emissions from the power grids from 2025 to 2050 will be made and shared in a conference article, see Twum-Duah et al. 2026, in the IBPSA (International Building Performance Simulation Association) conference.*

# Other

# What is self-consumption

## Scales for self-consumption




- **Individual Scale:** Most basic form of self consumption where the energy is consumed by an individual (usually the owner).
- **Building Scale Collective Self-Consumption:** This scheme is applicable in buildings with multiple dwellings. The locally produced energy is consumed within the building by different occupants.
- **Community Scale Collective Self-Consumption:** For this scheme the boundary extends to the local community (and is usually defined in legislature). Thus different buildings and consequently load demand profiles are combined to improve self-consumption

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European Commission. Collective self-consumption of Photovoltaic. 691876. European Commission, 2016

# Energy sharing

*Intelligent report 2024, Energy Pool resources*

The Directive 2018/2001 in the promotion of the use of energy from renewable sources (where REC are detailed)
“Member States shall ensure that consumers are entitled to become renewables self-consumers, to generate renewable energy, including for their own consumption, store and sell their excess production of renewable electricity, including through renewables power purchase agreements, electricity suppliers and peer-to-peer trading arrangements, [...].”
*Art 21*

In states:
Austria:

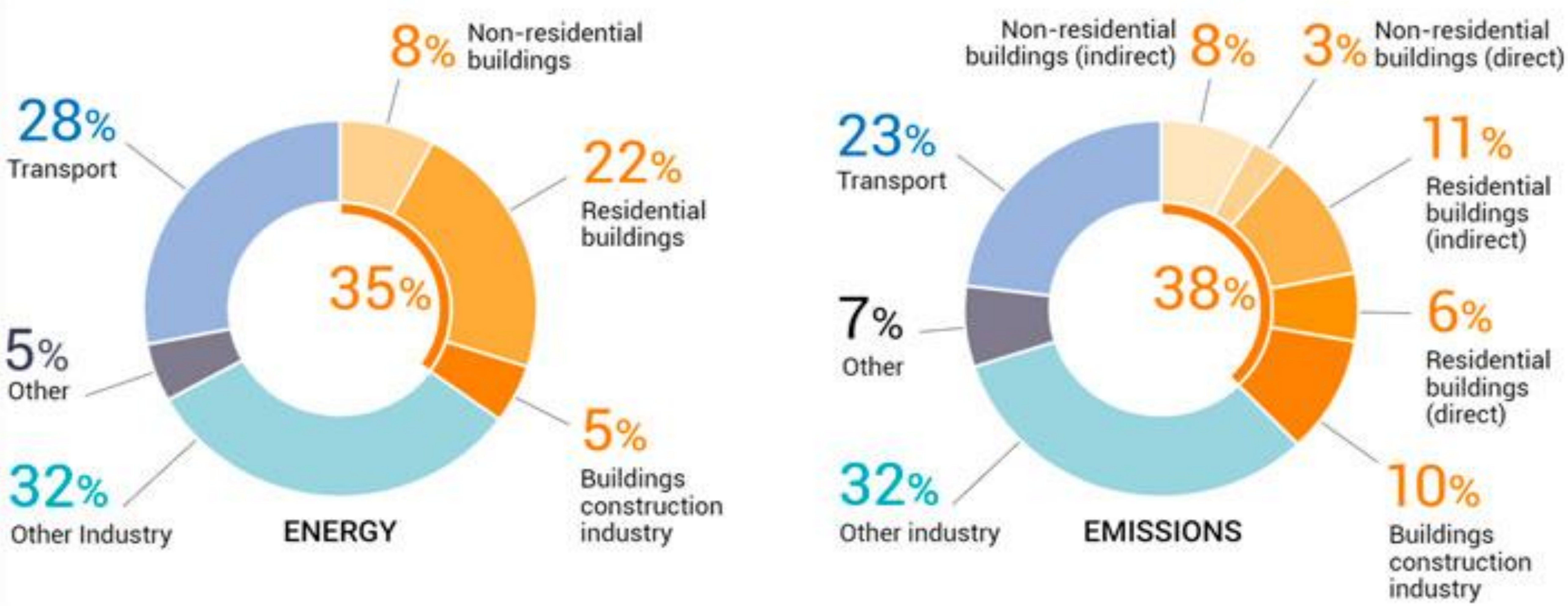
- Local Energy Communities (low-voltage substation) and Regional Energy Communities (medium- high-voltage);
- network tariff reductions 57% reduction for LEC, 28% reduction for RECs;
- facilitated by a digital platform.

France:

- energy sharing within a radius of 2km in urban areas, 20km in rural areas, up to 3 MW

Analysis in Switzerland, Ireland, Portugal, Spain, Italy and Belgium

# Why The Focus on Self-consumption Matters?




**Buildings account for:**

- **30% of global final energy consumption (35% including construction)**
- **28% of global carbon emissions (38% including construction)**

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[2] IEAGlobalABCUN Environmental Programme (2020). Global Status Report for Buildings and Construction: Towards a Zero-Emissions, Efficient and Resilient Buildings and Construction Sector. Tech. Rep. Available at: https://wedocs.unep.org/handle/20.500.11822/34572.