Renewable Energy in Data Centers: the Dilemma of Electrical Grid Dependency and Autonomy Costs

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- ❑ Harnessing Renewable Energy
- ❑ Objectives of the work

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- ❑ System infrastructure
- ❑ Modeling

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- ❑ Summary
- ❑ Future work

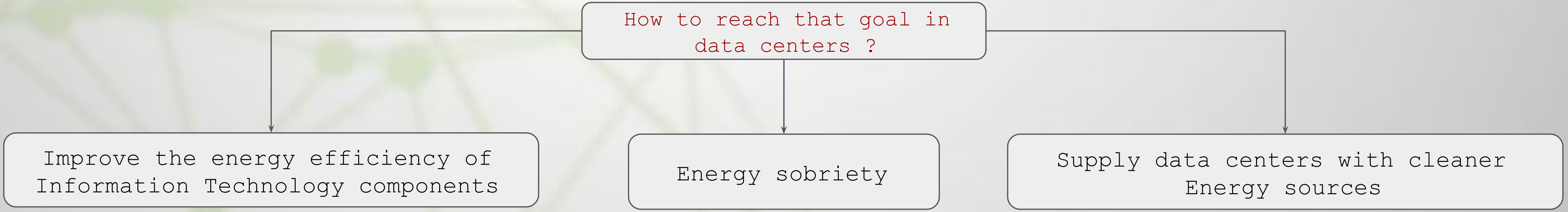
Introduction

- Internet traffic has increased by 30% per year since 2010[1].

- Data centers consumed 200-250TWh of electricity in 2020 (1% of the world electricity consumption)[1]

- Data centers contributed to **0.3%** of the global emission in 2020 [2]

- **European Green Deal** : achieve power usage effectiveness and carbon-free energy by 2025
  \+ make data centers climate-neutral by 2030



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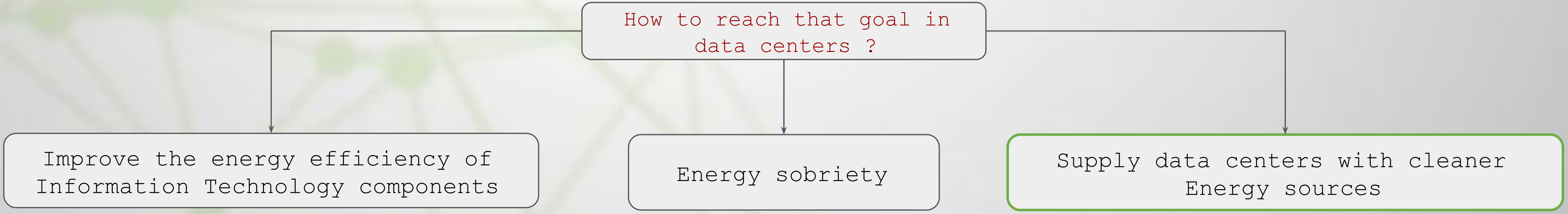

Introduction

Harnessing Renewable Energy

- The capacity of renewable energy production covers 100% of some data centers needs
  Google (12 TWh in 2019) Apple (1.7 TWh in 2020) Facebook (7 TWh in 2020)

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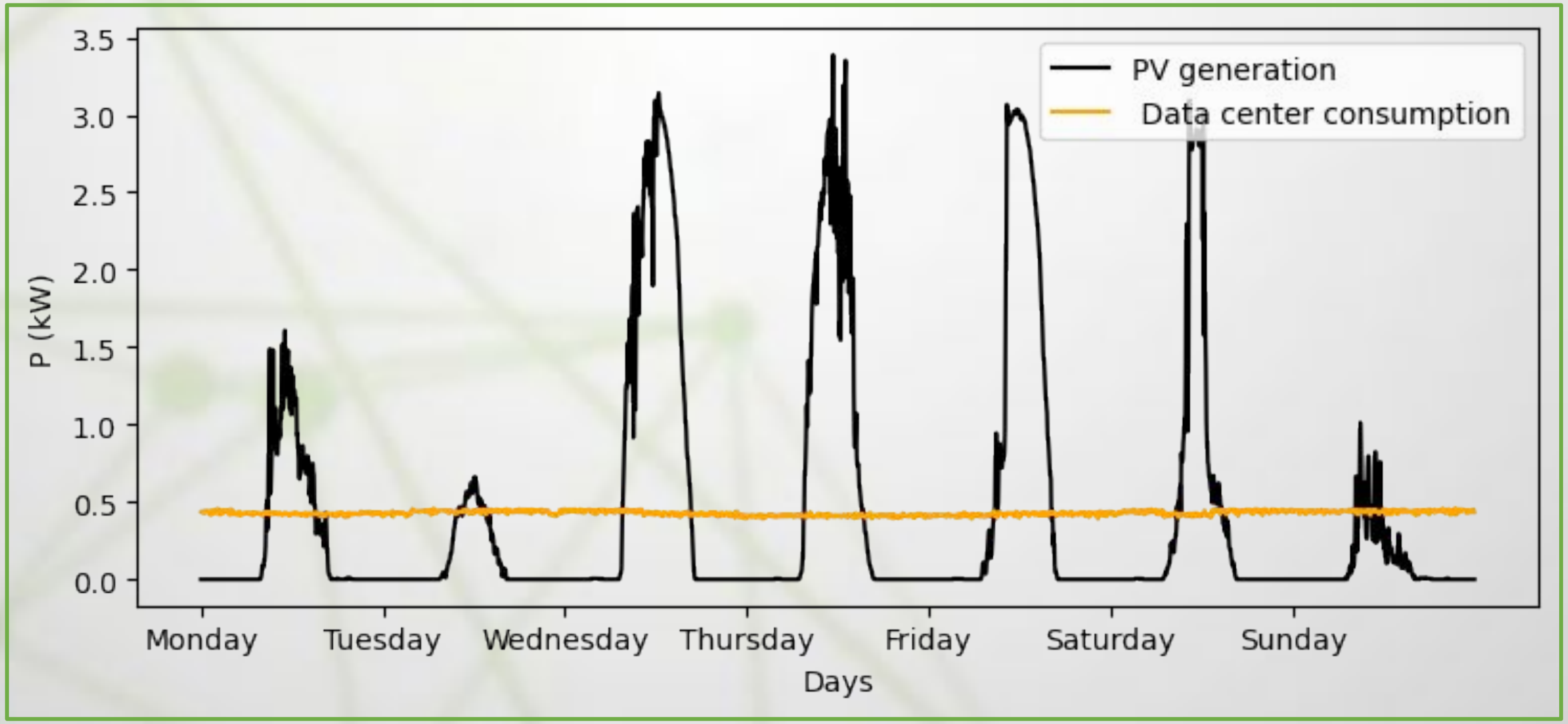
- Renewable energy sources are intermittent and non-fully controllable

- Renewable energy availability is not synchronized with its usage



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Harnessing Renewable Energy

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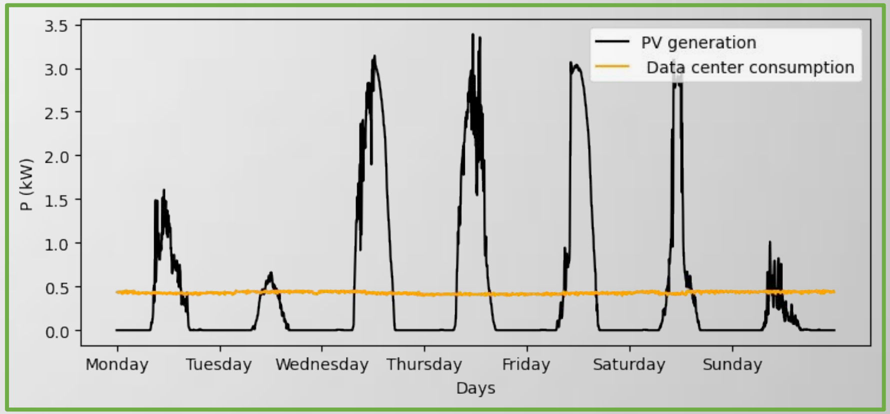
Flexibility means

Schedule bash jobs according to the abundance of green energy

Use a secondary source

- Electrical grid
- Energy storage systems



Introduction

Objectives of the work

In practice, cloud service providers use the grid to transmit and store Renewable Energy

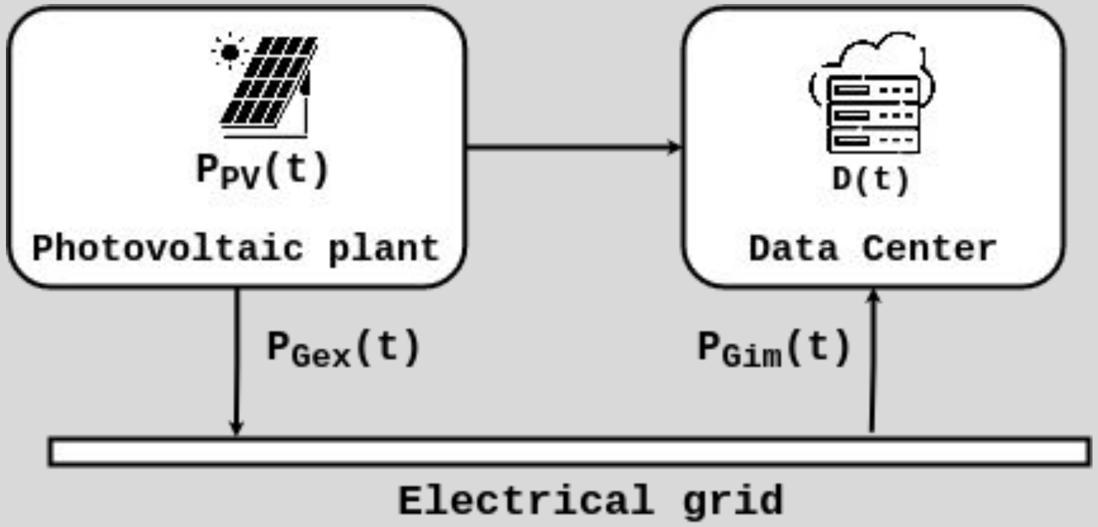
- ❑ What is the on-site and instantaneous renewable energy consumption of the data center?
- ❑ May the energy exchange between the data centers and the grid raise new challenges in the grid?

- ❑ What is 100% autonomy cost for a data center operator ?
- ❑ Which autonomous infrastructures are economically viable in the present or near future ?

Regarding climate-neutral policies, data centers should be exclusively powered by renewables

Methodology

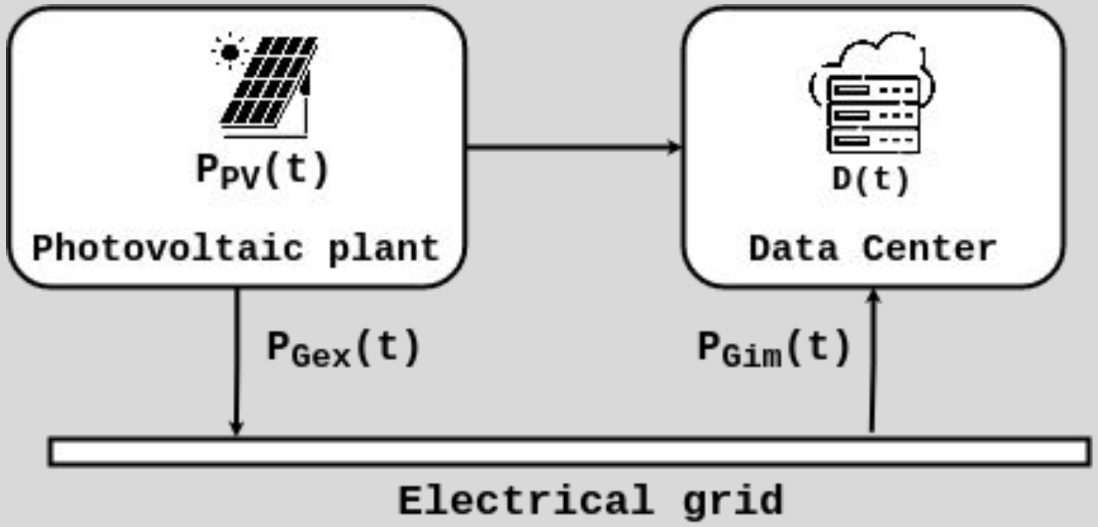
System infrastructure



Grid-dependent infrastructure

Methodology

System infrastructure



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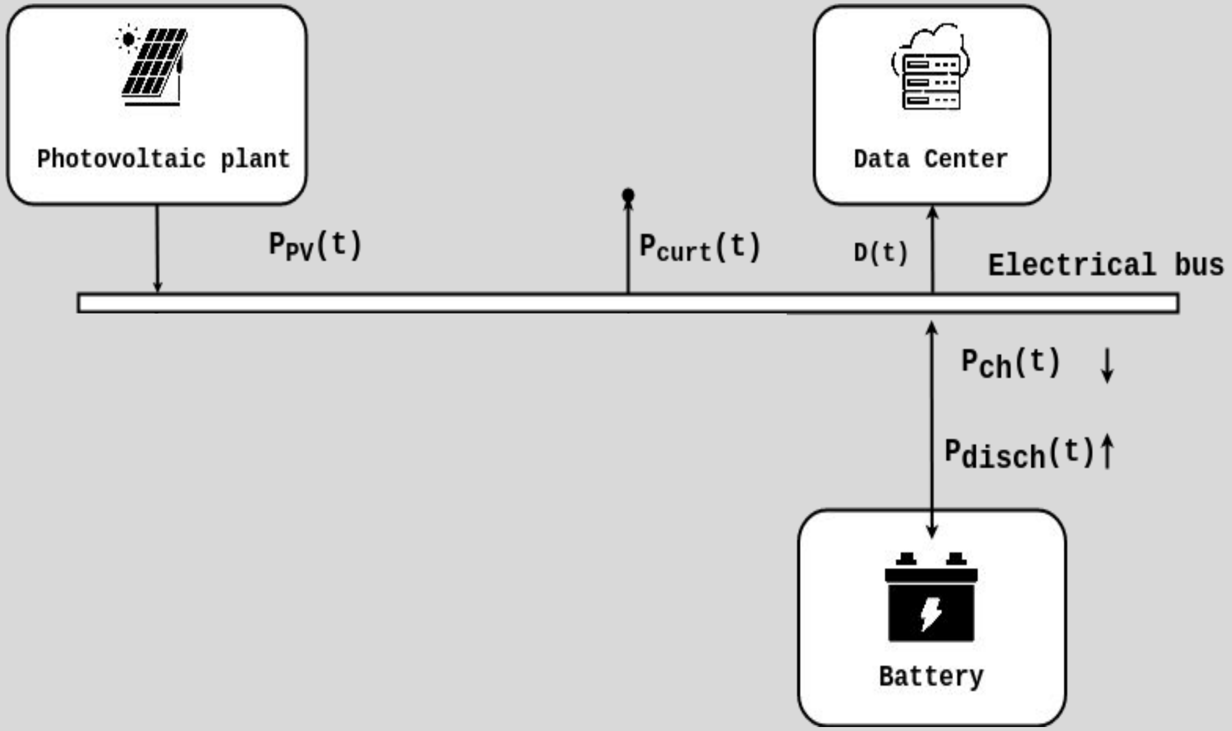
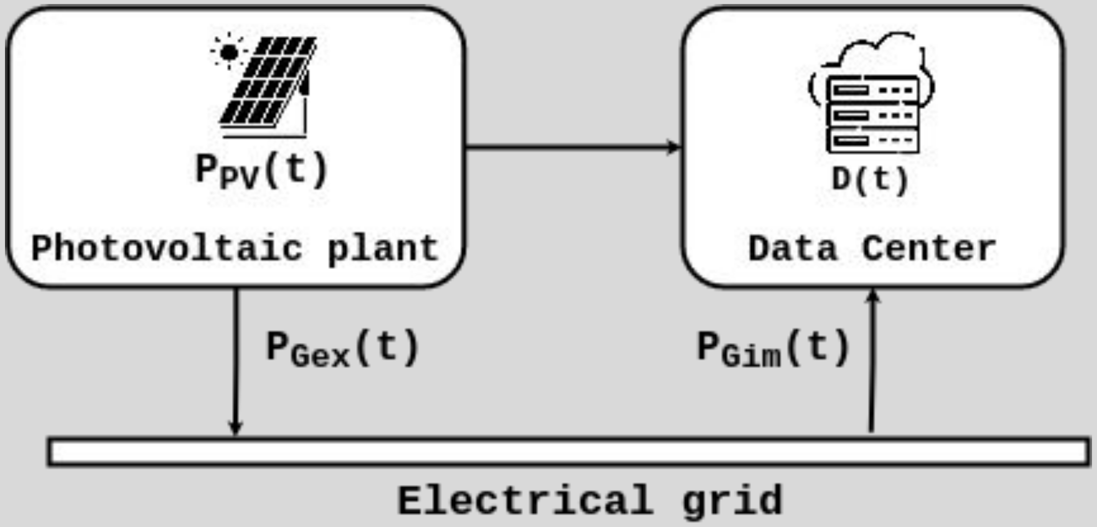


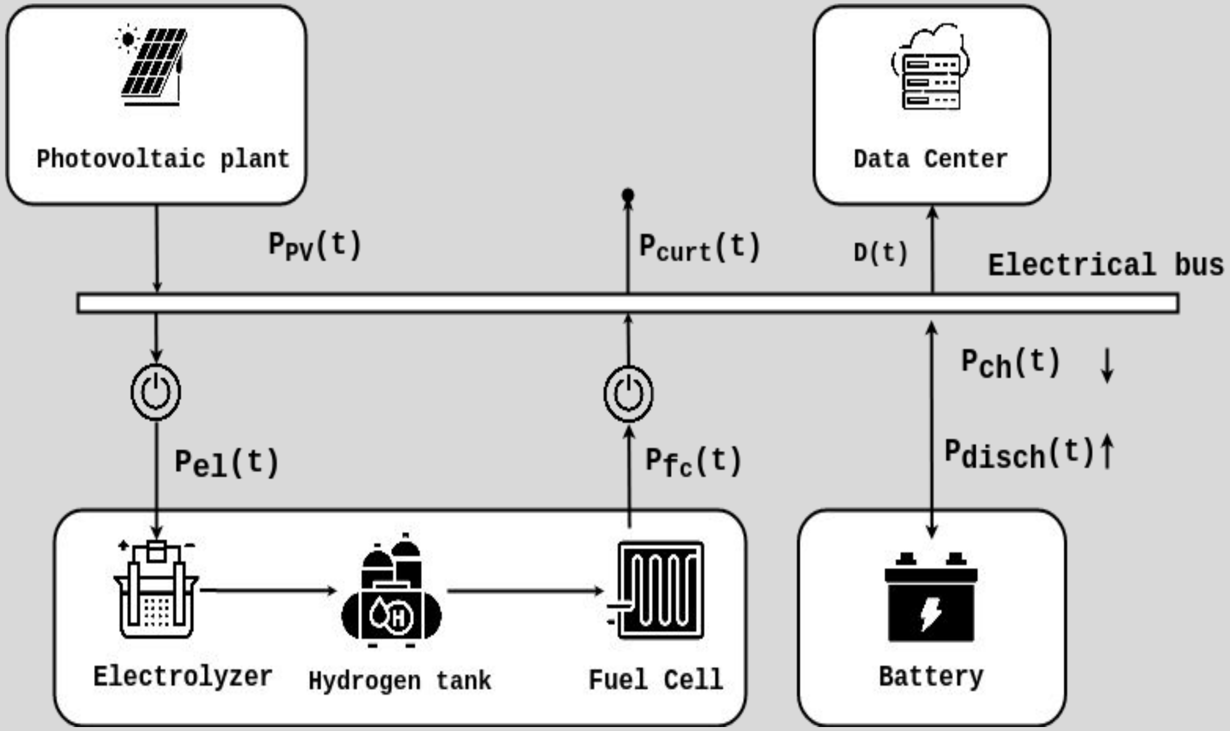
Autonomous infrastructure

Methodology

System infrastructure



<u>Grid-dependent infrastructure</u>



<u>Autonomous infrastructure</u>

Methodology

Modeling

Models used to realise this project

Photovoltaic model

Output : PV production

Cost model : Spread initial investment over calendar lifetime

Parameters :

- Solar irradiance
- Panel's area
- Efficiency of conversion

Methodology

Modeling

Models used to realise this project

Battery model

Output :
- State of charge (SOC)
- State of health (SOH)

Cost model :
- Spread initial investment over operating lifetime (SOH)

Parameters :
- Power of charge/discharge
- Efficiency of charge/discharge
- Capacity of the battery

Photovoltaic model

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Battery model

Photovoltaic model

Output : PV production
Cost model : Spread initial investment over calendar lifetime
Parameters :
- Solar irradiance
- Panel's area
- Efficiency of conversion

Hydrogen storage system's model

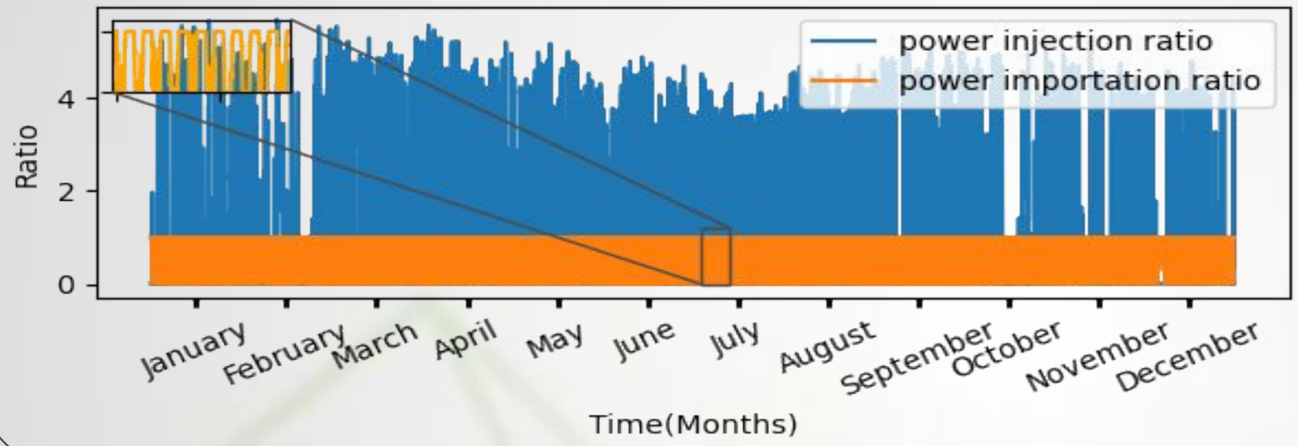
Output :
- Level of hydrogen (LOH)
- State of health(SOH)

Cost model :
- Spread initial investment of fuel cell and electrolyser over operating lifetime (SOH)
- Spread tank initial investment over calendar lifetime

Parameters:
- Power of fuel cell / electrolyser
- Efficiency of fuel cell / electrolyser
- Hydrogen density + Capacity of the tank

Results

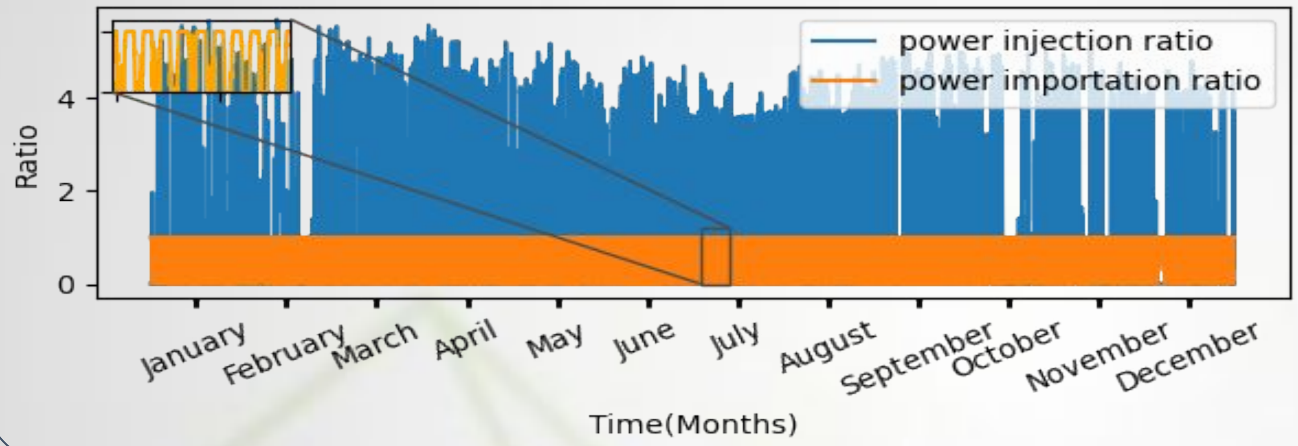
Grid-dependent case study



- Only 35.9% of energy is directly consumed from the power plant
- The data center is frequently powered at 100% from the grid
- The data center injects 310% of its nominal power

Results

Grid-dependent case study



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Autonomous infrastructure using only a battery

- Unit operation cost estimated to 1.114$/kWh
- Compared to the European electricity tariffs in S2 2021[3]
  - **5.7 times the average cost**
  - **3.2 times the highest cost(recorded in Denmark)**
  - **5.35 times the French tariff**

Infrastructure not economically viable

Results

Autonomous infrastructure using a battery and a Hydrogen storage system

- Unit operation cost is estimated to 0.450$/kWh
  - ➪ 248% cheaper than using only a BESS
- Compared to the European electricity tariffs in S2 2021[3]
  - ➪ **More competitive with the Danish tariff (0.3203 $/kWh)**
  - ➪ **Less competitive than the average (0.1954 $/kWh) and the French (0.2082 $/kWh) electricity tariff**

Conclusions

Summary

- The grid-dependant infrastructure relies strongly on the grid and injects important amounts of power into it

- 100% electrical autonomy may be reachable in the future when combining a battery and hydrogen system.

Future work

- Consider flexible jobs

- Combine the grid with on-site energy storage system while maintaining a good threshold of autonomy

REFERENCES

[1] EA. (2021) Data Centres and Data Transmission Networks.

[2] Ezra, “Renewable Energy Alone Can’t Address Data Centers’ Adverse Environmental Impact,” Forbes, https://www.forbes.com/sites/forbestechcouncil/2021/05/03/renewable-energy-alone-cant-address-data-centers-adverse-environmental-impact/, May 2021

[3] Eurostat, “Electricity price statistics” https://ec.europa.eu/eurostat/databrowser/view/NRGPC205custom3477477/default/table?lang=en, 2021

Thank you for your attention

Any question ?

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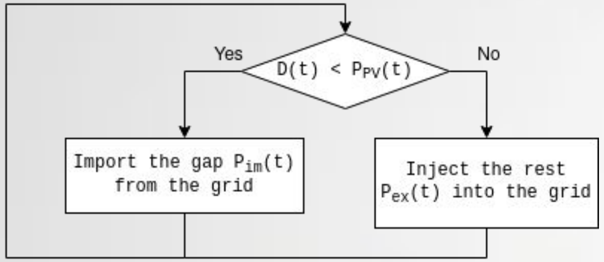
Methodology

Energy management and system sizing

Grid-dependent infrastructure

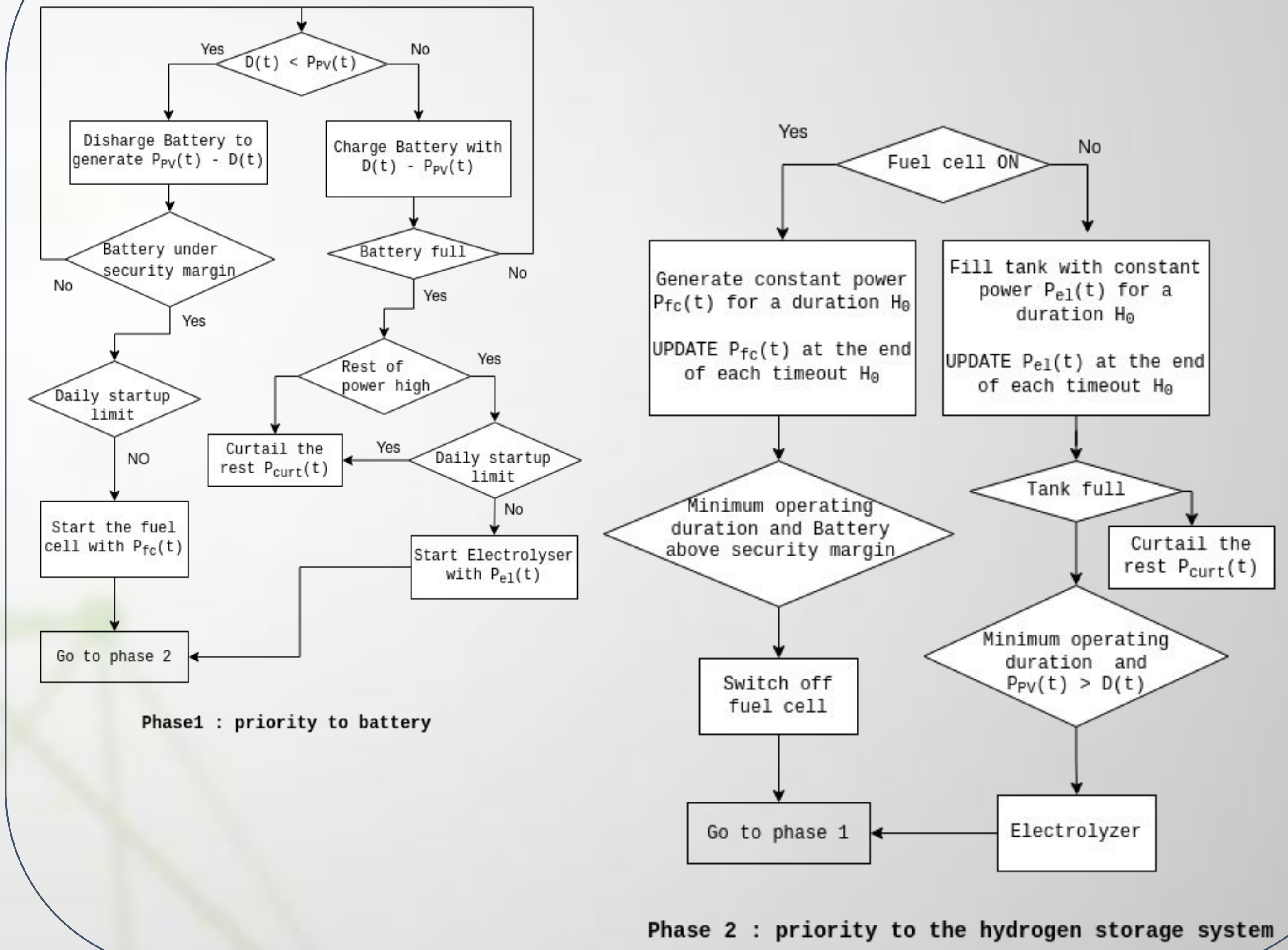


Autonomous infrastructure using only a battery

Input: N_{PV}, $C_{Bat}(0)$, P_{max}, $SOC(0)$
OFFGRID-BESS-ONLY-ENERGY-MANAGEMENT(N_{PV}, $C_{Bat}(0)$, P_{max}, $SOC(0)$)
for $t \in [0, End\ of\ year]$ **do**
  Run workload and get $D(t)$; Get $P_{PV}(t)$ from trace
  if $P_{PV}(t) > D(t)$ **then**
    Charge battery with $P_{PV}(t) - D(t)$
    if *Battery full* **then**
      Curtail the rest of power P_{curt}
    end
  end
  if $P_{PV}(t) < D(t)$ **then**
    Discharge the battery to generate $P_{PV}(t) - D(t)$);
    if *Battery law* **then**
      The rest of power demanded cannot be delivered since the battery is low
    end
  end
end
End Function

Algorithm 3: Power management when using PV and only a battery

Autonomous infrastructure using a battery and a Hydrogen storage system



Methodology

Energy management strategy

Grid-dependent infrastructure

- **Excess of solar generation :** Inject the excess into the grid
- **Deficit in solar generation :** Import the miss from the grid

Autonomous infrastructure using only a battery

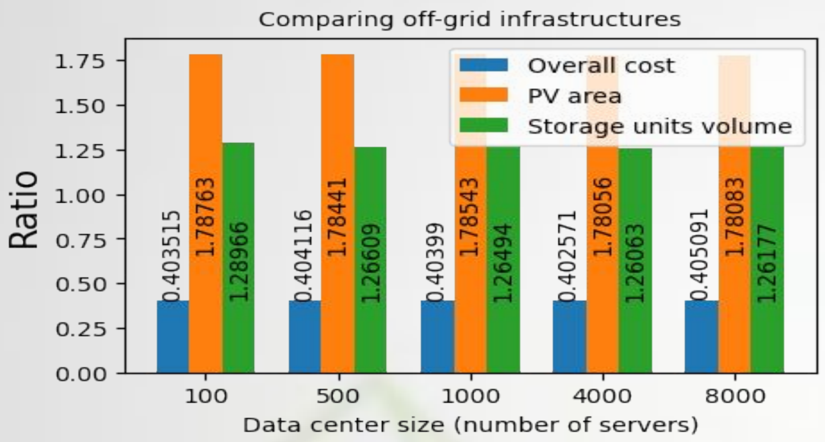
- **Excess of solar generation :** Charge the battery
- **Battery full :** Curtail the rest
- **Deficit in solar generation :** Use the battery

Autonomous infrastructure using a battery and a Hydrogen storage system

- First **prioritize the battery** to balance the excesses and deficits of solar generation
- **Battery almost drained/full :** Prioritize the Hydrogen system and use the battery to meet energy balance.

Results

Autonomous infrastructure using a battery and a hydrogen storage system case study



Projections:

- ❑ Hydrogen equipment cost will decrease in the future
- ❑ Hydrogen system efficiency keeps increasing
  - ➪ Reduce sizes and costs

Main findings :

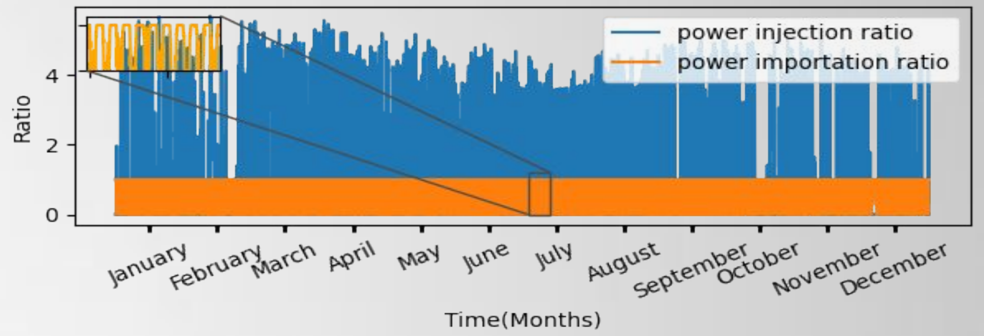
- ❖ Unit operation cost is estimated to 0.450$/kWh
  - ➪ 248% cheaper than using only a BESS
- ❖ 63% of battery degradation in 10 years.
- ❖ Compared to the European electricity tariffs(for consumers of more than 500MWh/year)[3]
  - ➪ **More competitive with the Danish tariff (0.3203 $/kWh)**
  - ➪ **Still less competitive than the average and the French electricity tariff**

Results

Grid-dependent case study

Table II: Grid-dependent infrastructure results with Google trace

# Servers	A_{total}	Injection rate (%)	Self-consumption rate (%)	Peak exportation (kW)	Peak importation (kW)	Peak injection ratio
10	40.4	63.1	37.7	4.3	0.8	2.96
50	211.3	64.1	35.9	22.5	4	3.1
100	422.5	64.1	35.9	45	7.9	3.1
500	2,112.6	64.1	35.9	225	39.6	3.1
1,000	4,224	64.1	35.9	449.9	79.1	3.1
4,000	16,894.6	64.1	35.9	1,799.3	316.5	3.1
8,000	33,787.9	64.1	35.9	3,598.3	633.1	3.1



Main findings :

- ❖ Only 35.9% of energy is directly consumed from the power plant
- ❖ The data centers inject 310% of their nominal energy consumption
- ❖ The data centers are frequently powered at 100% from the grid

- ❖ **Tableau a virer**
- ❖ **Agrandir la figurer.**
- ❖ **Drawback en backup**

Drawbacks of injecting high pics of renewable energy into the grid

- ❑ Not synchronized with users consumption in the grid
- ❑ Grid operator needs to invest in re-dispatching
  - ➪ Re-dispatching costs
- ❑ Grid operator needs to invest in storage devices
  - ➪ Grid operator takes the responsibilities shifted by Cloud operator