Challenges and solutions related to DC microgrid

Is the Current War revived?

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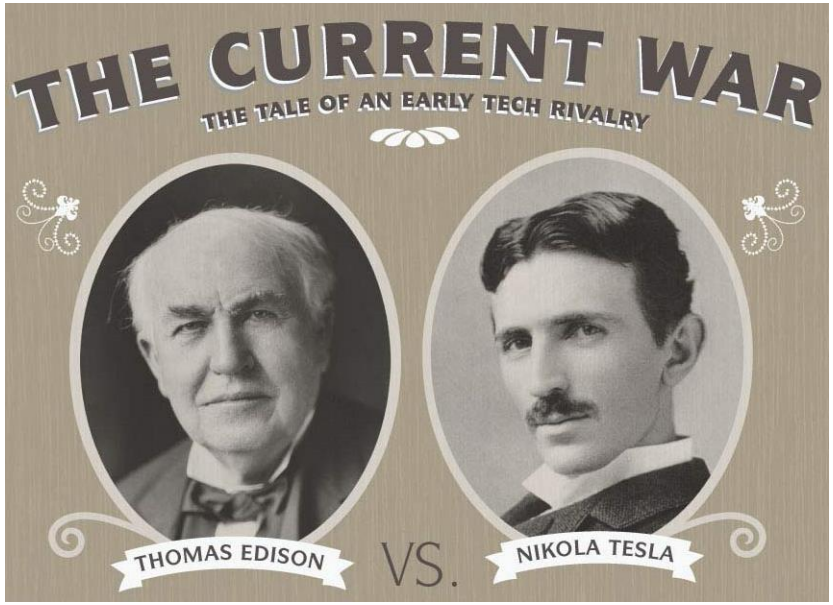
March 23, 2021

The Current War



- **Early electricity distribution in XIXth century**
- **End of XIXth, opposition between Direct Current (DC) promoted by Thomas Edison and Alternating Current (AC) promoted by Nikola Tesla and George Westinghouse**
- **Duel won by AC**
  - Niagara falls hydroelectric power plant at Chicago 1893 World Exhibition
  - High voltages achievable via transformers → smaller line losses
- **Some Edison's DC networks survived until the early XXIth century.**
  - 4600 DC US customers in 1998
  - Lifts directly supplied by a DC network until 2007 in Manhattan

CE+T group offers electrical conversion solutions

for security of supply of critical applications

for energy management

200+ employees

40-M€ turnover

5 R&D and production sites
Belgique (Wandre), Luxembourg, Chine, Inde and USA

Founded en 2017

5-people team
(full time)

CE+T Power spin-out, close collaboration

Is the Current War revived?

Focusing on « private » distribution infrastructure,
not public distribution or transport systems in particular

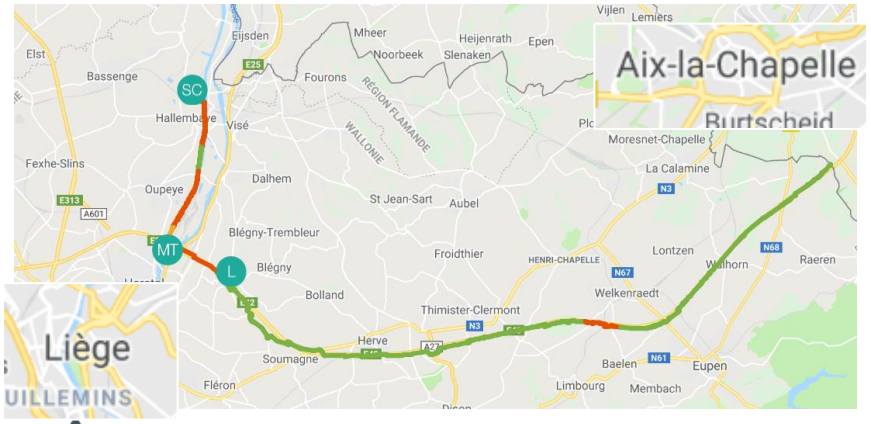
- **What are the pros and cons for DC distribution?**
- **What are the specifics of DC distribution infrastructure?**
- **What are the new applications of DC distribution?**

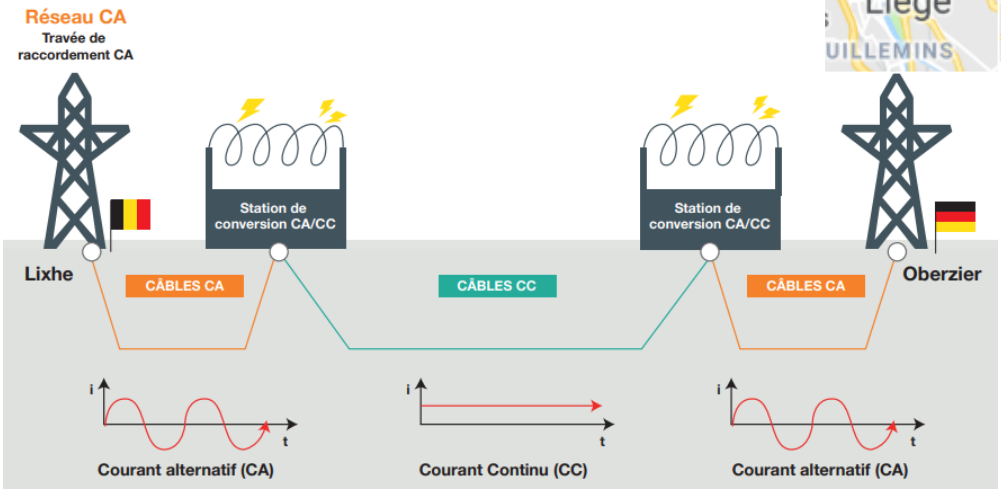
Part 1

Pros and cons

The drivers for DC back to business (1/2)

- **Significant progress of equipment used for DC distribution, power electronics in particular**
- **More and more high-voltage DC circuits appear**
- **Example: the ALEGrO project**
  - Underground HVDC link between Belgium and Germany
  - 320kV, 1GW
  - Commissioned on Nov 9, for 2020

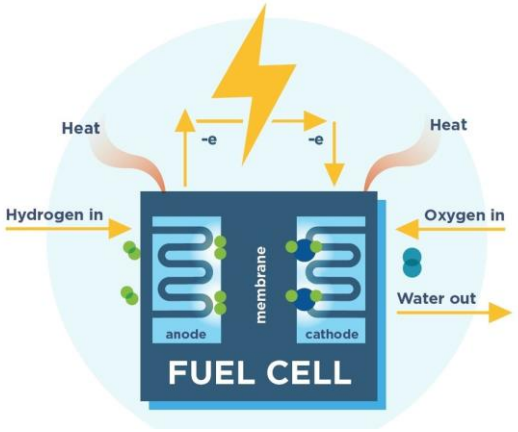




https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/alegro

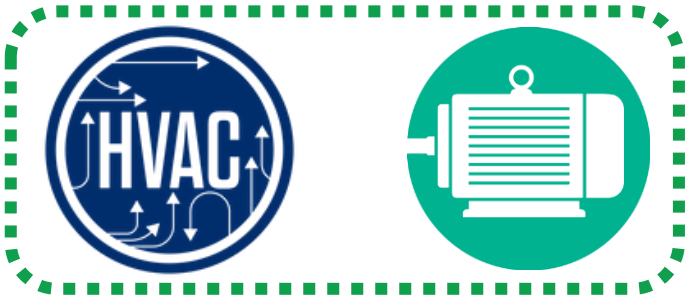
The drivers for DC back to business (2/2)

- **DC energy sources**



- **DC-supplied equipement**

Typical consumption of a commercial building



22% ***34%*** ***11%***

AC loads: 31%

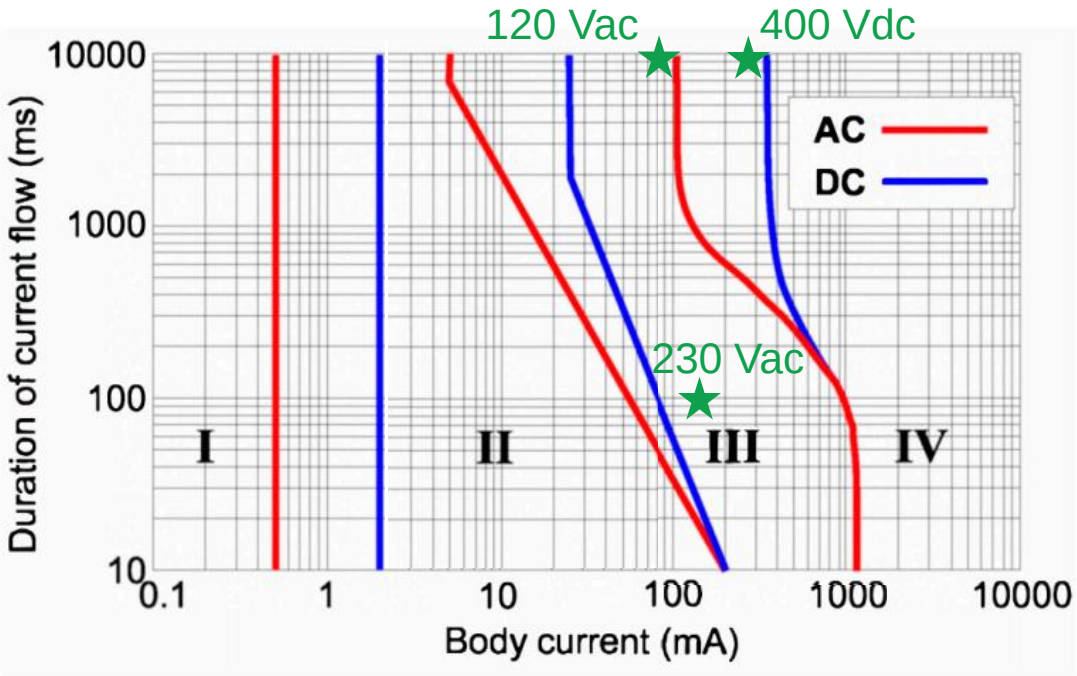
About electrical hazard…

- **Generally speaking, at equal value, AC is more hazardous than DC**
- **AC frequency can yield**
  - Muscle tetanization
  - Heart fibrillation
- **Voltage ranges**

Domaines de tensions		Tensions nominales	
		Alternatif	Continu
Très basse tension	TBT	$U \leq 50$ V	$U \leq 120$ V
Basse tension (BT)	BTA	$50 \text{ V} < U \leq 500$ V	$120 \text{ V} < U \leq 750$ V
	BTB	$500 \text{ V} < U \leq 1000$ V	$750 \text{ V} < U \leq 1500$ V
Haute tension (HT)	HTA	$1000 \text{ V} < U \leq 50000$ V	$1500 \text{ V} < U \leq 75000$ V
	HTB	$U > 50000$ V	$U > 75000$ V

- **But need for arc interruption in DC!**

Human body effects of current depend on its nature, its value and the exposure duration



I. No effect

II. Small pain but no dangerous effect

III. Muscular contraction and respiratory distress, reversible effects

IV. Ventricular fibrillation, critical effects

Hence, as human body resistance amount at ~1500 Ω,
no critical effects (zone III) for

- **US 120-Vac low-voltage grid (80 mA)**
- **European 230-Vac low-voltage grid (153 mA)**
  thanks to differential protections limiting exposure duration
- **A 400-Vdc network (266 mA)**

Part 2

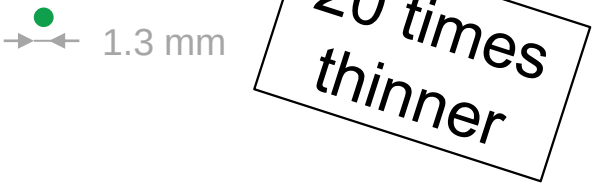
Infrastructure

The right wire…

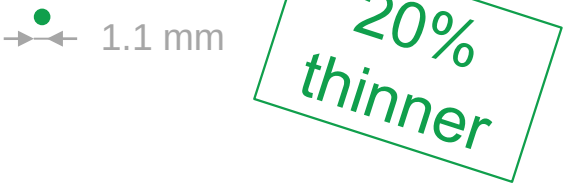
to supply a 1.2-kVA air conditioner

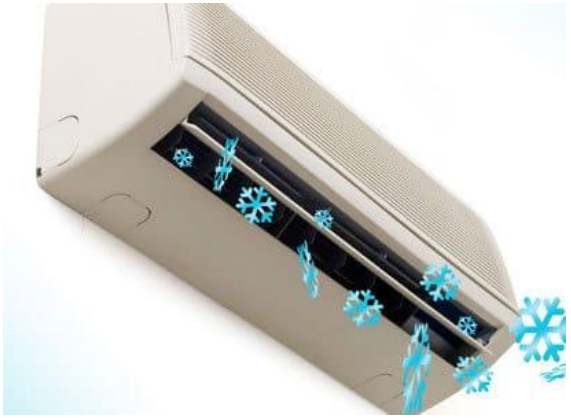
- **from a car battery (12 V) ?**

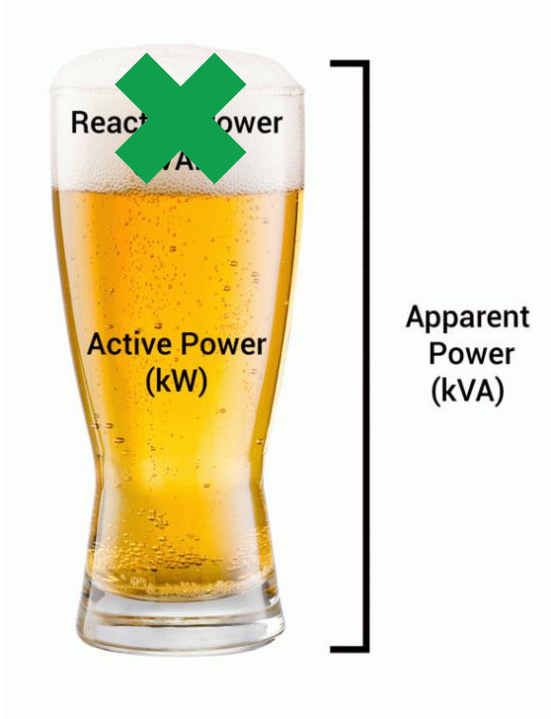
- **from a low-voltage AC grid (230 V) ?**



- **From a low-voltage DC grid (230 V) ?**







4 main examples of infrastructure choices

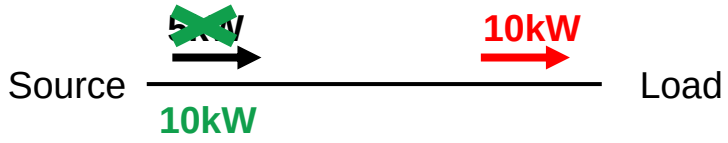
- **Working voltages are much varied than with AC**
- **The number of conductors and the earthing system condition personal safety characteristics**
- **Protections and connectors must be able to break current**
- **Converters are used to stabilize the distribution circuit**

but standards and regulations lack or remain conservative!

The resilience of electrical distribution systems require appropriate control strategies

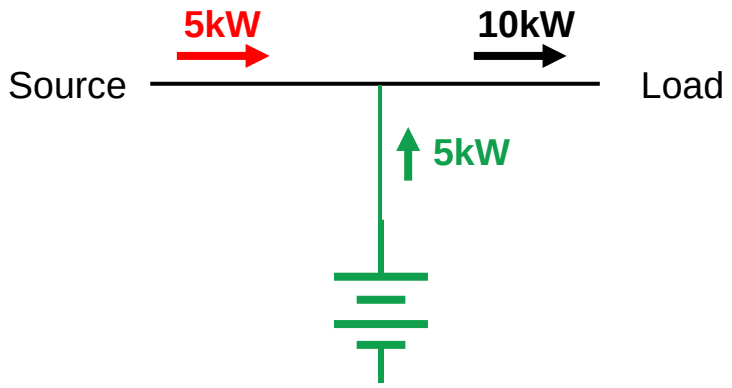
AC public systems

- Objective: ensure equilibrium between controllable centralized production and uncontrollable consumption
- Solution: monitor frequency and adapt production



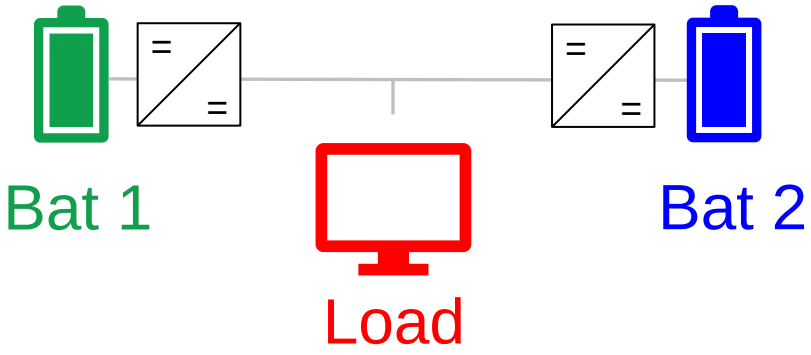
DC local systems and microgrids

- Objective: ensure equilibrium between uncontrollable distributed production and partially controllable consumption
- Solution: monitor voltage and transfer power from/to batteries

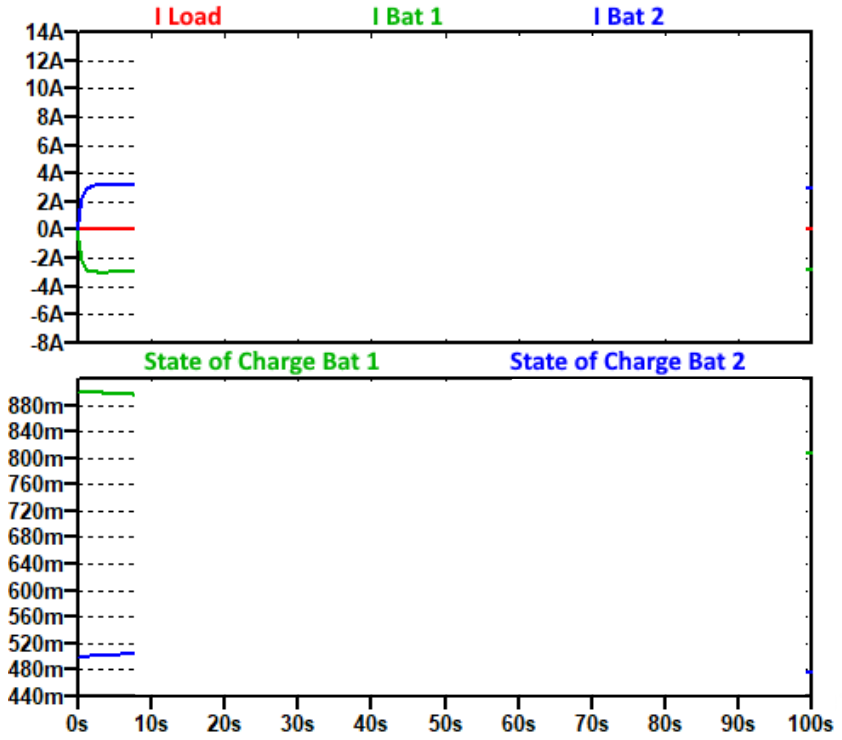


A passive, decentralized control of the distribution circuit mutualizes energy stocks

e.g., with 1 load and 2 batteries



→ Load supply and state-of-charge balancing between the 2 batteries



Part 3

New applications

5 examples of new « private » infrastructure applications of DC distribution to

- **Mutualize energy sources reducing grid dependency in datacenters**
- **Supply distributed equipment of transportation infrastructure based on a limited number of public AC utility connections**
- **Minimize voltage drops in a distributed equipment supply system for telecommunication infrastructure**
- **Combine LED lighting supply and building management infrastructure**
- **Avoid successive conversions between DC sources and loads in a building**

New telecommunication infrastructure rely on more and more distributed equipment

Technological evolution

- **Higher frequency**
- **Shorter wavelength**

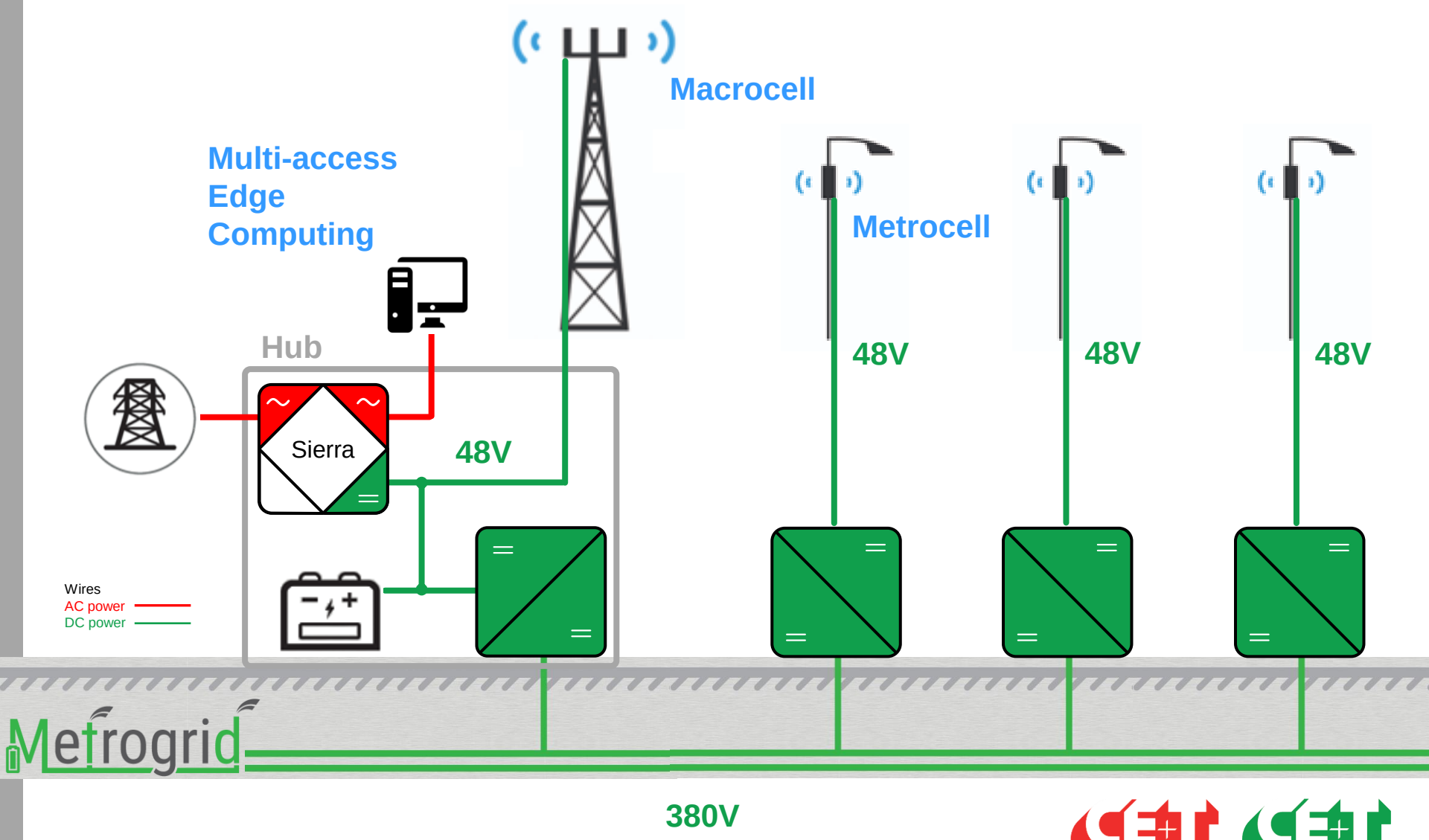
	4G	5G
Frequency	6 GHz	30 to 300 GHz
Wavelength	Tens of cm	1 to 10 mm

Consequences

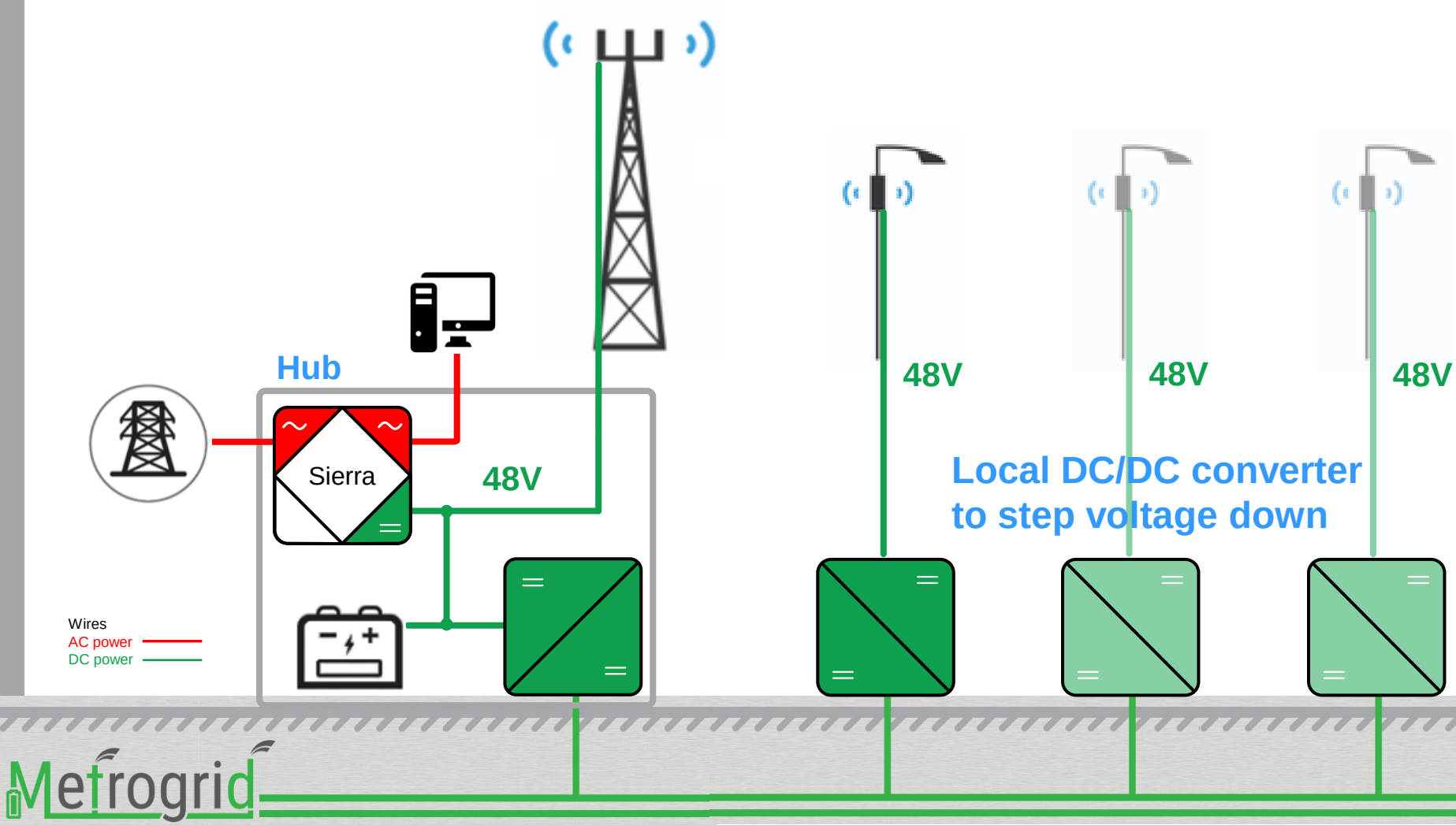
- **Shorter range → need for more antennas for same coverage**

- **Waves fading through walls → need for both inside and outside antennas**

A 5G infrastructure may involve 3 entities requiring power

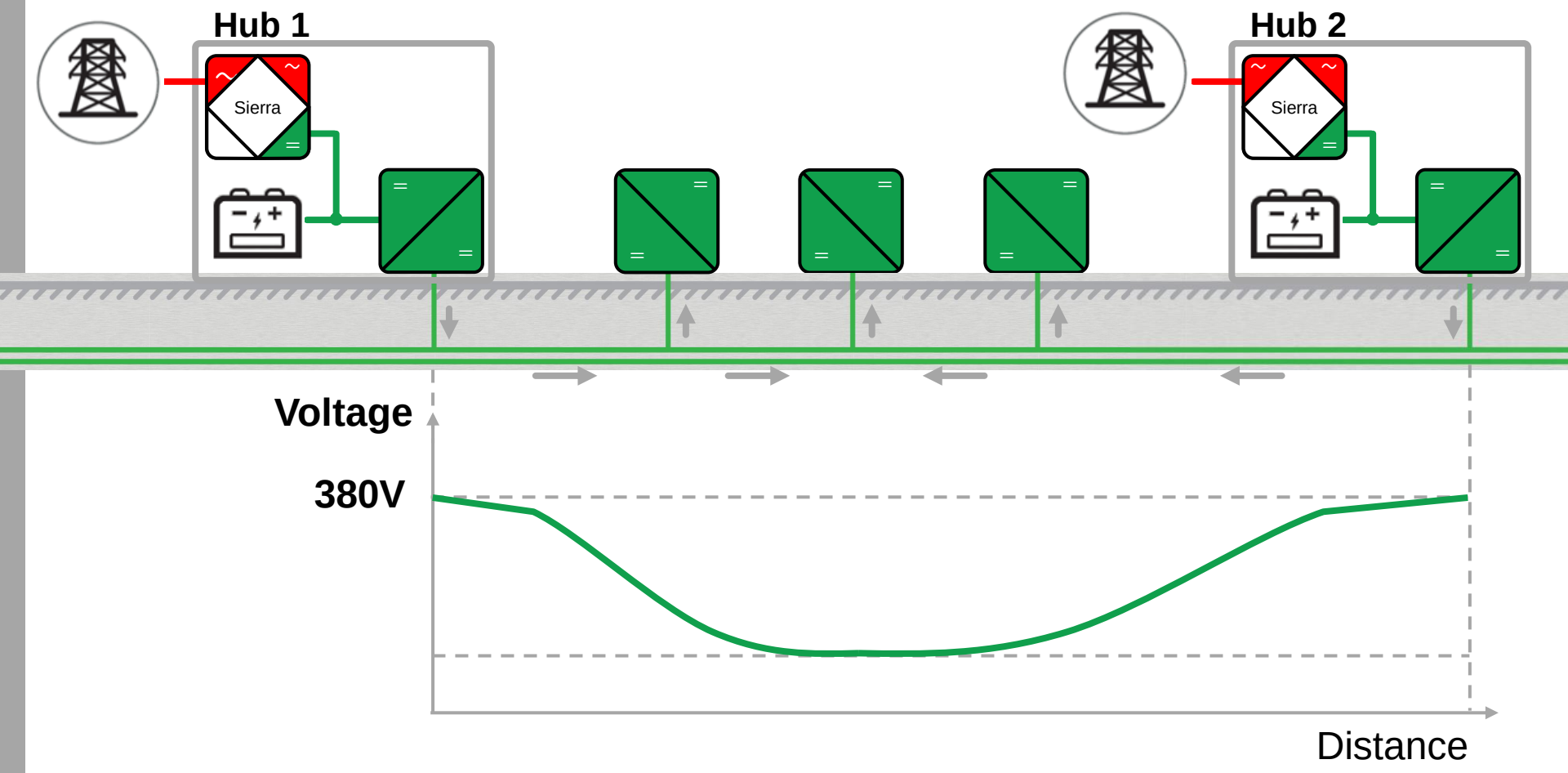


A local 5G infrastructure can be efficiently powered by means of 3 entities



380-Vdc bus embedded into a hybrid cable

Voltage drops can be limited by multiplying the DC bus supply locations



Conclusion

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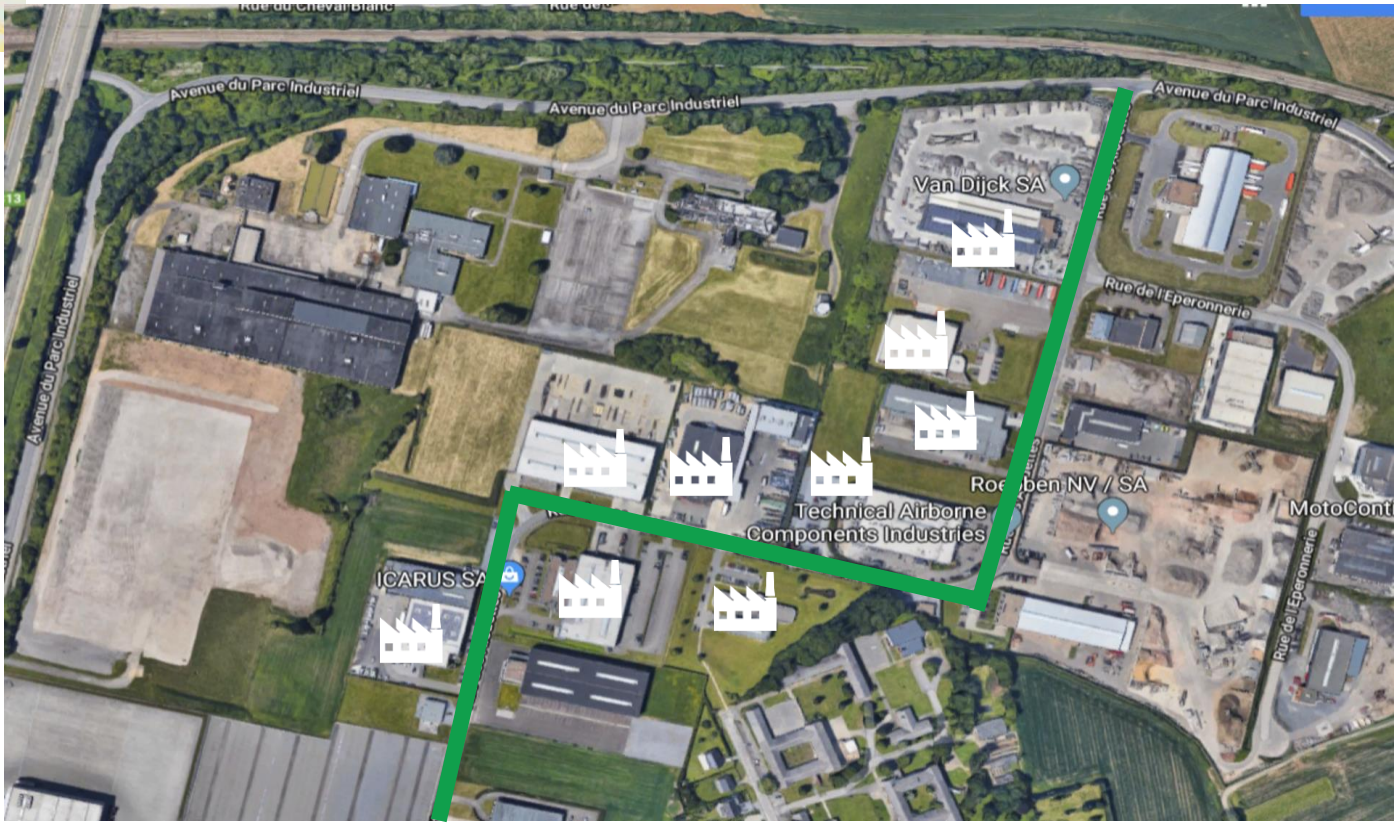
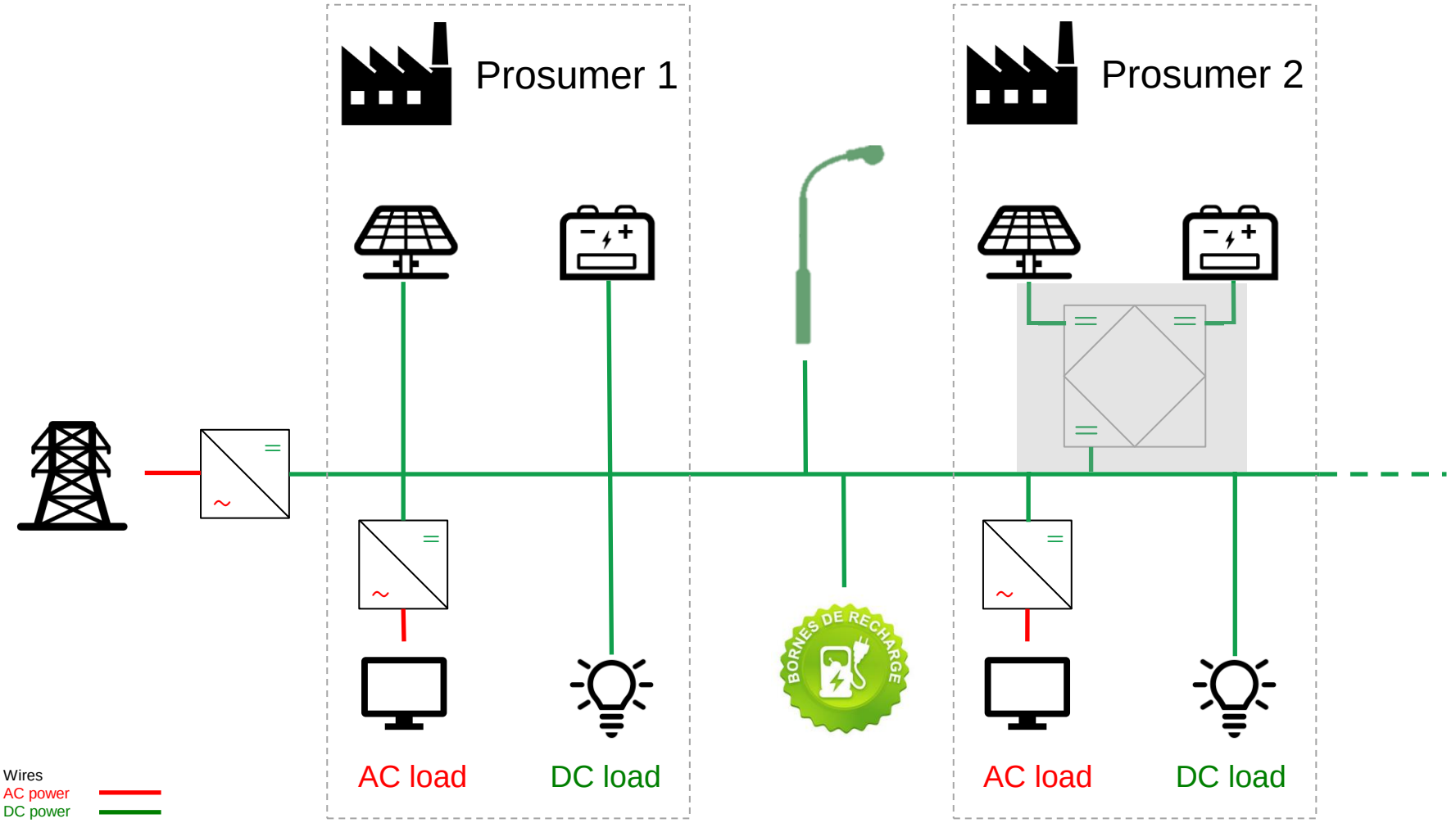
- **The breakthrough of Distributed Energy Resources (DER) paves the way for the creation of distributed microgrids at residential, commercial building or even district scales**
- **A DC microgrid provides several advantages**
  - Higher efficiency
  - Simplified integration of DC sources and loads
  - No reactive power, nor frequency to synchronize with
- **DC equipment must be selected carefully to ensure arc interruption and personal safety**
- **Standards under definition will enable to streamline DC systems and generalize them**
  For instance, not yet covered
  by Belgian General Regulation on Electrical Installations

CE+T contributes to the Walloon MIRaCCLE project aiming at deploying a pilot DC microgrid close to Liège



https://klinkenberg.be/miraccle/

MIRaCCLE will enable to define the typical characteristics of an industrial DC microgrid



War revived or not, we have what's needed for peace!

Looking forward to learning about your energy and grid challenges!

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