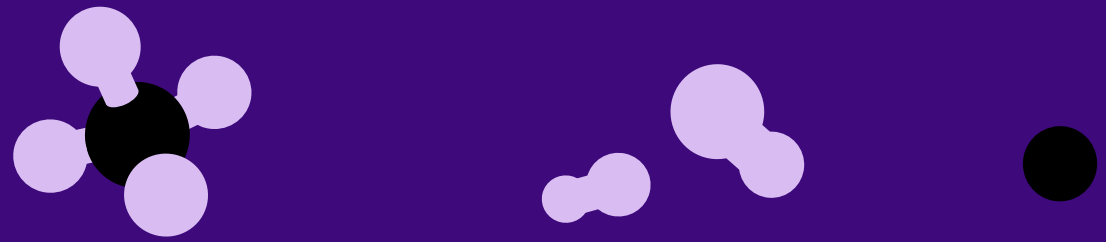
deCarbonized Hydrogen

Exec Summary

Spark is pioneering a new way to produce de**Carbon**ized **hydrogen**: **methane plasmalysis**, which has (1) **low electrical consumption** and (2) co-produces **solid carbon**, a valuable industrial material.



$$CH_4 > 2\,H_2 + \text{solid carbon}$$

Spark brings :

- A **worldwide-unique, patented technology**: **Nanopulsed Plasmalysis**, which optimizes efficiency.
- Competitive hydrogen **as a substitute to natural gas** to decarbonize industrial heat.
- Sustainable solid carbon **avoiding CO_2 emissions** due to traditional solid carbon manufacturing.
- Modular units directly at the consumption site

1 - SPARK's team: from lab to industry - 15 people team

Erwan Pannier

Engineer at Centrale Paris '14 (top2 France)
Ph.D Plasma Physics Paris-Saclay '19 / Invited St. Researcher Stanford University

CentraleSupélec · Stanford University

Co-founder & CTO
Science

- **Developed the cold pulsed plasma technology** for energy applications through his Ph.D at Paris-Saclay & as invited researcher at Stanford
- Lead Spark's Lab program (0.55 m€, 5 people), built the Lab prototypes, won the 2022 French Innovation Prize i-Lab Prize (+0.5m€)

Patrick Peters

20+ years of experience in Management, Finance & Biz dev in the environment and energy sectors

Adionics The Advanced Ionic Solution · SUEZ

Co-founder & CEO
Business

- **CEO Biogas subsidiary of Suez**
  150 employees
  €45m invested in green energy
- **CEO Adionics (lithium extraction)**
  Lithium positioning, raised €12m, scaled the team from 10 to 30 and deployed 3 industrial pilots.

Alban Reboul Salze

20+ years of experience in Industrial project management & Biz dev in the oil & gas sector

TotalEnergies · Haffner Energy Making Hydrogen Super Green

Co-founder & COO
Industry

- **Engineering and Construction Department Manager at TotalEnergies**
  Industrial project management (1 to 225 MUSD, 10 to 600 people)
- **COO Haffner Energy**
  Structuring and scaling operations to industrial level (30 people)

+ 8 very talented Engineers & Business people.

2 - The challenge: how to source clean, on-site and affordable H_2

Today's H_2 production is not environmentally friendly

10 T CO_2 / T H_2

produced with current process
(steam methane reforming)

Electrical alternatives require huge power

6 250 TWh

¼ of worldwide electricity production
needed in 2030 for hydrogen production target with **water electrolysis**

Transport costs are important

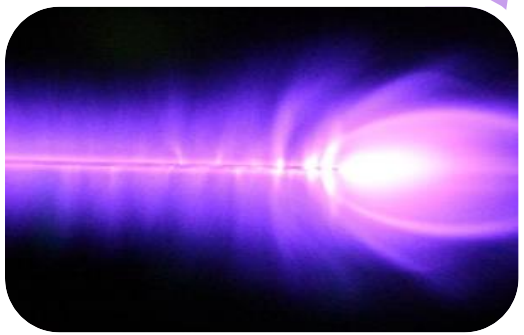
70%+

of the global H_2 cost for decentralized consumption are **distribution costs**

3 - A new way for H_2: plasmalysis

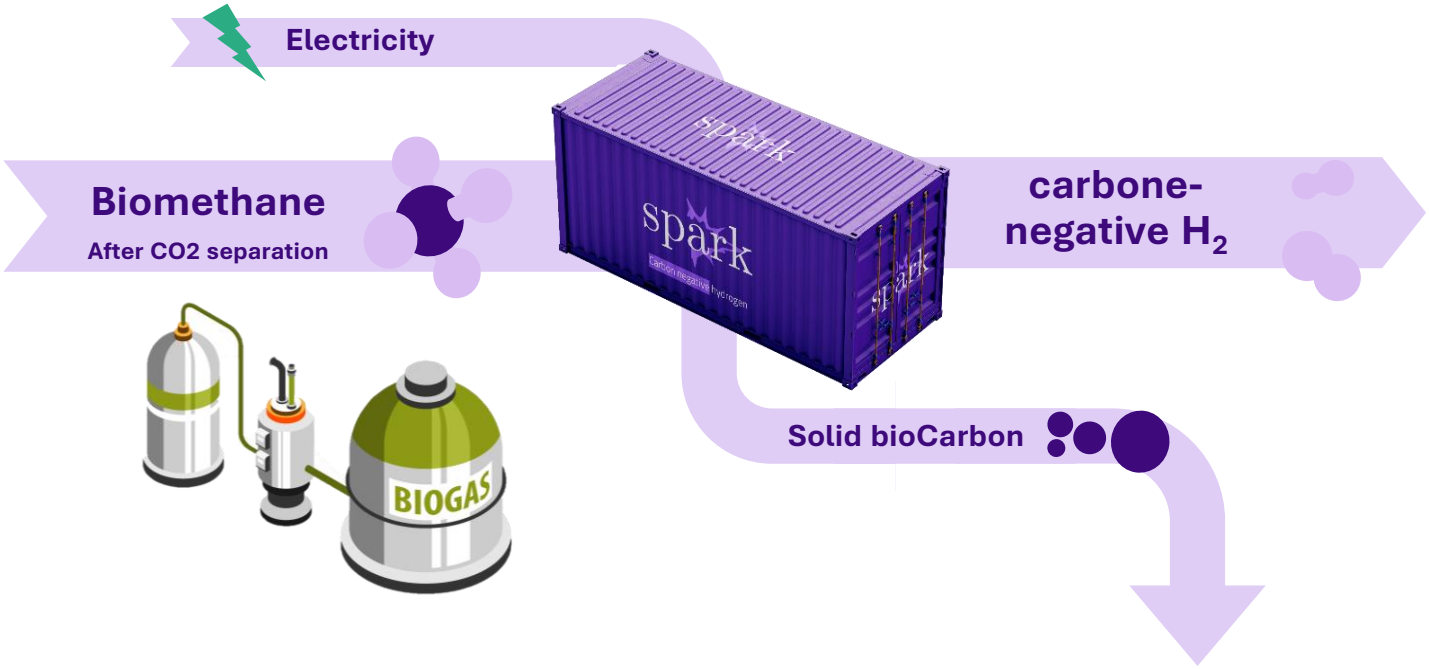
CH_4 > $2\,H_2$ + solid carbon

(3kgC / kgH_2 produced)

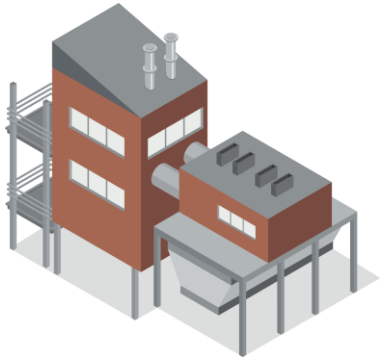


Cold Nanopulsed Plasma *("Lightning in a box")*
a world-unique, patented technology, converts methane into hydrogen and valuable solid carbon **without CO_2 emissions** and **low electricity input**

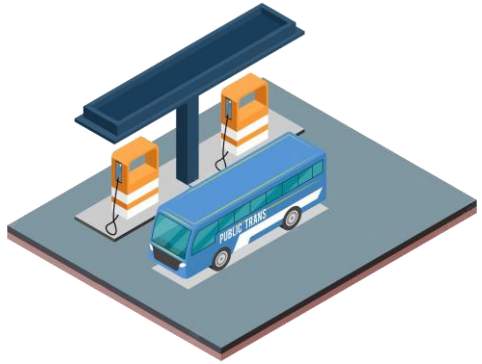
4 - Plasmalysis boosts biomethane's decarbonizing effect tenfold



Distributed industrial usages



Local use in internal logistics



A **negative carbon footprint** for hydrogen

BioPlasmalysis boosts the decarbonizing effect of biomethane tenfold, by sequestering carbon in solid form.

Solid bioCarbon production and valorization

for industrial usages

Typical Client :

Methanization plant

Spark :

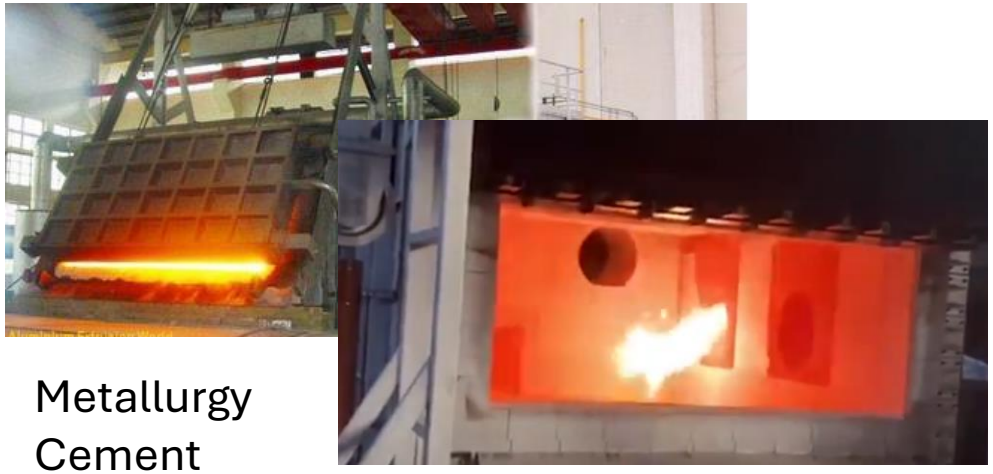
Modular for all sizes of plants

Deployment of an CH-5 industrial pilot in Q1 2024

4 – Clean hydrogen to decarbonize hard-to-abate industrial heat

Spark offers **competitive hydrogen**, produced directly at the consumption site, as **a substitute to natural gas to decarbonize hard-to-abate industrial heat**.

CH_4-POWERED FURNACE



Metallurgy
Cement
Glass
Chemical

SPARK H_2 **+** **UPGRADED BURNERS & RE-USE FURNACES***

Gas is already available

- **Low cost** (5x less electricity than electrolysis, solid carbon valorization)
- **Low carbon footprint** (client's premium prices, ESG quotes, …)
- **Non-intrusive in the process** (low CAPEX, modular & plug-and-play)

Typical Client :

12t Aluminium Pilot Furnace = 1.8t H_2/day
150t Aluminium Furnace = 10 – 12t H_2/day

Spark :

Modular, Plug-and-play production units

Start and stop

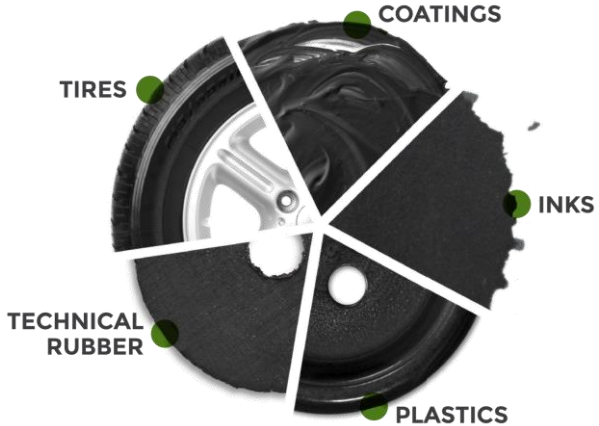
5 – Valorization of solid (bio)Carbon

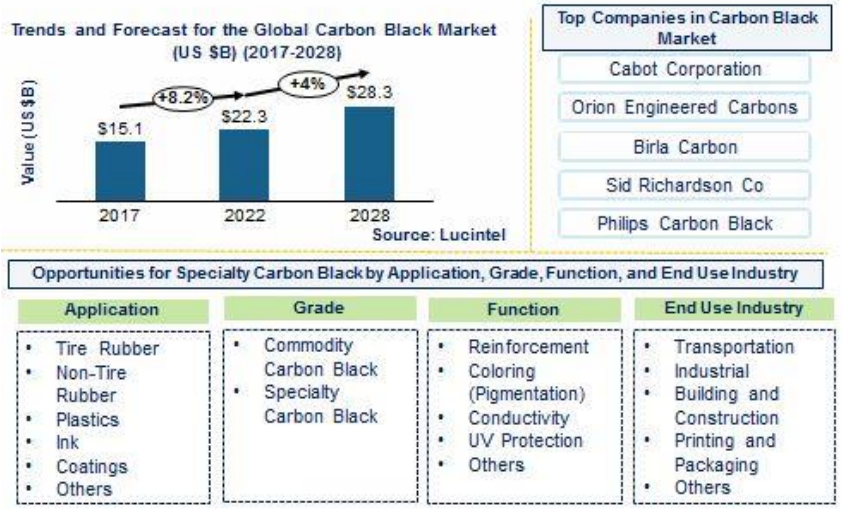
3kg C / kgH_2 produced

Solid Carbon / BioCarbon

Solid carbon plays a **vital role in various industrial applications**.
Solid (bio)carbon **offsets the hard-to-abate emissions** of carbon-intensive sectors.

Solid carbon valorization drive down hydrogen cost





deCarbonized H_2

Solid carbon generates an **additional revenue stream** allowing a low pricing on H_2.

7 – Spark improves a proven concept …

Monolith Materials were the first to industrialize a **plasmalysis process (2012+)** using **thermal plasma**

2012 – MinesParistech (France)
Prototype - **20 kg/day H_2**

86 kWh/kg H_2 *

2014 - Redwood City– **200 kg/day H_2**

2020 – 12 t H_2/day **Economically viable size**

25 kWh/kg H_2 – $100m investment

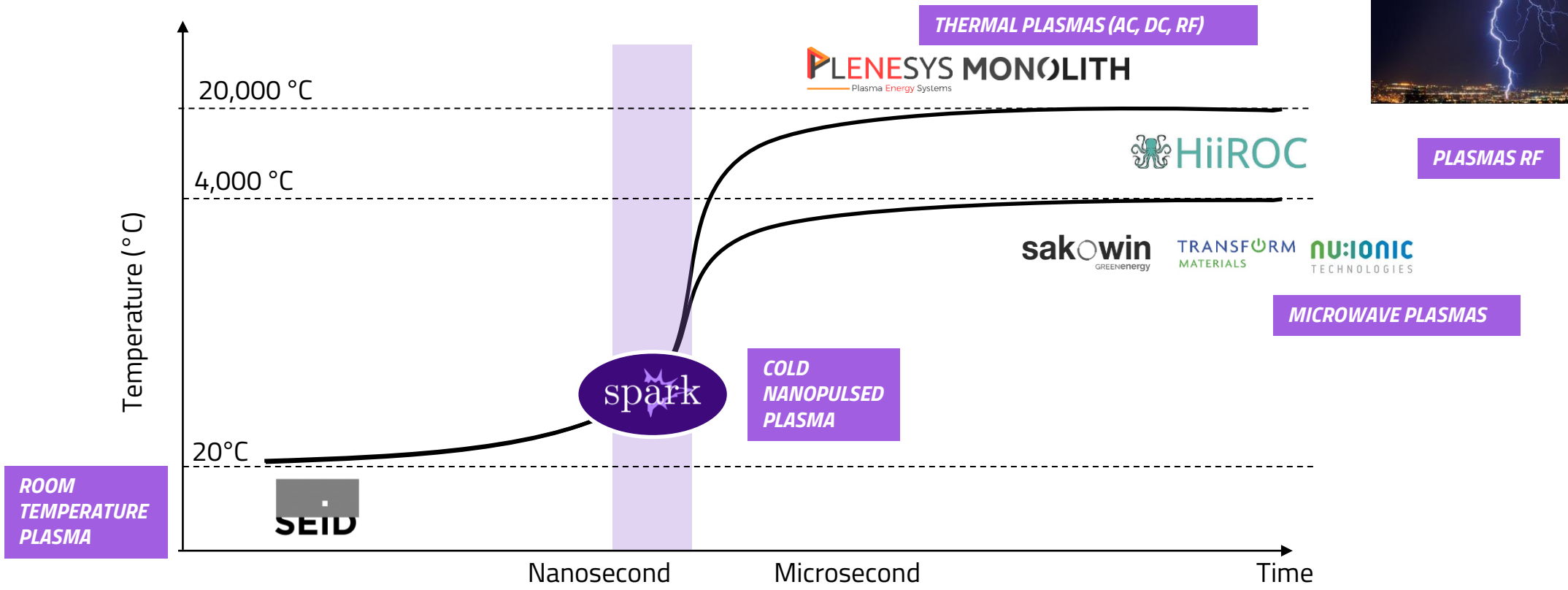
+**1B$ granted** by the Department of Energy (DOE)

Thermal plasma was energy inefficient but Monolith mitigated heat losses by scaling : they reached 25 kWh/kg H_2 at industrial size (half the consumption of an electrolyzer)
Spark uses a new, first-principle approach to cancel losses already at small scale using a **cold plasma**.

*Fulcheri et al 2022. doi.org/10.1016/j.ijhydene.2022.10.144

8 - … with a new approach: nanosecond-control of temperature

The transition between a cold gas and a thermal plasma (e.g. lightning) spans over merely few nanoseconds.



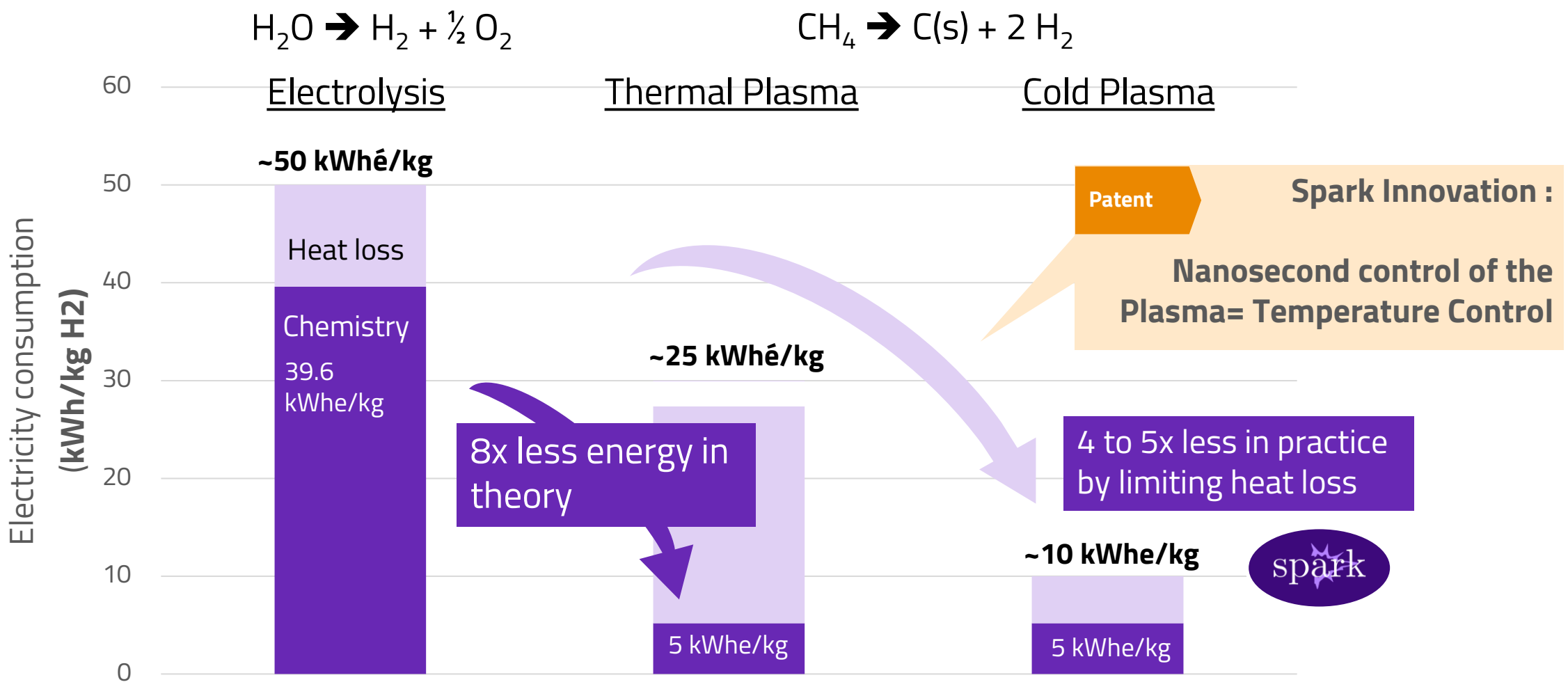
Temperature too low: the reaction is too slow, hydrogen is not produced and energy is lost: **inefficient.**

Sufficient and **controlled** temperature for a **fast** and **efficient** reaction

Temperature too high: material stress and heat losses: **inefficient reaction**

Spark's nanopulses are a **unique technology** that allows to control the temperature in the plasma to obtain the optimum between fast reaction & low heat losses.

9 - … with a new approach: nanosecond-control of temperature



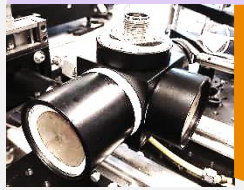
Temperature control brings us closer to the theoretical minimum of 5 kWh/kg H2.
Spark aims for 10 kWh/kg (4 to 5 x less than electrolysis).

10 – Development plan : 2 pilots towards commercial scale

2021 | 2022 | 2023 (oct) | 2024 (May) | 2025 | 2026

MATURATION PROGRAM

CentraleSupélec — SATT PARIS-SACLAY Innovating with confidence — cnrs



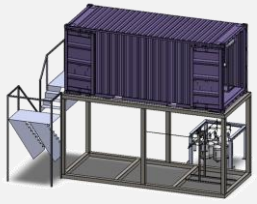
Patent 1

Patent 2

✓ Proof of concept
0.02 kg H_2/d

✓ One Cell
1kg H_2/d

SKID + INDUSTRIAL PILOT



Demonstrator CH-5*
5 Cells

Industrial Pilot CH25*
25 kg H_2/d

COMMERCIALIZATION

Production Modules
0.2 – 1 T H_2/d

TRL 3 — 4 — 5 — 6 — 7

5+ years in-Lab technology development

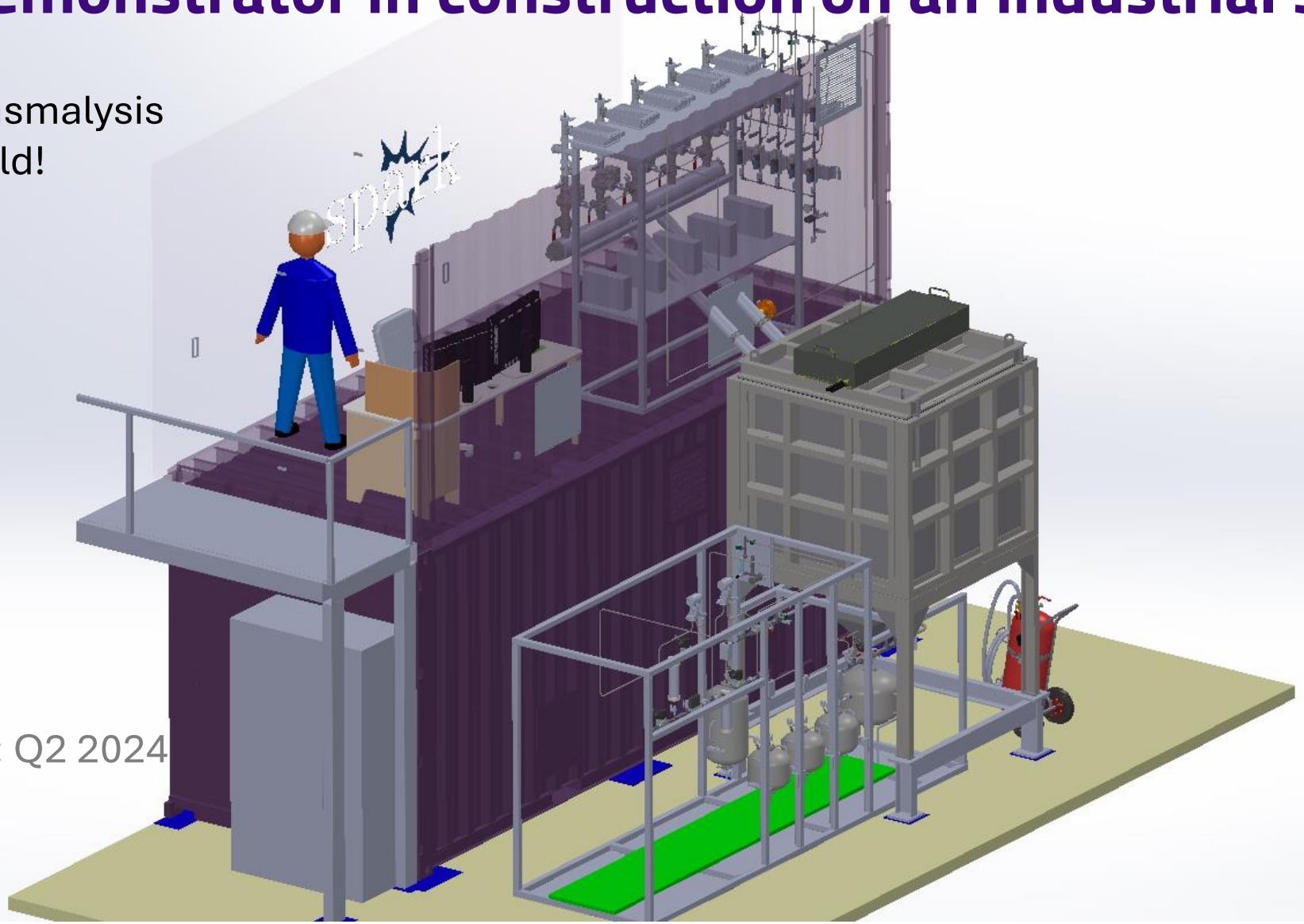
Demonstrator (Q2 2024) will demonstrate operation **in real conditions on an industrial site**.

✅ **Pre-Seed Fund Raise : 4m€ (July 2023)**

*: CH5; CH25 : Clean Hydrogen 5 and 25 kg/d

Q1 2024 : 1st Demonstrator in construction on an industrial site

✨ First Nanopulsed Plasmalysis Demonstrator in the world!



Construction : on-going
Factory Tests : Q1 2024
Client Site deployment : Q2 2024

Our Next Step :

Pilot Operation + larger Fund raise Q4 2024 to design our **~1T/day** commercial unit in 2025

spark

Let's meet!

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