

CIPEA Innovation Day
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RF heating as smart alternative to fossil fuels

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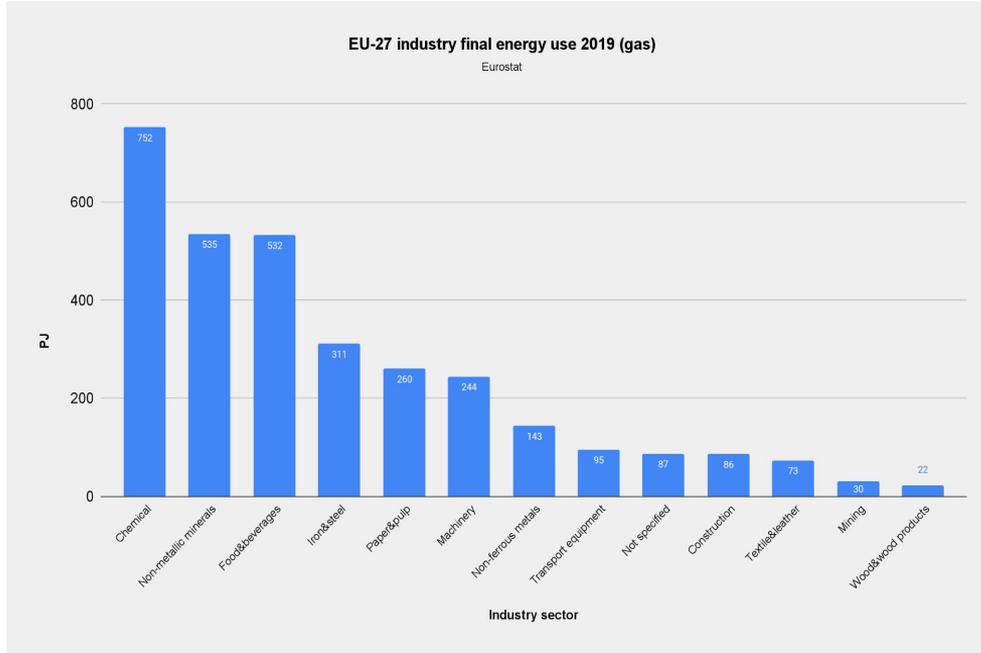
The year 2022 marks a turning point in the usage of natural gas:



- Prices increasing steadily and unpredictably
- Carbon credits increasingly expensive
- New awareness of fossil energy dependence
- Unknown short and long term availability
- Usage and sourcing increasingly ethically problematic
- True for all fossil fuels beyond gas



Why use microwaves for heating? Some numbers:



Source: <https://ec.europa.eu/eurostat>

- Industry consumes gas mainly for heating processes (~100GW installed in the EU)
- Increasing renewable energy will mostly deliver electricity as energy form

→ All sectors of industry will need to transition from fossil to electric at some point in the near future

→ Microwaves can (easily) replace gas in about 10% of all industrial heating applications



Impact

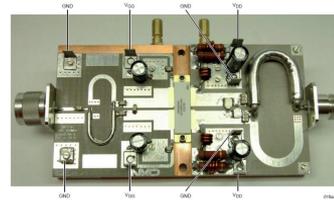
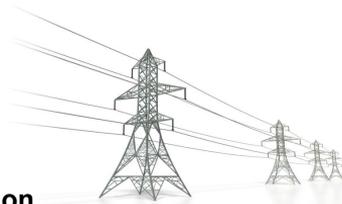
Why use RF for heating? Environmental impact:

- A potentially **green** and **sustainable** heating system
 - Annual **CO2 emission** savings through gas to RF replacement **EU: 42 Mt**
 - **Investment cost** for “easy” RF replacement EU: **4.5 billion CHF**
 - Estimated number of industrial heating installations EU: **approx. 70,000 units**
 - Time left for full energy transition (until 2050): **28 years**
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- **Numbers for the entire world are roughly 10 times the EU numbers**

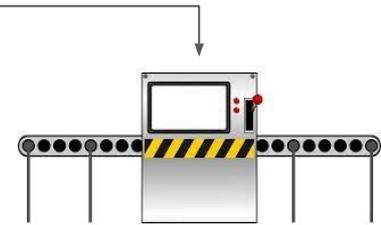
→ Global annual potential CO2 emission savings: approx. **400 Mt**



Green electricity production

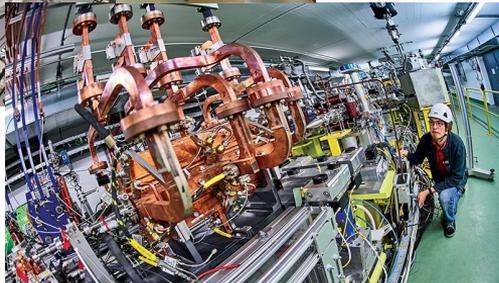
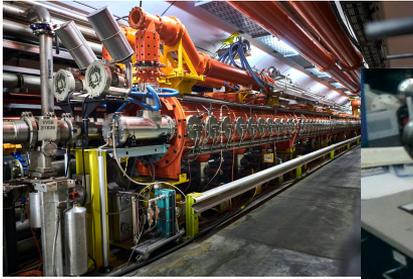


Microwave generation



Application

RF seen from the accelerator physicist viewpoint:



What is usually requested:

1. CW-operation + high peak power, short pulses
2. All frequencies possible
3. High stability in phase and power, low(est) jitter
4. Intra pulse phase and amplitude control possibility
5. Typically custom designed sources

'Nice to have':

1. Low cost
2. High efficiency
3. Reliability, uninterrupted operation
4. Compact
5. Lifetime
6. Low and simple maintenance

RF seen from the industrial viewpoint:



What is usually requested:

1. CW operation, 24/7
2. ISM frequencies (27MHz or 2.45GHz most often used)
3. Current applications require 1-100kW per machine, future applications will require >1MW
4. Standard equipment preferred
5. Lowest cost
6. Simple or no maintenance
7. Lifetime >10 years

'Nice to have':

1. Precise phase and frequency control
2. Amplifier instead of oscillator

Why use RF for heating? You actually know the advantages!

You already made the experience here:



You all know well the advantages of microwave (MW) or radio frequency (RF) heating:

- Heats fast
- Heats uniformly, even inside solid and powder goods
- Heats only the goods to heat, not the oven
- Very efficient power transfer

Industrial scale microwave heating exists up to several 10 kW but has not yet been deployed in large scale. Scaling is difficult due to cost of single high power microwave sources.

Why use RF for heating?

An example for a new, RF (27MHz) based system:



Packaging foam machine: **10 fold reduction in energy consumption** after switching from gas to RF!

RF sources have significantly lower costs than microwave sources. But RF is not always the best solution for the heating process...

→ **Microwave sources need to become more affordable and more versatile!**

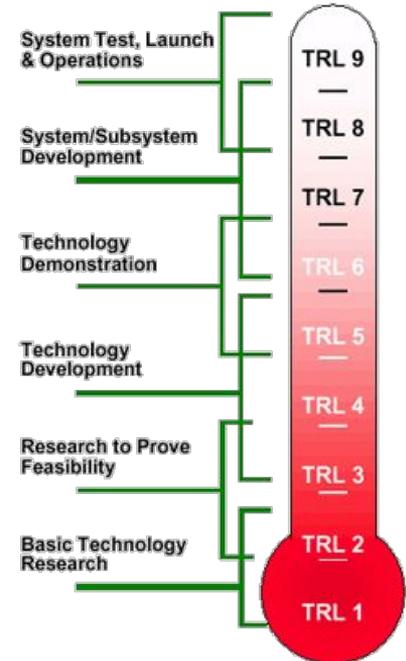
Summary of CIPEA project proposal:



Project scope: Increase TRL (4→ 7) of magnetron injection locking technology towards a potential industrialization.

Which **problems** do we **solve** with injection locking magnetrons specifically?

1. Very affordable microwave power source up to medium energy ranges (~10kW CW, scalable)
2. Directed material heating (phased array, CW)
3. Uniform, volumetric heating with high power density and no hot spots, especially for low loss materials (CW)
4. Known and configurable field distribution in microwave power applicator (CW, pulsed)
5. Low cost driver for small scale accelerators in industry and medical (X-ray etc., pulsed)
6. Once demonstrated, low(-er) cost amplifiers for large accelerators (FCC?)



Summary of CIPEA project proposal:

Project host: CERN SY-RF-AC section
Planned overall project duration: 30 months
Planned overall budget: 100kCHF

Potential collaboration with: Amos Dexter, Lancaster University
Identified external industrial partner: SolidWatts SA (www.solidwatts.ch)



Timeline & Resources



Partners

Project description:

- Together with SolidWatts SA, we would like to adopt their solid-state power amplifier (SSPA) technology for this injection locking task.
- Design and build a first prototype of a combiner for 2-8 phase locked low cost 2.45GHz magnetrons and combine their power into one output.
- Adapt and improve locking SSPA and develop feedback loop implementation.
- Lock and stabilize the magnetrons so that combination can be done efficiently.
- Test in CW (heating) operation.
- Evaluate potential usage of hardware in pulsed operation (accelerators).

Thank you for your attention!

I would be happy to try to answer any questions...

