ENABLING RESILIENCE AND CIRCULARITY IN SEMICONDUCTOR MANUFACTURING

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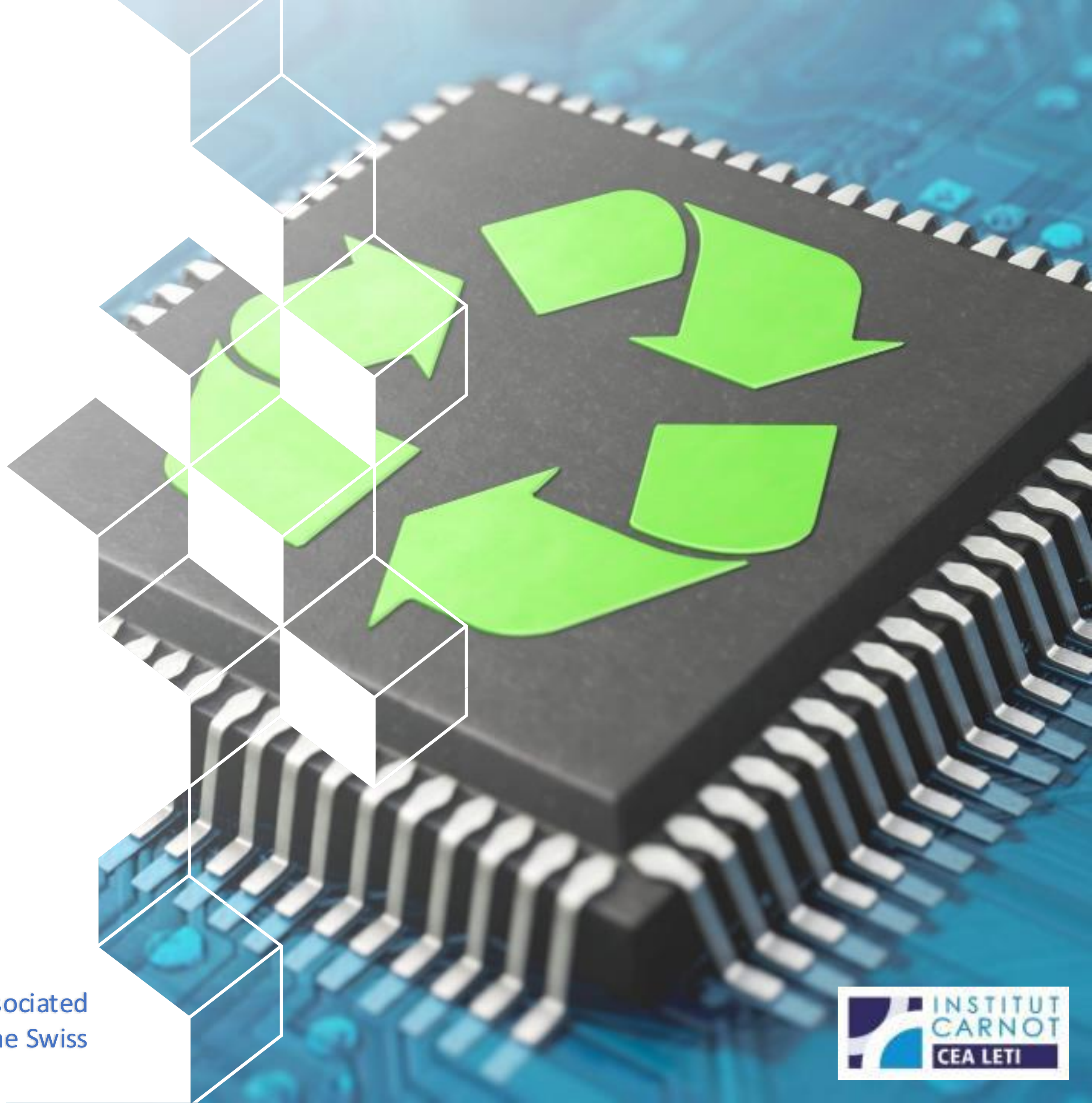


GENESIS and FAMES are EU programs supported by CHIPS JU and its associated members states. In addition, GENESIS Swiss partners are supported by the Swiss state secretariat (SERI)

Summary

1. Introduction
2. 1st need : impact identification
3. A more sustainable ICT manufacturing

   The **SUBFAB Labs** initiative

4. Development around integration & systems
5. Conclusions

ICT INDUSTRY PARADIGM

Health

Automotive

Industry

Smart cities

Energy management

Agriculture

ICT INDUSTRY PARADIGM

Health

Automotive

Industry

Smart cities

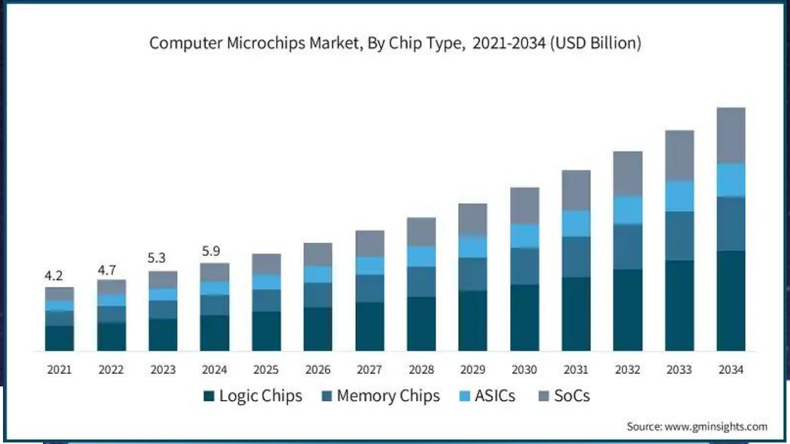
SUSTAINABLE

Economical Sustainability	*Environmental Sustainability*	*Societal Sustainability*
PPAC principle	« R » policy Resources Climate …	Use phase & societal gain

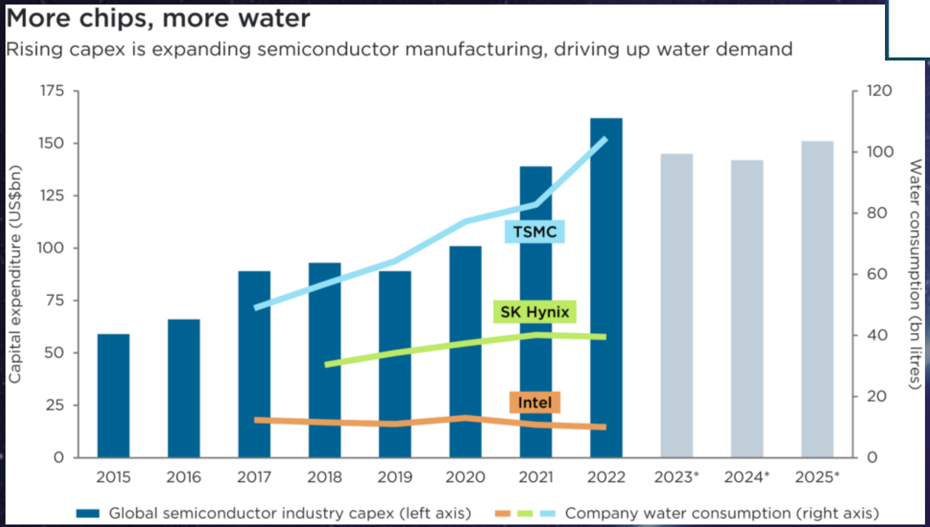
TECHNOLOGY

HOW TO MATCH IC MARKET WITH SUSTAINABILITY CONCERNS

ICT FORECAST…



…More chips…

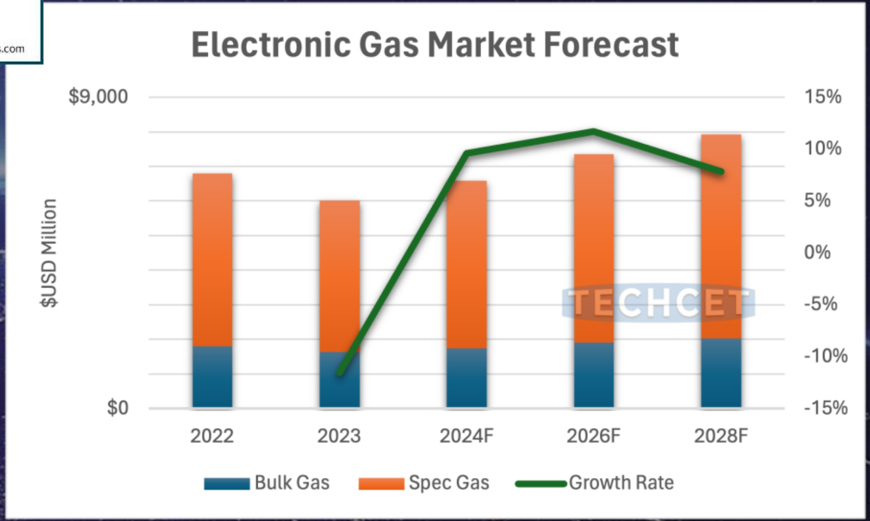


…more water…

63 Mton of e-waste in 2030

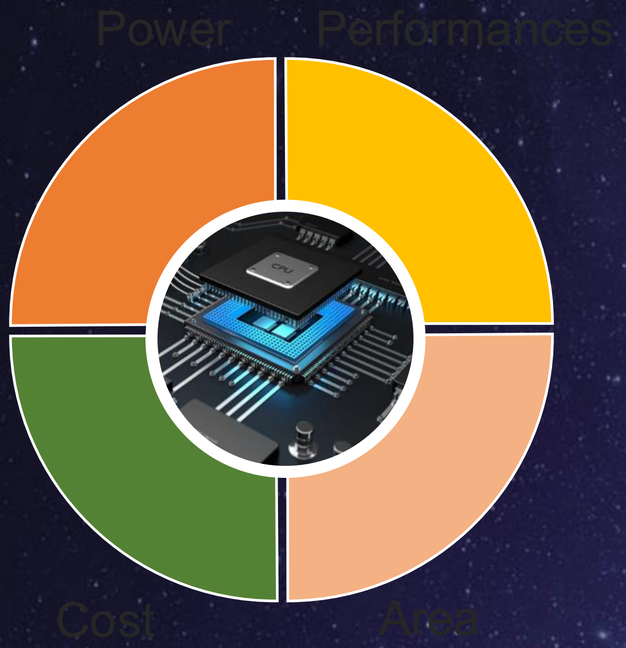
0.4-2.5 from data centres Due to generative AI

…more wastes…

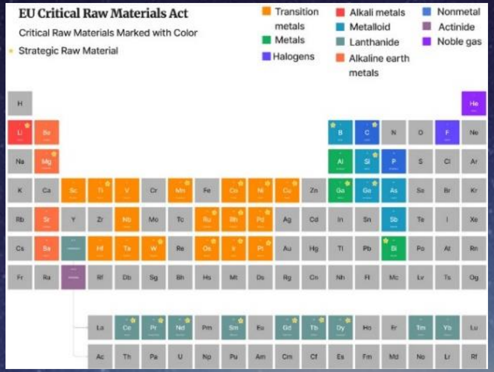


…more PFC!

Urgent need to pave the route toward a sustainable electronic



https://mobilitynotes.com/european-critical-raw-materials-act/



Sustainable Electronic

Green Manufacturing

PPAC - E

Eco-design

Anticipate technology needs & evolution

Address the full value chain from design&manufacturing to system

Summary

Understand environmental impact

Dynamic LCA solutions

FAMES
greener electronics
FD-SOI • NVM • 3D • RF • PMIC

1

LCA methods comparative, absolute

16 enviromental footprint impacts

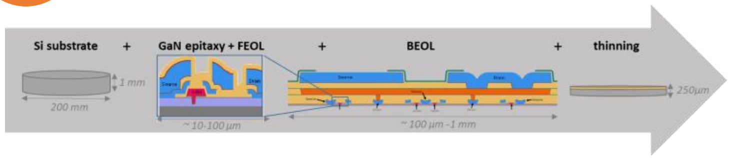
2

Dynamic e-score LCA SW platform

e-score

Clean room

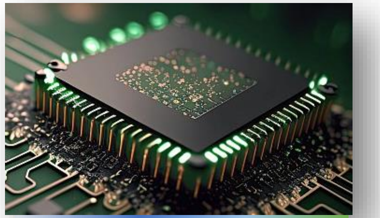
Process & equipments



Technologies

3

Eco design solution



PPAC - E

Design & Modeling

Joint work with : imec UCLouvain

Summary

1. Introduction
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3. Partnership & engagement toward a more sustainable ICT manufacturing

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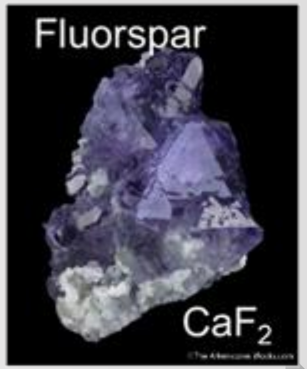
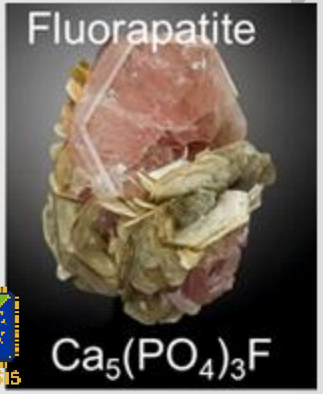
The challenge for a more sustainable IC industry
Etch gas process example

Revisit raw materials



HF sources



Optimise material process

Literature carbon intensities
CH2F2 manufacturing
~10 kg CO2eq/kg CH2F2

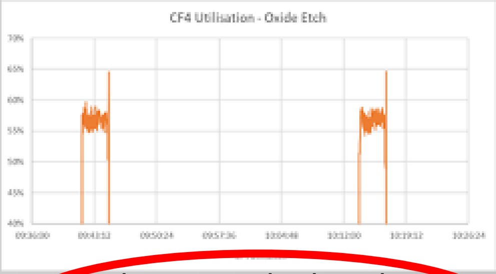
Fluorinated Materials

Electronic grade purification impact

increase carbon footprint
10-1000x

Courtesy from ARKEMA

Fab Process
Consider global impact
Use phase and by-product



dielectric etch chamber
45% of CF4 not used

Applications & Abatement

Contact etch chamber
Up to 85% of CF4 not used

Results from CEA-Leti pilot line with EDWARDS

Final waste

Emissions:
- Production
- Use
- Abatement

Deposition
- Soil
- Surface Water
- Ocean

1ST CEA-LETI PARTNERSHIP ENGAGEMENTS

GENESIS

JU Chips GENESIS

Develop & qualify solution to improve ICT manufacturing sustainability

(TRL 3 → 6)

JU Chips FAMES

CEA-Leti FDSOI 10/7nm Pilot line

WP Sustainability

Methodology & impact scoring

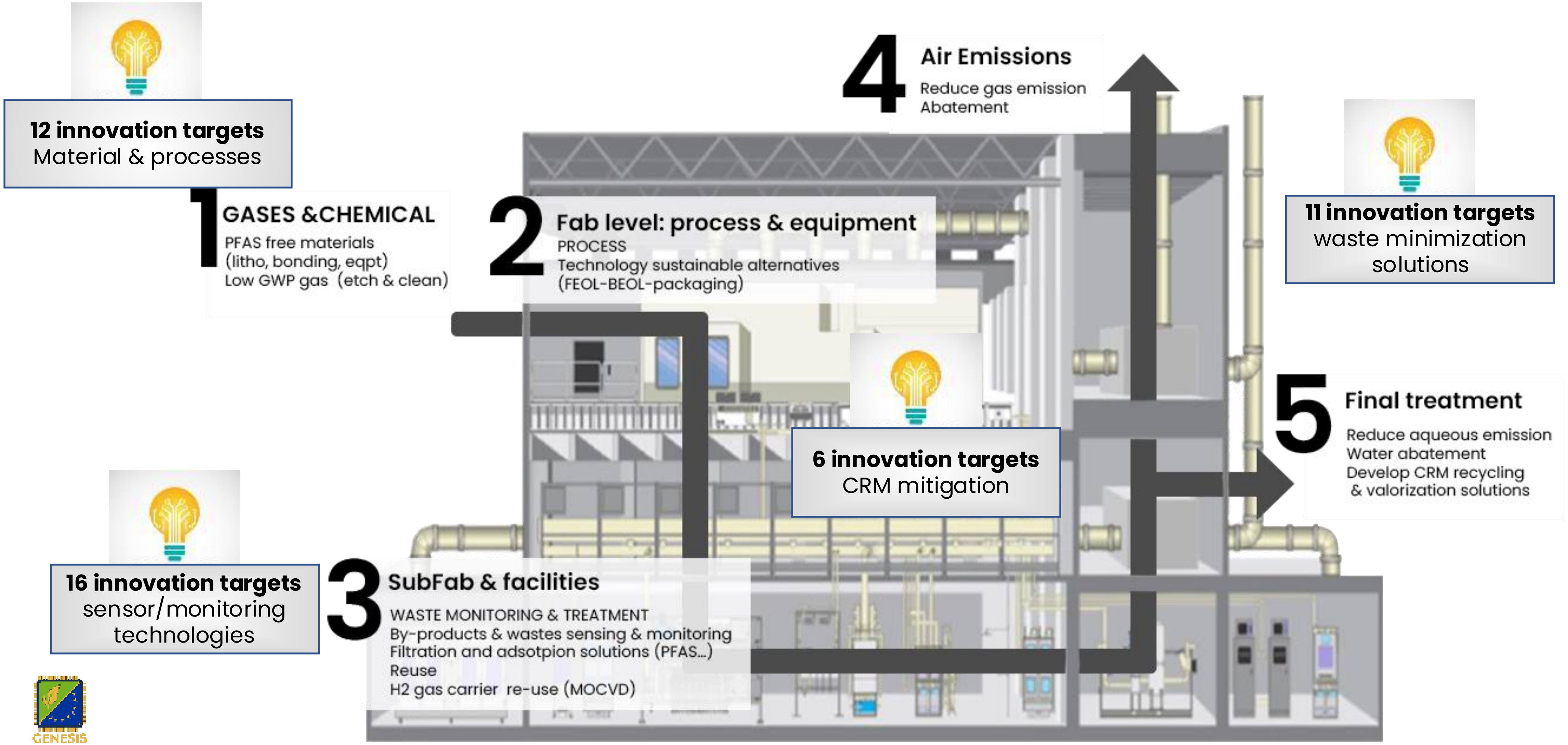
Pilot line impact reduction

Eco-design

Improved IC manufacturing

GENESIS objectives

→ Improve the entire manufacturing sustainability chain value



GENESIS

1ST CEA-LETI PARTNERSHIP ENGAGEMENTS

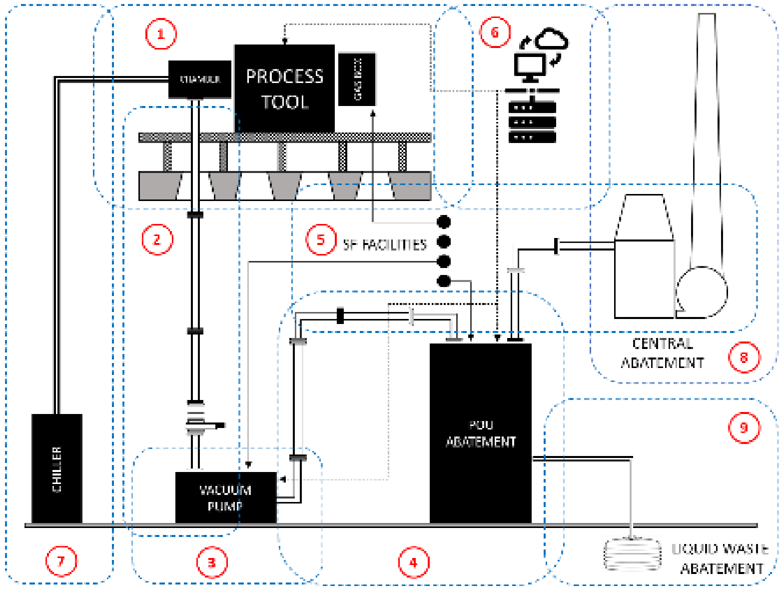
JU Chips GENESIS
Develop & qualify solution to improve ICT manufacturing sustainability
(TRL 3 → 6)

SUBFAB LABS
(Program frame work : Affiliate & institutional)
Scale up solution to boost technologies & sustainability improvement in SUBFAB environment
(TRL>5)

JU Chips FAMES
CEA-Leti FDSOI 10/7nm Pilot line
WP Sustainability
Methodology & impact scoring
Pilot line impact reduction
Eco-design

Improved IC manufacturing

SUBFAB LABS AMBITION
A dedicated environment to RETHINK SUBFAB



Program
Co-driven with

- → **Objectives :**
  - → **Improve material and Hardware use, waste management policy (sensing, circularity, waste treatment…)**
  - → **Qualify new solutions in « certified prod- like condition mode »**
  - → **Fab modelling data to evaluate economical and sustainability impacts**
- → **An environment open tailored for partners to :**
  - → **Evaluate new Hardware (pumps, abatement…) in intensive mode**
  - → **Qualify new materials (Low GWP gas, PFAS free resist..)**
  - → **Mature new breakthrough solutions on process, sensing strategy, waste management incl. minimization, recycling/re-use, data handling**

SUBFAB LABS environment

Rethink a more sustainable SUBFAB

Affiliate program
Co-driven with

ISRL semi

P1 - Data Analytics
P2 Etch
2026-2029

. . .

P3 - Deposition
P4 CLEAN
P5 - CMP

P 1 – ICT By-product catalogue

- → Location :
  - → 200:300mm Pilot line in operation
- → Objectives
  - → Exhaustive waste data base
  - → Waste composition
    - → After process
    - → After abatement

Work on tools of the R&D pilot line

P 2 – SUBFAB - Etch LAB

WP 1.
- New Materals & sensor

WP 2.
- New Hardware (pump, tubes, ancillaries)

WP 3.
- New abatement strategies

WP 4.
- Final waste optimization (air/water) Reduce, recycle, reuse

WP 5.
- Heat transfer fluid

ETCH Platform

PM1
PM2
PM3
PM4

ABATEMENT
PUMP
ABATEMENT
PUMP
PRE ABATEMENT
PUMP
ABATEMENT
PUMP

4th chamber can be split for additional test line

CHILLER

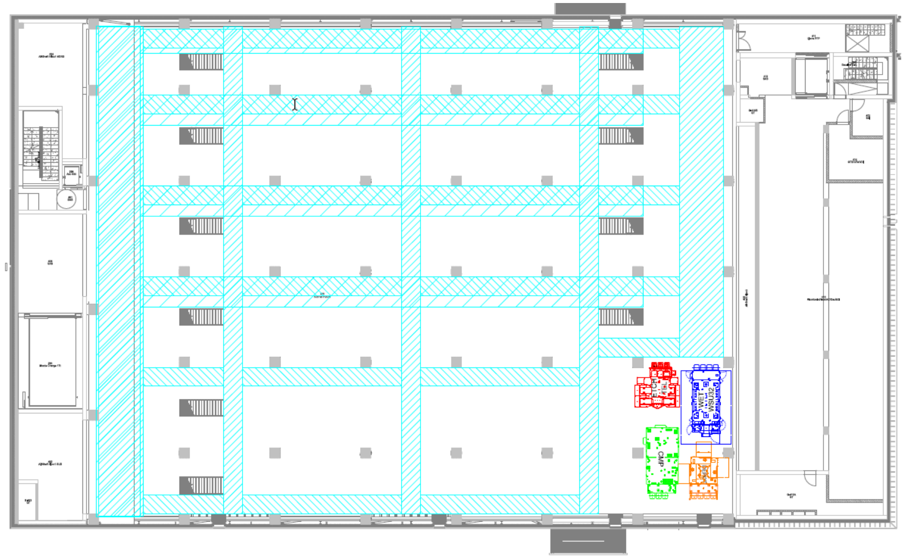
WASTE RECLAIM

ISRL

cea

SUBFAB LABS location
4103– New LETI fab

Building:	4103	✓
Environment:	2 level of basement (clean & dirty)	✓
Facility status :	Facilities already pre-aquiped 6 aqueous segregation lines available	✓

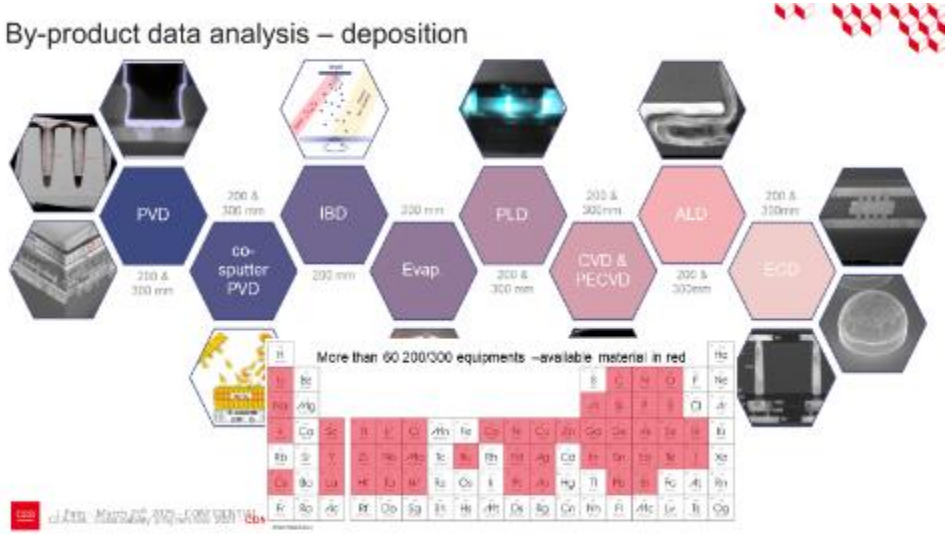


4103 new CEA-Leti facilities
State of the art facilities
Experimental floorplant reserved compatible with 4 equipments config

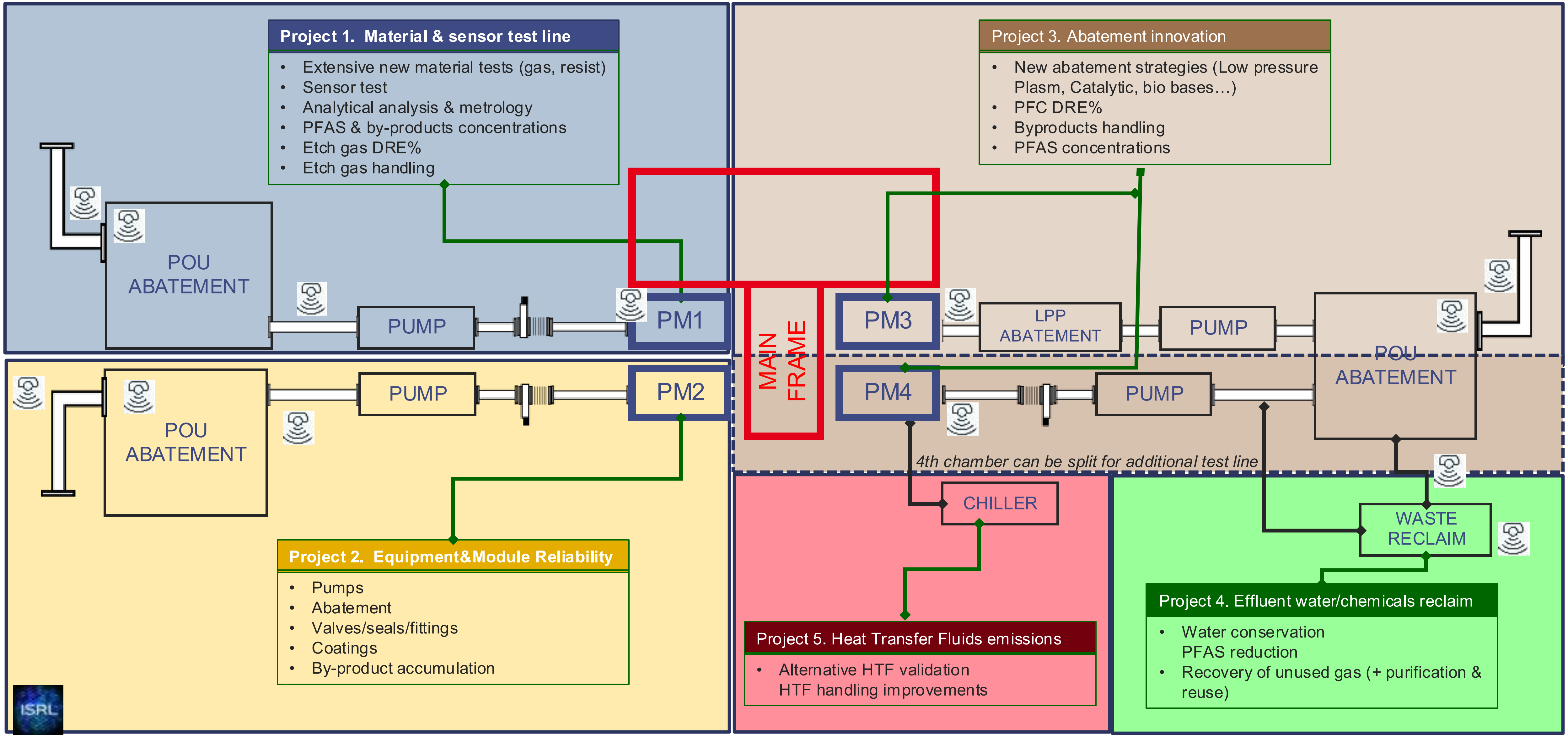
PHASE 1 – By-product data analysis

- **Test line infrastructure**
  - 200/300 CEA-Leti pilot line
  - Data analytic performed with sensor partners
- **Test protocol (per process family)**
  - DOE : define process boundaries and experimenal set-up
  - Process tests
    - Specific DOE
    - Hook-up (if needed) of post process line for sensor installation
    - Measurement campaign
    - Result analysis and report
    - Removal of sensor for next process monitoring

CEA-Leti pilot line etch & deposition potential portfolio



PHASE 2 – SUBFAB LAB Etch post process

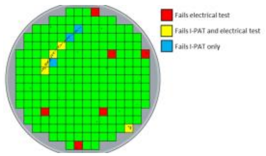


SubFab solution outcomes

- **Cost reduction :** energy efficiency, raw materials, waste reduction, …
-  **Unique opportunity** to access a dedicated HVM line platform **without impacting your production environment**
- **Competitive advantage:** product innovation + "green" differentiation
- **Access to green financing and public subsidies**
- **Improved ESG score**
- **Less dependence on critical resources** (rare gases, materials, water, energy, …)

Summary

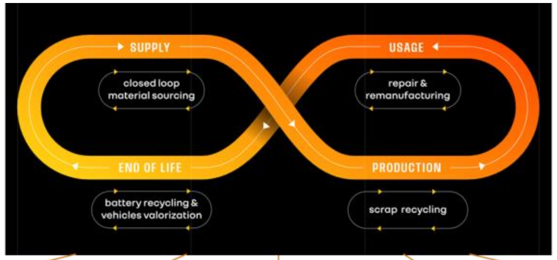
6R POLICY FOR CIRCULAR & LONG LASTING



The cohabitation challenge between Sustanability & ICT

Renault group ambition

First company with 360° operation across the entire automotive value chain, from the supply of parts and raw materials to the vehicles' end-of-life (ELV).



INDRA (Recycling ELV) | **GAIA** (Recycling Materials) | **THE REMAKERS** (Remanufacturing) | **BCM** (Metal waste Mgt) | **Battery Recycling**

RG

THE FUTURE IS NEUTRAL

EXTEND LIFETIME : POWER CONVERTER CASE

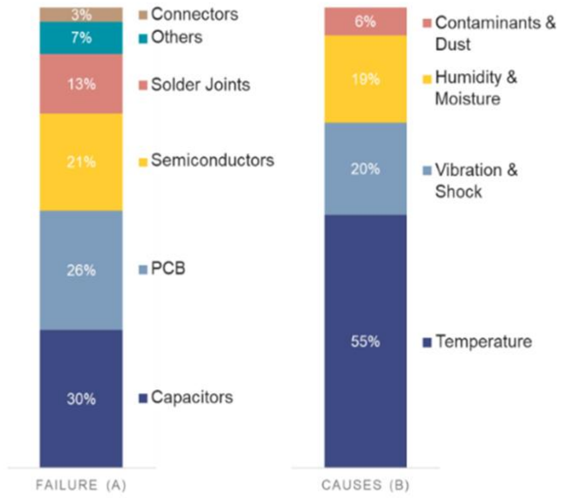


Fig. 1. Failures impacts (a) and associated causes (b) in power electronic systems

Y. Fassi et al. "Towards Physics-Informed Machine Learning-Based Predictive Maintenance for Power Converters – A Review," *IEEE Transactions on Power Electronics*, pp. 1–33, 2023

1 - Model based

- Grounded in physics,
- Allow to simulate multiple failure modes
- But complex to implement, time consuming, no real time

2 - Data driven

- Flexible
- But often ignore physics
- Lack of experiment data of failure

3 - PINN

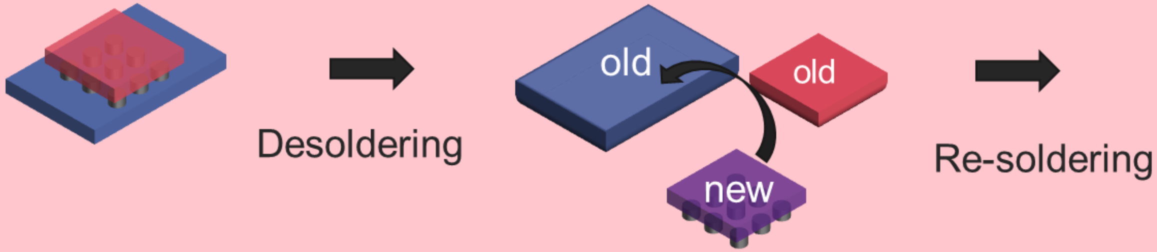
(Physics Informed Neural Network)

- Combining AI & physics
- Trade-off: accuracy vs. physical consistency

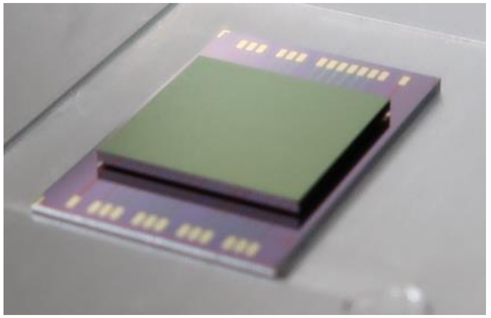
REPAIR

At component level

with retronix europe

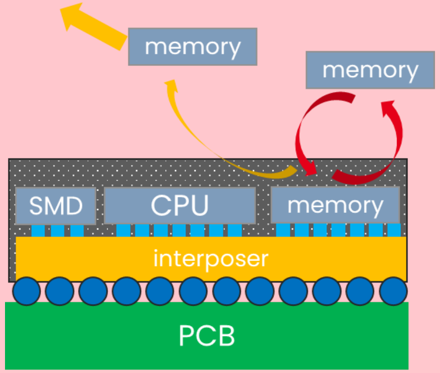


Test on several interconnexion sizes

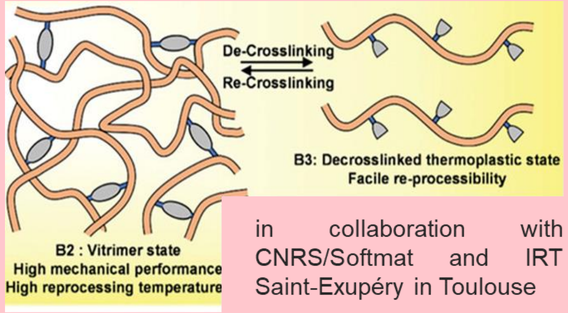


Source: CEA

At package level



New polymer needs Vitrimers ⊗ Additive manufacturing



in collaboration with CNRS/Softmat and IRT Saint-Exupéry in Toulouse

with HUMMINK

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THE ROAD TOWARD A MORE SUSTAINABLE INDUCTRY

+1,5°C Global warning before 2030 becomes nowadays an evidence

« Science without conscience is only ruin of the soul"

… AND A MOTIVATION TO SPEED EFFORT

PARTNERSHIP

SUSTAINABLE

Economical Sustainability	*Environmental Sustainability*	*Societal Sustainability*
PPAC principle	« R » policy Resources Climate …	Use phase & societal gain

TECHNOLOGY

BREAKTHROUGH PROGRESS

SUBFABLABS synergies

Synergies

SUBFAB LABS

Target : Worldwide consortium
- → Close link with SEMI for roadmap
- → Dedicated experimental environment
- → Evaluate and qualify solutions (material, HW) in HVM mode
- → Operational platform 24/24 5/7
- → Calculate impact benefits on HVM condition (environmental & economical) – Upscale result through modelling to real fabs

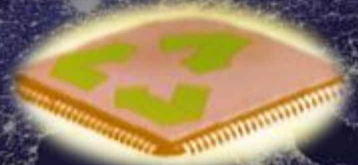
Complementarities (Top/down data…)

SEMI & SCC

Worldwide consortium – 100 partners approx
- → Draw roadmap to reach carbon neutrality @2050
- → Identify potential technologies for the members
- → Create standards and reporting rules for IC industry

IMEC & SSTS

Worldwide consortium
- → SW environment to calculate technology impact (climate and coming water, resource)
- → Data base issue from top/down industry & estimation from R&D (with industry projection)



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