

Technology of free piston linear generators

Opportunity and challenges for research and industrialization



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Consorzio Nazionale delle Ricerche
in tema di "Sistemi di conversione dell'energia"

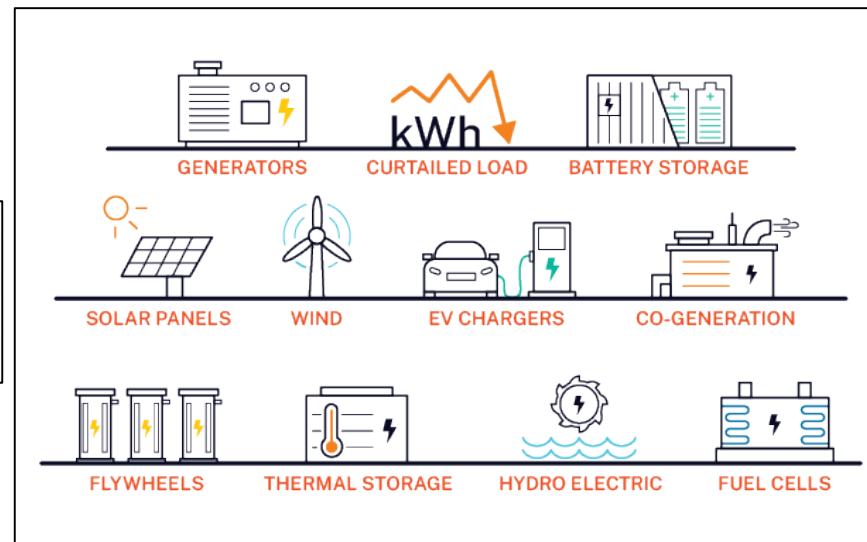
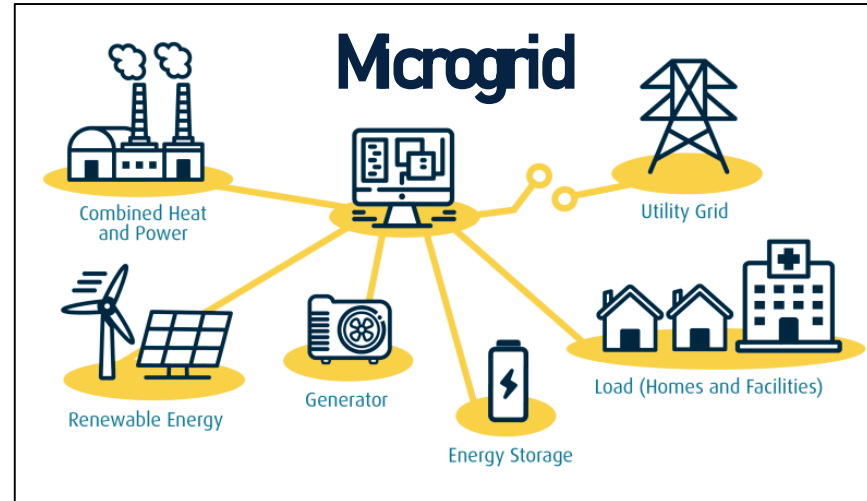
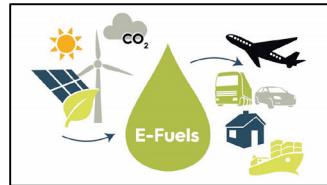


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Background

Changes in mobility, energy systems and power generation



Which role for IC Engines?

HEV, PHEV, EREV



Gensets



- Efficiency increase (~50%)
- Multi-fuel operation
- Near-zero emissions
- Reduced number of parts
- Fast response, integration in complex systems

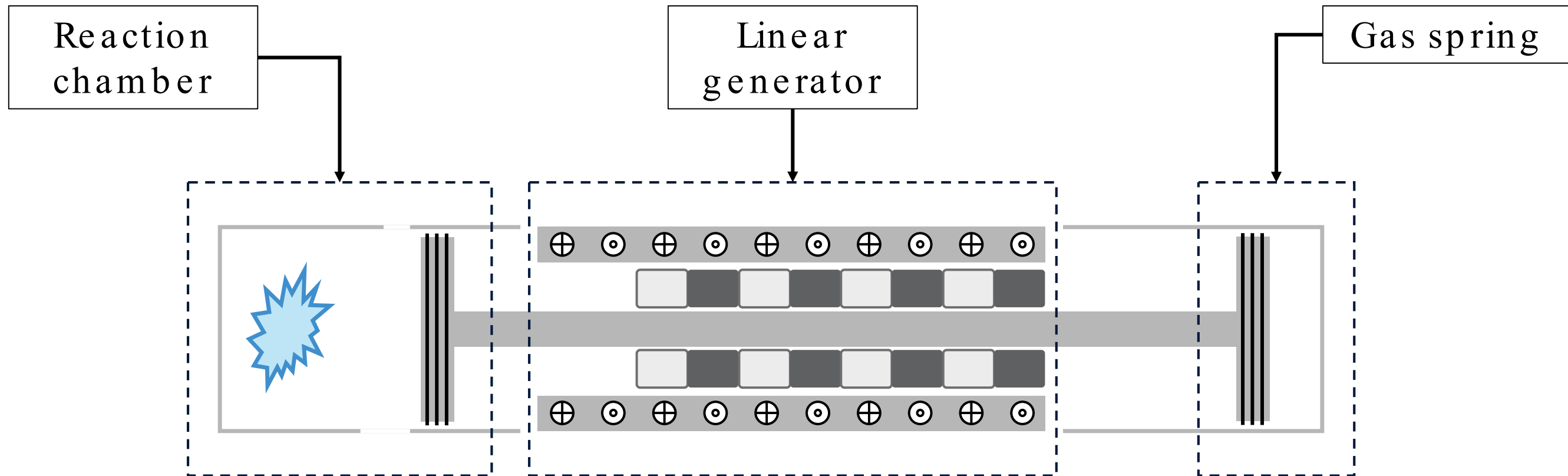
Evolving the IC Engine concept?



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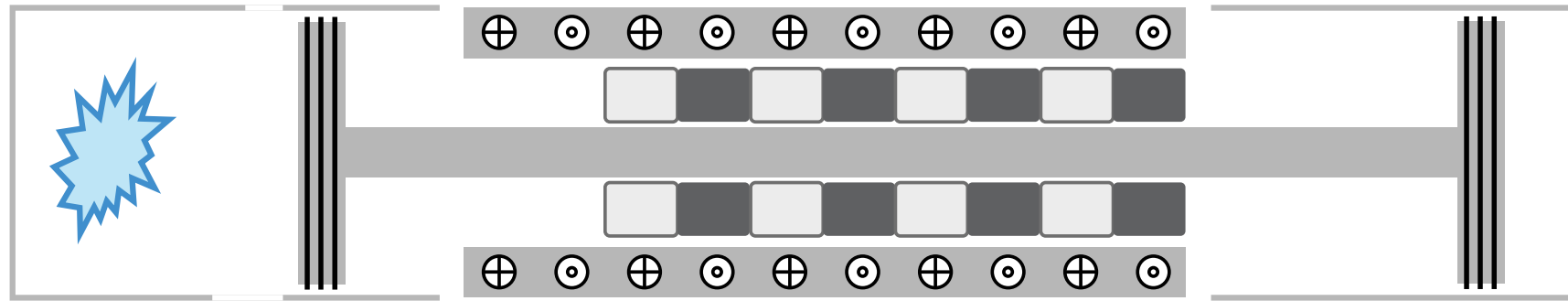
The free-piston linear generator (FPLG)



Evolution of the internal combustion engine concept:

- Crankshaft mechanism replaced by linear generator
- Electricity directly produced from the piston motion

FPLG vs Conventional IC Engines



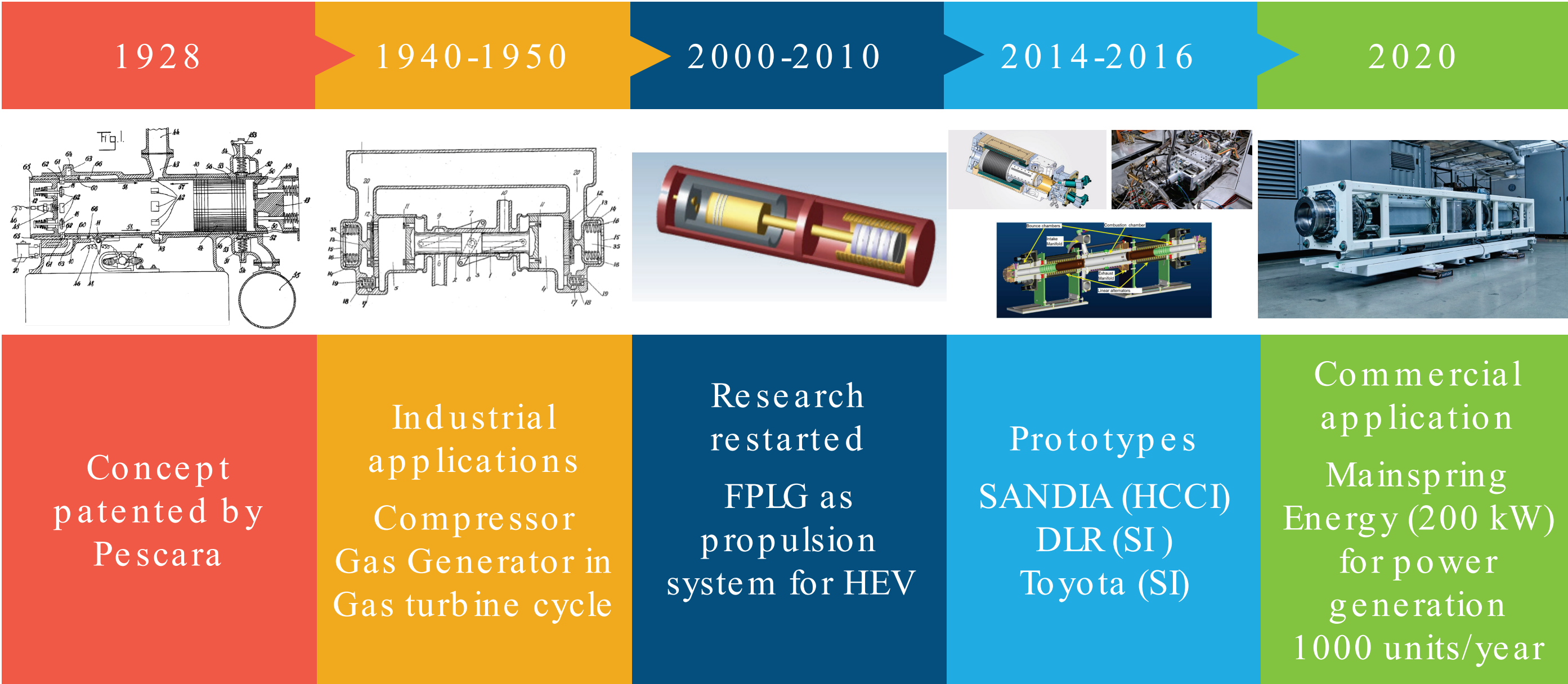
Advantages

- Higher Global Electric Efficiency
- Reduced number of parts
- Limited maintenance
- Multi-fuel operation
- Direct electricity generation
- Modular design

Drawbacks

- Piston motion control
- Technology maturity
- Lubrication and cooling
- Operation stability
- Cost
- Noise-vibration

FPLG history



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STEMS



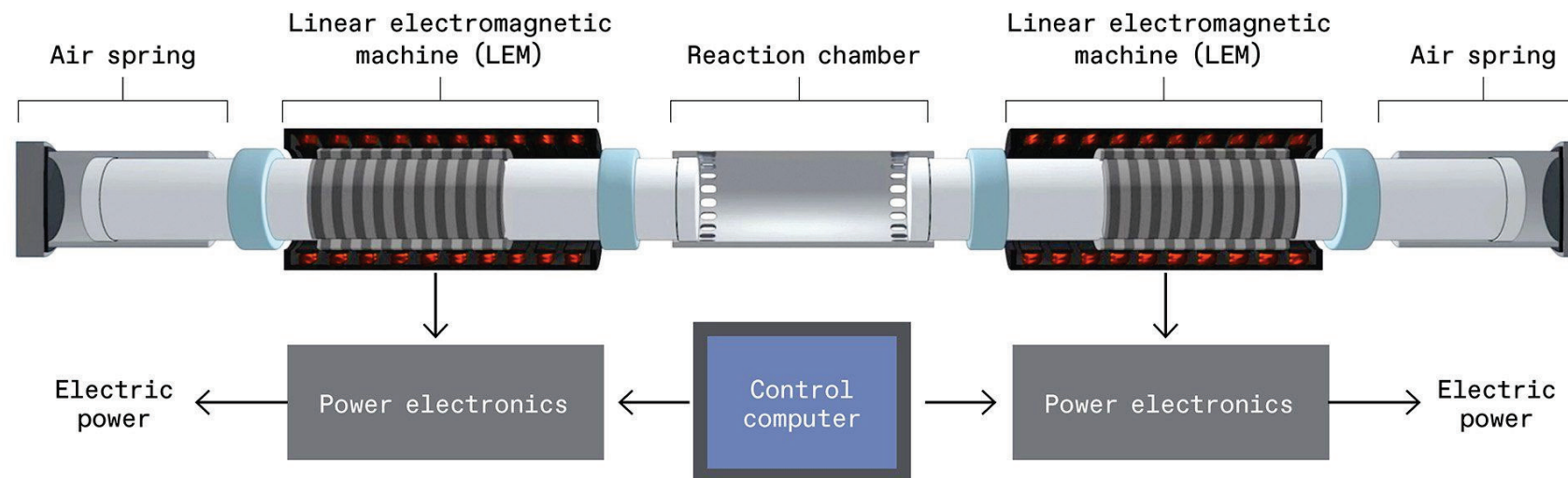
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FPLG today

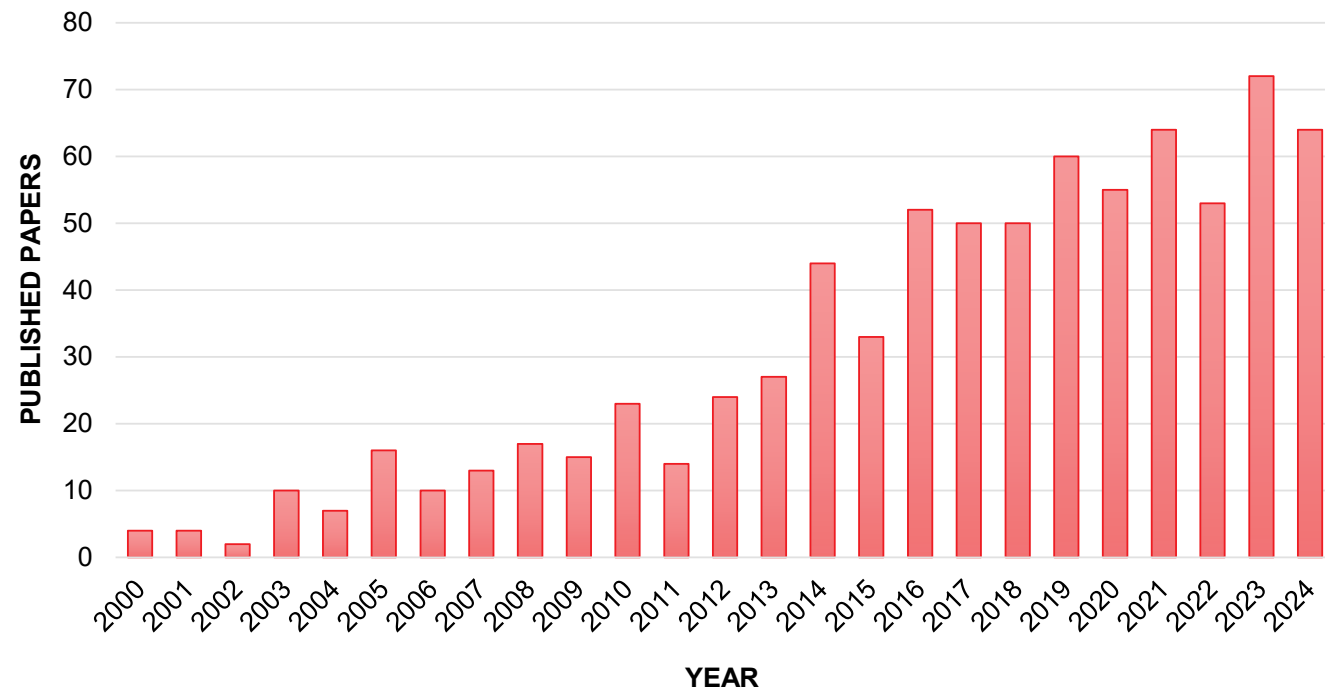
Emerging solution for stationary power generation

- Commercially available, series production;
- Opposed piston unit, operating with HCCI diluted combustion;
- Multi-fuel;
- Modular;
- High efficiency (46%), near zero emissions;
- Current applications: Industrial, Healthcare, Biogas, EV charging, Data Center, Utilities & IPP, Energy Infrastructure.



FPLG research and challenges

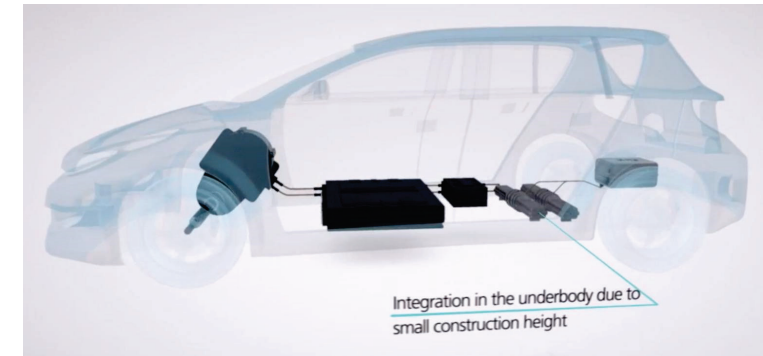
Ongoing research



- Use of alternative fuels (hydrogen, ammonia, methanol)
- Control
- Combustion system
- Configuration (single piston vs opposed-piston)
- Mobility applications
- Main contributors (from 2015): Beijing Institute of Technology, University Teknology Petronas, Chinese Academy of Sciences, Newcastle University

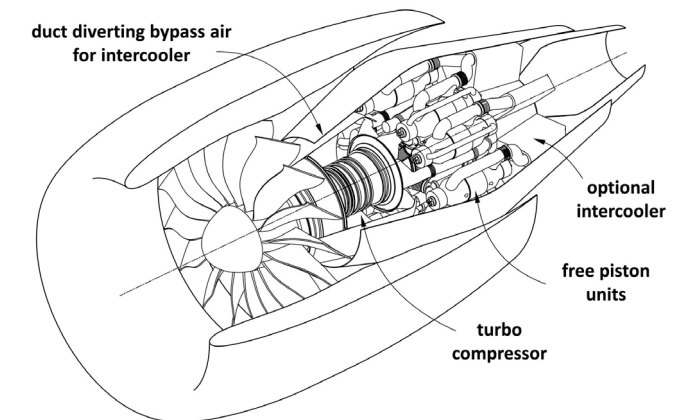
Challenges

Mobility applications:
use in series-hybrid (S-HEV) and E-REV



Source: DLR

Aero-engines:
the free-piston composite cycle



Source: <https://www.minimal-aviation.eu>

FPLG research in Italy



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- Friendly collaboration (started in 2020) involving ICE Group and Electrical Section;
- Integrated model development and validation:
 - Thermal engine (0D);
 - Electrical system (Simulink).
- 4 MSc theses;
- 1 published paper.



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- Funded by MUR focused on fundamental studies of FPLG operation:
 - Combustion system modeling (1D and CFD)
 - Linear generator characterization and modeling



CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

- Advanced modelling of electromagnetic generator
- Design of a prototype FLPG
- Case study analysis of FLPG as range extender application in road and off-road heavy-duty vehicles



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Why this workshop?

- Presenting the FPLG ongoing activities in Italy:
 - Ing. Giancarlo Dellora – STC;
 - STEMS, Politecnico di Milano, Politecnico di Torino – Flex-Gen Project;
 - Politecnico di Milano;
 - Unisannio – Free-Most project.
- Understanding if FPLG is an opportunity for Italy in an open-discussion:
 - Research excellences in IC engines and electric machines;
 - Unique capabilities for fast development of prototypes and components;
 - Availability of biofuels (biogas, HVO);
 - Relevant renewable share in electricity production;
 - Smooth transition towards electrification.



3D

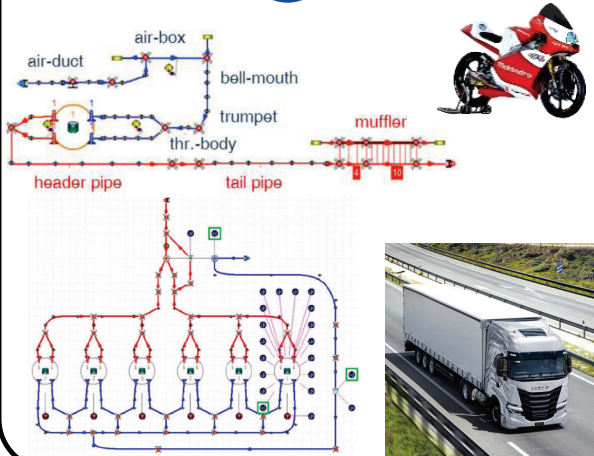
OpenFOAM

Services/Engineering



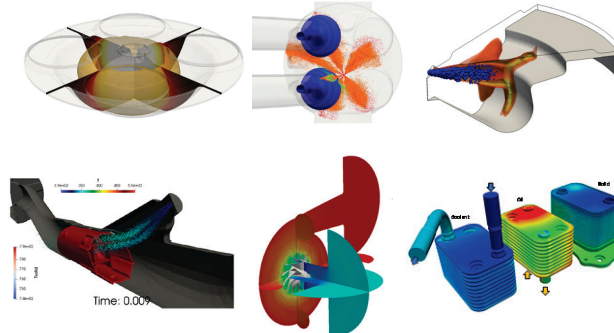
Sursum-Mi
modeling the future

1D



3D

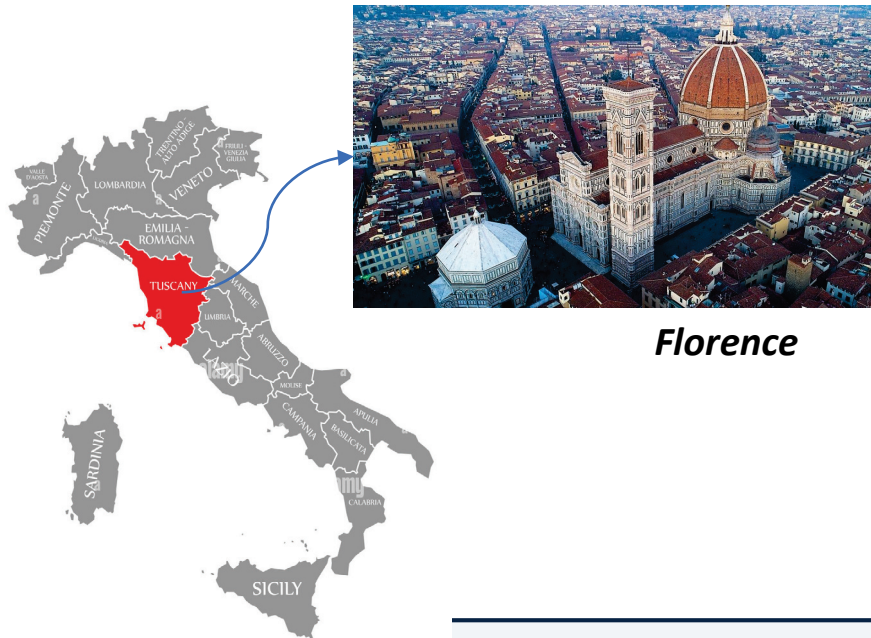
LibICE



- Founded in 2021 by ICE Group
- Industrialization of ICE Group innovative numerical models
- Application of developed tools in different areas
- Involving enterprising, valuable, motivated and skilled students (MSc and PhD)
- Attracting investments from interested entrepreneurs



Small powertrains and Energy systems Technology Conference



Florence

<http://setcflorence.com>



- Abstracts ● 31 January 2025
- Draft papers ● 30 April 2025
- Final Manuscript ● 31 July 2025
- EICMA ● 4-9 November 2025
- Technical Visits ● 10 November 2025
- Conference ● 11-13 November 2025