Finno Exergy's PGC Technology: a novel solution for efficiency improvement and fuel flexibility in gas turbines

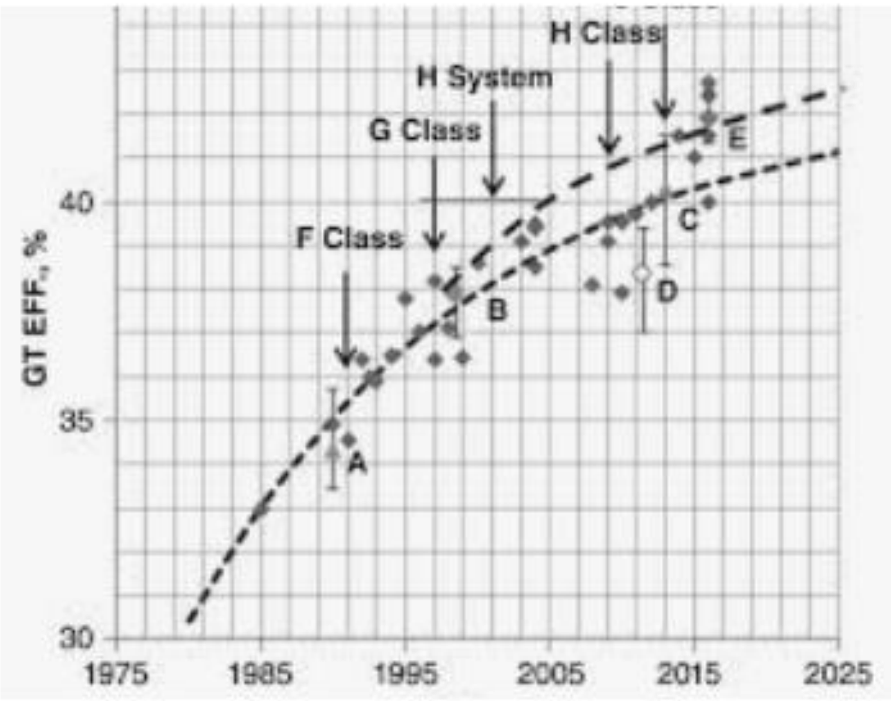
FINNO EXERGY

ENABLING RENEWABLE FUEL TRANSITION FOR GAS TURBINES

Winner of the Shell
New Energy Challenge
2020

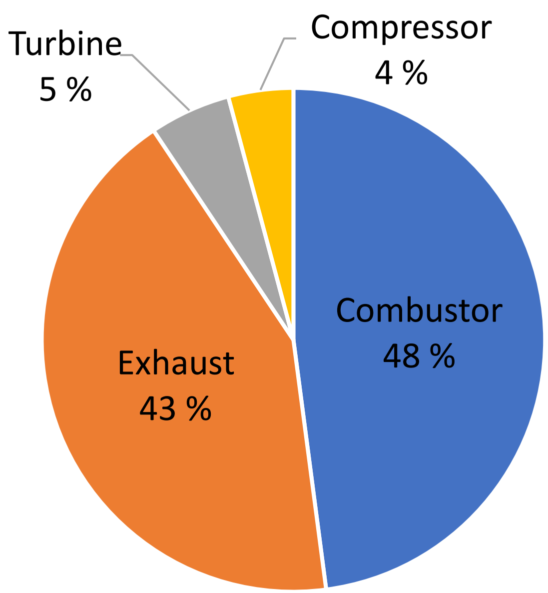
GAS TURBINE EFFICINECY AND EXERGY DESTRUCTION

Gas turbine efficiency evolution



Source: Gülen, S. Can. 2019. Gas Turbines for Electric Power Generation. Cambridge: Cambridge University Press.

Gas turbine exergy destruction (loss of available energy)



Sources: Elfeituri, I.A., 2017, "Exergy Based Performance Analysis of a Gas Turbine Unit at Various Ambient Conditions", International Journal of Energy and Power Engineering

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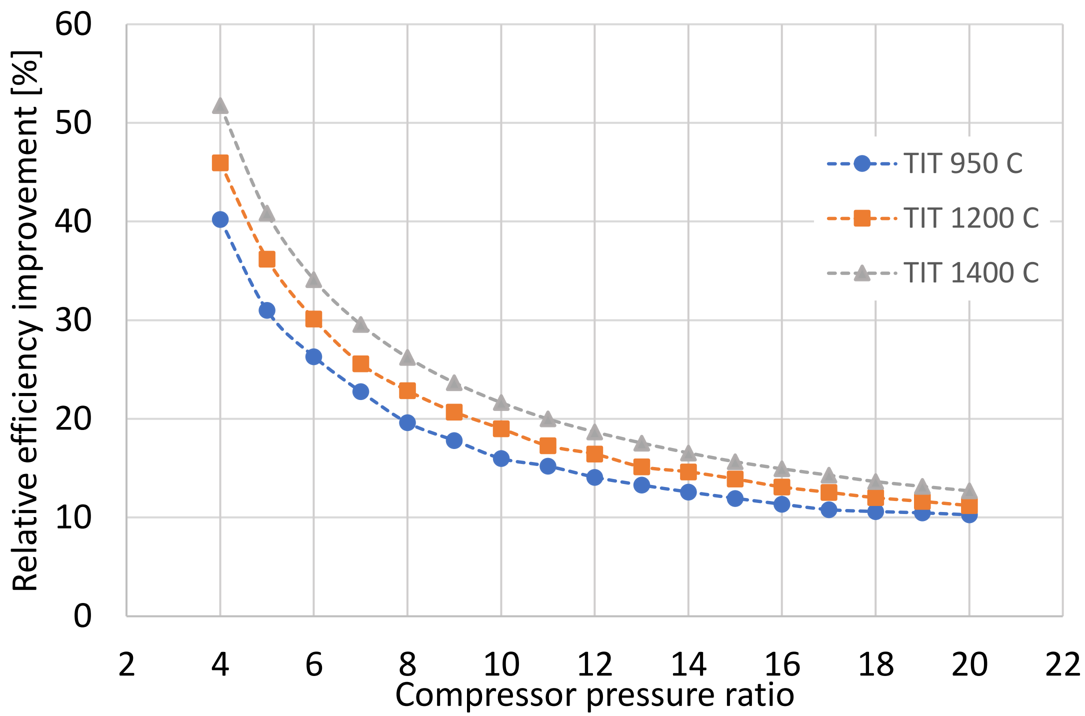
PRESSURE GAIN COMBUSTION

- Replacing Isobaric Heat Addiction with Isochoric Heat Addiction **(Pressure Gain Combustion) will greatly reduce entropy**
- From continues combustion to **periodic combustion.**
- For the same compressor pressure ratio and heat input, **higher turbine inlet pressure**.
- **More power** can be extracted from turbine, for the same amount of fuel burned.

Higher thermal efficiency!

Potential gas turbine efficiency improvement due to PGC*



*Finno Exergy's calculation

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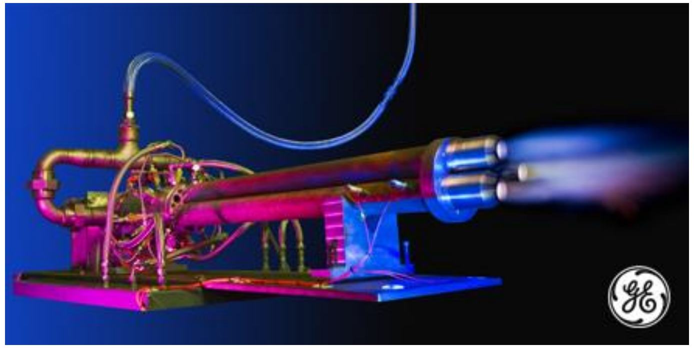
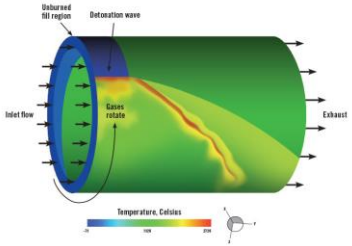
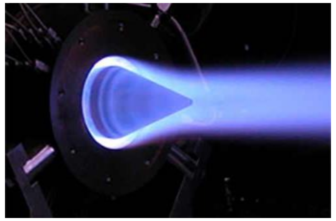
PRESSURE GAIN COMBUSTION

Pulsating detonation engine



Rotating Detonation Engine





DETONATION

DEFLAGRATION

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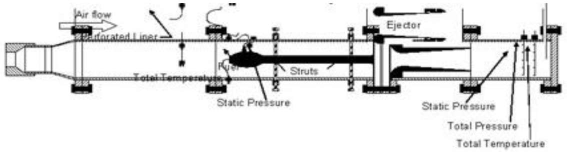
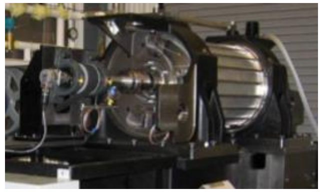


Pulsejet



Constant volume combustion

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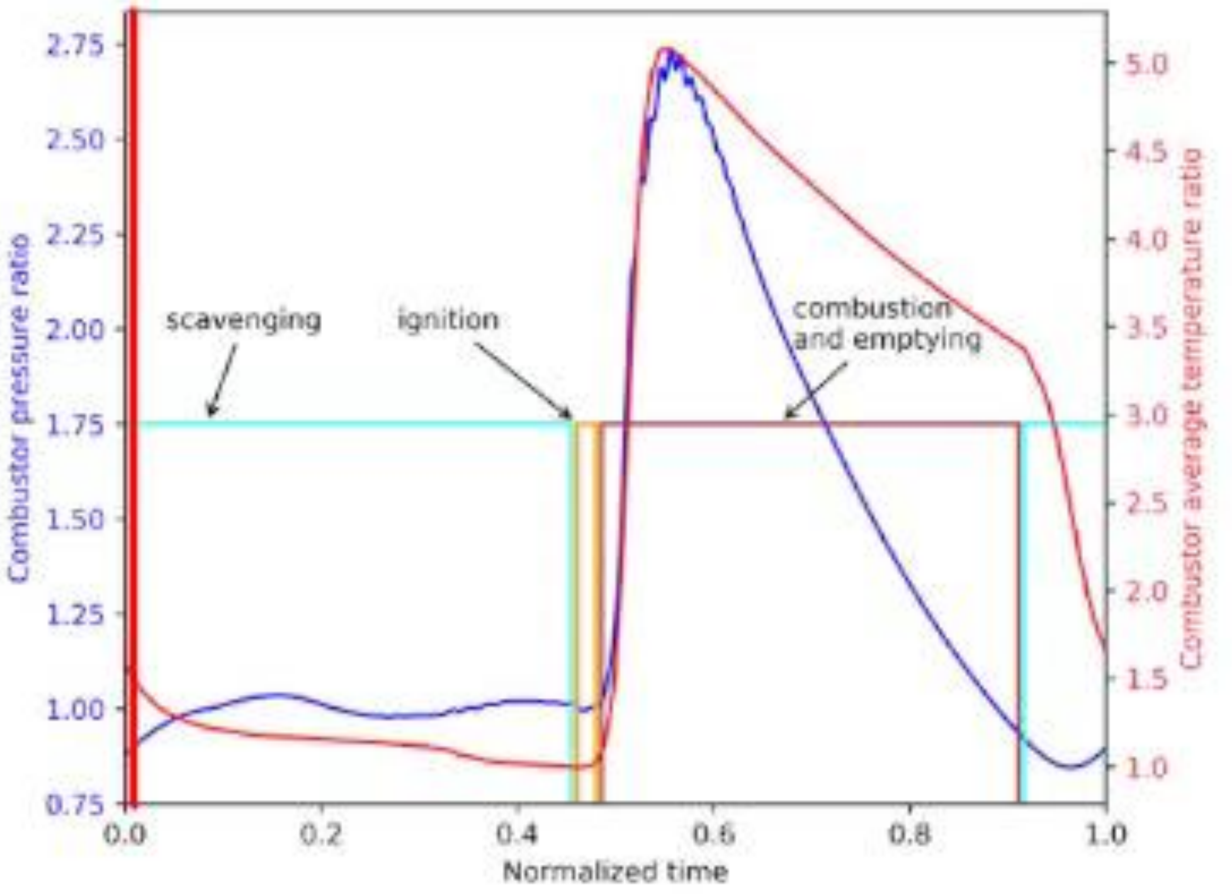
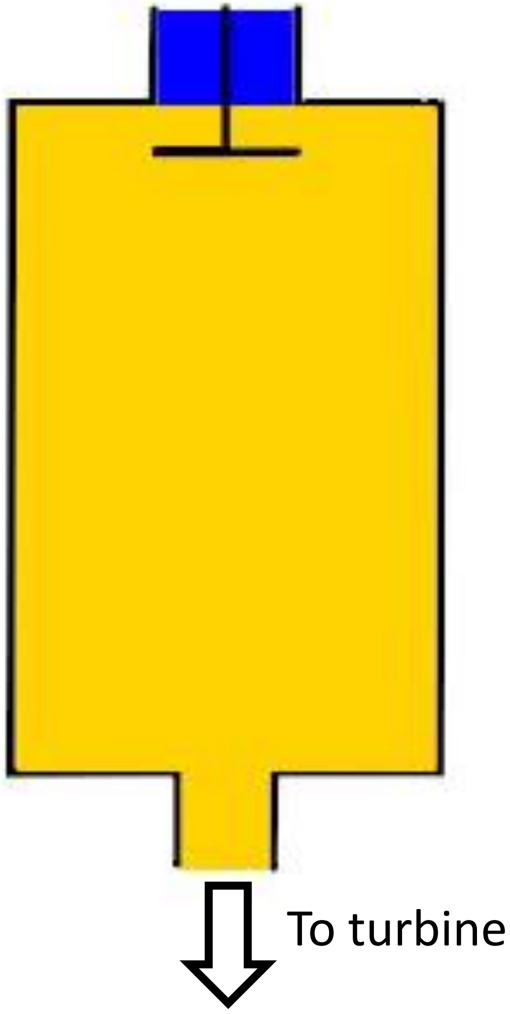
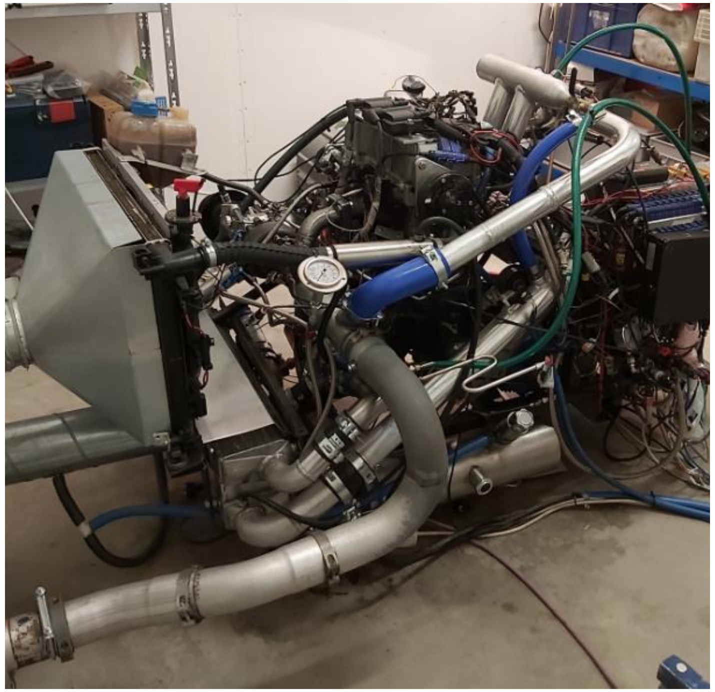
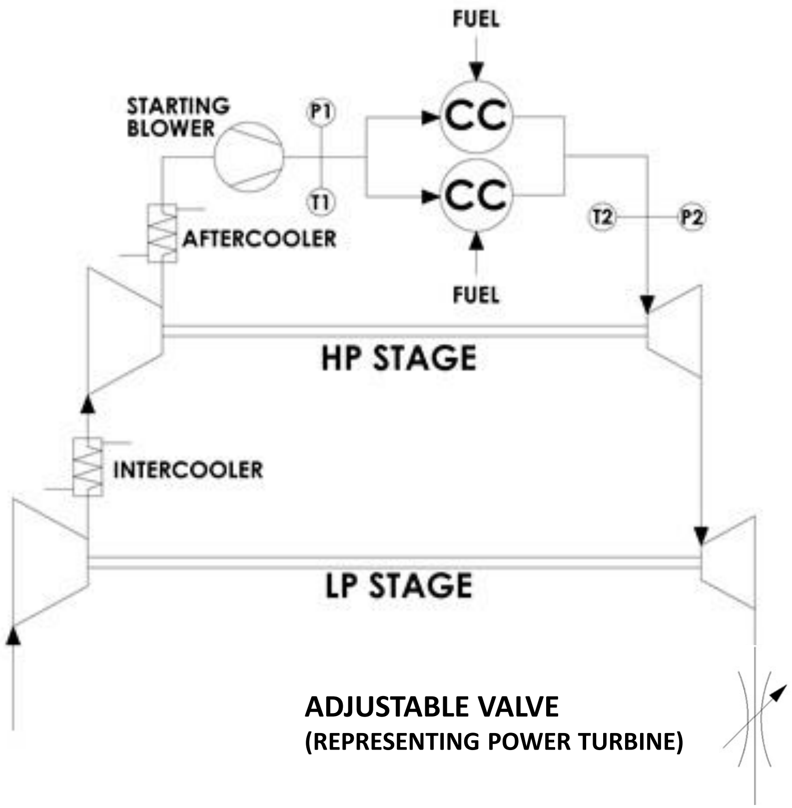
FINNO EXERGY'S PGC TECHNOLOGY BASIC WORKIN PRINCIPLES





PROVE OF CONCEPT TEST UNIT: EXPERIMENTAL FACILITY DESCRIPTION





Main operative parameters for a typical test

Frequency [Hz]	15
Test duration [min]	3-5
Combustor pressure inlet [bar]	4
Turbine inlet temperature [K]	1193
Combustor Temperature Ratio	≈3.2
Air-Fuel Equivalent Ratio (λ)	2.0-2.8
Fuel Power [kW]	≈150
Automotive turbochargers type for LP and HP stages: (Mitsubishi)	TD02-TD04

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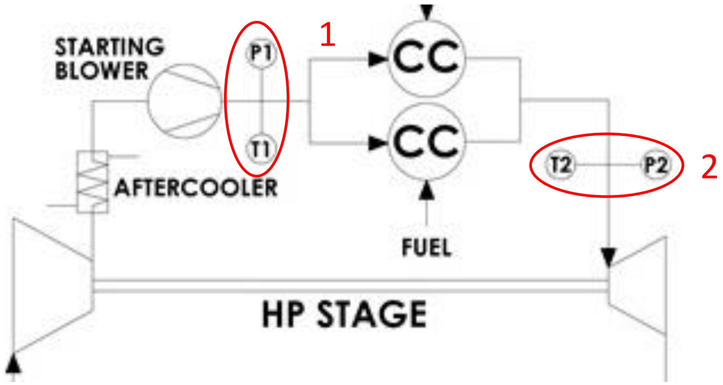
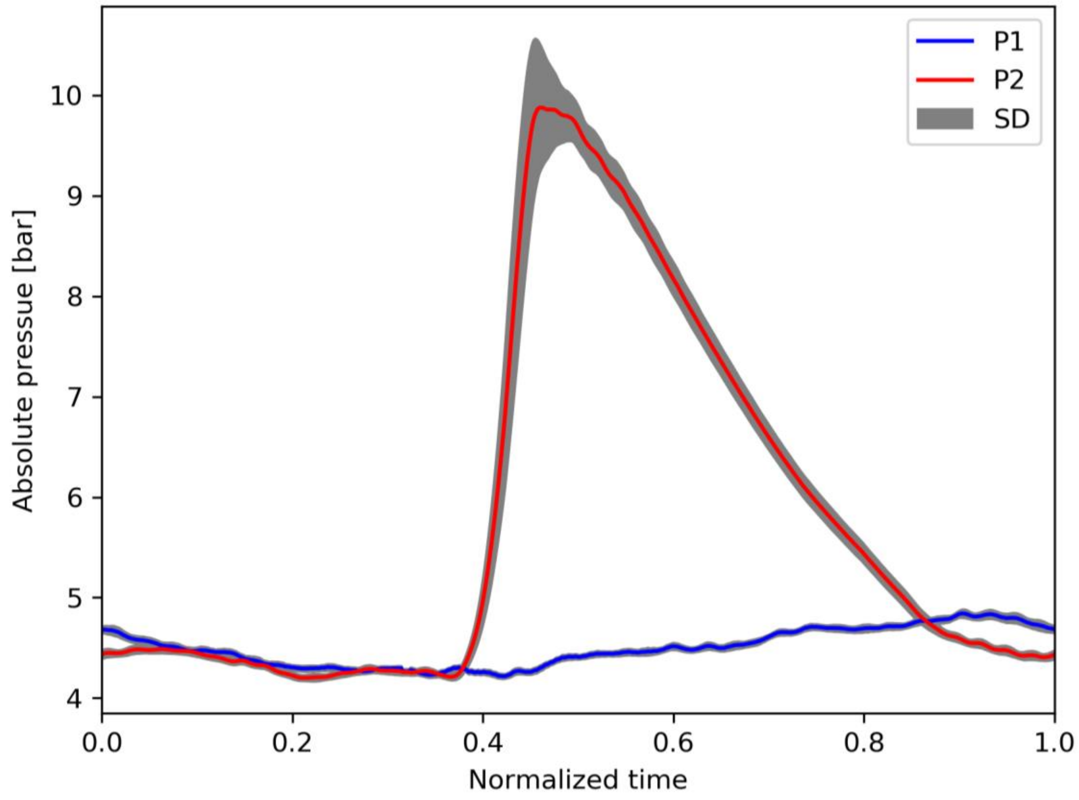
TEST UNIT: ***EXPERIMENTAL RESULTS ON PRESSURE GAIN CAPABILITY***

Operational frequency [Hz]	15
Logging frequency [Hz]	10800
N° of consecutive cycles	300
T_1 [K]	366
T_2 [K]	1222
P_1 [bar]	4.50
P_2 [bar]	5.75
Pressure Gain* [%]	27.9



Highlight of measurement stations 1 and 2

[Experimental Demonstration of a Novel Deflagration-based Pressure Gain Combustion Technology | AIAA Propulsion and Energy Forum]



Cycle average P1 and P2

The red and blue curves are the result of averaging the pressure measured in each point in 300 consecutive cycles. Standard deviation in each point is represented as the grey area in the plot

$$* \, PG\% = \left(\frac{P_2}{P_1} - 1\right) * 100$$

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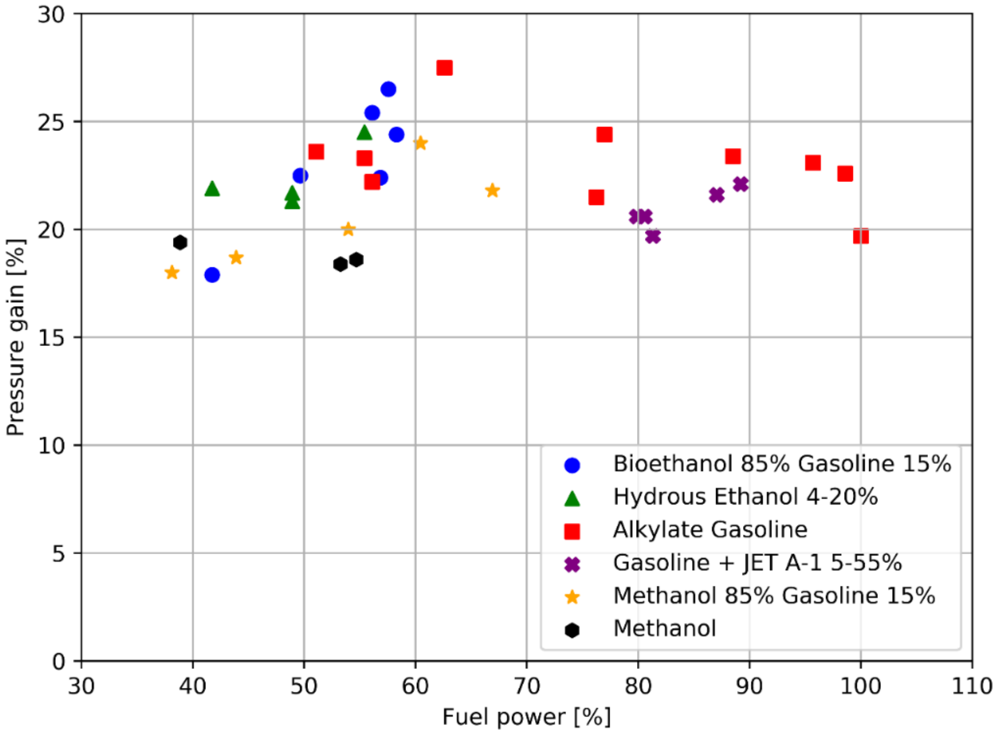
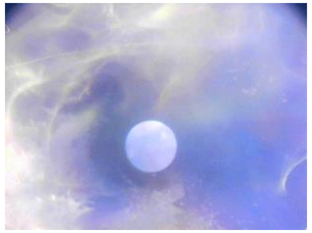
FUEL FLEXIBILITY AND HYDROGEN

Data collected from the test unit



Able to sustain pressure gain level over 20% with different setups, operating points, and types of fuel

Inside the combustor



Bioethanol

Methanol

Alkylate gasoline

Perfectly suited for hydrogen

- Pressure gain combustion technology are commonly operated on hydrogen.
- Finno Exergy's combustion system contains functions which enables extreme fuel flexibility

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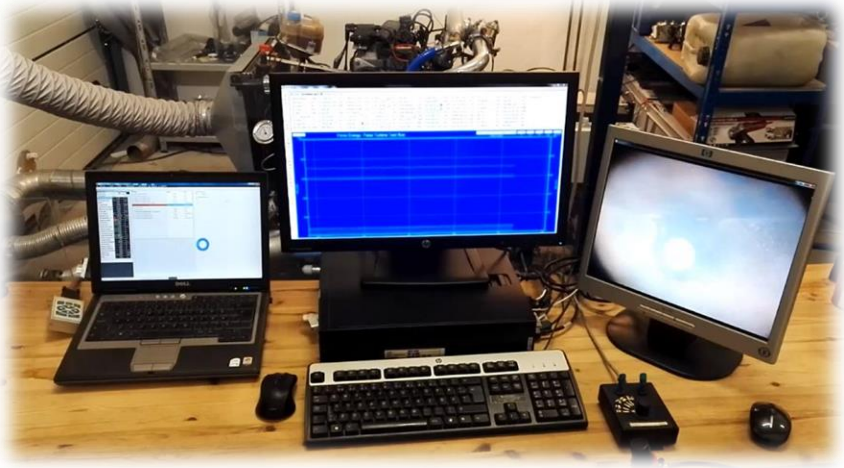
NEW ENERGY CHALLENGE



Finno Exergy won the Shell New Energy Challenge 2020

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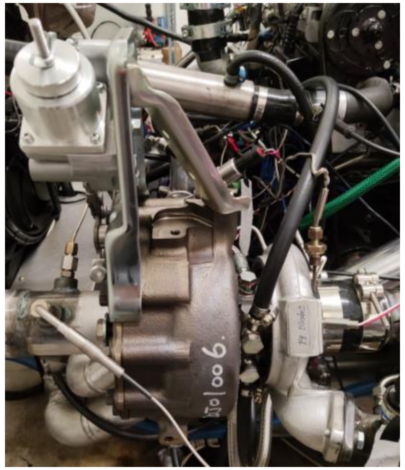
NEW ENERGY CHALLENGE 2021: PROJECT RESULTS

12 months

- **Extract power from the test unit** ✓
- **Measure turbine efficiency and identify eventual losses** ✓
- **Optimize the system for highest efficiency and compare it with an equivalent traditional gas turbine** ✓

PROVE HIGHER GAS TURBINE EFFICIENCY IN A SMALL-SCALE APPLICATION



↑ 39.5% MORE EFFICIENT

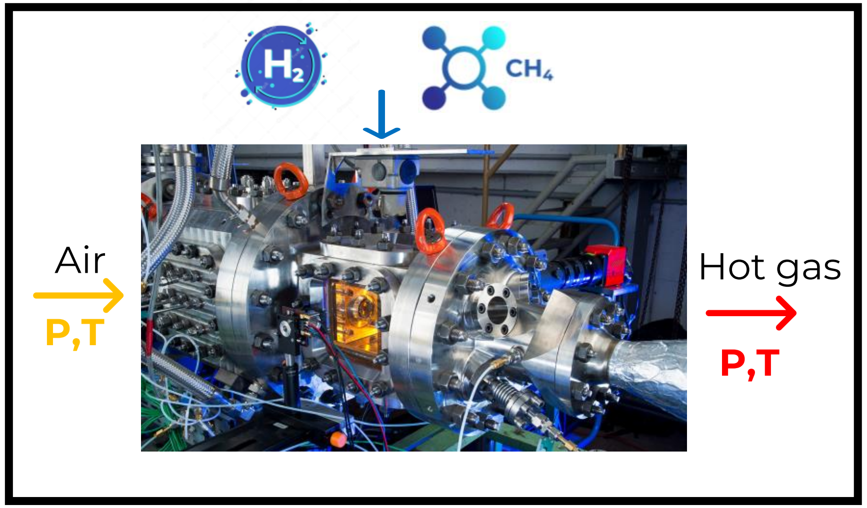
SHELL GAME CHANGER PROJECT

18 months

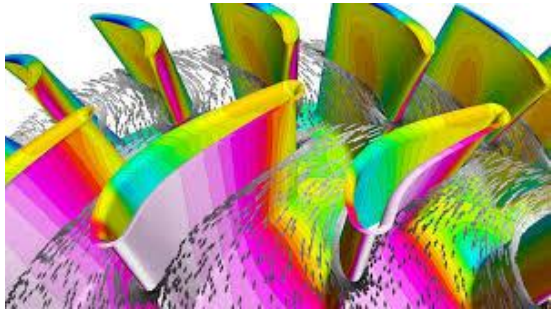
- Project planning and design of new test rig
- Combustor test in new lab in Finland
- Retrofitting analysis and start commercial discussions with GT OEMs

PROVE HYDROGEN METHENE FUEL FLEX

TECHNOLOGY DEVELOPMENT ROADMAP FOR RETROFITTING



TEST RIG IN HELSINKI



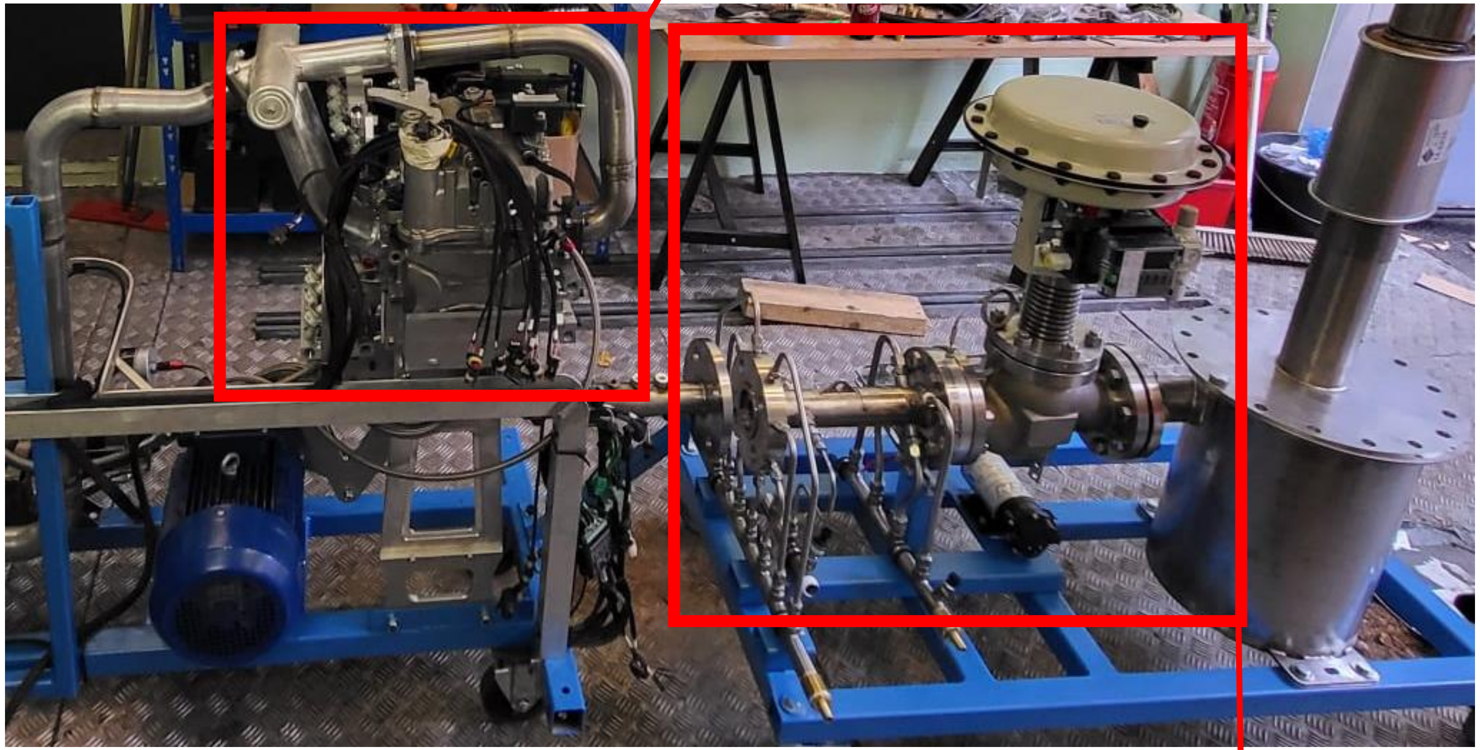
RETROFITTING SIMULATIONS

START COMMERCIAL RELATION WITH GT OEMS

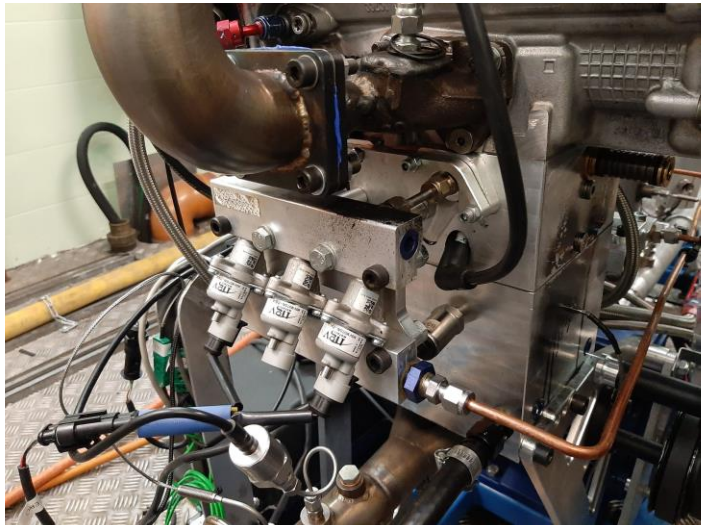
COMBUSTOR AND TEST RIG UPGRADE

New test rig

Improved combustor design



New hot section to simulate the presence of a GT



New H2 and CH4 fuel system

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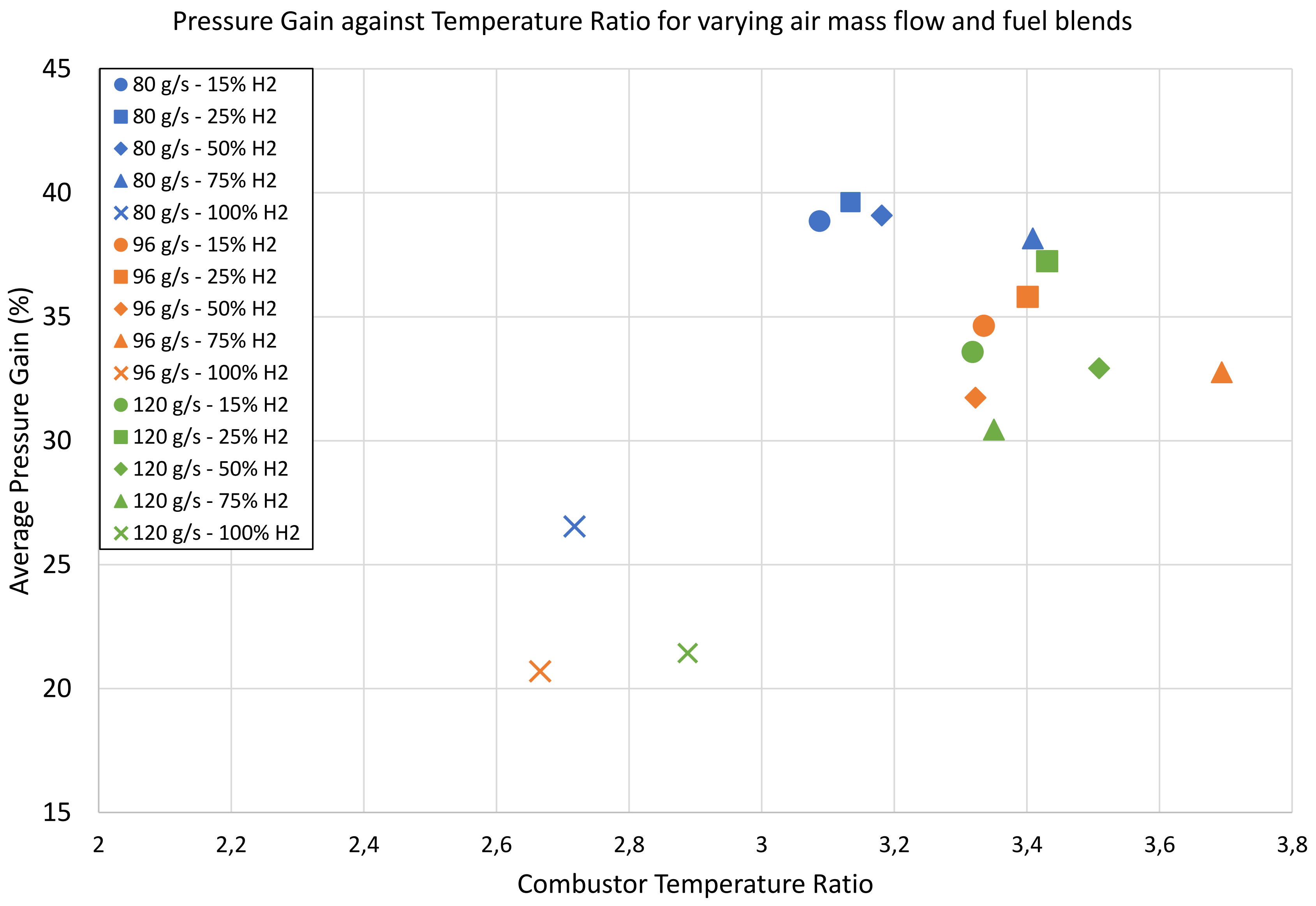
EXPERIMENTAL TEST RESULTS



An ideal industrial gas turbine with or without FE PGC system

	FE-PGC	Brayton
Compressor work [kW]	50,7	50,7
Heat input [kW]	100,8	100,8
Extracted turbine's work [kW]	87,0	81,1
Turbine efficiency	0,88	0,88
System thermal efficiency	36,0	30,2

Potential for 20% reduction in fuel consumption

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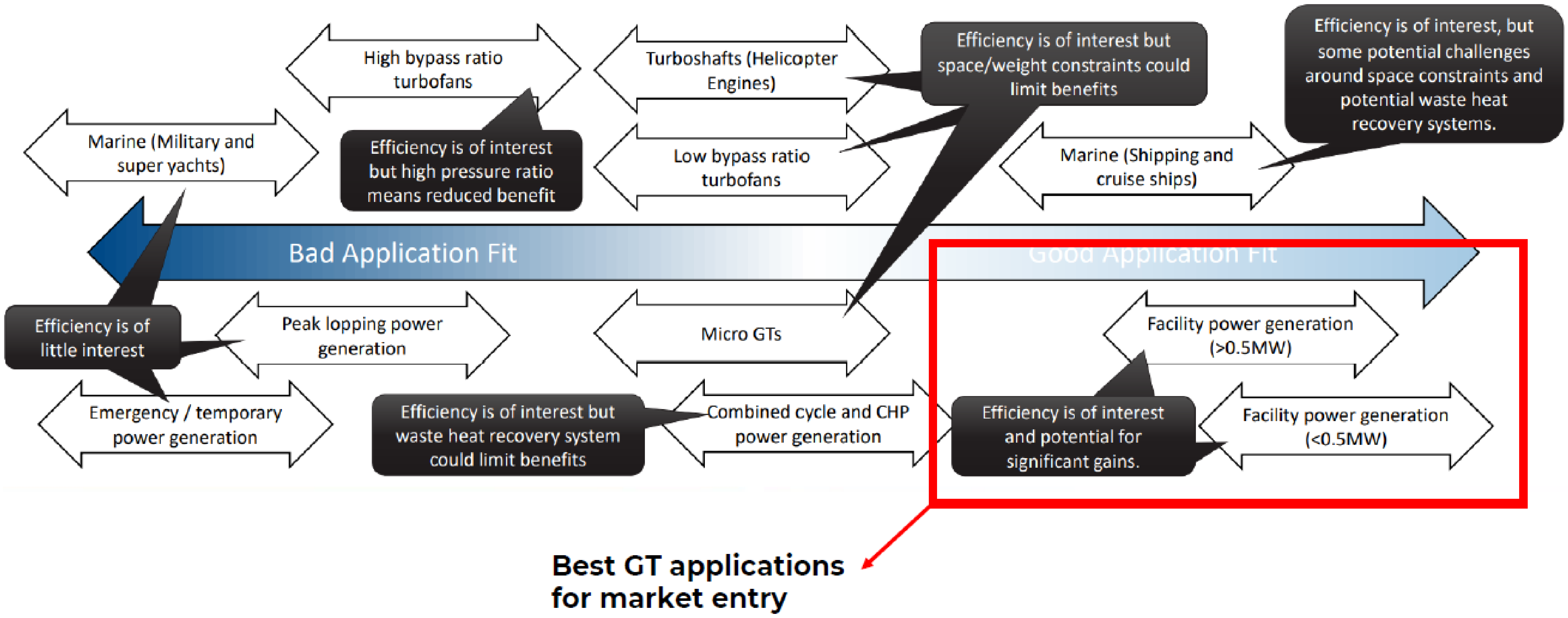
MARKET STUDY RESULTS



MAJOR TECHNICAL RISK FOR RETROFITTING

Integration challenges

- Mechanical vibration (High Risk)
- Axial load balancing (High risk)

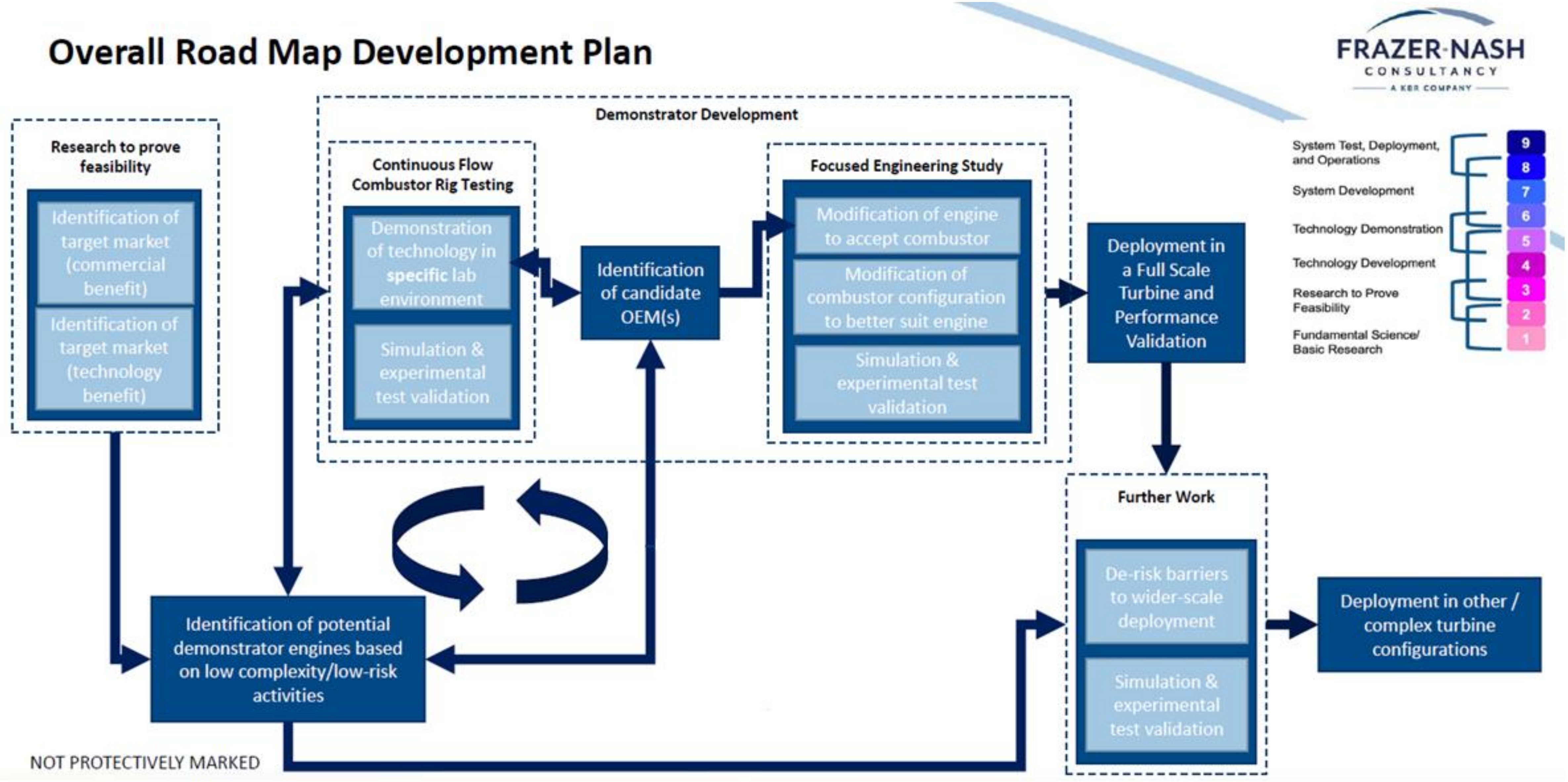
- Bearings life and lubrication (Medium Risk)
- Turbine cooling (Medium Risk)
- Compressor surge and stall (Medium risk)
- Reliability of valves and ignition sources and fuel injectors (Medium Risk)
- Material degradation (Medium Risk)
- Turbine performance (Low Risk)

Best GT candidates for first retrofit (examples)

Solar Saturn

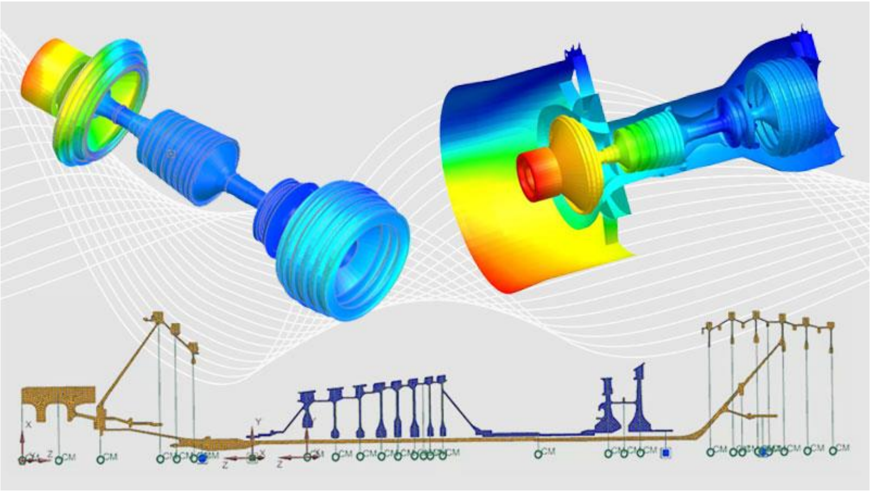
MAM MGT6000

TECHNOLOGY DEVELOPMENT ROADMAP

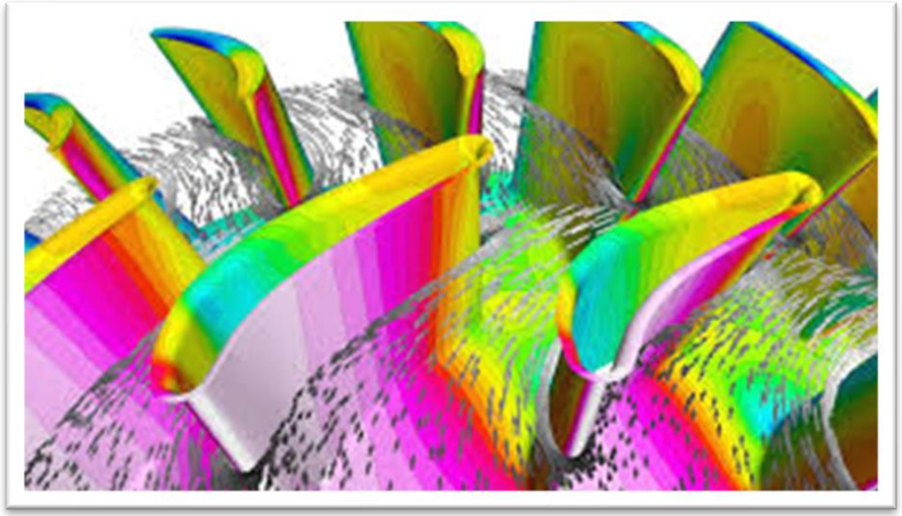


NEXT TECHNOLOGY DEVELOPMENT PROJECT

FINNO IS STARTING A NEW PROJECT IN COLLABORATION WITH SHELL, GAS TURBINE'S OEMS, UNIVERSITIES AND SPECIALIZED RESEARCH CENTER



The project will use rotordynamic models, 1D and 3D CFD models to simulate the effect of integrating Finno Exergy's PGC system in one selected industrial Gas Turbine.



The objectives will be:

- **Calculate overall GT efficiency improvement / power increase**
- **Verify mechanical integrity of the retrofitted GT**
- **Calculate cost of GT retrofit**

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LONG TERM DEVELOPMENT PLAN

2023-2024

- Turbine Retrofitting Simulations

Objectives:
- Simulated the integration of Finno Exergy's combustor with one selected industrial gas turbine
- Prove by simulation potential of 20% reduction of fuel consumption
- Estimate the cost of retrofit

2024-2026

- Lab Test of singular components

Objectives:
- Scaled up combustor and interfacing components tested in lab conditions equivalent of the industrial gas turbine application

2026-2027

- Gas Turbine Demonstrator

Objectives:
- Industrial gas turbine demonstrator retrofitted and tested in operational environment

>2027

- Market entry

Objectives:
- Industrial gas turbine retrofitted and tested in field operations
- Retrofitting package technology validated in field operation

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ETN Global

Thank you for your attention