Number of buildings in europe

160 million

BUILDINGS ACCOUNT FOR

[40%]

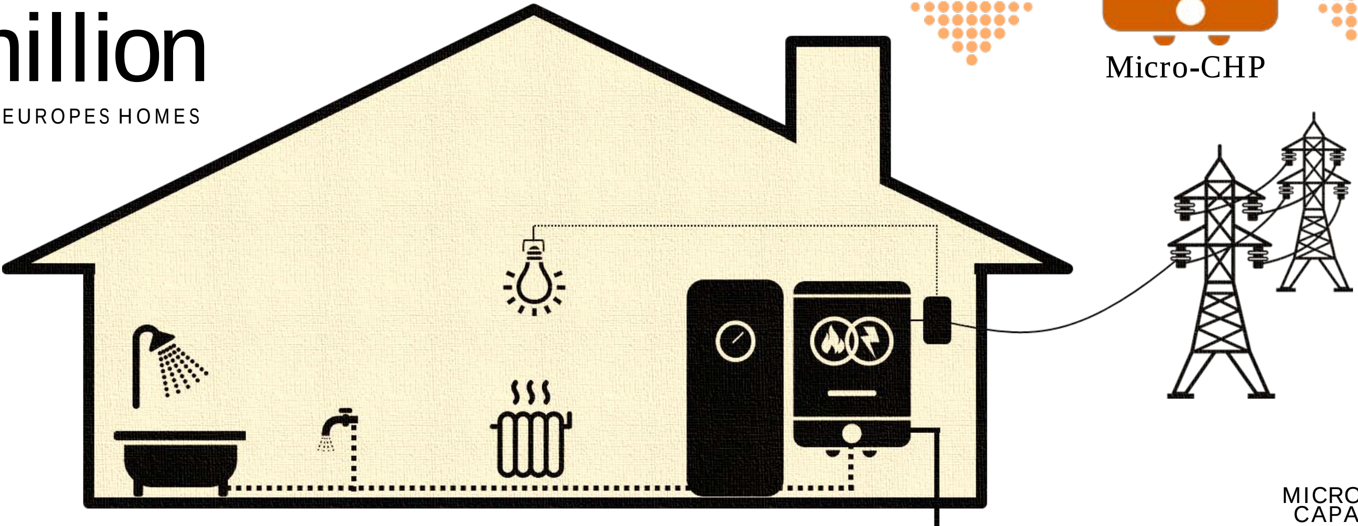
100 million

GAS BOILERS INSTALLED IN EUROPES HOMES

~38% GHG emission reduction

Micro-CHP

Cuts energy bills by 25% to 34%



GLOBAL ANNUAL MICRO-CHP SALES

14%

14% OF GLOBAL MICRO-CHP SALES ARE IN EUROPE ALMOST ALL THE REST ARE IN JAPAN

MICRO-CHP: DISTRIBUTED HEAT AND POWER GENERATION

MICRO-CHP IS CAPABLE OF

BALANCING RENEWABLES

8 million

GAS BOILERS SOLD ANNUALLY IN EUROPE

FUDIPO learning system for Micro-CHP fleet monitoring.

(Optimal Control, Diagnostics and Decision Support System)

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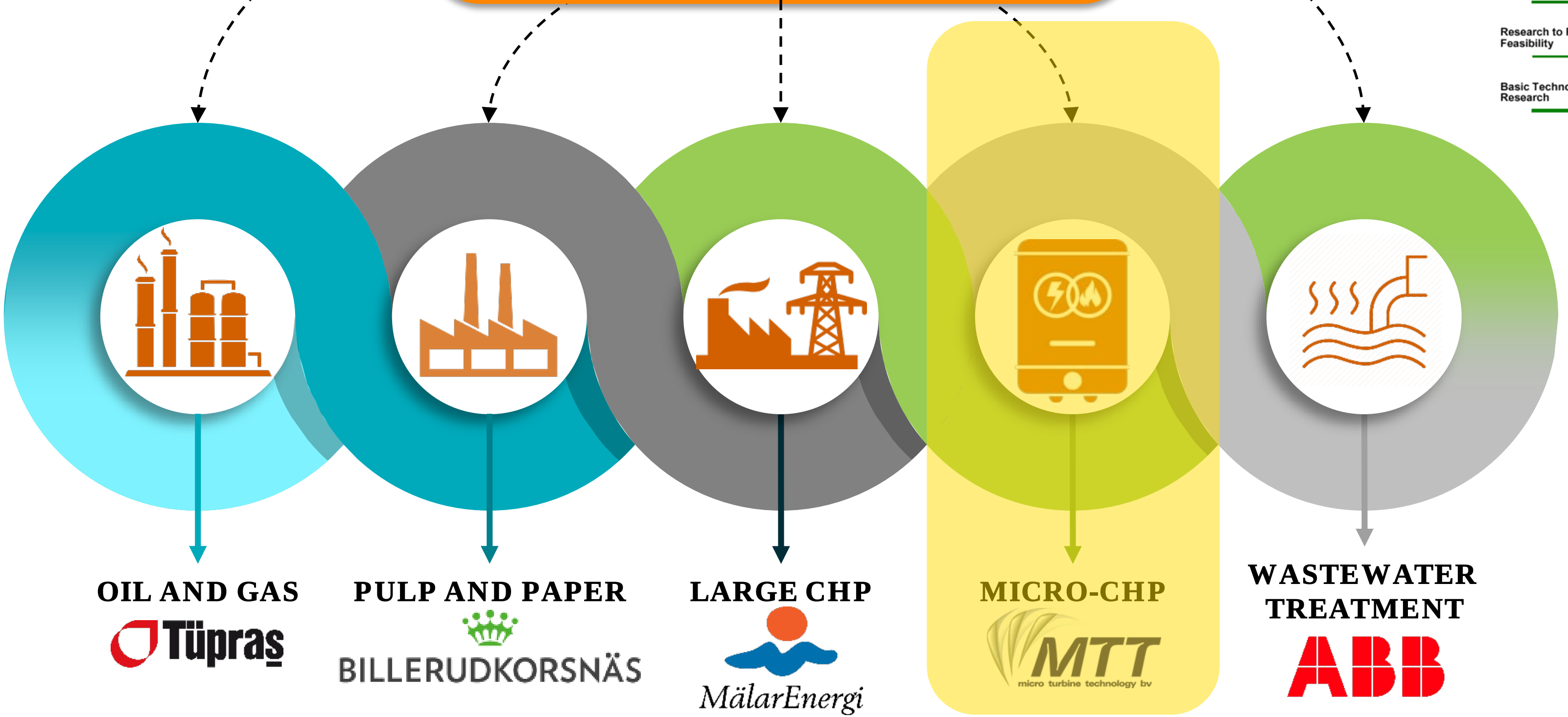
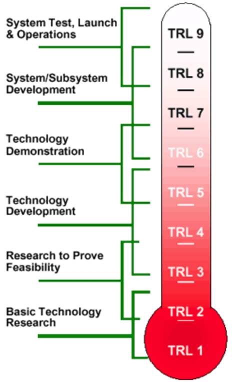
Mälardalen University

Funded by the Horizon 2020
Framework Programme of the
European Union

FUDIPO

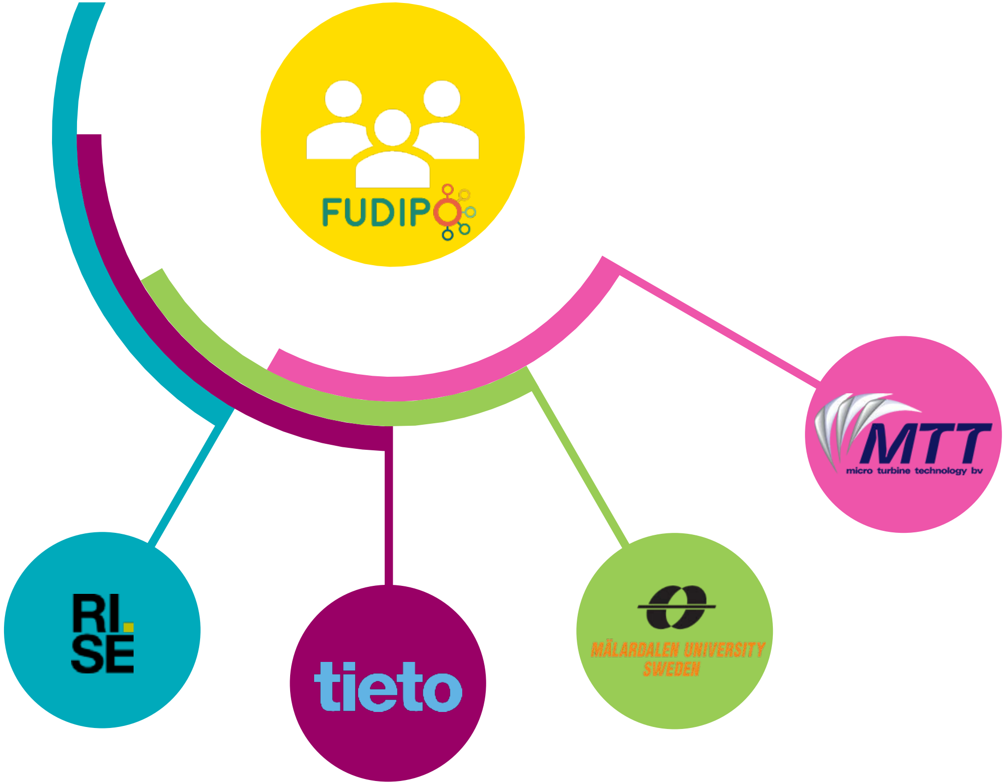
Start date	1st October 2016
Duration	48 months
Budget	5,740,676.25 €
Coordinator	Prof.Erik Dahlquist, MDH





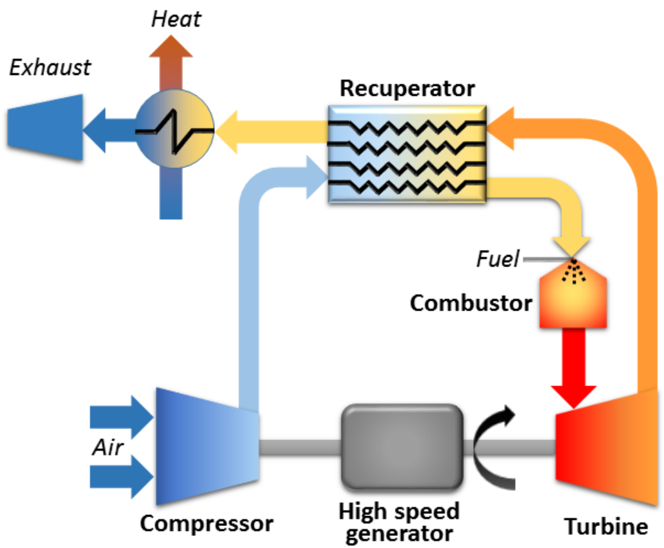
FUDIPO Micro-CHP Demonstrator

Decentralised heat and power generation:



The big picture

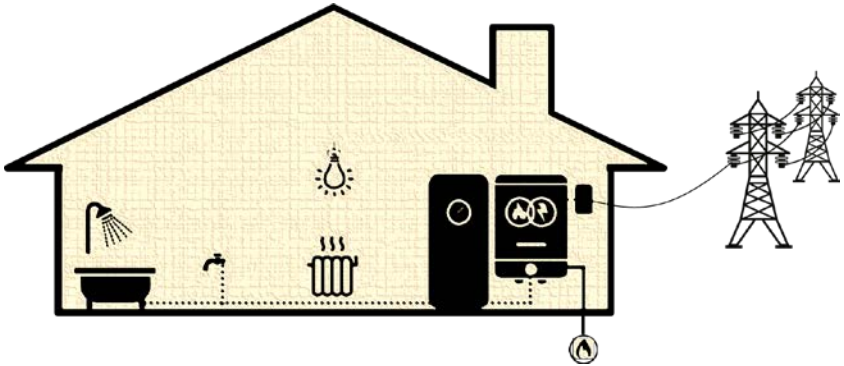
Micro gas turbines for CHP application:



Net electrical output:	3.2 kWe
Net thermal output:	17 kWth
Net electrical efficiency:	12%
Fuel:	NG
Shaft speed:	240 krpm

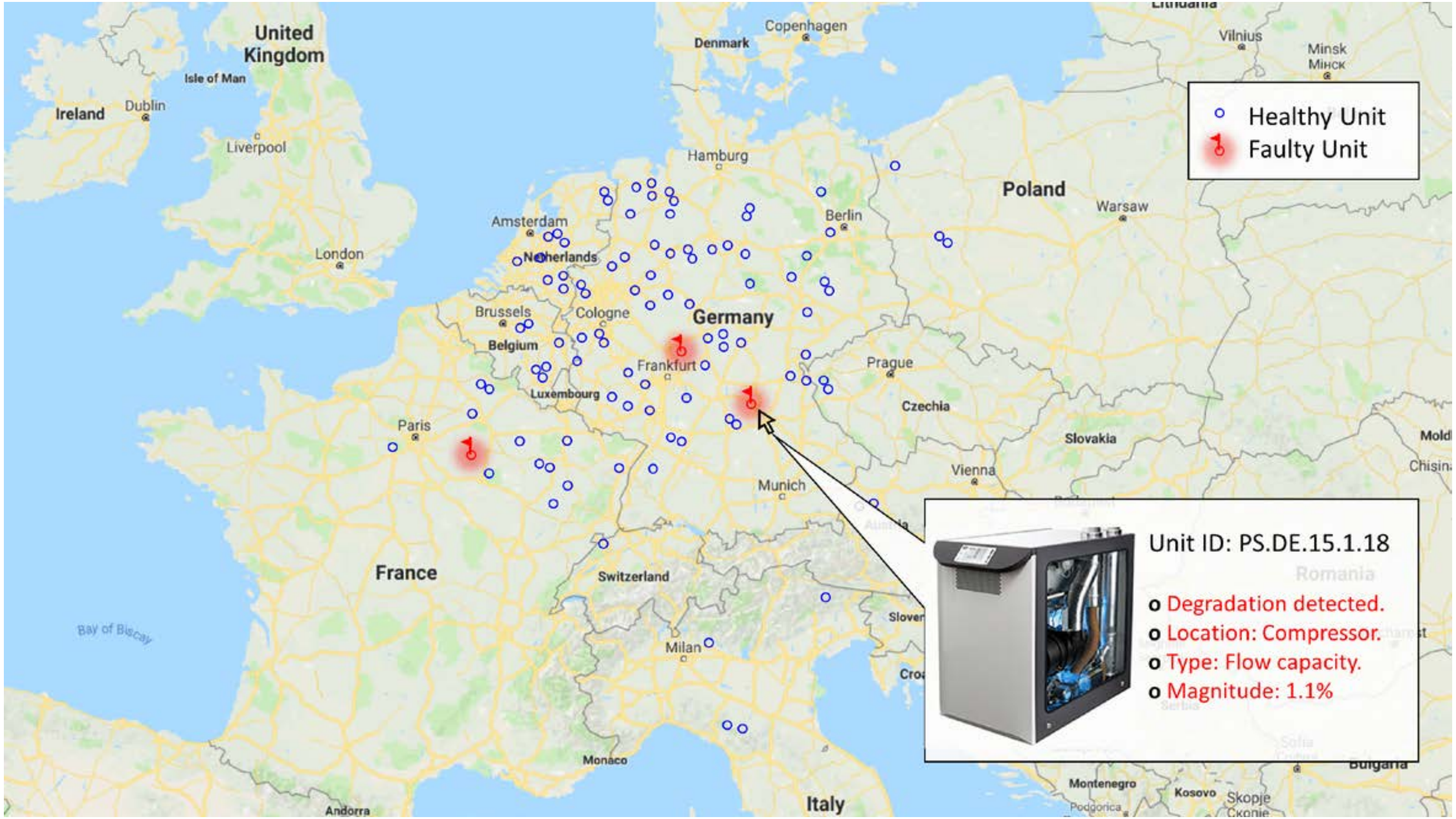
Barriers

Hindering mass adoption:



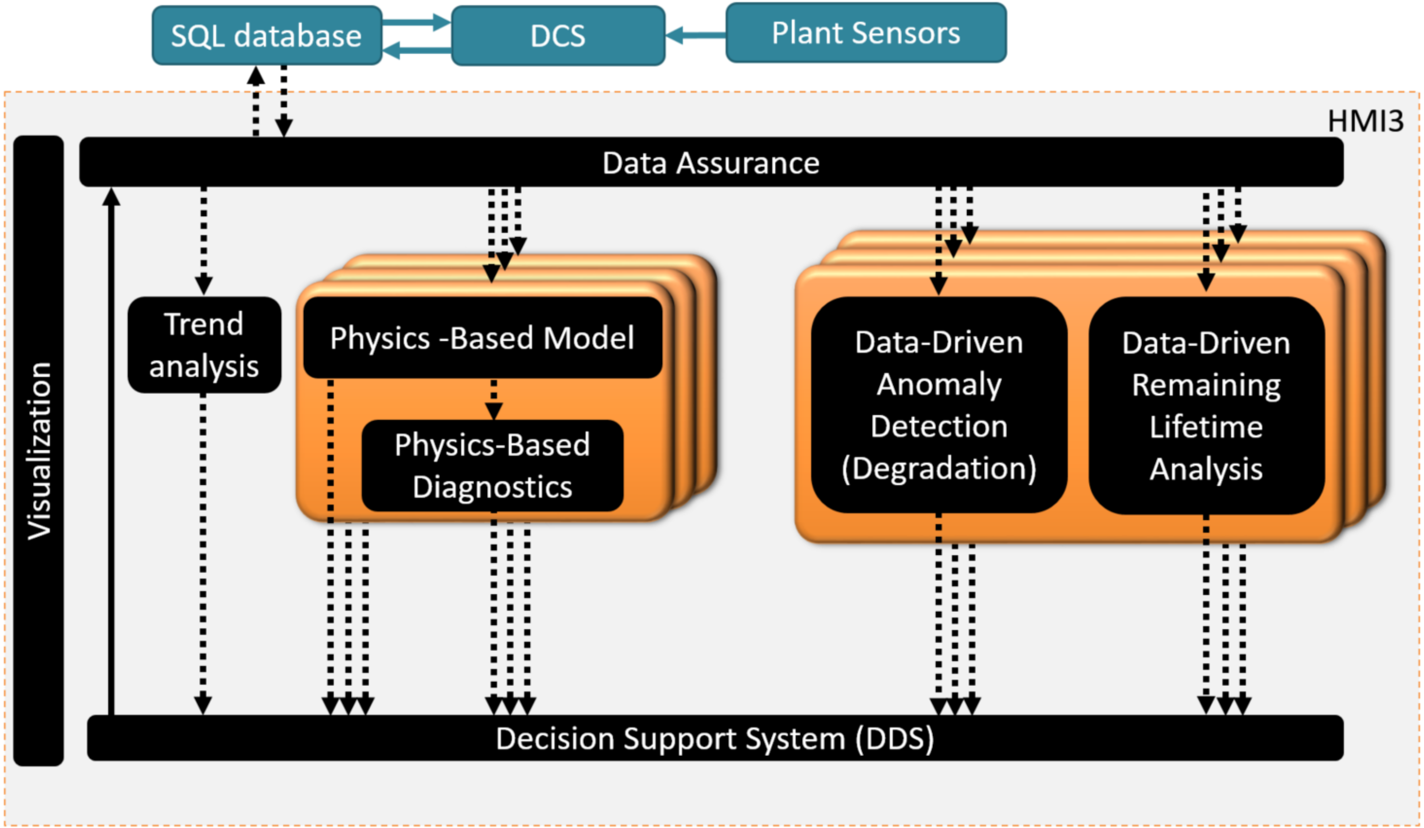
Our Solution

Fleet monitoring and Maintenance optimization:



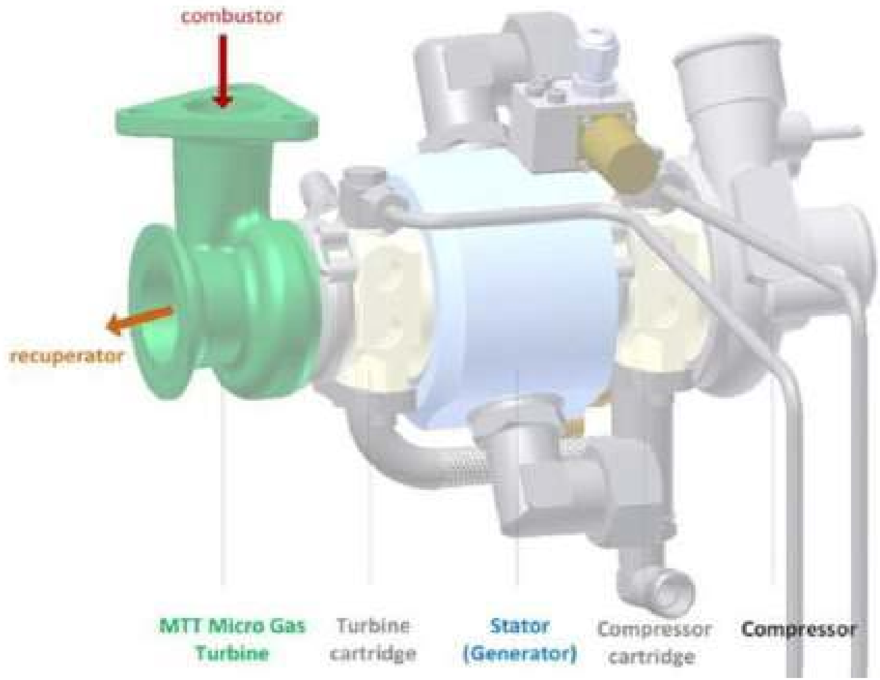
Learning system architecture

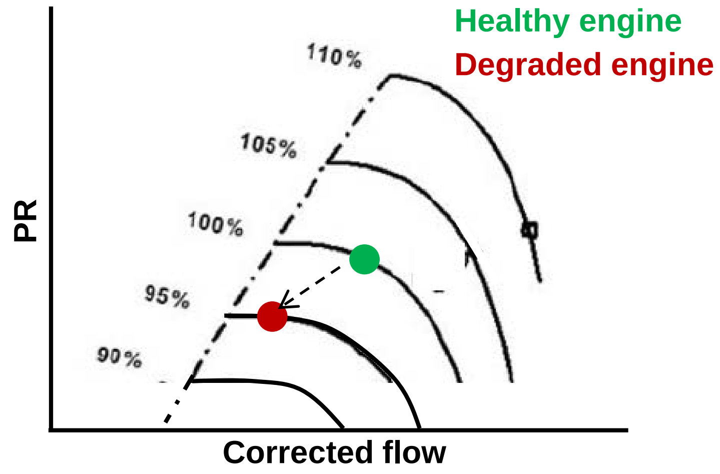
Components and interfaces:



Common faults and deterioration

Micro gas turbines:





fouling

erosion

creep

Increased clearance

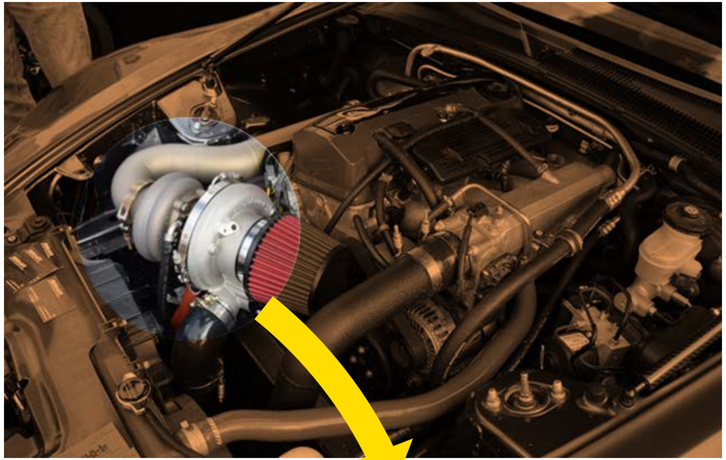
abrasion

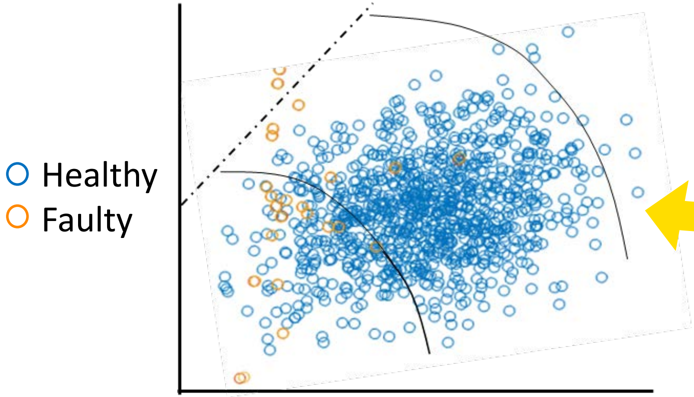
hot corrosion

Physics-based diagnostics

Challenges and opportunities:

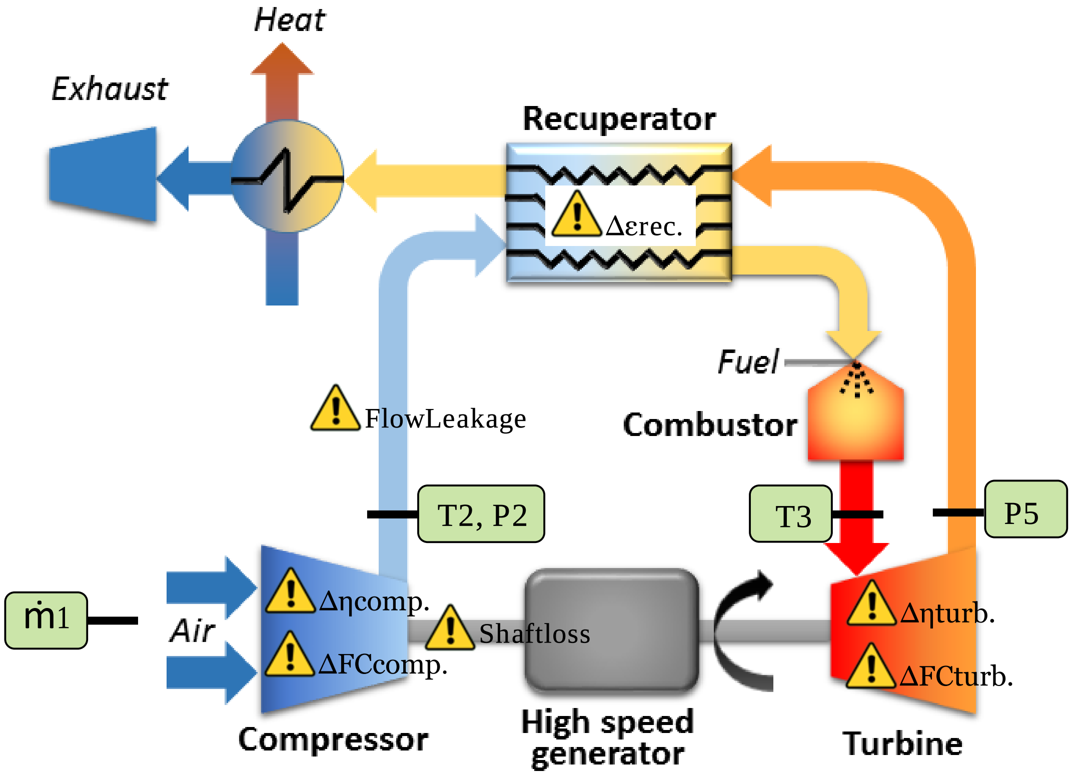
- COTS components>>automobile turbo-charger industry.
  - \+ High reliability.
  - \+ Low cost.
  - – High production tolerances.
  - – Not optimized for micro-gas turbines.
- Engine to Engine variation.
  - o Model tuning.





Physics-based diagnostics

Problem space:

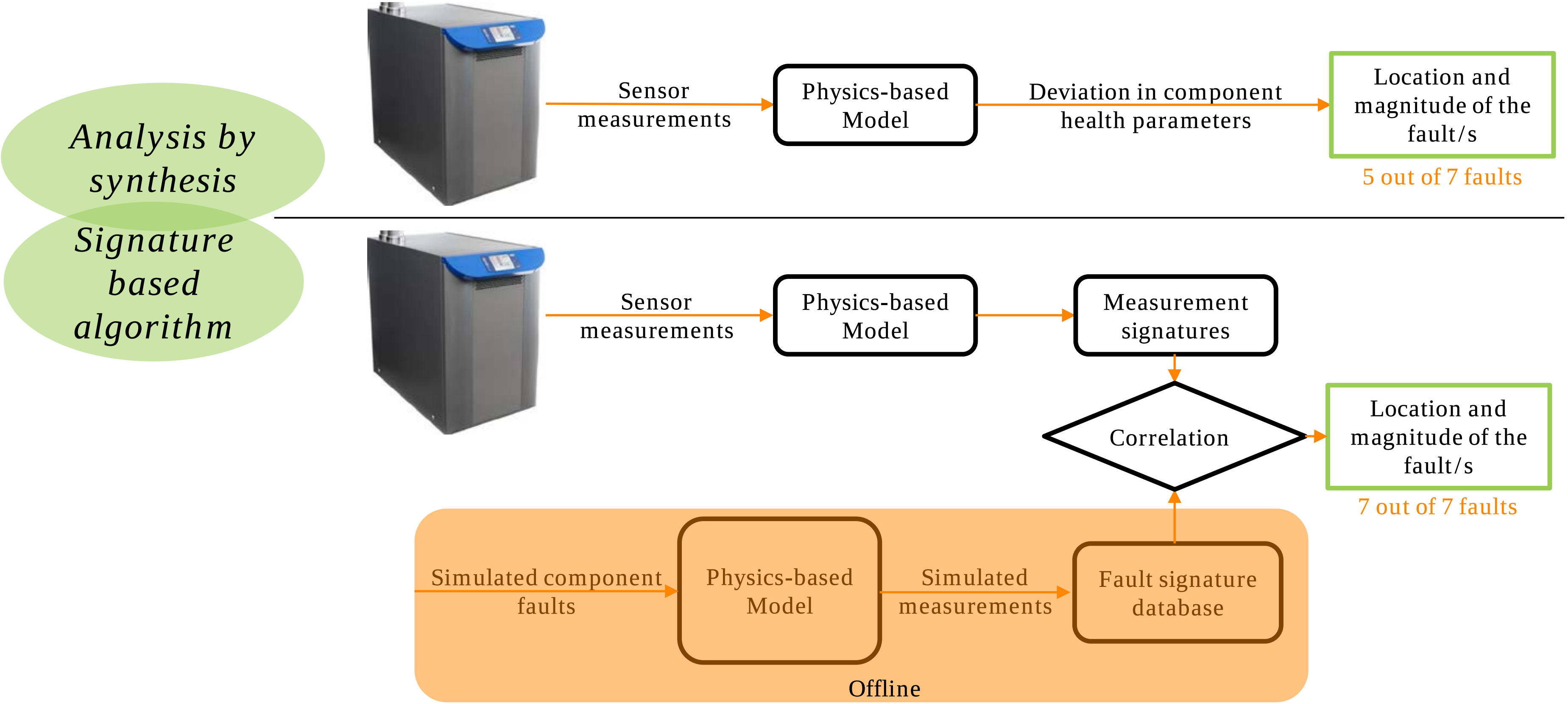


7 different types of faults

5 different measurements

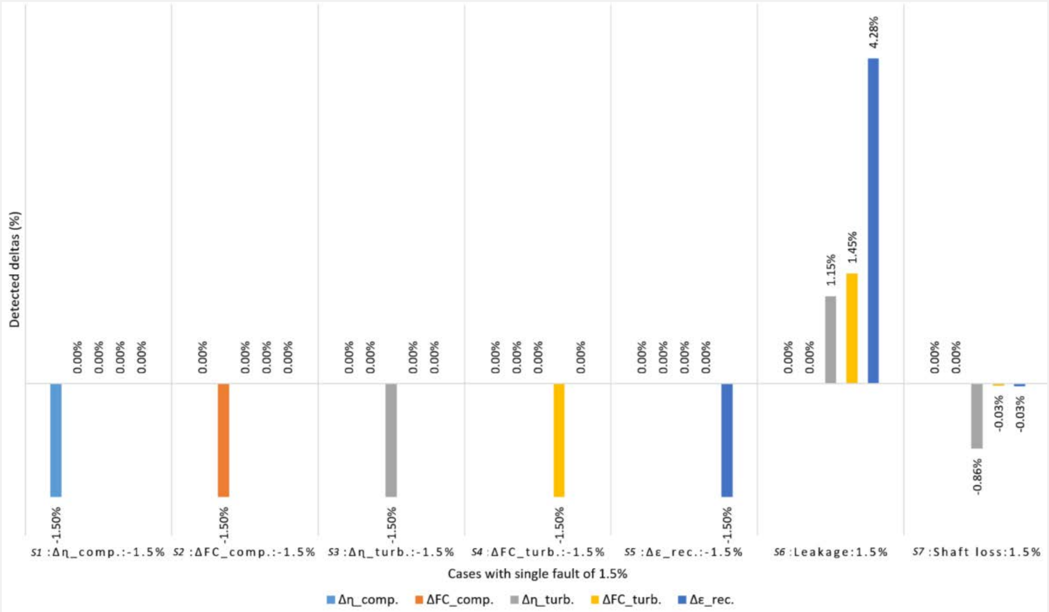
Physics-based diagnostics

Scheme:



Physics-based diagnostics

Results: Single faults:



Fault location and severity for cases with single faults detected by AnSyn.

Correlation coefficients for cases with single fault.

Cases	Correlation between exchange rates and signatures for cases with single fault						
	$-1\%\Delta\eta_{comp.}$	$-1\%\Delta FC_{comp.}$	$-1\%\Delta\eta_{turb.}$	$-1\%\Delta FC_{turb.}$	$-1\%\Delta\varepsilon_{rec.}$	1%*Leakage*	1%*Shaft loss*
S1	**1.000**	0.693	0.783	0.496	-0.754	0.129	0.790
S2	0.694	**1.000**	0.863	0.505	-0.815	0.134	0.869
S3	0.784	0.863	**1.000**	0.247	-0.994	0.476	0.997
S4	0.497	0.506	0.248	**1.000**	-0.145	-0.733	0.268
S5	-0.754	-0.814	-0.994	-0.144	**1.000**	-0.565	-0.992
S6	0.127	0.135	0.477	-0.733	-0.566	**1.000**	0.459
S7	0.790	0.869	0.997	0.267	-0.992	0.457	**1.000**

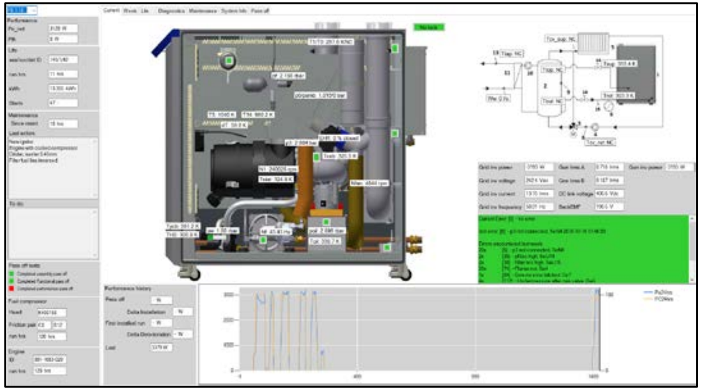
Fault magnitudes for cases with single fault.

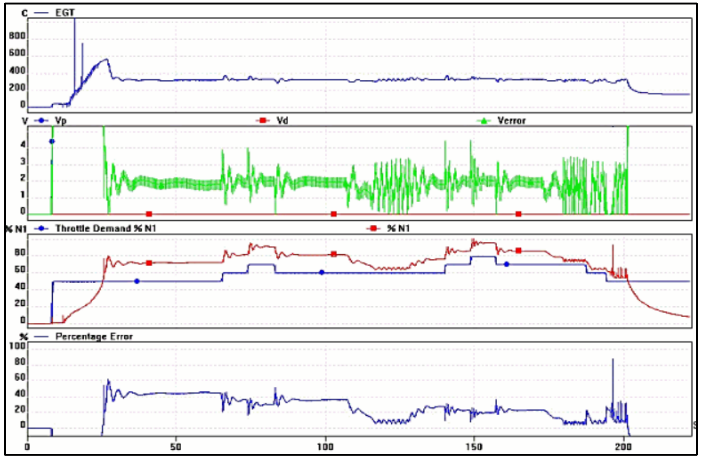
Cases	Fault magnitude	Detected fault magnitude using	
		AnSyn	Regression
S1	-1.500	-1.500	-1.511
S2	-1.500	-1.500	-1.506
S3	-1.500	-1.500	-1.509
S4	-1.500	-1.500	-1.503
S5	-1.500	-1.500	-1.500
S6	1.500	-	1.506
S7	1.500	-	1.508

Data-driven diagnostics

Challenges and opportunities:

- All systems are connected to a on-board computer.
- Large amount data are logged.
- Not enough faults related data.
  - Limited number of system (in total 6).
  - Only one have multiple failures.
- The goal is to predict and quantify degradation of the micro CHP.
  - There is no explicit measure of the degradation.



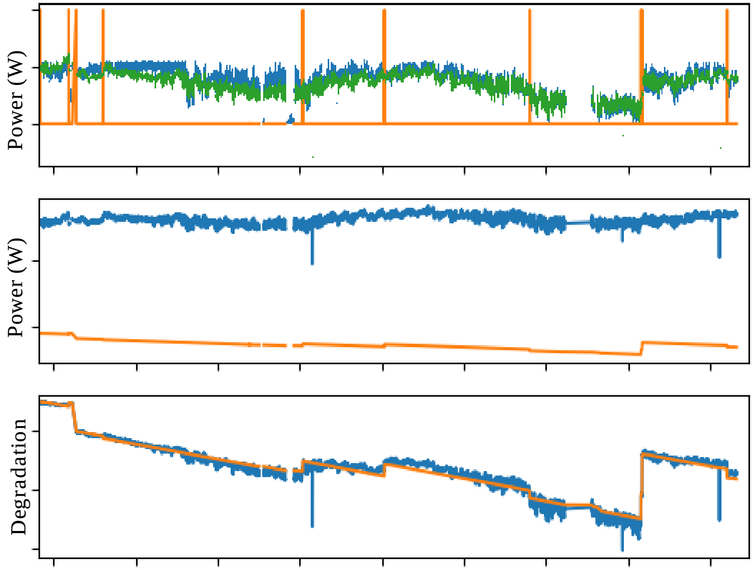


Data-driven diagnostics

Results:

The degradation model is based on multivariate linear regression method.

- **1st power vs time:**
  - Blue, — y, true power
  - Green — g(x)+e(x,t), Corrected power
  - Orange — maintenance action
- **2nd power vs time**
  - Blue — g(x), ideally produced power
  - Orange — e(x,t), degradation over time
- **3rd degradation vs time**
  - Blue — f(t), normalised degradation
  - Orange — e(x,t)/3200, smoother plot



Future steps

- Bayesian network based decision support system development.
- Integration of different machine learning techniques and framework automation.
- Application and test on real units.

Thanks for your attention!!!

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