INLINE -

An innovative design of a flexible, scalable, high quality production line for PEMFC manufacturing.

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Programme Review Days 2019

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PROJECT OVERIVEW

- **Call year:** 2016
- **Call topic:** H2020-JTI-FCH-2016-1: PEMFC system manufacturing technologies and quality assurance
- **Project dates:** 1.02.2017– 31.1.2020
- **% stage of implementation 01/11/2019**: 97 %
- **Total project budget:** 3,287 MIO €
- **FCH JU max. contribution:** 3,287 MIO €
- **Partners:** Fronius International GmbH, ElringKlinger AG, OMB Saleri S.P.A., KIT wbk, PROFACTOR GmbH

PROJECT SUMMARY

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The project aims at the development of the **design of a flexible, scalable, high quality production line (process steps) for the manufacturing of PEMFC's (Proton Exchange Membrane Fuel Cells).**

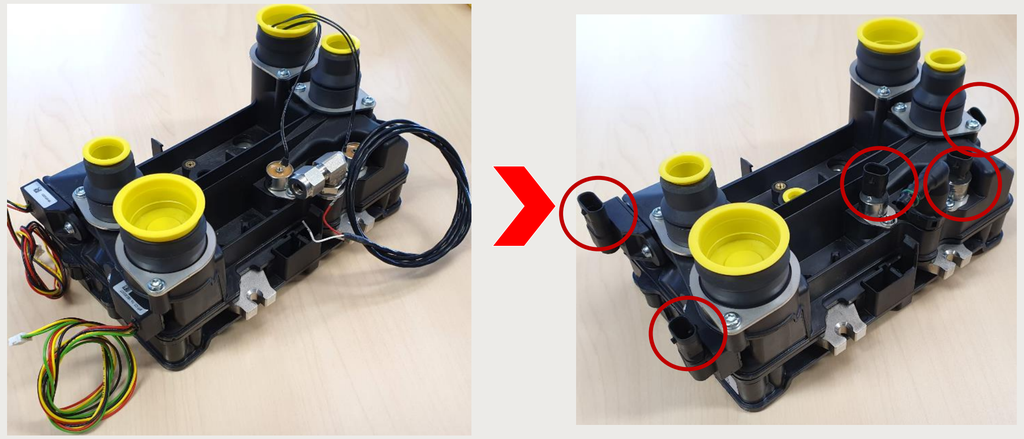
The spectrum of tasks for automation of fuel cell manufacturing investigated in the project includes:

- Process designs enabling **scalability up to 50.000 parts per year**
- Definitions for **automatic quality control strategies and processes**
- The development of **flexible assembly stations**
- Traceability requirements based on **tracking methods of parts,** assembly **data collection and documentation**

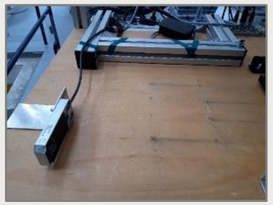
The INLINE manufacturing process has to meet both small and very large PEMFC system production.

Objective (A): Redesign of the MSU and Integration into assembly process

- Reduction of Manufacturing Steps (e.g. deburring)
- Development of a plug in connector for exchangeable, standardized interfaces e.g. SAE/VDA
- Simplification of Connections -> no wires
- Poka Yoke, considering the development of manufacturing processeses
- Development of injection moulding process -> avoidance of burrs in sealing surface
- Integration of electrical connection jacks into sensor/valve
- Elimination of production steps (mounting wires and jacks)
- Reduction of production time at final-assembly of 36 min



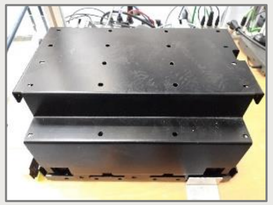
Objective (B): Smart camera sensor for traceability of critical components



Ready to start mounting

4. Red: wrongly mounted stack
3. Green: middle layer ok
2. Green: bottom layer ok
1. Green: lightning ok

4. Orange: wrongly oriented stack
3. Green: middle layer ok
2. Green: bottom layer ok
1. Green: lightning ok



Final check after housing operation: “all layers ok”

	bottom layer		middle layer		top layer	
	cell set (front)	cell set (back)	cell set (front)	cell set (back)	cell set (front)	cell set (back)
true positive	68	70	66	68	68	68
true negative	69	68	67	68	69	68
false positive	1	2	3	2	1	1
false negative	2	0	4	2	2	2
F-Score	0,98	0,99	0,95	0,97	0,98	0,97

- Overall, the achieved F-Scores are good results
- However, the false positive pose a severe problem
  → A safety-critical mounting passes the quality control
- Lightning conditions are improved and feature detection is aimed to be stricter with false positive in final development

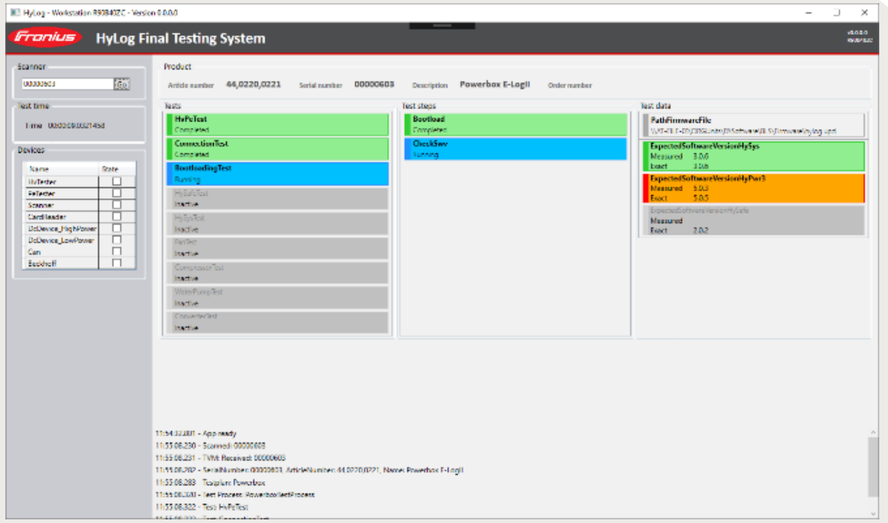
False positive/negative are due to extraordinary environmental conditions
→ stronger LEDs have been implemented and new tests are pending

Objective (B): Semi-automated End-of-line test

Automated EOL-Test chamber:

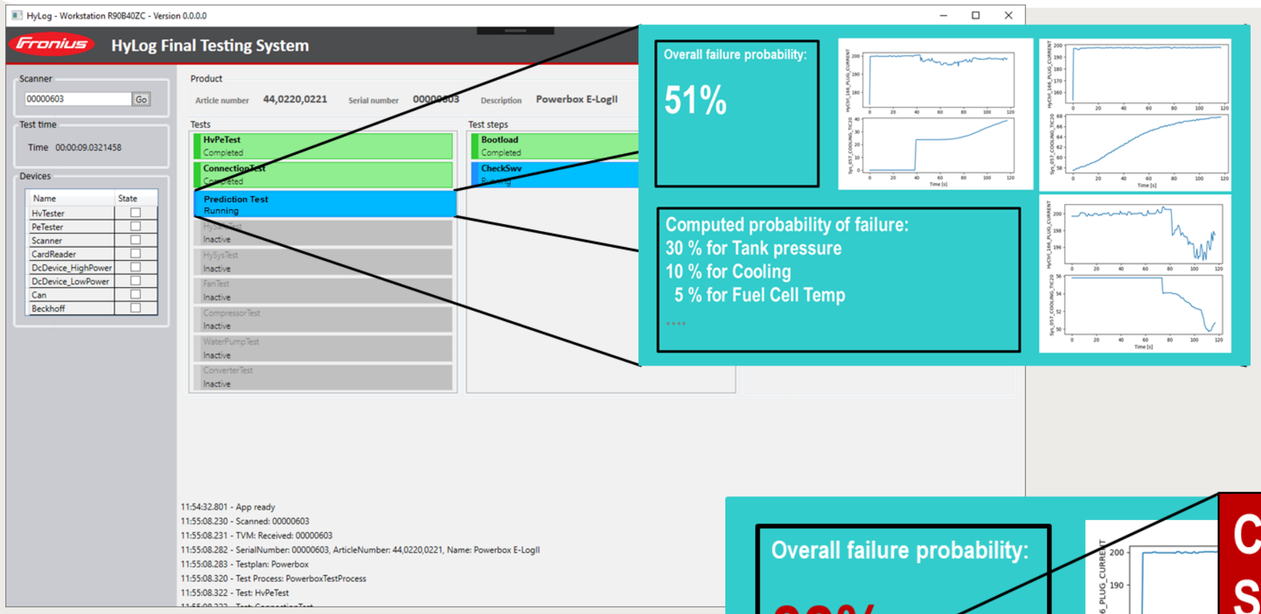
- High voltage test
- Protective conductor test
- Hydrogen -Tightness test

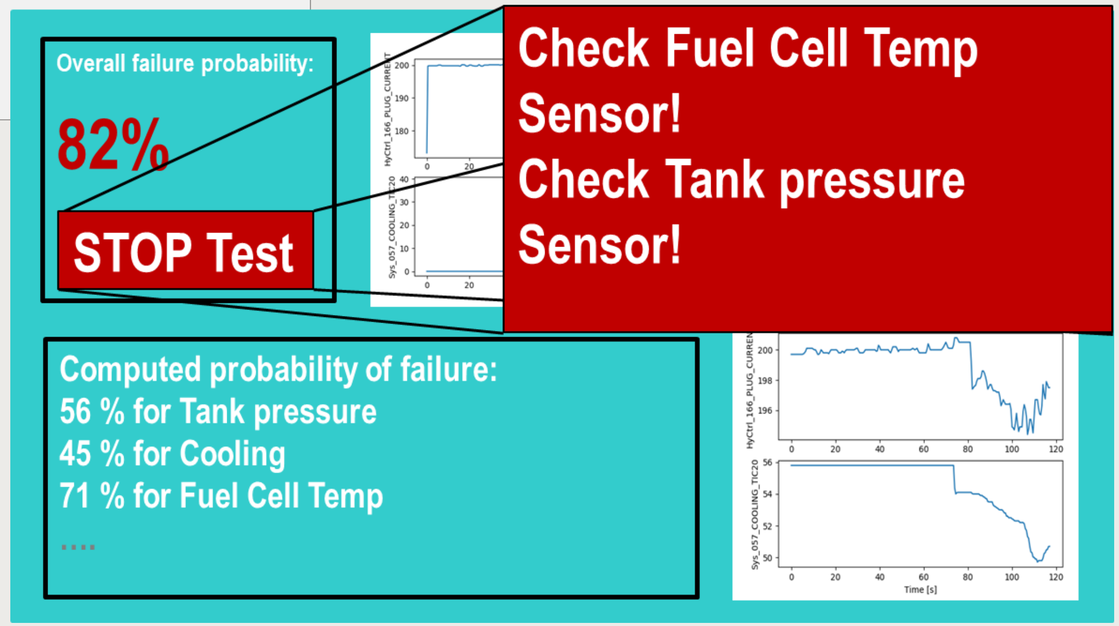
  up to 350 bar



- Functional tests of safety devices and the fuel cell system
- Development of Software for the execution of the Test

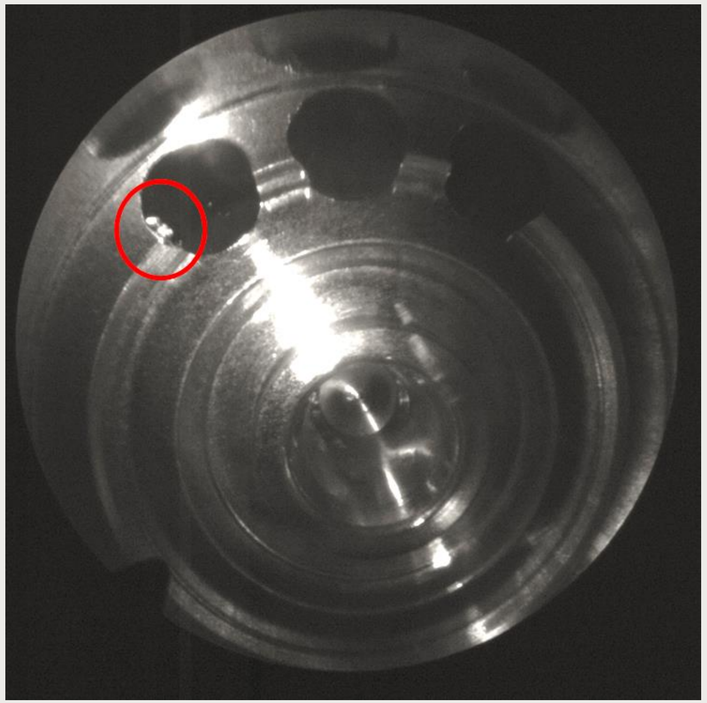
Objective (B): Usage of predictive models and data acquired through inline quality control to improve end-of-line Test.





- Prediction Visualization Tool integrated into EOL Test Software
- Real time curves
- Immediate Alert for worker
- Provide suggestions for re-work of sensors

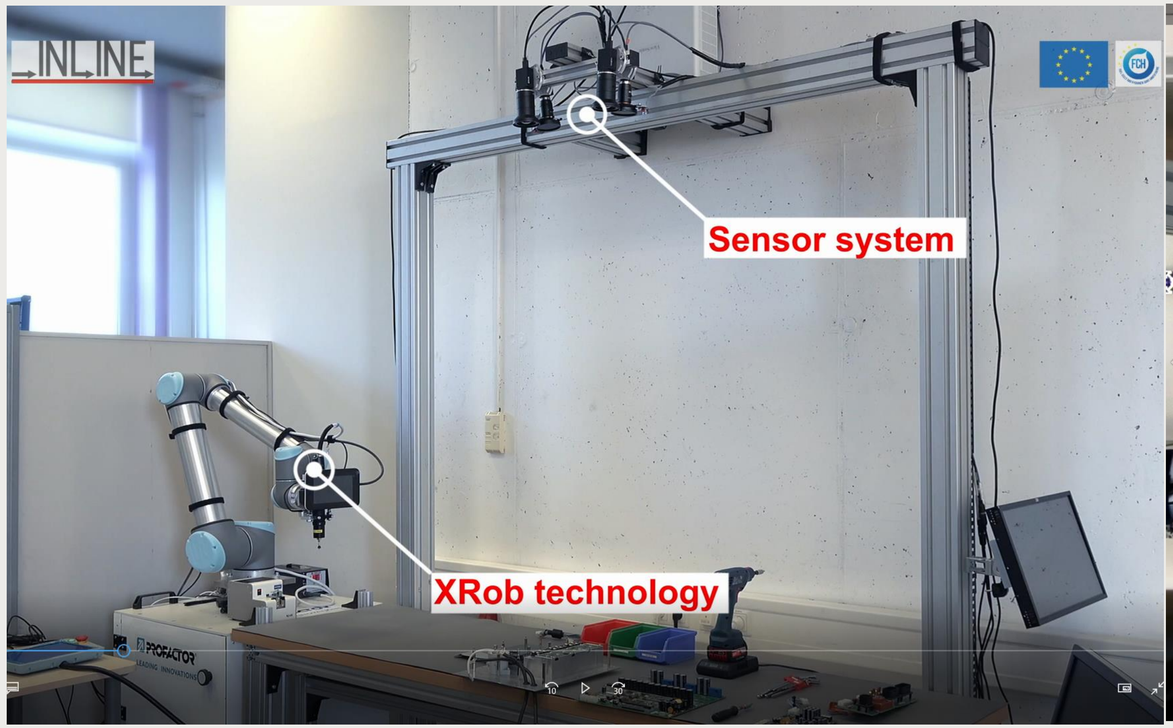
Objective (B): Inline quality control during production of tank valves

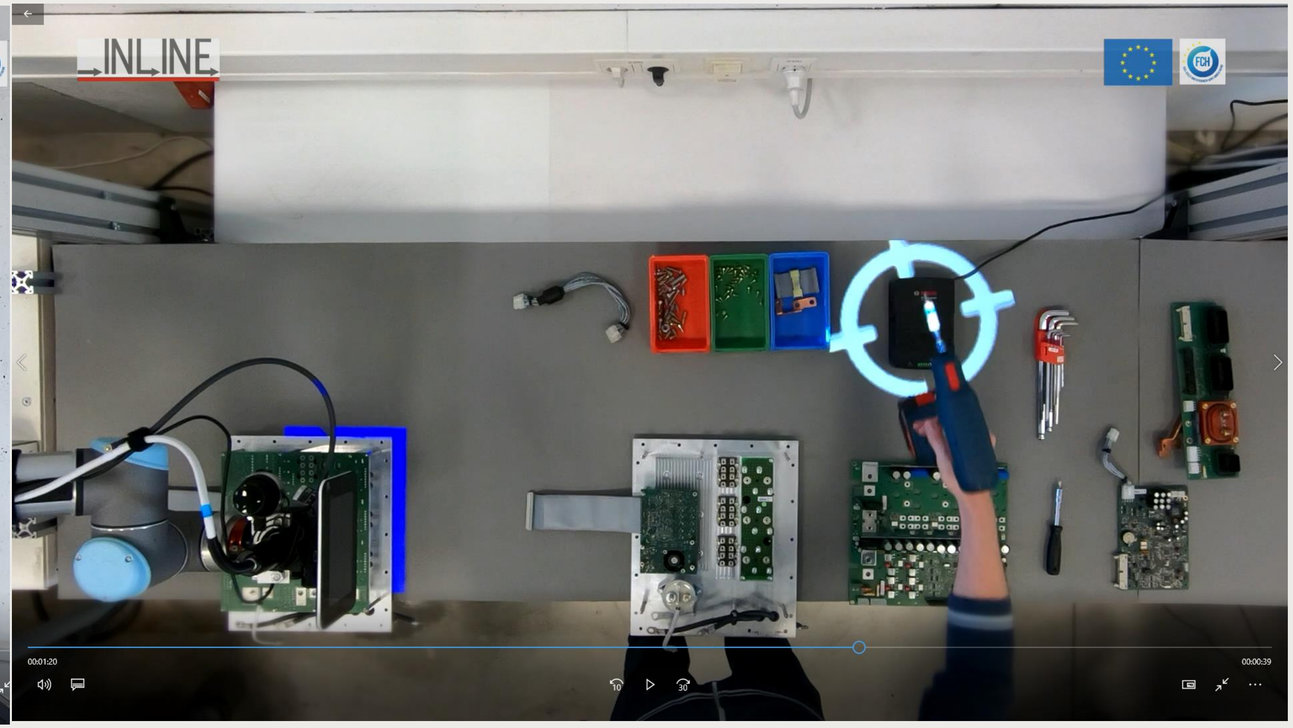


- Automated burr detection in the drill holes in the tank valves
- Robot moves tank valve to sensor
- Inspection Time 20s per valve
- 100 % quality control
- Decreased scrap rate

Objective (C): Assisted assembly process with parallel screwing

- Projection-based support of worker during assembly of the power box
- Inline quality control of execution of assembly steps
- Parallelization of assembly steps through collaborating robot -> reduction of assembly time of 50 %





Objective (C): Improvements in manufacturing process of the tank valve to produce large quantities with high quality and safety requirements.

- **Dimensional control of the valve body** – [out of production line] – **QUALITY IMPROVEMENT**

Before: measurement with manual instrument, not all the dimensions measured. Production rate: less than 1 pcs/h

INLINE result: all the dimensions are automatically inspected. **Production rate: 6 pcs/hour**

- **Ultrasonic washing of the valve body** – [in the production line] – **QUALITY & PRODUCTION IMPROVEMENT**

Before: washing made with an older technology at an external supplier. Production rate: strongly depending on the supplier

INLINE result: washing of the parts at the entrance of the assembly room with a better technology. **Production rate: 25 pcs/h**

- **Cleanliness analysis** – [out of production line] – **QUALITY IMROVEMENT**

Before: No cleanliness analysis

INLINE result: **taking under control** the efficiency of the ultrasonic washing and in case adjust it

- **Semi-automated assembly line** – [in the production line] – **PRODUCTION IMPROVEMENT**

Before: the valve assembly was completely manual. Production rate: 1 pcs/h

INLINE result: the assembly operator is assisted with semi-automatic tools. **Production rate: 4 pcs/h**

- **Automatic EOL test** – [in the production line] – **PRODUCTION IMPROVEMENT**

Before: EOL test was almost manual. Production rate: 1-2 pcs/h

INLINE result: EOL test is fully automatic. **Production rate: 4 pcs/h**

RESULTS OVERVIEW

- Scraps (at the EOL)

Before: 10%

INLINE result: **< 1%**

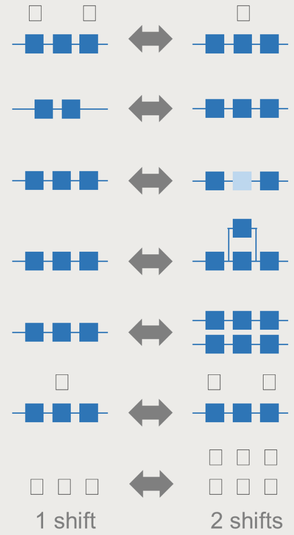
- Production time (100 valves)

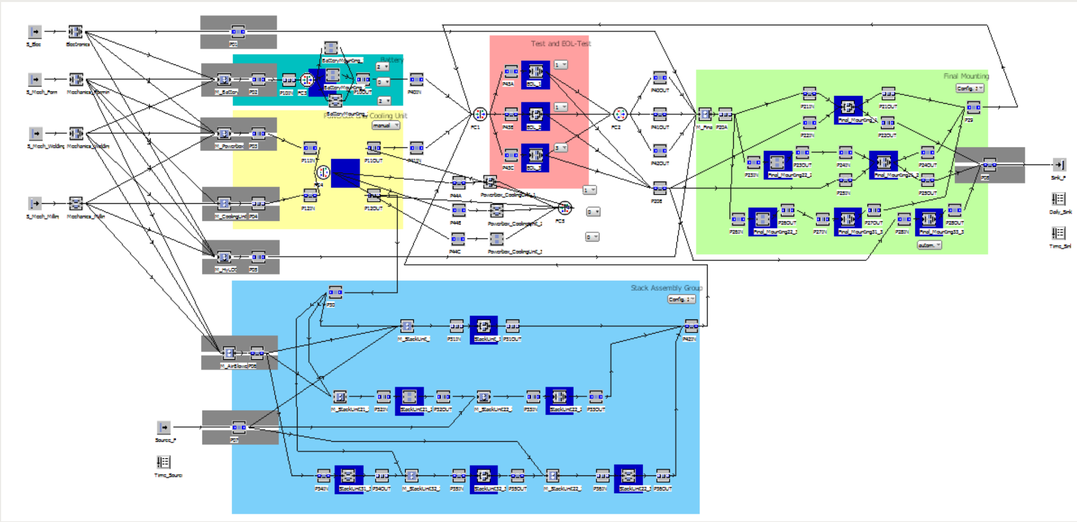
Before: more than 16 weeks

INLINE result: **8-12 weeks**

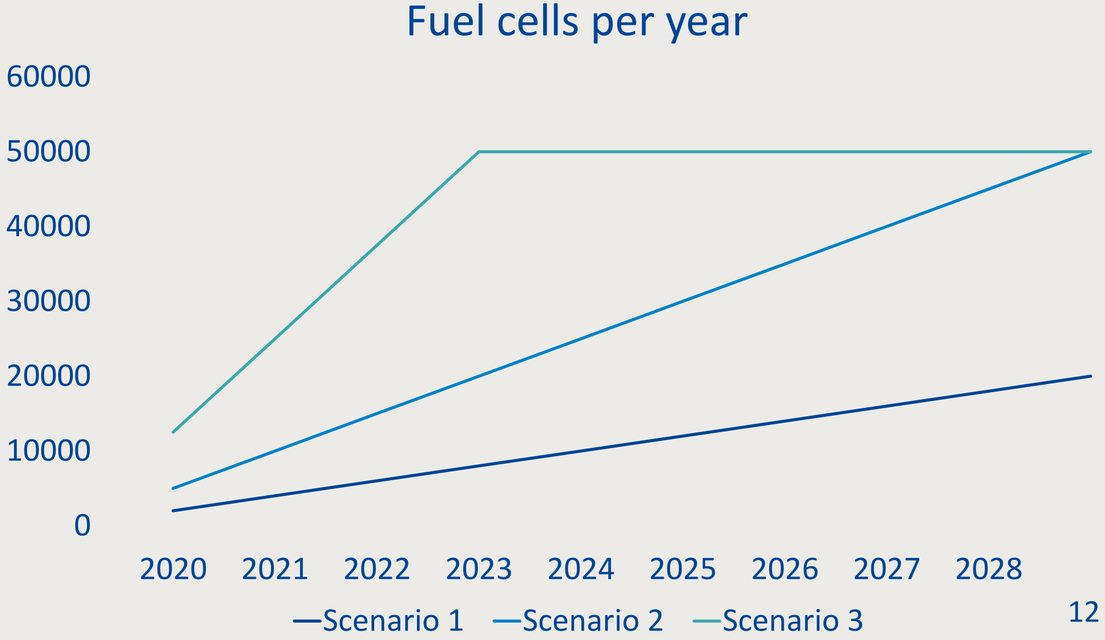
Objective (C): Simulation of scalability of the manufacturing process up to a level of 50.000 pcs/year.

Intrastationary scaling mechanisms	Scalable automation
	Splitting/joining of stations
	Reconfiguration
Interstationary scaling mechanisms	Duplication of Bottlenecks
	Duplication of the line
Organisational scaling mechanisms	Number of workers
	Shift model





- Simulation of existing manufacturing processes
- Integration of new developed fuel cell components and processes
- Development of scenarios to reach 50.000 pcs/year



Risks and Challenges

- Delay in the hardware setup of the improved End-Of-Line Test
  - Due to delivery problems of hardware components and difficulties in planning the setup was slightly delayed but was then set up nevertheless in time

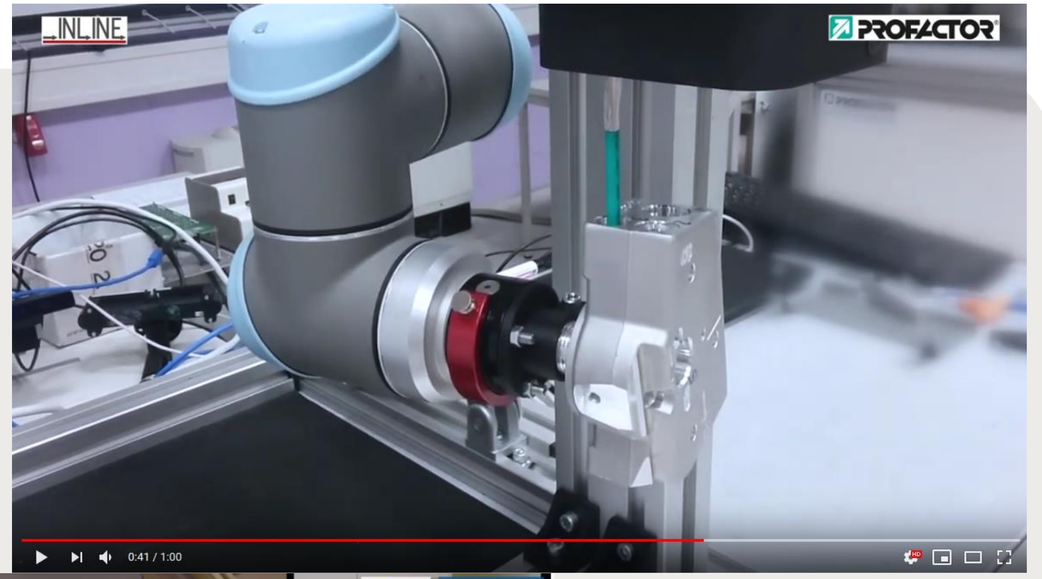
- Changes in project team at partner Fronius
  - Personal changes in the R&D fuel cell competence team slowed down the development of the improved end-of-line test, the result was a slight delay in the project timeline.

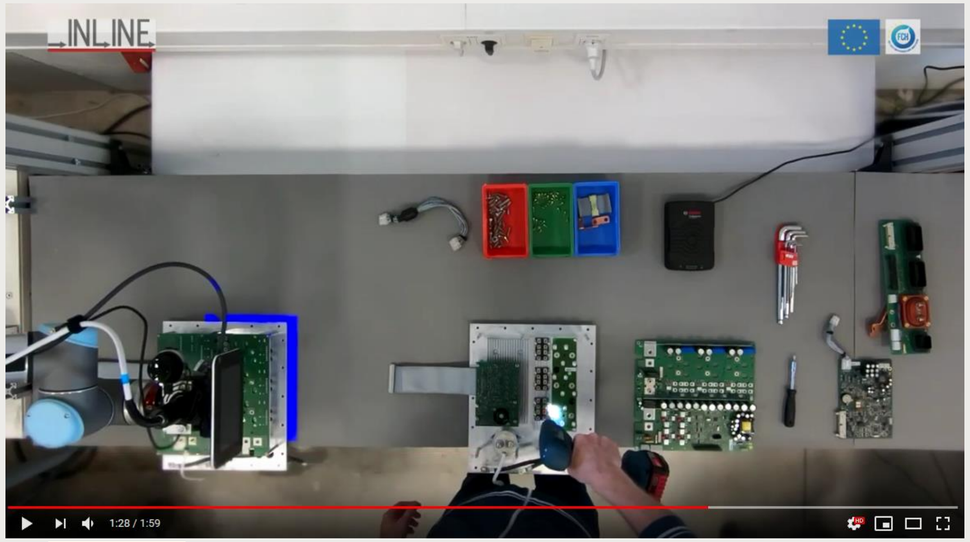
Communications Activities

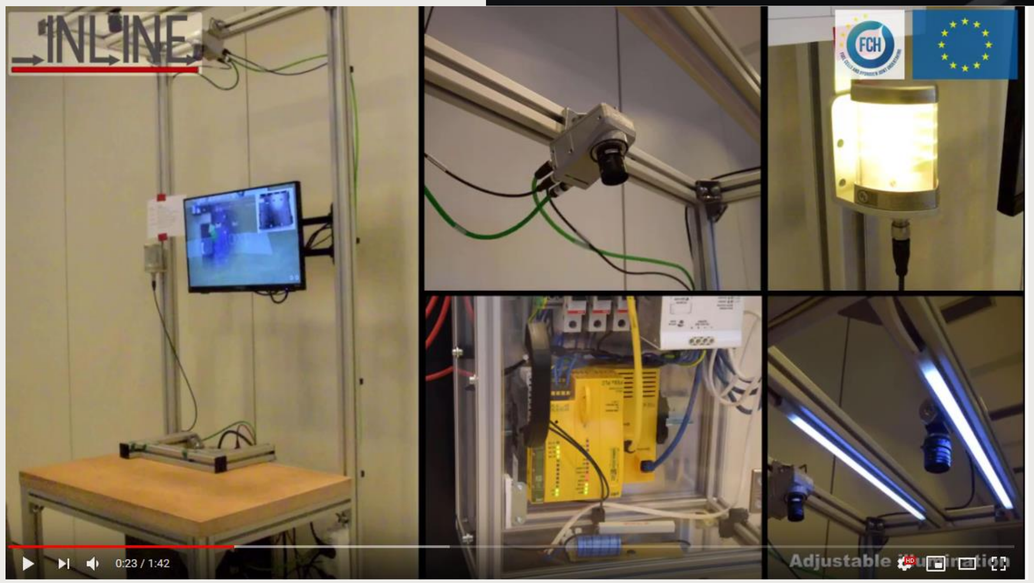
The project website is: www.inline-project.eu

Project results presented at PROFACTOR you-tube channel:

- **Endoscope Sensor**
- **Assisted Assembly Station**
- **Smart Camera Sensor**







EXPLOITATION PLAN/EXPECTED IMPACT

Exploitation

- Implementation of the **endoscopic sensor** at partner OMB in production process
- **Prediction Visualization tool** to be used also **in other** (welding machines, solar energy,..) **departments f**or the end-of-line test of Fronius
- **Simulation tool** for scenario analysis, configuration of modular assembly lines and the calculation of optimal scaling paths

Impact

- Manufacturing Process at partner OMB has significantly changed, **cycle time has been reduced by 50 %** and the quality of the products was increased (**Scrap rate <1%**)
- Manufacturing process at partner ElringKlinger has significantly reduced cycle time and **simplified the design of the MSU** (assembly time reduced by 36 min)
- **Prototypic manufacturing line** with automated assembly steps and quality control has been set up at partner Fronius

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

INLINE

Thank you for your attention!

Questions?

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