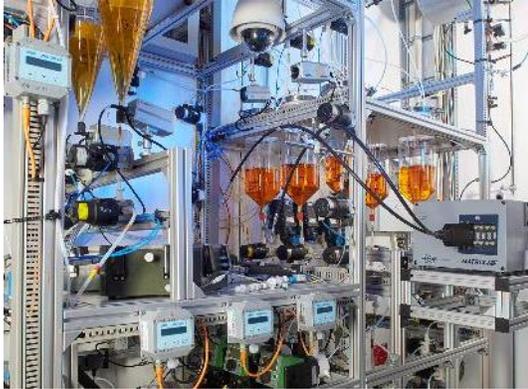


Research for a better tomorrow

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**Fraunhofer Institute for  
Chemical Technology (ICT)**

# Fraunhofer ICT: Core competencies



## Chemical processes



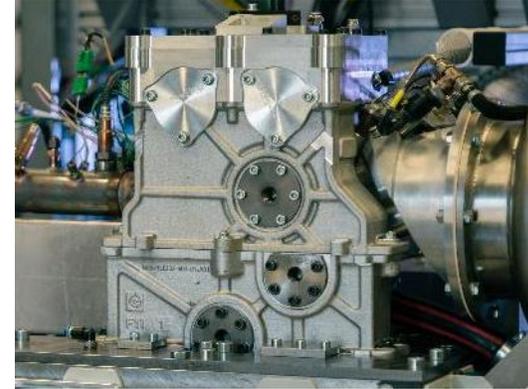
- Non-fossil chemistry
- Electrochemistry
- Chemistry with hazard potential
- Continuous and microprocess engineering
- On-line process analytics
- Process and operational safety of chemical plants



## Polymer Engineering



- Polymer synthesis
- Material and formulation development
- Processing technologies
- Component development and service life analyses
- Lightweight construction and composites
- Recycling and sustainability concepts



## Energy and drive systems



- Drive systems for mobility
- Batteries
- Fuel cells and electrolysis systems
- Thermal storage devices
- Battery and hydrogen safety



## Explosives technology, safety and security



- Development of propellants and explosives
- Synthesis, processing and manufacturing methods
- Performance measurement and characterization
- Modeling and simulation
- Stability and aging behavior
- Explosives detection

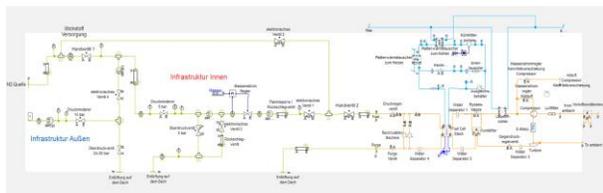
## Work Group Technical Safety (TES)

Researching energetic systems:  
How we make them more safe & resilient

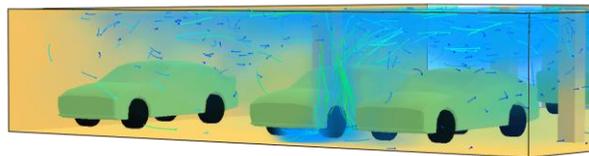
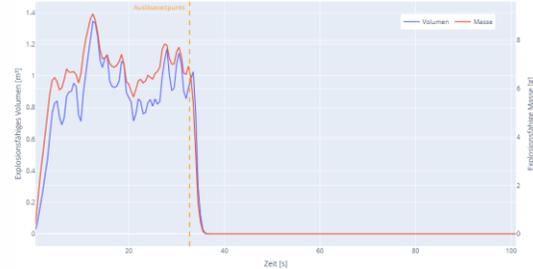
# Fraunhofer ICT: Work Group Technical Safety (TES)

We analyze and assess the risks associated with **energetic** (reactive and explosive) fluids and solids. **Including**, but not limited to, **H<sub>2</sub>**. From laboratory to plant scale. We look at everything from design via **failure behavior and resilience** up to safe disposal.

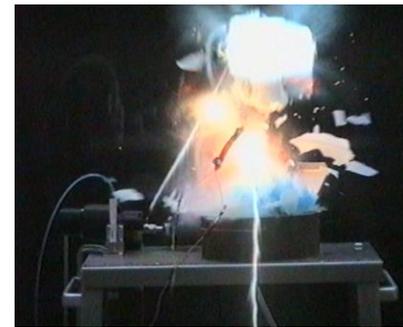
## Whole System



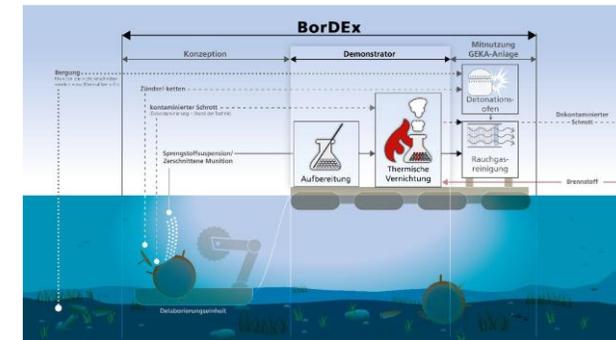
## Simulation



## Lab Testing & Validation



## Disposal of Munitions & Explosives



Work Group Technical Safety (TES)

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# TES – Activities & Projects

# TES: Part of Flame, Fire & Explosion Protection @ ICT

## Tasks and Objectives

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- **Develop solution strategies**  
for flame, fire & explosion protection issues, taking into account different research areas
- **Combining competences**  
to develop overall solutions and systems
- Develop and establish **application-oriented test methods**
- Strengthen synergies and bundle know-how



# TES: Safety Investigation Topics

## Recent and ongoing industry projects

### Small, unrecognizable H<sub>2</sub> leaks effects in a FCH vehicle:

- distribution simulation validation
- explosion impact:  
pressure, noise, heat transfer, car structure deformation on surrounding (passersby), passengers, tanks, FC-battery subsystem, car structure

### Repair- and maintenance workshop shop safety

- concept extension towards flammable refrigerants in existing building environment
- Upgrade needs for technical building equipment

### Automotive Safety:

- Ignition behaviour of accidental flammable refrigerant release in a realistic engine compartment
- Development of suppression strategies and experimental validation
- UN ECE GTR 13 H<sub>2</sub> pressure tank testing



# TES: Public safety projects

## Recent and ongoing german publicly funded projects

### HyBit

- Converting an industrial harbor & a Steel plant to H<sub>2</sub> fuel (see slides 28ff)

### HYGHER

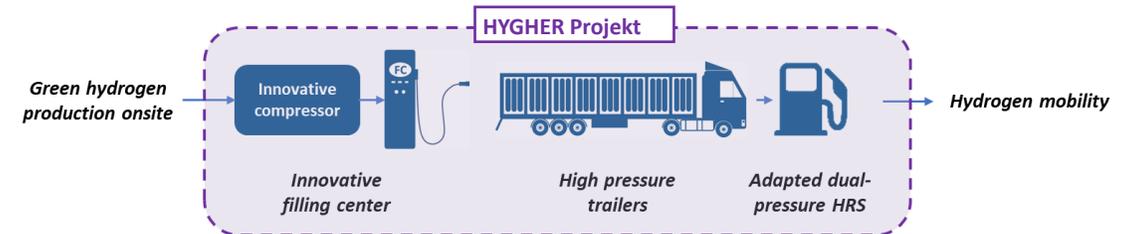
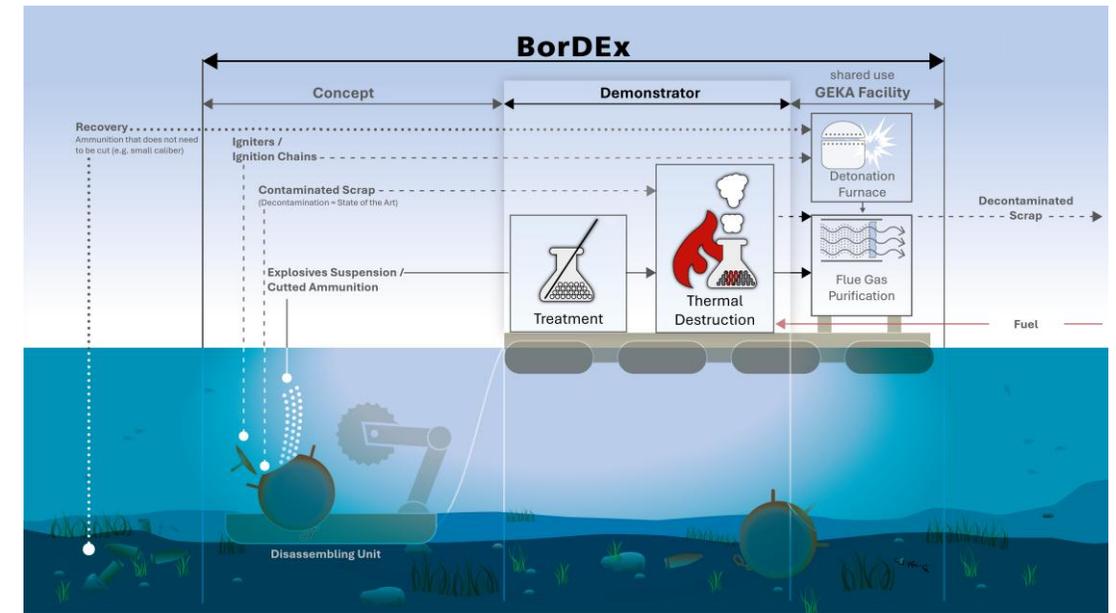
- Increasing H<sub>2</sub> trailer capacity
- Improving green H<sub>2</sub> mobility

### H2-Mare

- Offshore direct Wind → H<sub>2</sub> conversion

### Bordex

- Offshore munitions disposal (North & Baltic Sea)



H2-Mare / Offgrid Wind – offshore direct production of hydrogen

Work Group Technical Safety (TES)

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# TES – Infrastructure & Equipment

# TES Infrastructure: Outdoor testing facility (Building 77)

## Half-Open Bunker

### 2-part building construction:

- Inner „box“ – open only to one side
- „Courtyard“ – surrounded by bunker walls, ~ 50% roofed, 50% open to sky

### Explosion proof:

- Up to 1 kg TNT equivalent ( $4,18 \text{ MJ}_{\text{th}}$ )
- Splinter safe
- Well-shielded control room nearby with remote control and monitoring options



# TES Infrastructure

## Open-air testing range

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- Detonation tests up to 3 kg TNT equivalent
  - $\cong 12,54 \text{ MJ}_{\text{th}}$
  - $\cong 2 \text{ kg H}_2$  at 700 bar



Work Group Technical Safety

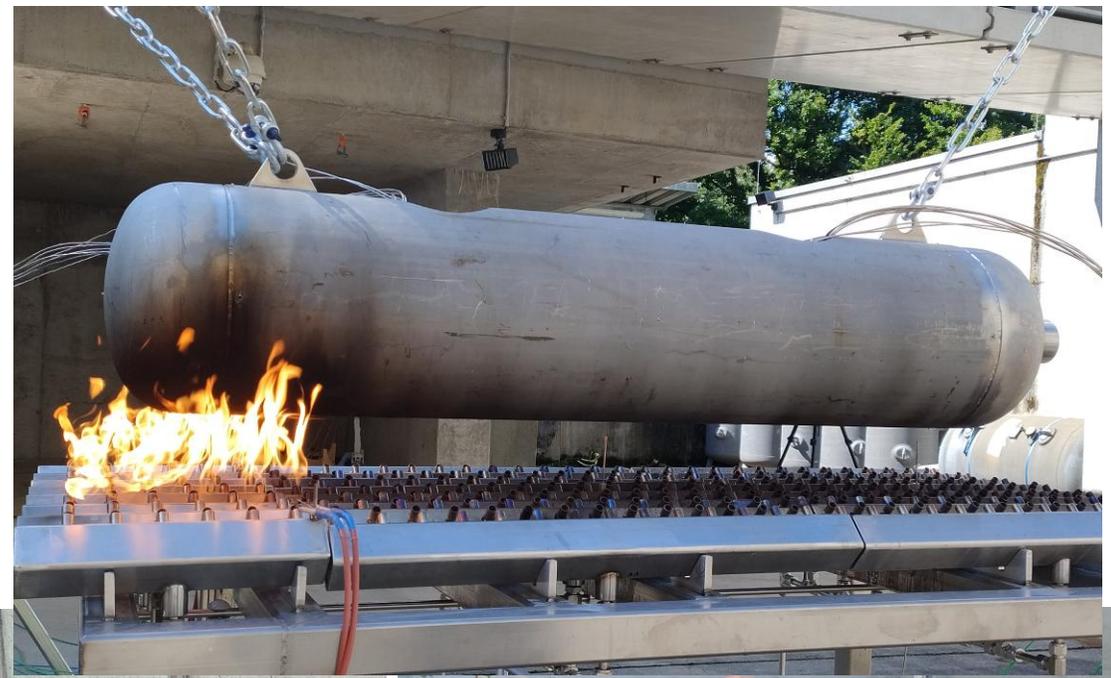
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# TES – Hydrogen / H<sub>2</sub>

# TES: UN GTR13 Burner

## For flame testing H<sub>2</sub> tanks

- **We built a burner for flame tests of H<sub>2</sub> tanks.**
  - Almost in accordance with UN ECE GTR 13.
- **Almost: Ours is wider, split in 3 parts instead of 2.**
- **We can do „exactly GTR 13“ because it's modular**
  - ~ 50 kW localized flame for 10 minutes
  - ~ 800 kW engulfing flame until failure or 1 h
- **We can also test:**
  - Wider specimens
  - For longer durations
  - With higher thermal flux
  - In more complex scenarios



# TES: H<sub>2</sub> safety example

## Spontaneous H<sub>2</sub> high pressure jet release with autoignition

- Research object
  - autoignition, combustion and radiation of high-pressure jets
  - Hot surface ignition source efficiency by means of temperature, size & distance
- Experimental setup
  - 5 L hydrogen @ 260 bar in storage pipe with rupture disk
- Evaluation example with
  - Capturing area 3 m x 12 m
  - High speed cameras
  - Fast thermal imaging
  - UV-VIS & IR spectroscopy



# TES: H<sub>2</sub> safety example

Spontaneous H<sub>2</sub> high pressure jet release with autoignition



**Versuch H2 07**  
**H2 Hochdruckausströmung**

**HD Video**  
**Auslösedruck 260bar**  
**Ausströmrrohr 10mm Durchmesser/ 100mm Länge**

# TES: H<sub>2</sub> safety cooperation with Eifer

## System and plant safety

### High-temperature Electrolysis

- Long-term (4+ years) tests of high-temperature solid oxide fuel cells & electrolysis cells (SOFC/SOEC)
  - cells and stacks
  - degradation and post-mortem analysis
- Equipped laboratories with Eifer test benches
  - All relevant gases H<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub>, CO, CH<sub>4</sub>, O<sub>2</sub>
  - UPS-systems and trained personal for 24/7-operation
- Investigation of aged cell electrodes with X-ray diffractometry (-50 .. +1400 °C), REM-EDX,...

COSMHYC<sup>XL</sup> EC Horizon 2020 Fuel Cells & Hydrogen Joint Undertaking FCH2-JU <https://cosmhyc.eu/>

- Combination of metal hydride and mechanical compression for large scale hydrogen refueling of fuel cell electric vehicles.
- Long-term test phase of the compressor system under real-world conditions
  - TES role: Safety concept for the innovative hydrogen compression system



European Institute for  
Energy Research



# TES: Testing & Validation

## Safety & Simulation

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### Our measurement systems:

- Transient gas concentrations
- Splinter and Fragment exposure
- Heat, Radiation, Spectroscopy
- Pressure, Temperature

### Example: H<sub>2</sub> ignition

- On a hot surface
- Highly dynamic, explosive reaction
- Spontaneously released H<sub>2</sub> from a 300 bar reservoir.



Work Group Technical Safety (TES)

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# TES – Simulation

# TES: CFD simulations

## Overview

### Leak → Dispersion

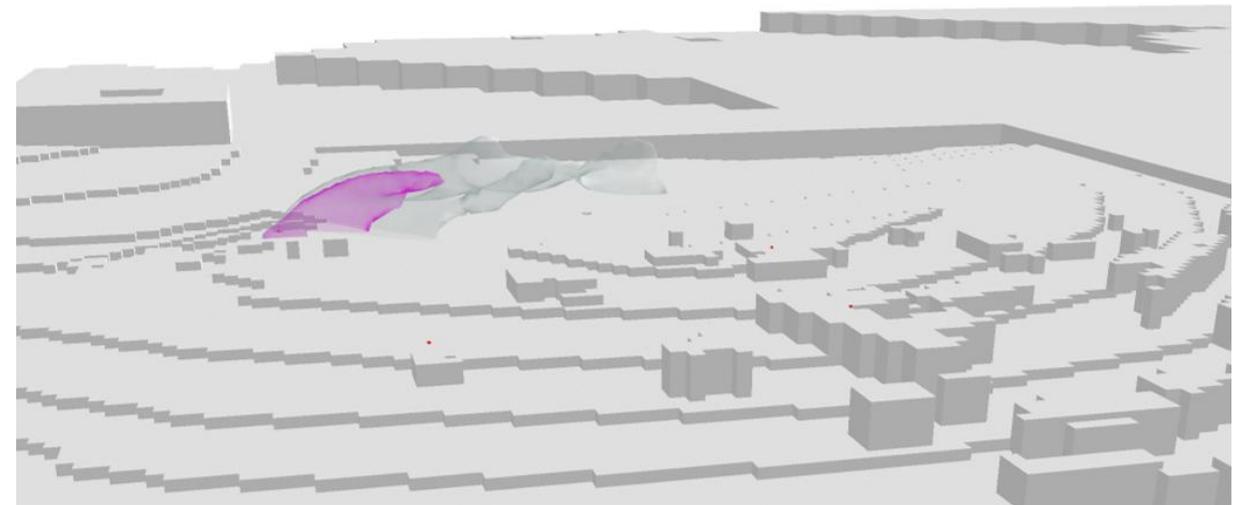
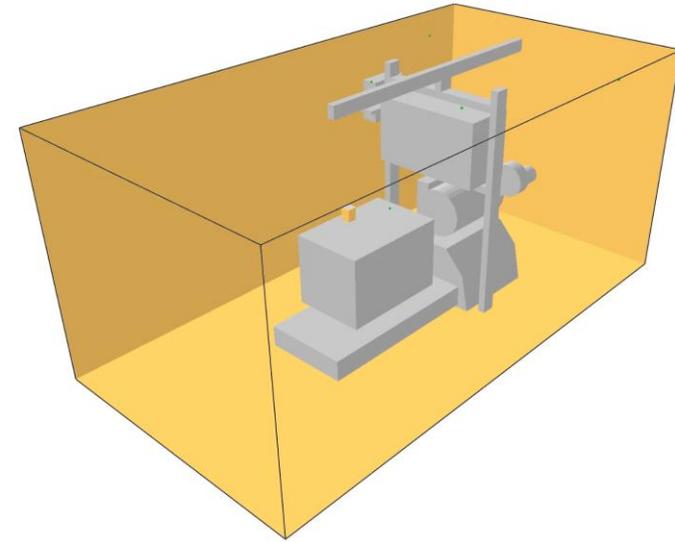
- Buoyancy is driving force
- Indoor and outdoor
  - Differences in terms of scales (spatial/temporal) and the influence of the environment (e.g. wind)

### Jet

- Momentum is driving force

### Combustion

- Premixed
- Non-premixed



# TES: CFD simulations

## Overview

Leak → Dispersion

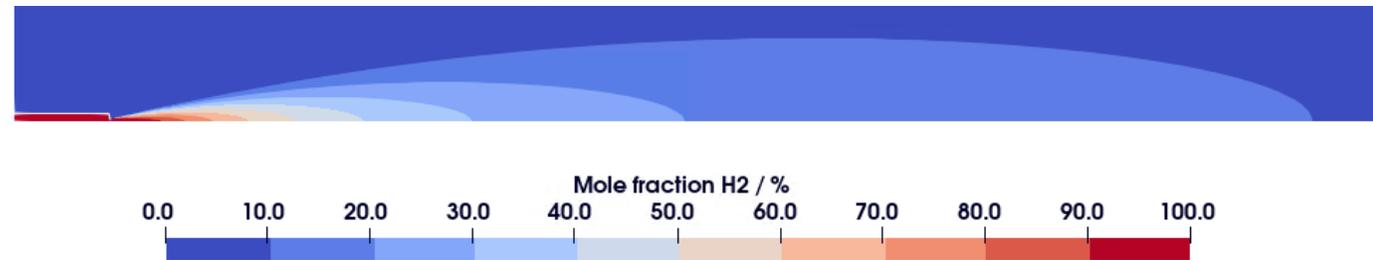
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Combustion

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- Non-premixed



# TES: CFD simulations

## Overview

Leak → Dispersion

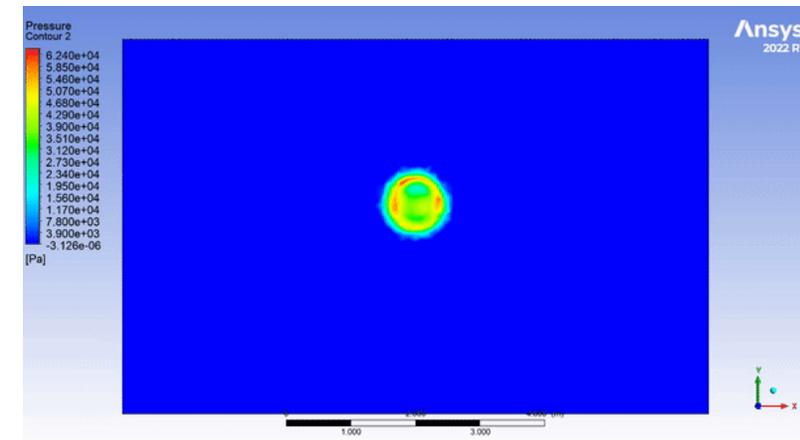
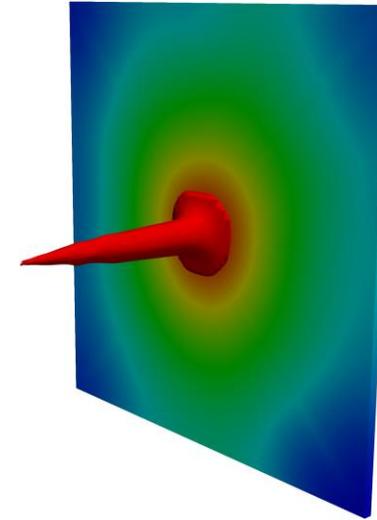
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Jet

- Momentum is driving force

Combustion

- Non-premixed
- Premixed



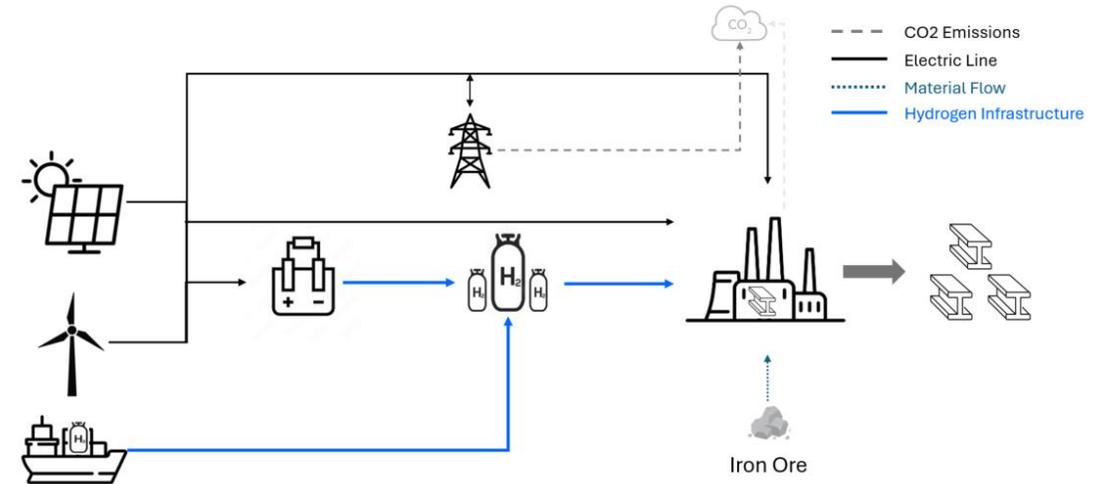
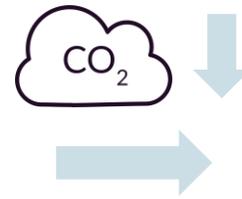
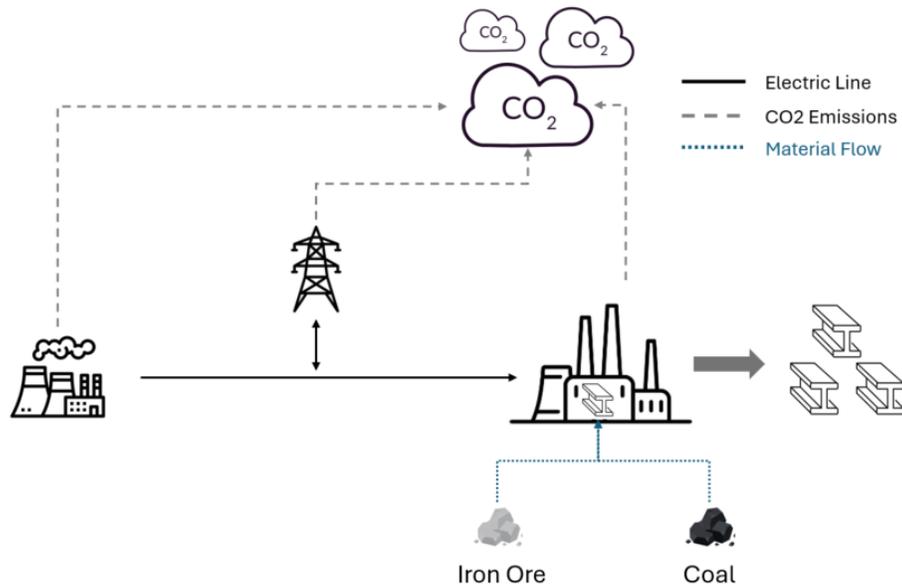
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# TES – Resilience

# TES: Resilience Assessment Example

## Steel Industry - Hydrogen-Based Energy System



- ~8 % of the global CO<sub>2</sub> emissions are produced by the steel industry<sup>1</sup>
- Steel mill emits 50 % of Bremen's CO<sub>2</sub> emissions

- New dependencies
- High electrification
- → *How can we design this new system to be resilient?*

<sup>1</sup>IEA, 2020, Iron and Steel Technology Roadmap - Towards more sustainable steelmaking.

# TES: Resilience Example: Steel plant

## Definition of System Performance

### System Performance

- Desired system capabilities
- Combination of various system variables
- Time-variable



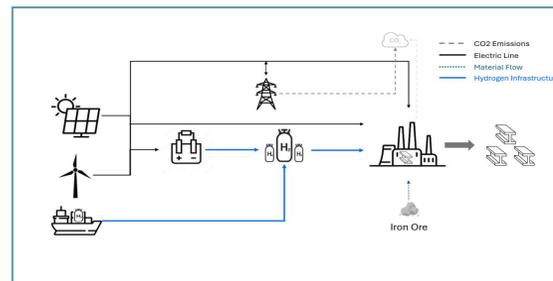
Capability	System Variables
Sustainability	CO2 Emissions
Productivity	Steel Production, Hydrogen and Electricity delivered
Profitability	System Operating Costs, Revenue

### Input

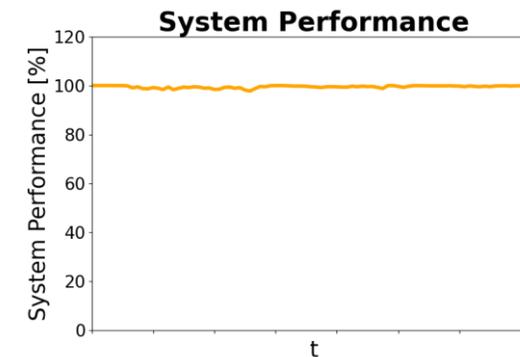
- Boundary conditions
- System data
- Weather data



### Digital Model

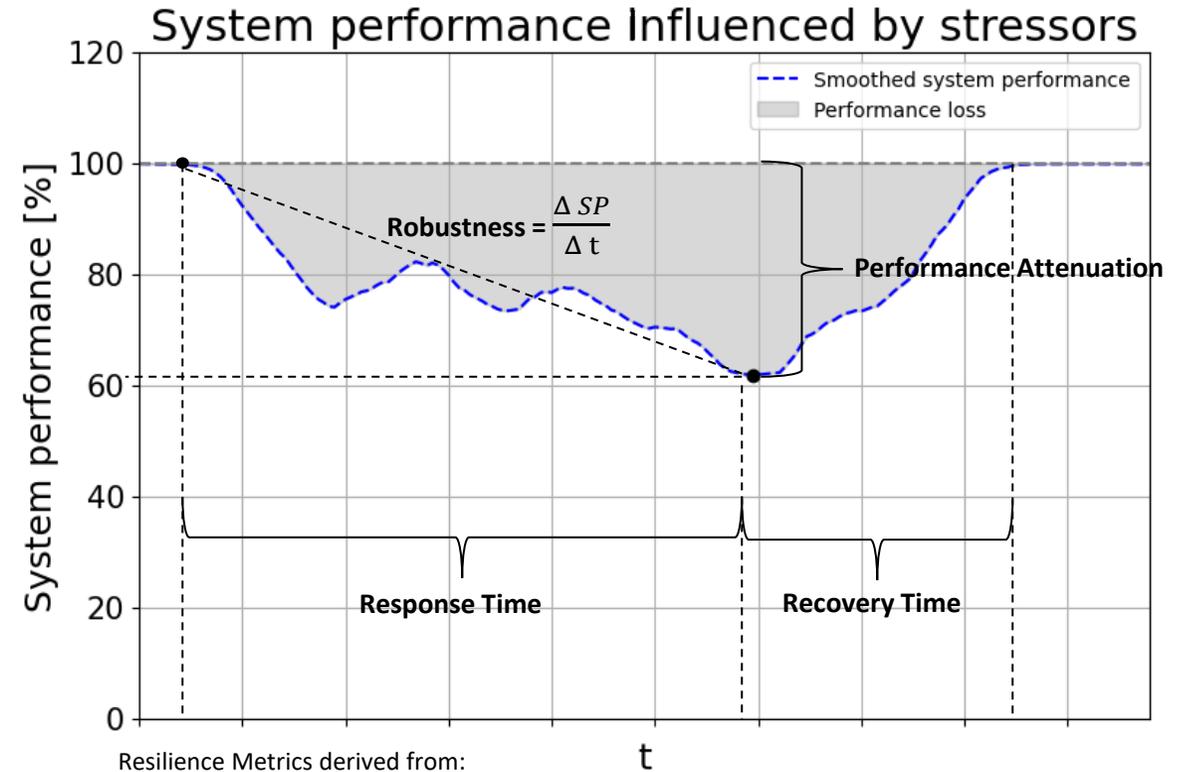
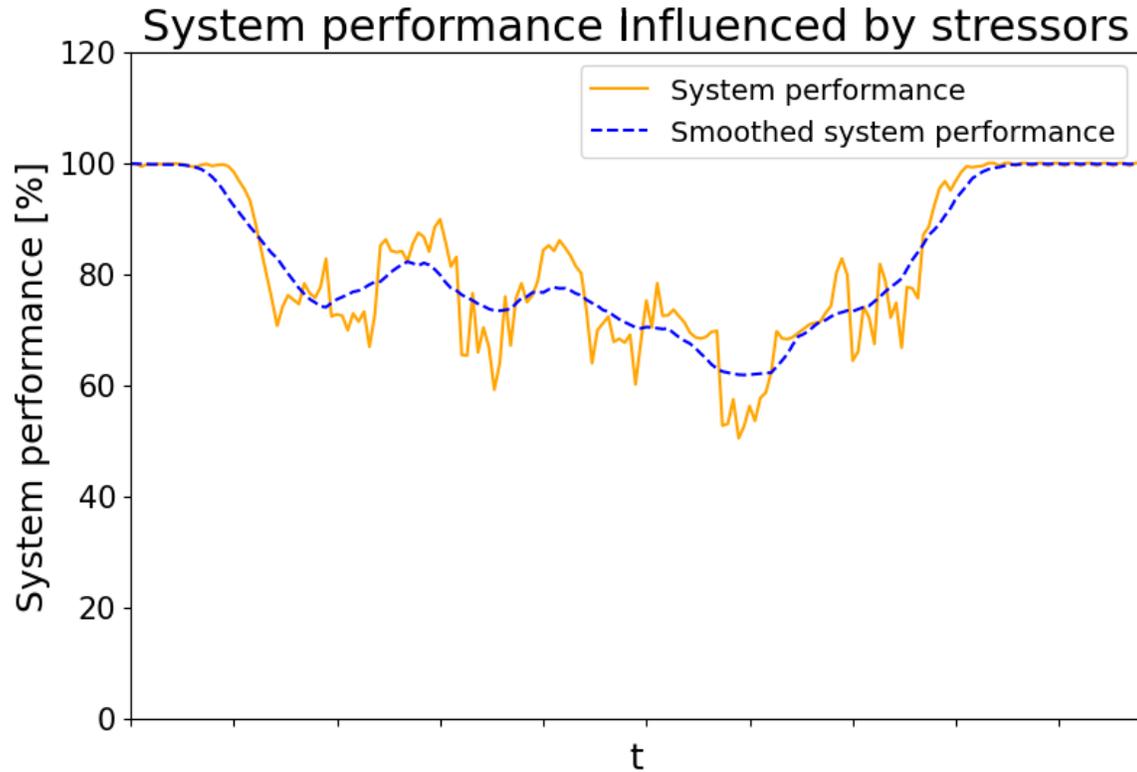


### Output



# TES: Resilience Assessment

## Performance-based Approach



Resilience Metrics derived from:  
 Tran et al., 2017, A framework for the quantitative assessment of performance-based system resilience. Reliability Engineering & System Safety, 158, 73–84.

# Cooperation opportunities with TES / ICT

Let's work together!

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- **Safety analytical studies:**

- Risk assessments of fires and explosions
  - Including protection concepts
- Risk and scenario analysis of operating states (HAZOP, FMEA, ... )
- Failure and malfunction cases
- Worst-case considerations

- **Cause and fault analysis:**

- Experiments & Simulations of critical states
- Failure or damage cases of systems or plants
- Reconstruction

- **Development, customization, adaptation of measuring systems**

- **System and Plant safety Experiments & Simulations:**

- Laboratory and real scale
- Gas (H<sub>2</sub> and others) release, propagation, combustion, explosion
- Failure behaviour of components, design optimization
- Resilience analysis

- **Visualization and image evaluation methods:**

- Color, b/w, IR
- High-speed cameras
- BOS method

Thank you for your attention!



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