HYDROGEN AND HYDROGEN BLENDED FLOX® COMBUSTION IN A TURBEC T100 MICRO GAS TURBINE COMBUSTOR

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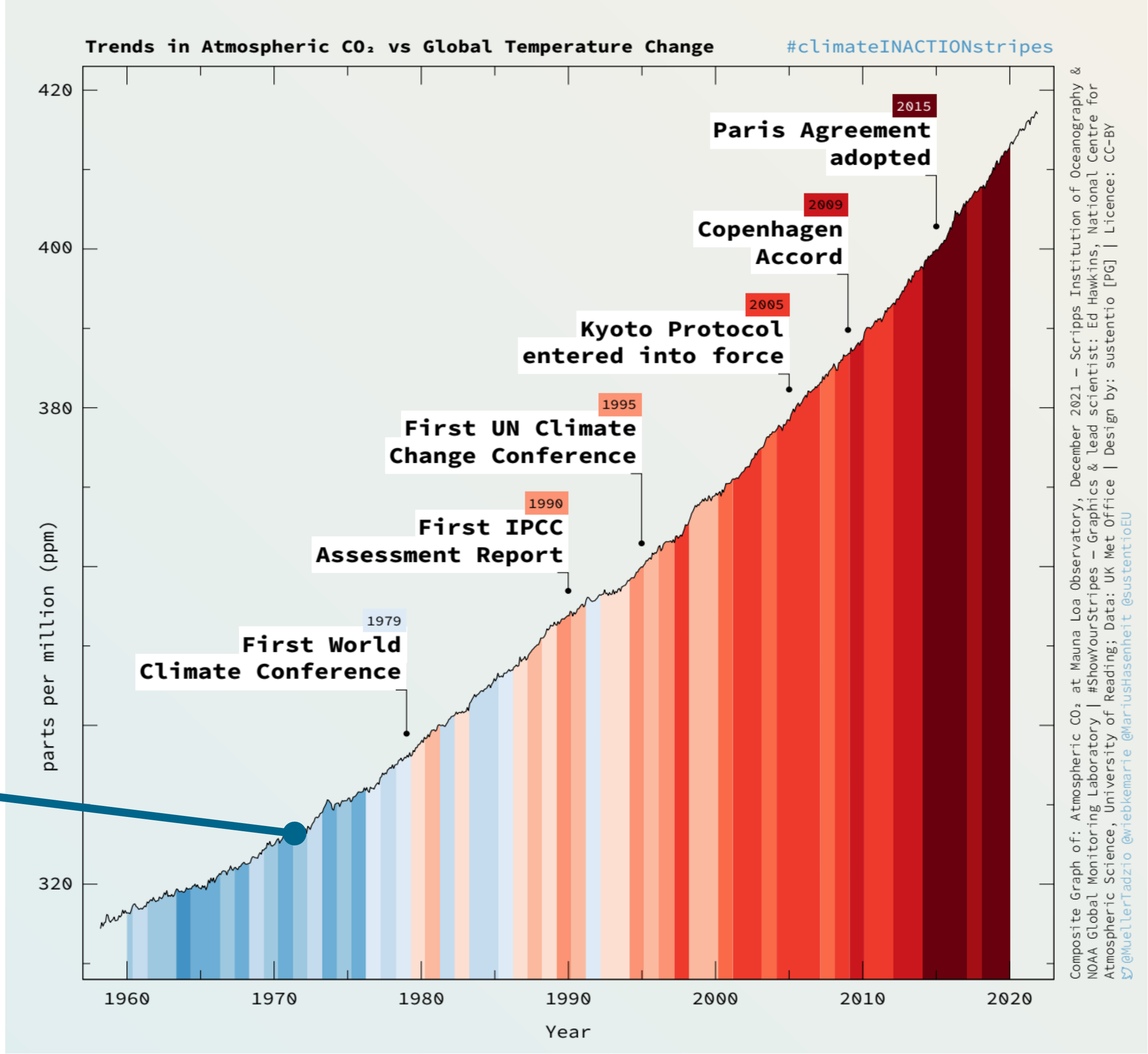
10/11/2023

DLR

Background / Motivation



Club of Rome – Limits to Growth

Background / Motivation


123rf.com

Background / Motivation


dpa-Zentralbild → rbb24.de


laenderdaten.info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Background / Motivation

Micro Gas Turbine

DLR Burner

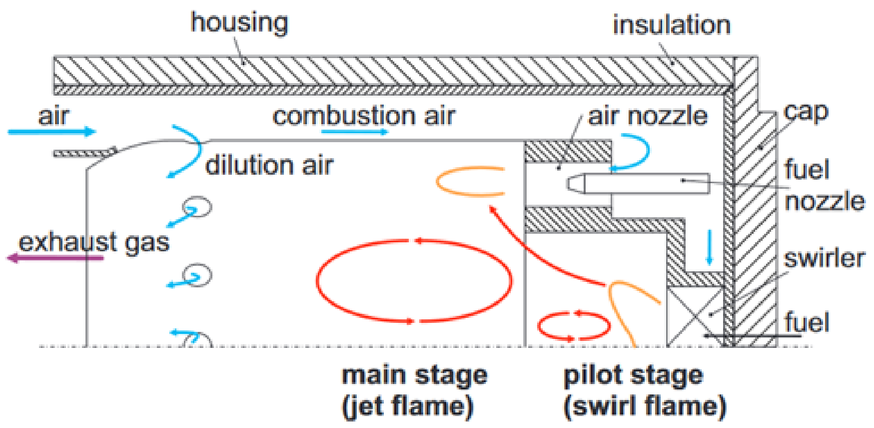
Contents

- Background / Motivation
- Retrofit Setup – T100 MGT with DLR Burner
- Study Results
  - Numerical (CFD) Simulation
  - Experiments
- Conclusion / Outlook

Retrofit Setup – T100 MGT with DLR Burner
Measurements

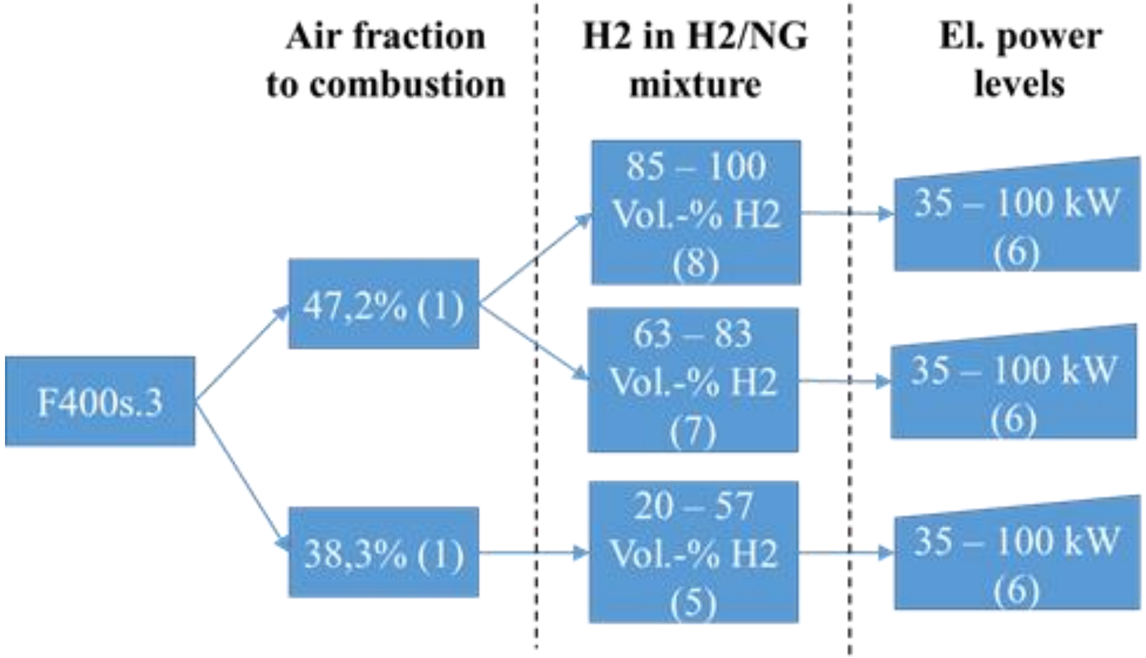
- **Retrofit:** Existing burner F400s.3, evaluated with hydrogen
  - F: FLOX®, 400: kW thermal, s: synthetic gas
  - Developed for 7 – 49 MJ/kg
  - Air-fuel ratios 1.5 – 3.6

- Combustor adaption: More air for combustion, less dilution



- T100 Gas Turbine operated at University of Stavanger
- Remote operation support from DLR

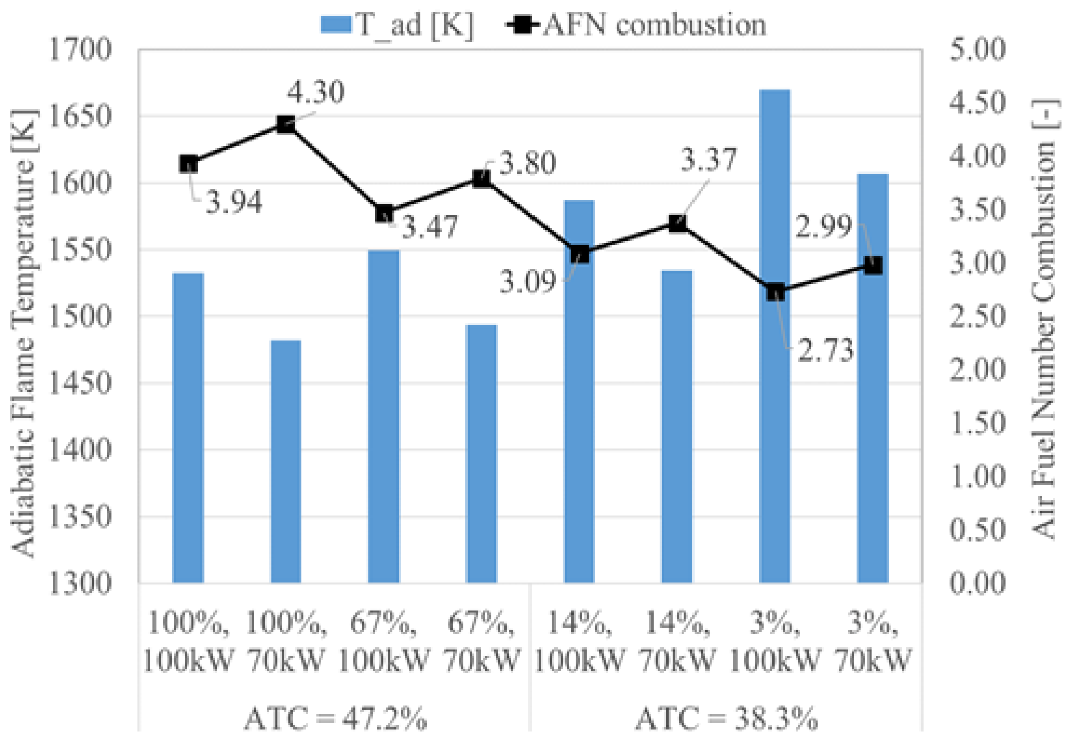
Retrofit Setup – T100 MGT with DLR Burner
Measurements



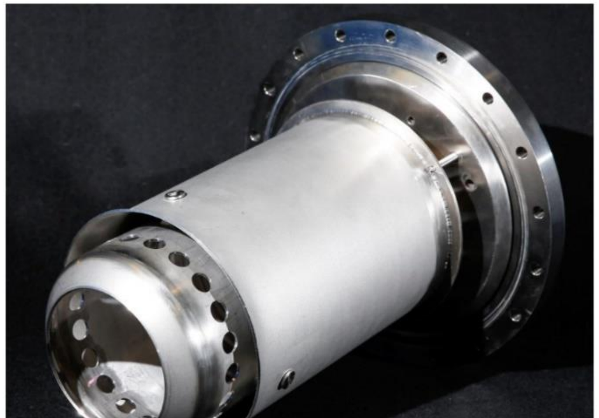

T100 - Micro Gas Turbine


DLR Burner

Retrofit Setup – T100 MGT with DLR Burner
Measurements



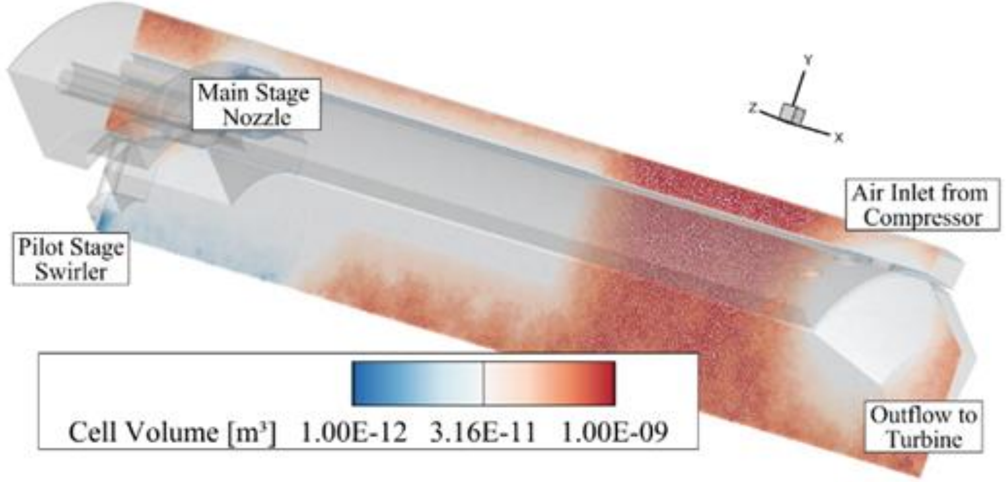
T100 - Micro Gas Turbine



DLR Burner

AFN: Air fuel number

Retrofit Setup – T100 MGT with DLR Burner
CFD Simulation



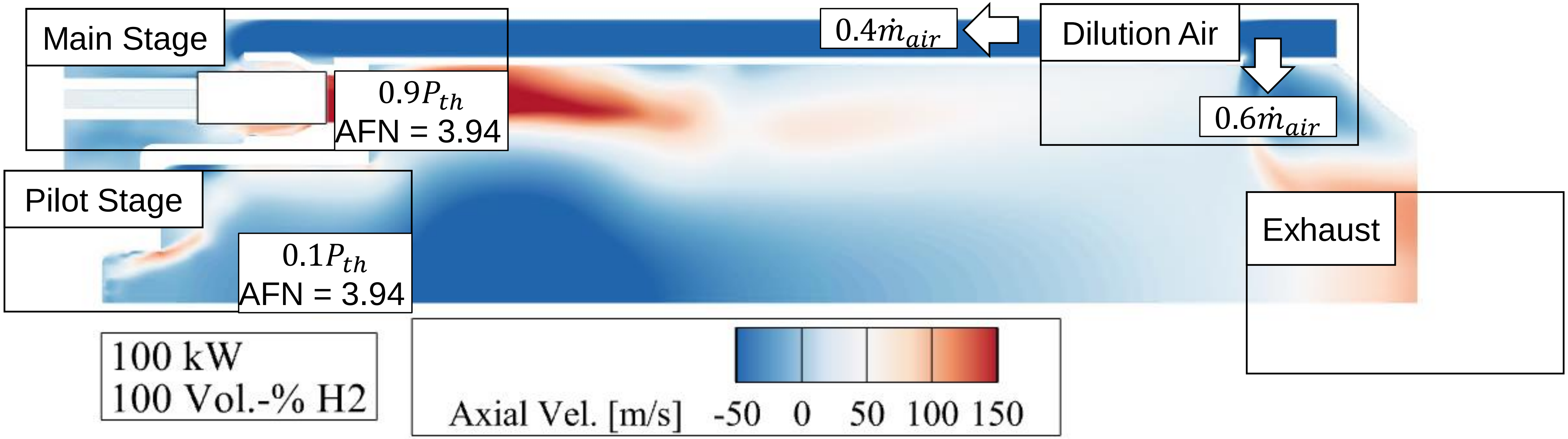
- 60° segment, 7.7m points, 44m tet elements
- ThetaCOM inhouse CFD

- Incompressible RANS with FRC chemistry

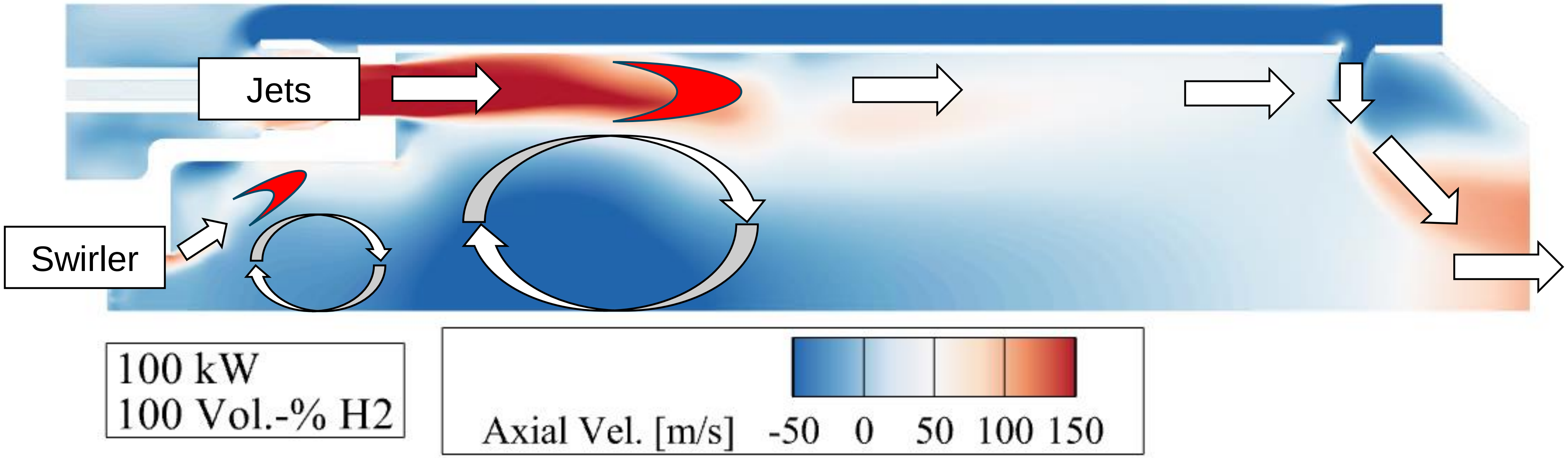
- DLR Concise reaction mechanism with NOx pathways

Contents

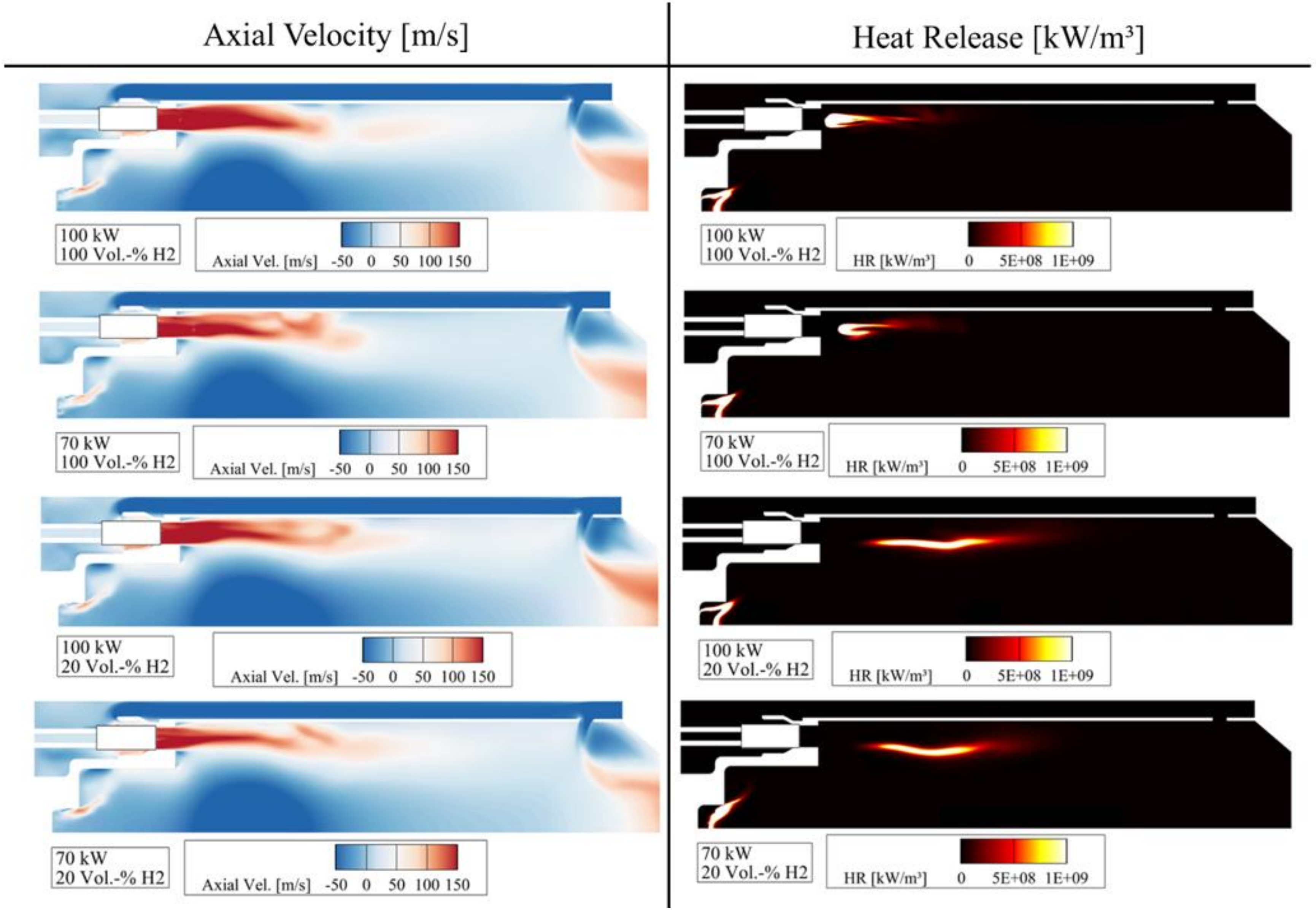
Study Results – JaRS Combustion



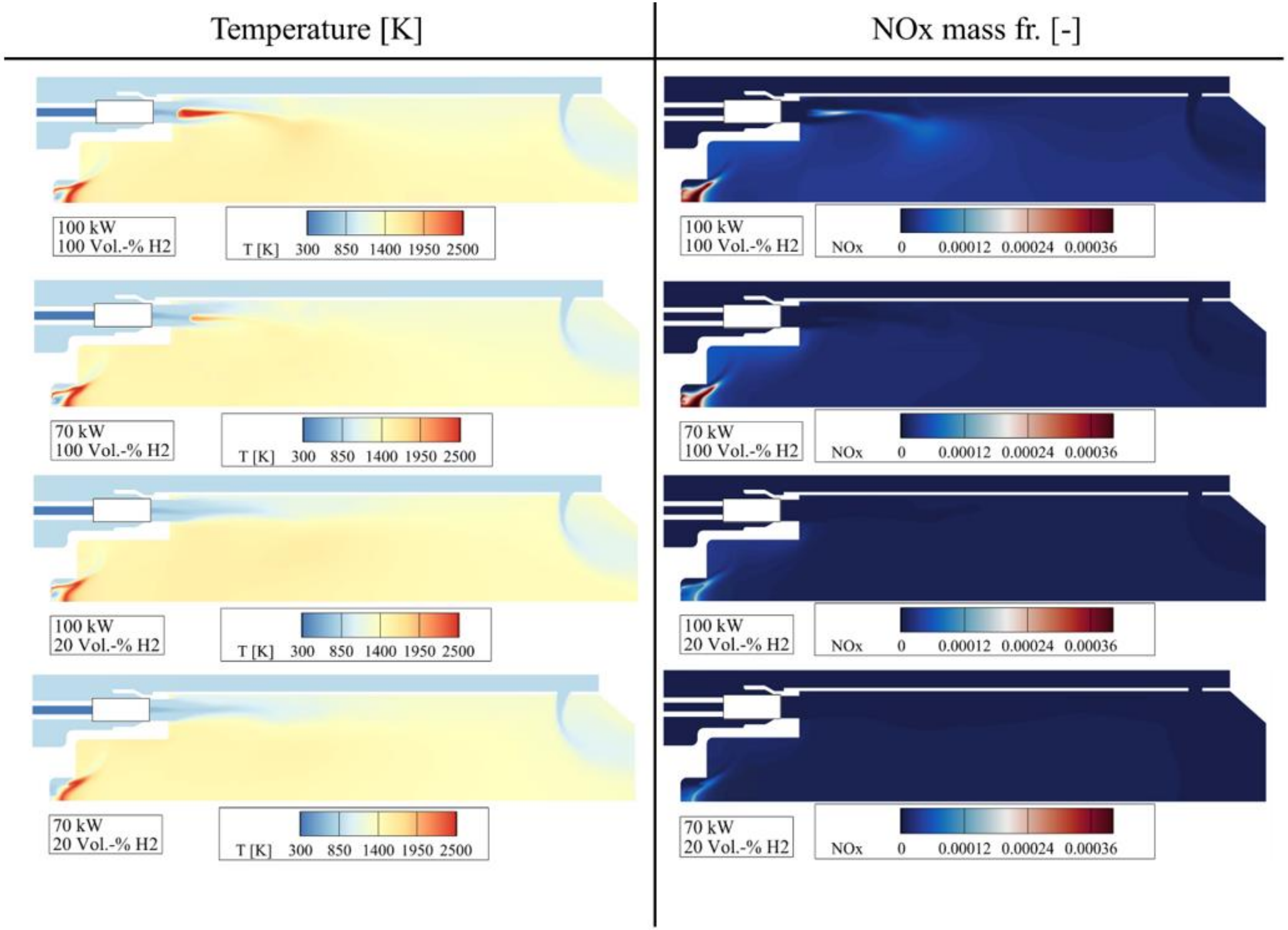
Study Results – JaRS Combustion



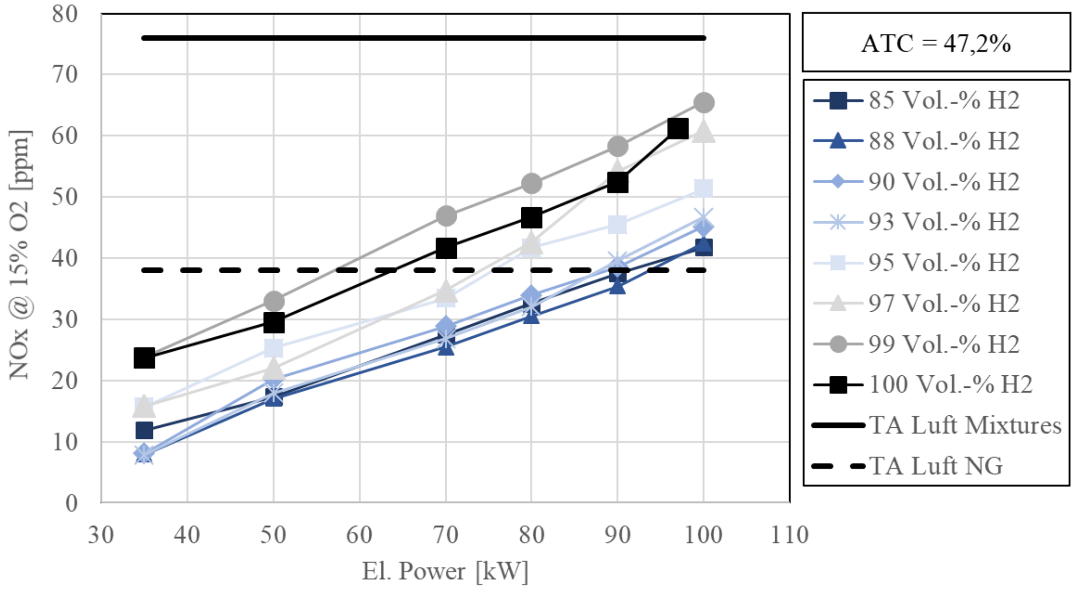
Study Results – CFD Field Solution

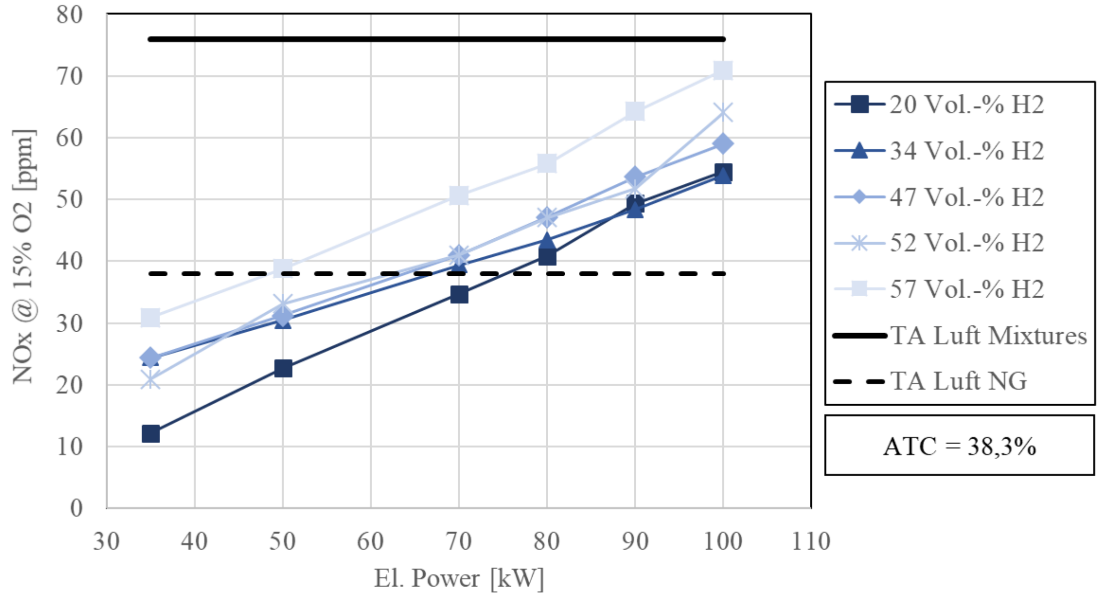


Study Results – CFD Field Solution



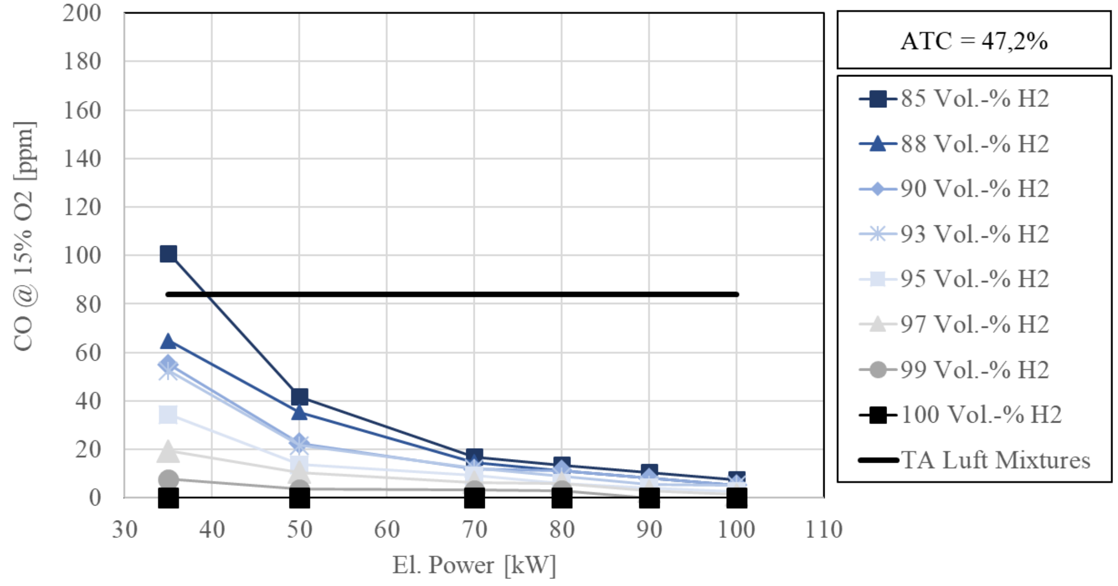
Study Results – Emission Measurements (NOx)

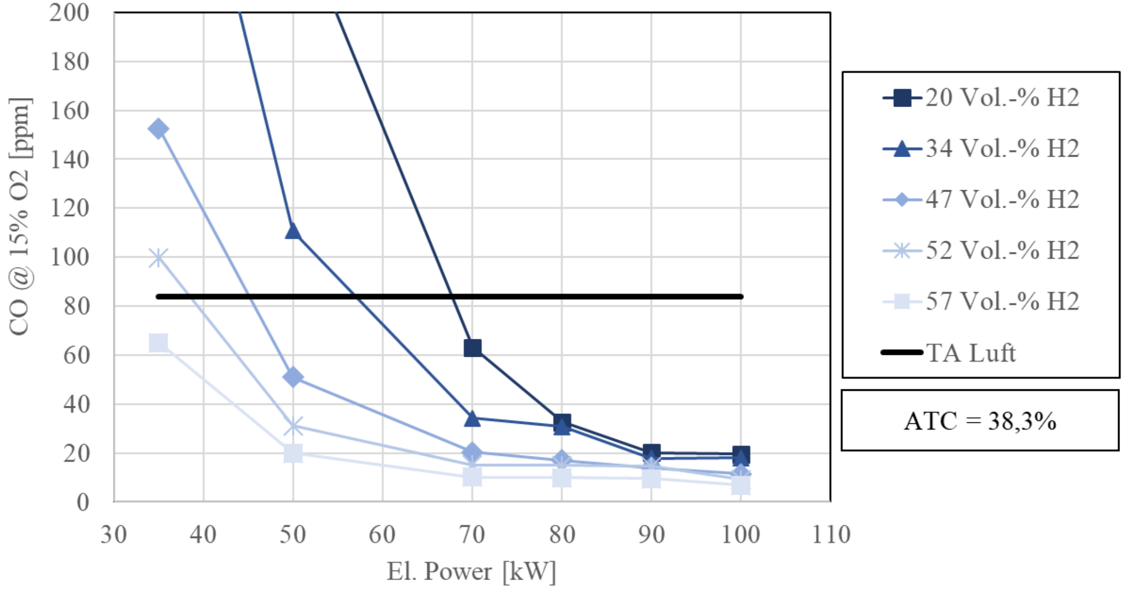




NOx [ppm]		Vol.-% H2																		
El. Power [kW]		20	34	47	52	57	63	67	71	74	78	81	83	85	88	90	93	95	97	99
	35	12.21	24.41	24.41	20.91	30.89	6.43	6.28	6.12	5.44	15.30	15.05	15.15	11.90	7.93	8.08	7.86	15.64	15.84	23.80
	50	22.72	30.44	31.17	33.15	38.82	8.71	8.33	8.24	7.63	19.83	23.17	23.80	17.37	17.05	20.26	17.95	25.30	22.05	33.06
	70	34.73	39.42	41.02	41.02	50.64	13.22	15.69	16.23	16.60	27.77	31.04	31.06	27.50	25.50	28.86	26.85	33.47	34.74	46.97
	80	40.83	43.44	47.11	47.10	55.78	17.72	20.70	20.70	21.16	32.45	35.16	36.04	32.60	30.58	34.00	32.08	41.74	42.59	52.25
	90	49.40	48.36	53.67	51.73	64.26	22.34	24.53	25.01	25.29	35.95	39.32	42.84	37.55	35.38	38.58	39.57	45.53	54.24	58.37
	100	54.49	53.89	59.05	64.08	70.94	25.63	28.47	29.17	29.75	42.26	45.86	46.84	41.78	42.50	45.21	46.69	51.39	60.83	65.53
		ATC = 38.3%					ATC = 47.2%													

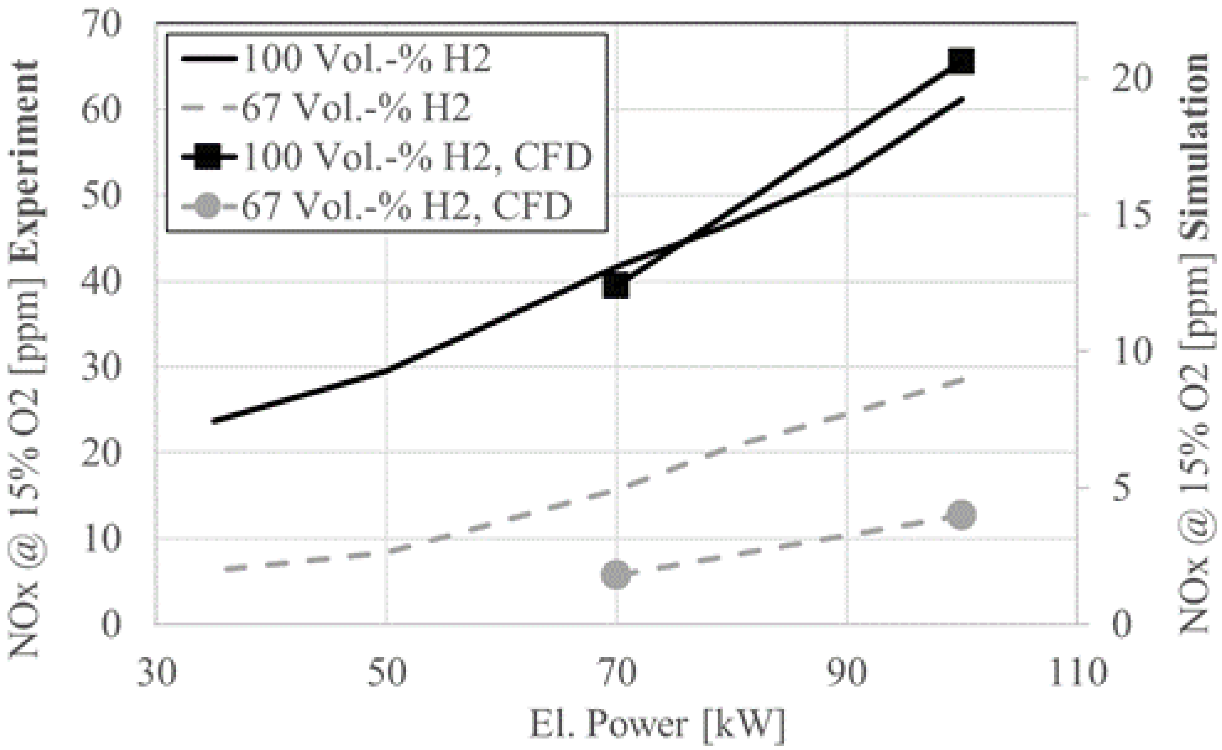
Study Results – Emission Measurements (CO)





CO [ppm]		Vol.-% H2																		
El. Power [kW]		20	34	47	52	57	63	67	71	74	78	81	83	85	88	90	93	95	97	99
	35	717	336	153	99.7	65	740	562	408	289	163	112	97.4	101	64.9	55.1	52.4	34.3	19.3	7.68
	50	243	111	51	31.2	19.8	334	223	140	101	70.2	47	41.8	41.8	35.4	22.5	21.6	13.7	10.5	3.48
	70	63.1	34.3	20.3	15.2	10.1	124	81.1	67.6	55.3	34	25.9	23.2	16.8	14.7	11.9	12.2	9.3	6.43	3.13
	80	32.7	30.7	17	14.9	9.92	78.5	56.9	44	39.7	24.3	18.9	16.8	13.6	11.1	11.3	8.75	5.92	6.04	3.02
	90	20.2	17.8	14	14.6	9.52	46.1	36.4	31.6	27.3	15.2	10.3	10.6	10.6	8.04	8.15	5.53	4.19	2.77	0
	100	19.6	18	11.4	9.15	6.87	27.5	23.3	23.3	16.7	9.71	7.44	7.6	7.6	5.15	5.2	5.34	2.7	1.33	0
		ATC = 38.3%					ATC = 47.2%													

Study Results – Evaluation of NOx prediction

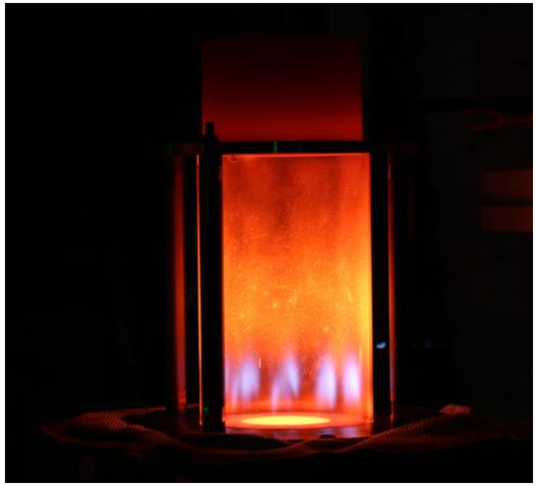


Contents

Conclusion / Outlook

- Highly promising retrofit of H2 in our F400s.3 combustor
  - Stable combustion with flame lift-off consistently
  - Emissions in range of existing requirements
  - CFD captures emissions and trends

- Currently: Development and testing of F400**h**.1
  - Successor to F400s.3 but optimization w.r.t. hydrogen
  - Improving mixing → less hot spot concentration → lower NOx
  - Test of different staging concepts → load variation to improve NOx and CO
  - ATM testing in Sept. 2023
  - T100 testing in 2024



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Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg

Thank you!

Hydrogen and Hydrogen Blended Jet and Recirculation Stabilized Combustion in a Turbec T100 Micro Gas Turbine Combustor

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DLR Burner

Backup

Retrofit Setup – T100 MGT with DLR Burner
Measurements

Air frac. Comb. (ATC)	H2 Vol.-%	El. Power	AFN Glob.	AFN Comb.
47.20%	100%	100kW	8.34	3.94
	100%	70kW	9.12	4.30
	67%	100kW	7.36	3.47
	67%	70kW	8.04	3.80
38.30%	14%	100kW	8.06	3.09
	14%	70kW	8.81	3.37
	3%	100kW	7.13	2.73
	3%	70kW	7.79	2.99

AFN: Air fuel ratio


T100 - Micro Gas Turbine


DLR Burner