



IMPACT ON CANADIAN RESIDENTIAL END USE APPLIANCES WITH HYDROGEN INTO THE NATURAL GAS STREAM

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FORT SASKATCHEWAN HYDROGEN BLENDING

IN FALL 2022

2,100 ATCO customers became the first in Alberta to use a 5% hydrogen/natural gas blend



Mostly residential homes



Some small businesses

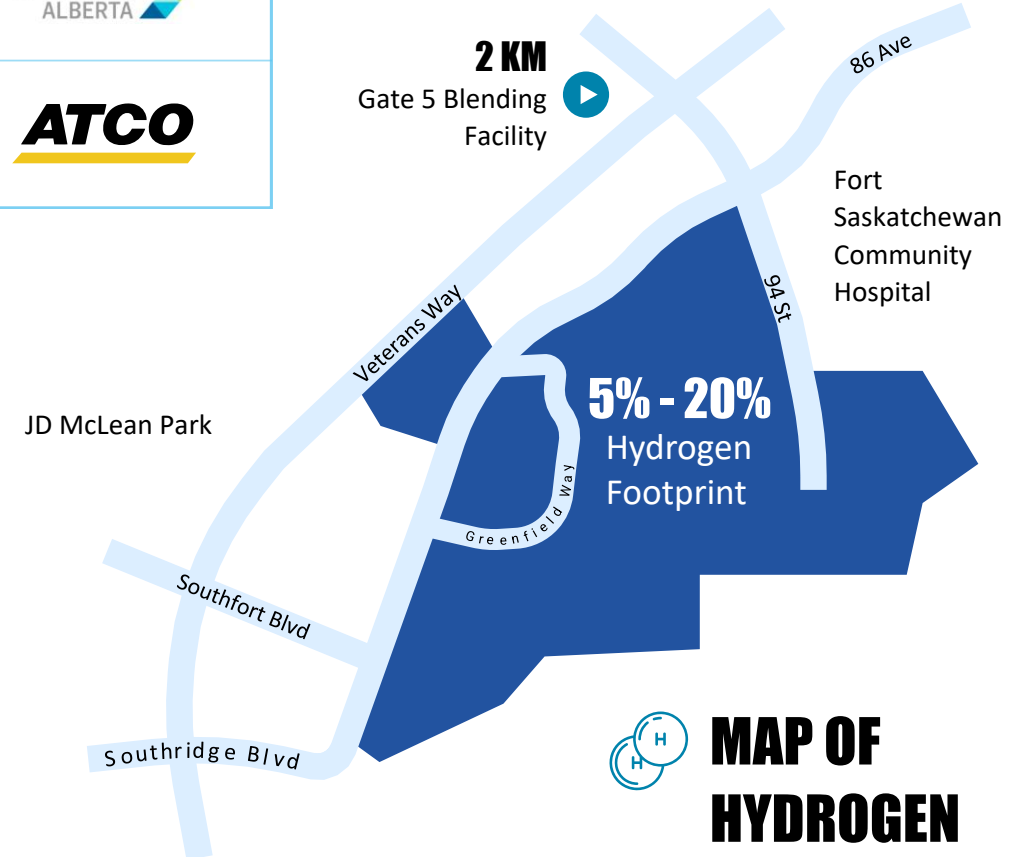


One school

EMISSIONS
REDUCTION
ALBERTA

ATCO

PROJECT OVERVIEW



**MAP OF
HYDROGEN
BLENDING PROJECT**

CUSTOMER ENGAGEMENT & APPLIANCE INSPECTIONS

ATCO has engaged with customers through:

- Open Houses
- Community Events
- Hydrogen Blending Home Inspections



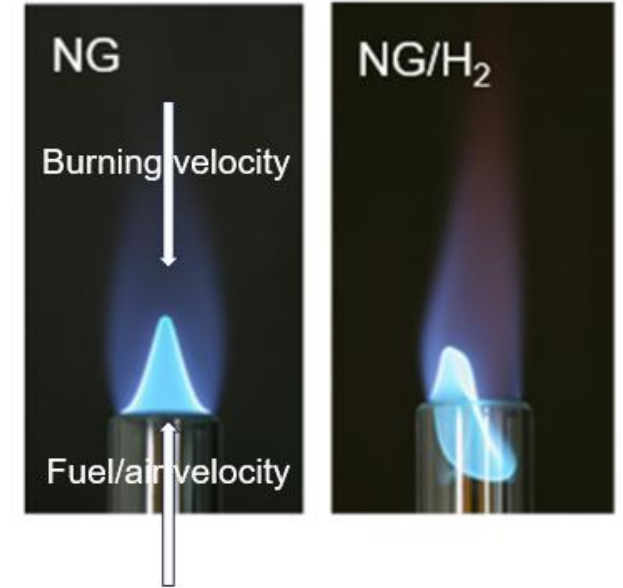
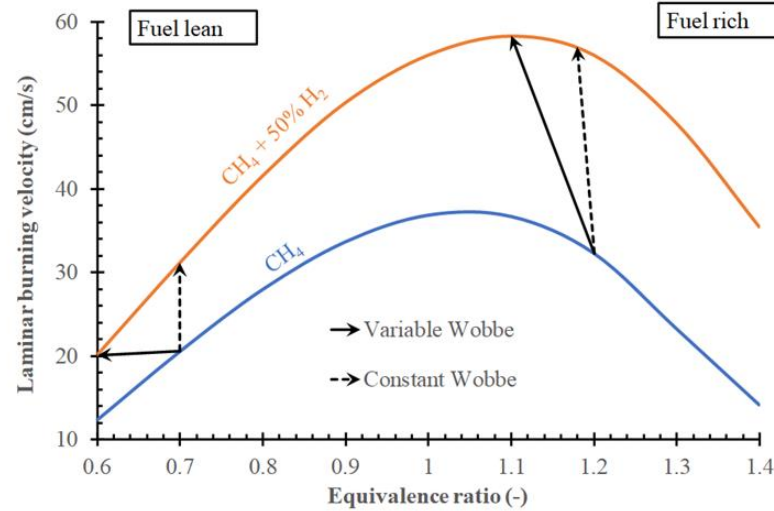
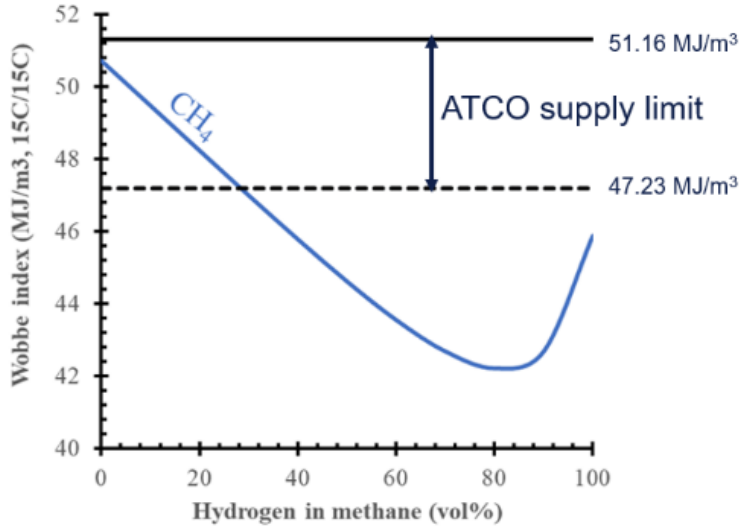
Over 85% inspection rate for private homes

Almost 1,800 customers
Over 5,800 appliances inspected

APPLIANCE TYPES AND COMBUSTION MODES

| Type | Combustion Mode | Air Supply | Burner |
|----------------------------|------------------|---------------|-------------|
| Gas Fireplace 1 | Partially premix | Natural draft | Log-set |
| Gas Fireplace 2 | Partially premix | Natural draft | Log-set |
| Cooktop | Partially premix | Natural draft | Ring |
| Stovetop | Partially premix | Natural draft | Ring |
| Oven | Partially premix | Natural draft | Tube Burner |
| Garage heater | Partially premix | Induced draft | In-shot |
| High efficiency furnace | Partially premix | Induced draft | In-shot |
| Mid efficiency furnace | Partially premix | Induced draft | In-shot |
| Hot water heater | Partially premix | Natural Draft | Pancake |
| BBQ | Partially premix | Natural Draft | Tube and IR |
| On demand hot water heater | Fully premix | Forced draft | Premixed |
| Clothes Dryer | Partially premix | Induced draft | Spoon |
| Radiant heater | Fully premix | Natural Draft | IR |

SELECTED GAS QUALITIES FOR HYDROGEN BLENDING - ATCO



Gas qualities tested for Fully premix appliances
(fuel lean, $\phi < 1$)

- Base gas methane (variable Wobbe case)
- Base gas natural gas (constant Wobbe case 51.16 MJ/m³)

Gas qualities tested for Partially premix appliances
(fuel rich, $\phi > 1$)

- Base gas methane (variable Wobbe case)
- Base gas natural gas (constant Wobbe case 47.23 MJ/m³)

TEST PROTOCOL - SAFETY AND PERFORMANCE

Test procedure:

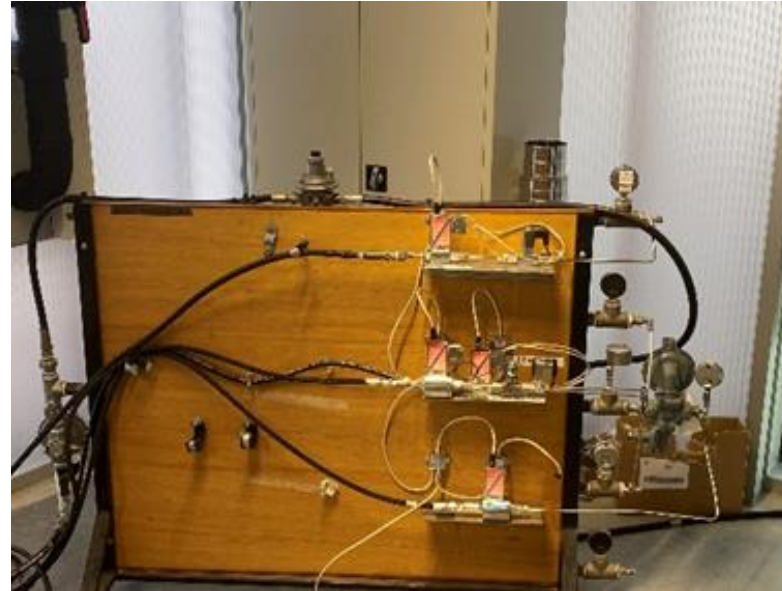
- Blending in H₂ at 'steady state' condition;
 - H₂ was gradually increased (**5, 10, 20, 30, 40, 50, 60, 70 vol%**) in natural gas until malfunctioning of the equipment occurred
 - The measurements are performed after **10-15 minutes** of stable operation and subsequently the H₂ percentage was increased
- **Fast/abrupt** changes in hydrogen percentage were performed;
 - changing the hydrogen percentage abruptly from 0-50 vol% hydrogen and from 50 to 0% hydrogen.
- **Cold start** and **hot reignition** with a high percentage hydrogen in natural gas have been performed
- If relevant; tests were performed at low and high thermal load
- Tests were performed at the average supply pressure provided in the instruction manual
- Rapid turndown for cooktop (from high to low thermal load)

GAS ANALYSIS SYSTEMS



Emission analyzers

- The analyzer used for measuring the NO_x emission was the ECO PHYSICS CLD 822 CM
- The oxygen concentration was measured using a paramagnetic O₂ (and CO₂) Maihak analyzer
- H₂ in the flue gas was measured using a Testo analyzer



Gas blending system

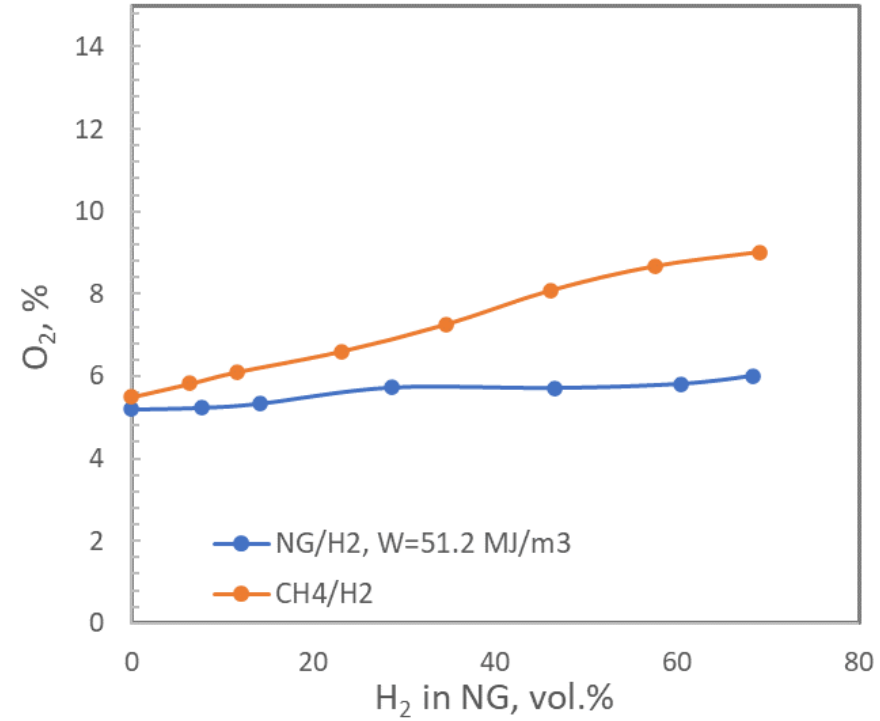
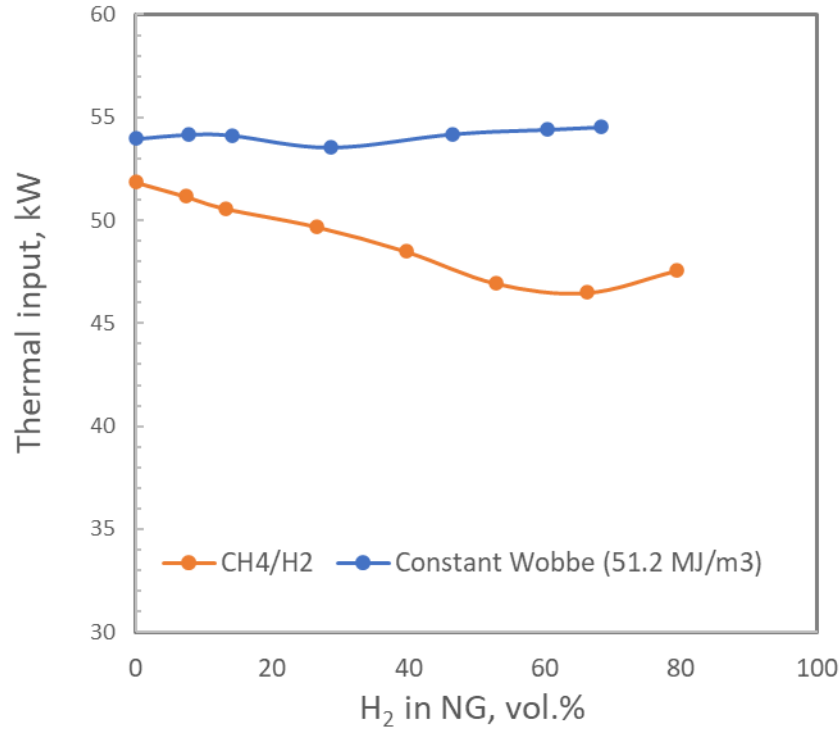
- Gas blends supplied by calibrated Bronkhorst flow meters
- Gas composition were set to the desired values using flow controllers
- The calorific value and Wobbe index are calculated based on the gas composition derived from flow meter readings



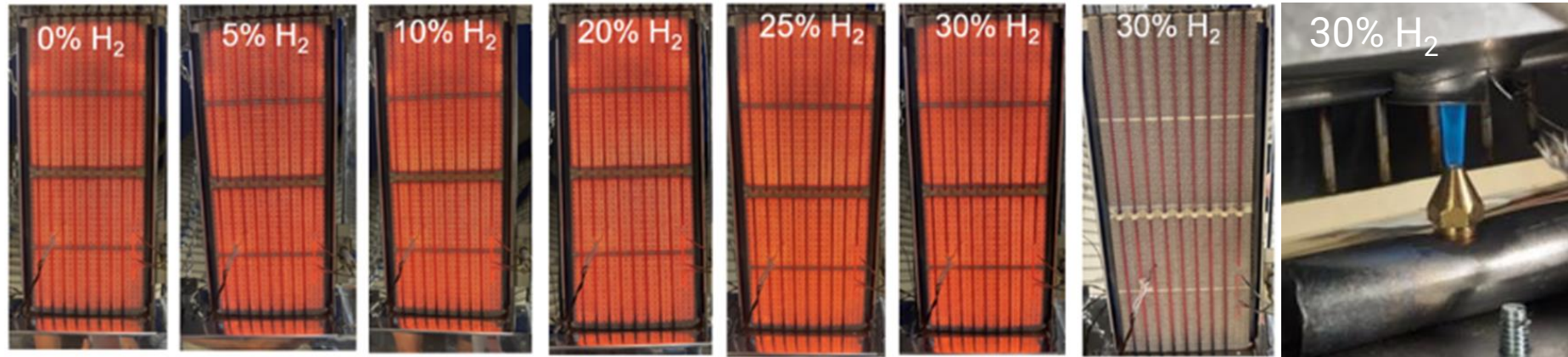
Gas chromatograph (GC) used for the tests:

- Agilent 3000 GC using Argon as carrier gas (mobile phase) equipped with a Molsieve column as stationary phase
- GC is used to check the accuracy of the flow meter settings for different hydrogen blends.

EFFECT HYDROGEN BLENDING ON THERMAL INPUT AND OXYGEN

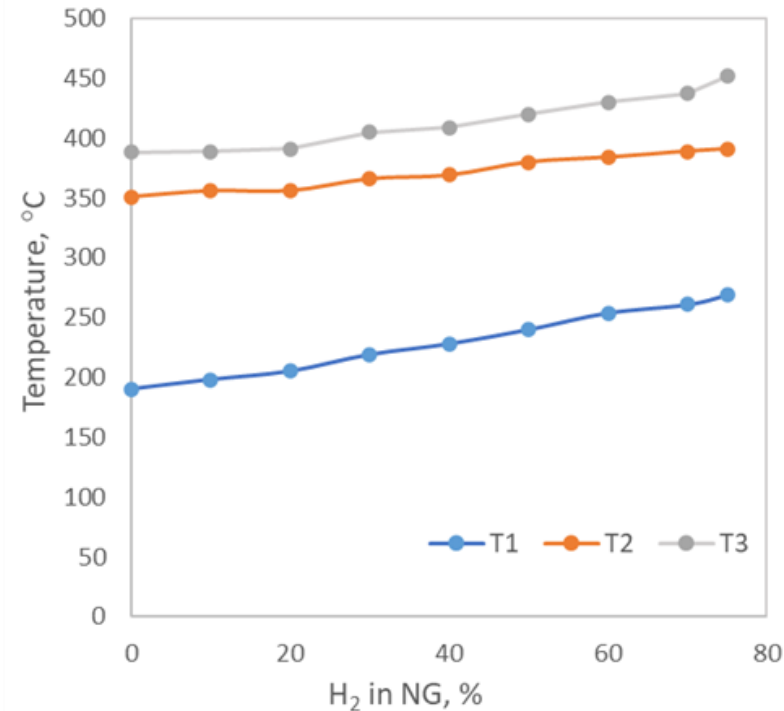
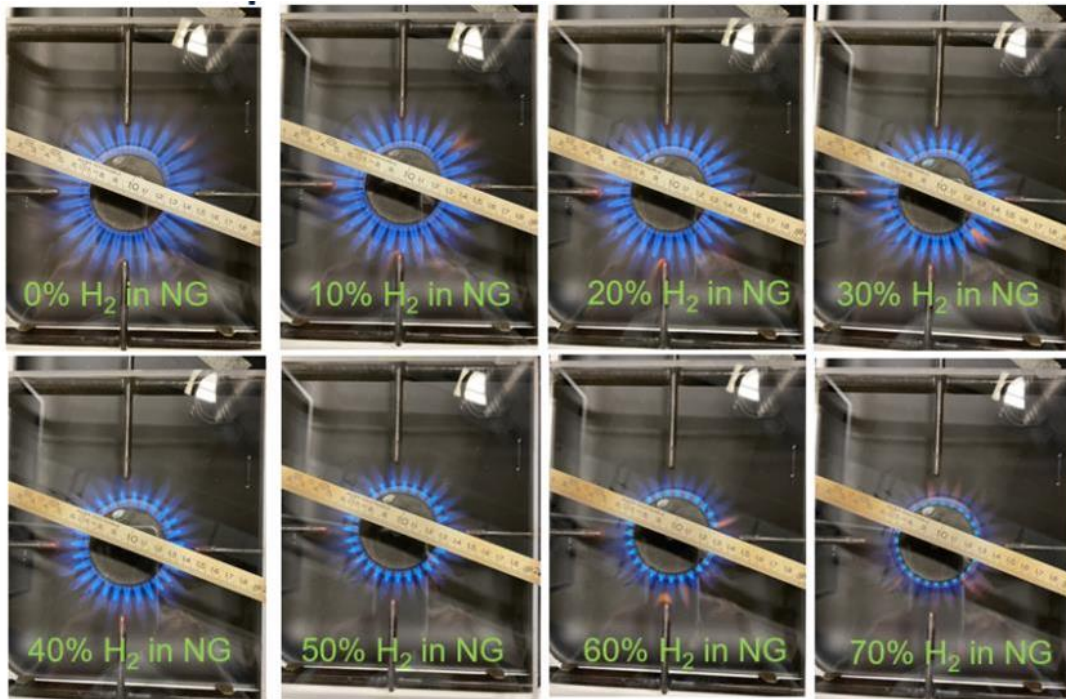


EFFECT HYDROGEN BLENDING ON FLASHBACK



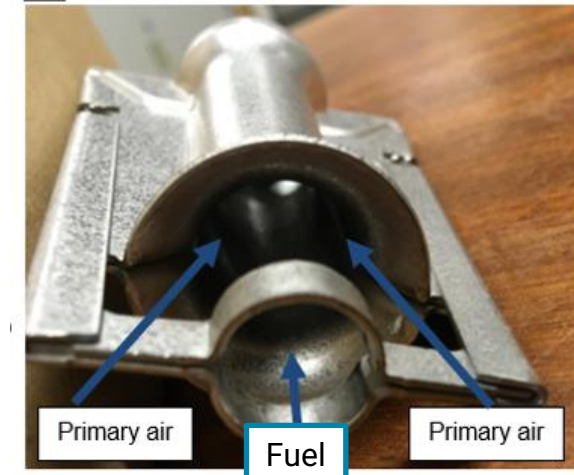
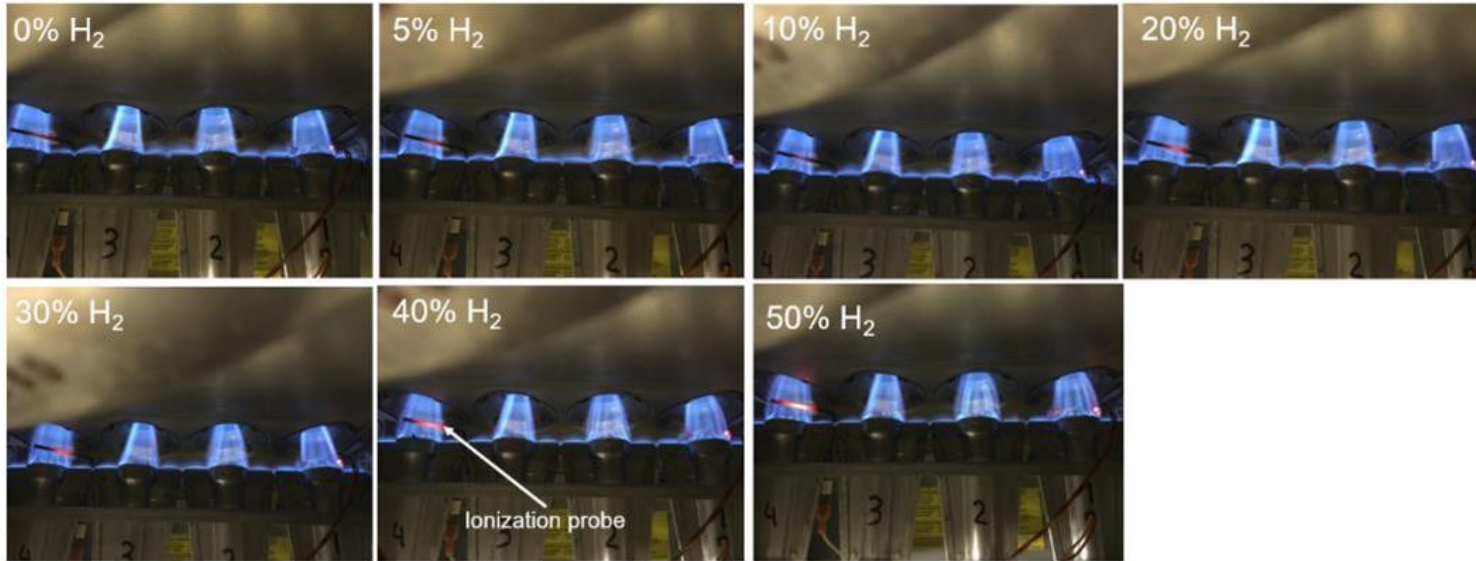
- Radiant heater most sensitive to flashback
 - Flashback at 30 vol% hydrogen after 15 min of operation
 - Flashback results in combustion in the venturi mixing tube
- Cooktop range: Flashback during rapid turndown at 50 vol% hydrogen
- IR heater BBQ: Flashback at 50 vol% hydrogen during cold start
- For all other appliances no issues were observed between 0-50 vol% hydrogen

EFFECT HYDROGEN BLENDING ON BURNER DECK TEMPERATURE



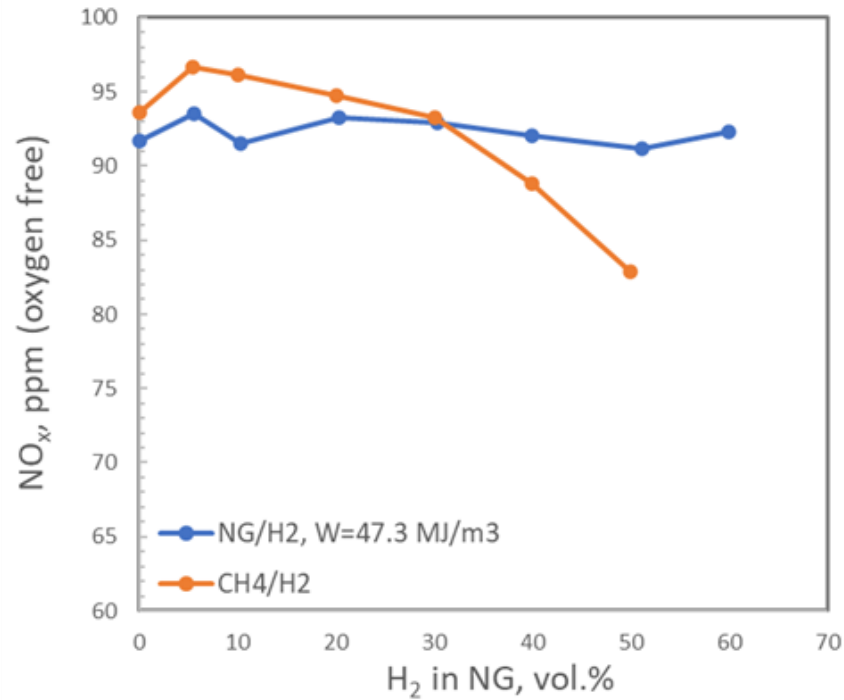
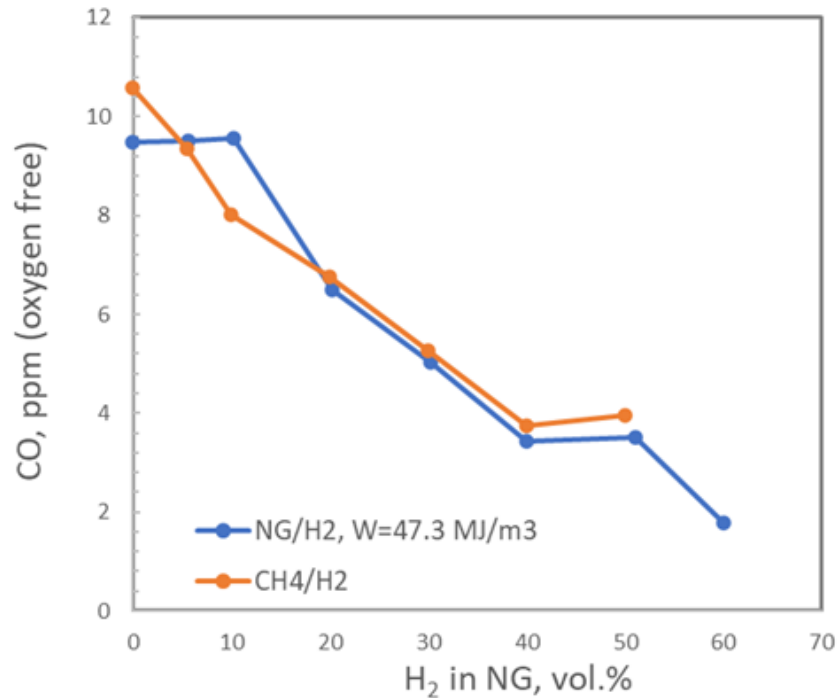
- Rule of thumb: 5% increase in temperature is acceptable (no long-term issues assumed)
- All appliances studied had <5% temperature increase for 0-20% hydrogen blends
- Above 20 vol% H₂: the burner deck temperature increase above 5% for:
 - Cookers, high efficiency furnace, storage tank hot water heater and clothes dryer

EFFECT HYDROGEN BLENDING ON FLAME DETECTOR AND IGNITOR



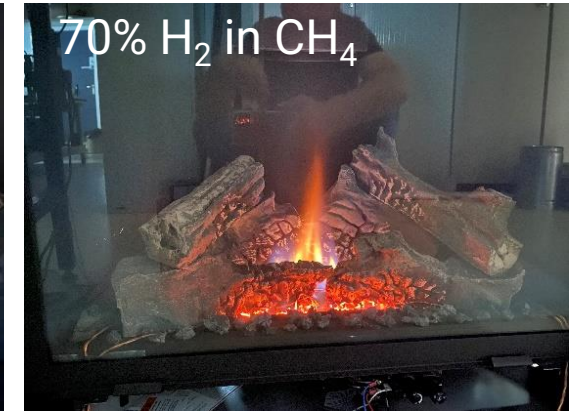
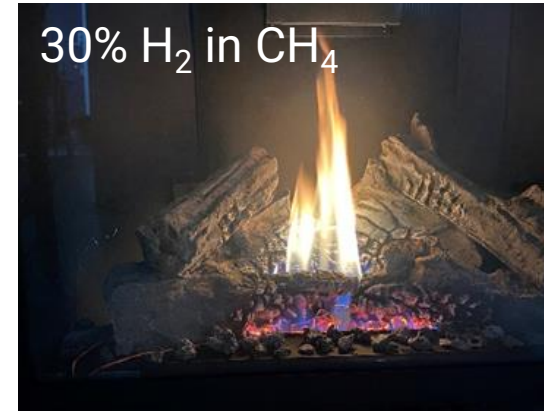
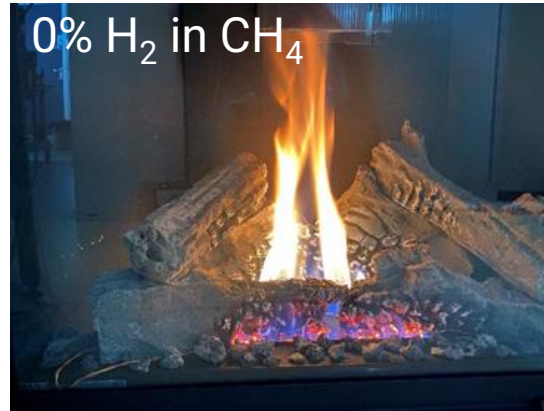
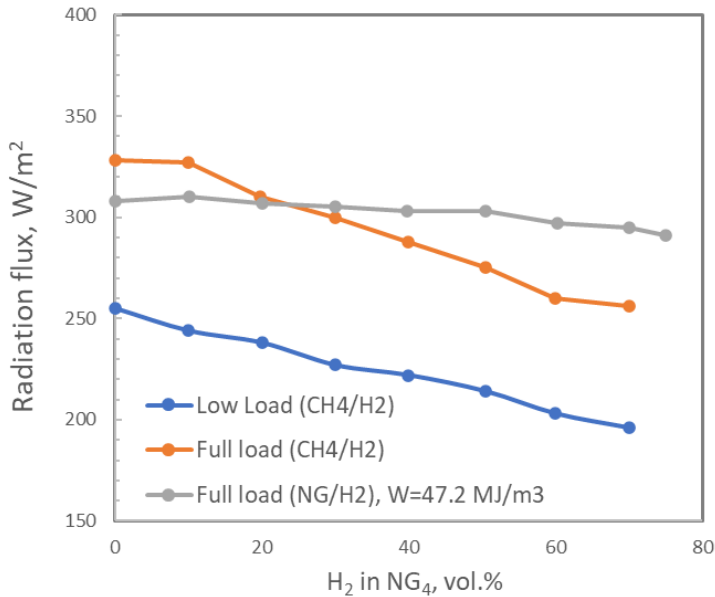
- **Mid-efficiency furnace:**
 - At 20 vol% and above the ionization probe increases in temperature.
 - No impact observed on the measured ionization signal
- **All other appliances**
 - Up to 20 vol% H₂ there is no significant changes
 - Between 20-30 vol% the ionization probe of the garage heater, high efficiency furnace and gas fireplace 1 started to glow more brightly

EFFECT HYDROGEN BLENDING ON EMISSIONS



- CO emission
 - For all appliances the CO emission remains constant or decreased upon hydrogen blending
- NO_x emission
 - NO_x was found to increase slightly (5% and 10% at 30 vol% H₂ respectively) for fireplace 1, the conventional and on demand hot water heaters
 - NO_x remained constant or decreased for all other appliances upon hydrogen blending

EFFECT HYDROGEN ADDITION ON THE HEAT FLUX GAS FIREPLACE



- The radiation decreases when blending in H₂ to CH₄. This can be explained by the decrease in 1) Wobbe index causing a lower thermal input and 2) the reduction in soot formation (produces radiation) as a result of lowering the C/H ratio and the increase in oxygen
- At constant Wobbe index the radiation flux is constant up to 40% H₂ since the thermal input is constant. Above 40% H₂ a slight decrease in heat flux is observed

CONCLUSIONS & RECOMMENDATIONS

Main conclusions:

- No short-term performance issues observed for all appliances up to 20 vol% hydrogen
- The study identified the radiant heater as most sensitive appliance: flashback at 30 vol%
- CO emission stays constant or decreases upon hydrogen blending (important safety parameter)
- Above 20 vol% hydrogen several appliances show an increase in burner deck temperature above 5%

Recommendation

- Study long term effect of hydrogen blending (e.g., burner deck and flame detection devices)
- To extend the program to other appliances such as;
 - Home Back-up Generators (contains a gas engine),
 - Rooftop Units,
 - others

JOINT INDUSTRY PROJECT



ATCO



JOINT INDUSTRY PROJECT HY₄HOMES

Short term tests to study the impact of H₂ addition on the safety and performance (on-going)

- Home back-up generator (gas engine)
- Wok burner
- Griddle
- Atmospheric boiler
- Rooftop unit (RTU)



Test Program for Long Term Performance and Integrity

- The test program for long term performance and integrity aims to assess the impact of hydrogen blending on the appliance performance within the 1-year maintenance interval.





QUESTIONS?

