Operational Considerations of an Integrated Syngas Production System using the SunGas System 1000 with Linde Hot Oxygen Technology

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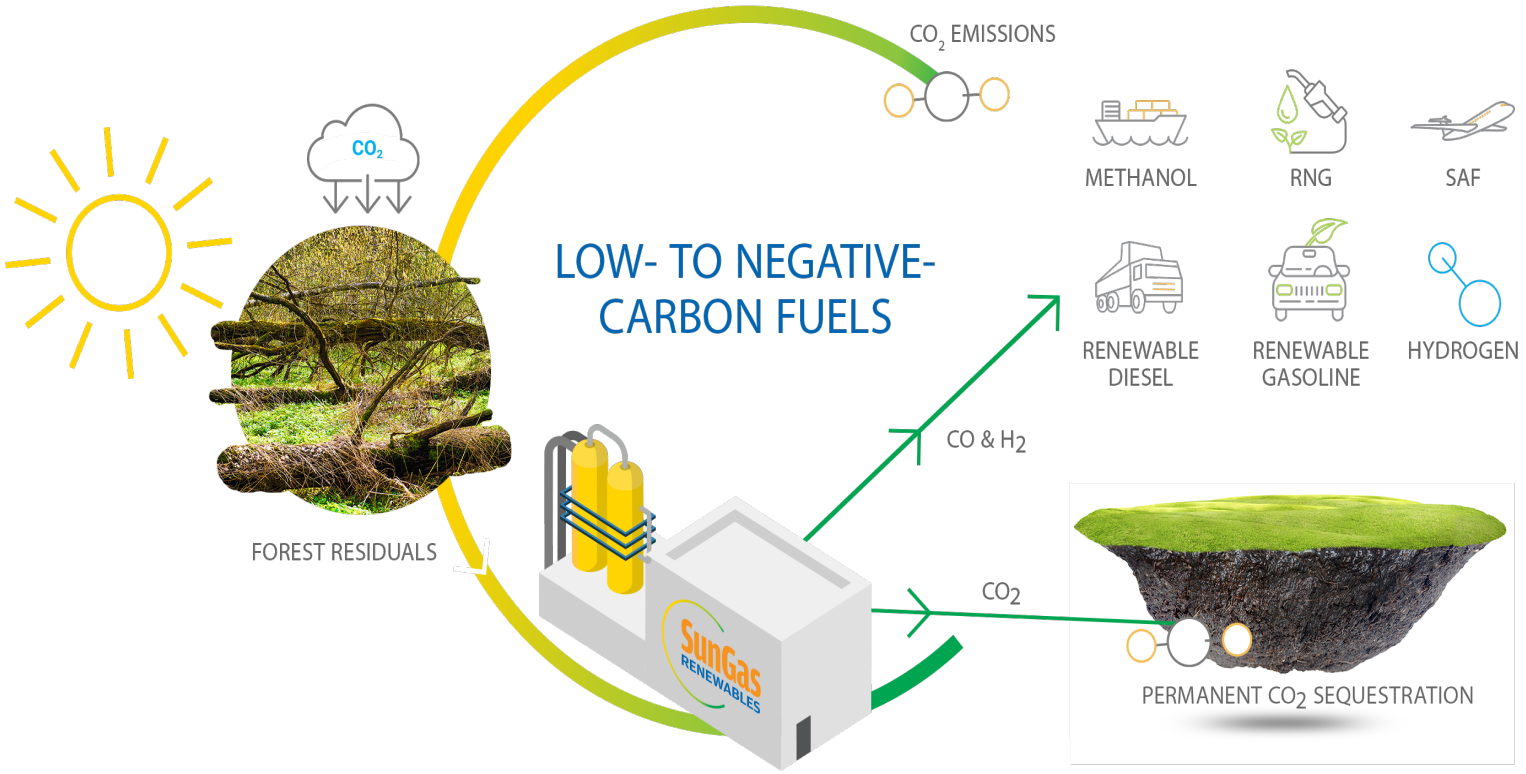
SunGas' Sustainability Pathway



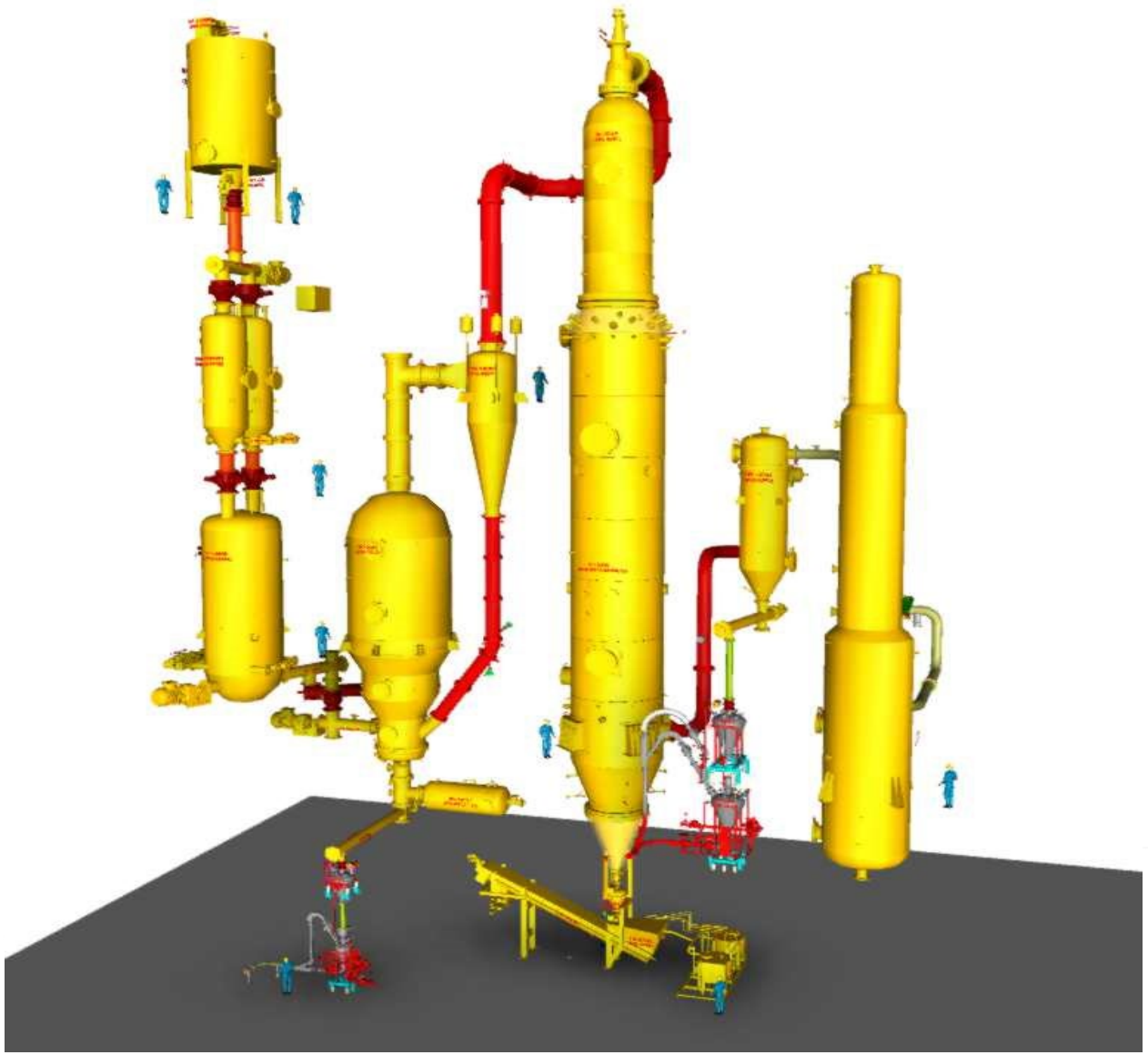
The natural air capture (NAC) approach to achieving carbon reduction TODAY

SunGas Proven Technology Embodied in the System 1000™ Offering Enables –

- Renewable Energy Production in Multiple Energy Segments
- Production of Low and Negative Carbon-Intensity Energy Products
- Qualification for Renewable Energy Incentives and Credits
- Criteria Pollutants Reduction by 99% Compared to Biomass Power Plants

SunGas RENEWABLES™

The S-1000 Product



Gasifier
- Versatile feedstock capabilities
- Unique Jet & Grid design creates optimum conditions for fast reactions and uniform temperature distribution

Feedstock Handling System
- Lock-hopper based design – crossing pressure barrier
- Flexible feed options – screw-feeding or pneumatic feeding

Ash Handling System
- Removes and cools bed and filter ash
- Conveys to silo storage pneumatically

Tar Reformer
- Complete reforming of all tars
- Immune to contaminants in feedstock

Syngas Cooler
- Capable of operating slagging/non-slagging conditions
- Self-cleaning design of heat transfer components

Syngas Filter
- High efficiency (99.9%) of removing fines
- Surface modified sintered metal provides extended life

Syngas Scrubber
- Primary gas cooling and moisture removal
- Trace contaminate removal, HCl, NH3

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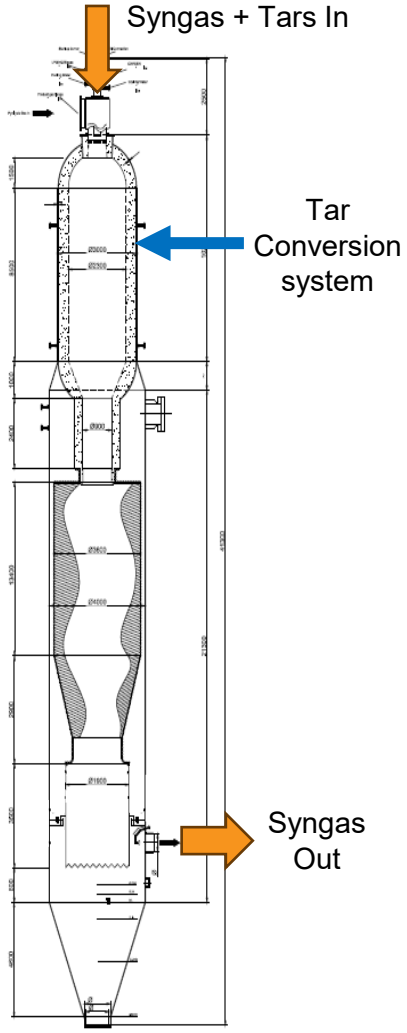
Tar Reforming System

- **Purpose:**
  - Eliminate tars
  - Minimize methane
  - Insensitive to process contaminants

Decision Criteria	Catalytic Option	Thermal Option
Reliability Risk	**High** Catalyst poisoning	**Low**
Readiness Risk	**Moderate** Needs development for System 1000™ scale	**Low** Ready to deploy for System 1000™ scale
Commercial Experience	**Limited** No operating units at scale suitable for the System 1000™	**Multiple** 1 operating unit at commercial scale Many operating units at smaller scale The burner fundamentals are widely used in various applications with proven performance.



The Thermal Option: A reliable, proven, and complete solution for tar conversion

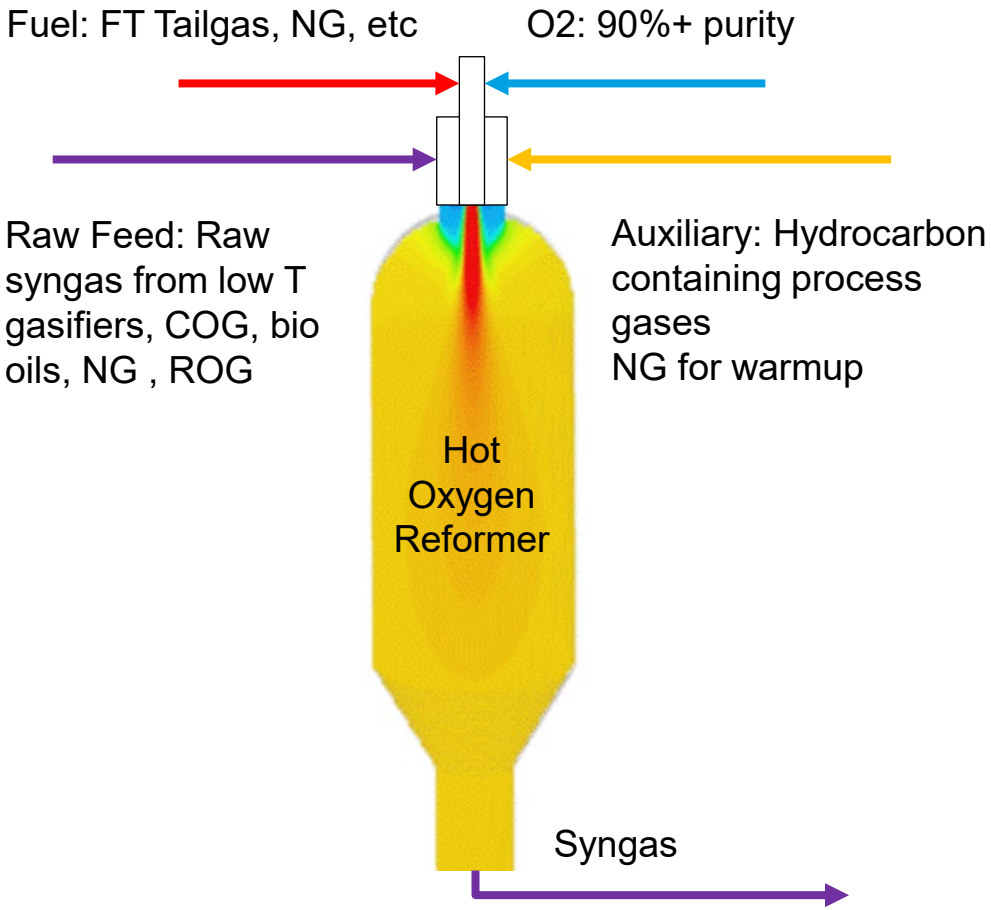
Hot Oxygen Technology for Syngas Production

Multi-feed HOB POx burner enables maximum flexibility

- Enables use of opportunity feeds
- Enables fast backup of POx operations in event of loss of feed
- Enables potential capacity increase for integrated systems
- Enables ‘tuning’ of syngas composition leaving the POx

Multi-feed HOB POx burner enhances system reliability

- Enables fast backup of POx operations in event of loss of feed

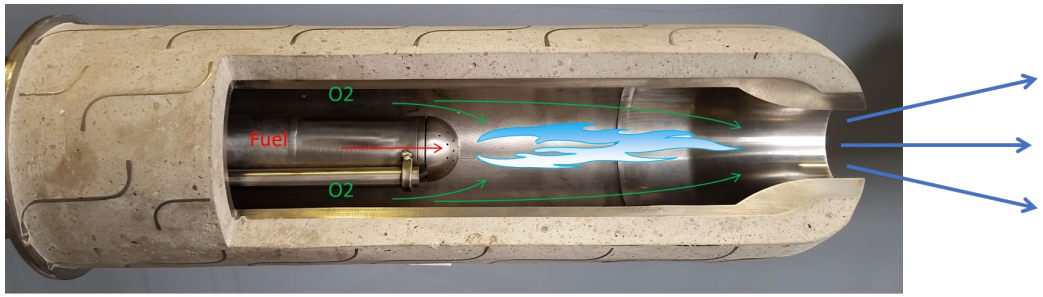


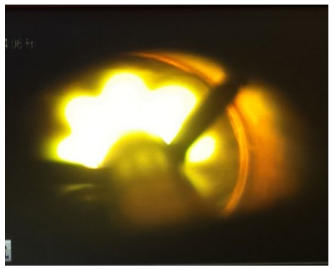
Multi-feed HOB provides maximum operating flexibility and reliability

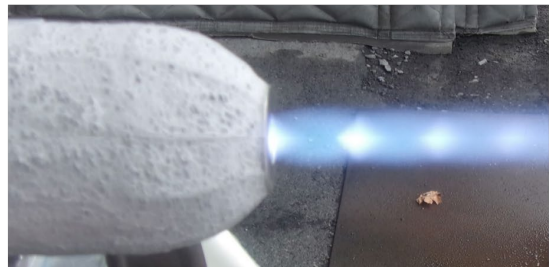
Hot Oxygen Burner

Internal oxy-fired flame

- Very fuel lean
- Designed to minimize or eliminate water cooling requirement
- Very stable and ‘protected’ from downstream process
- Includes flame monitoring (acts as pilot for downstream flame)







Hot oxygen jet creates rapid mixing and reaction

- Hot gas ~ 80-95% O2, 1200-1700°C or higher
- High momentum + low density causes fast mixing with surroundings
- Mixing is easily estimated using standard correlations
- Hot gas is very reactive resulting in rapid ignition and stable flames downstream of nozzle

Combination of stable, monitored, internal flame and very fast mixing enables wide range of uses for hot oxygen

HOT Integrated with SunGas System 1000

- SunGas System 1000 produces raw syngas from biomass feeds
- HOT upgrades raw syngas – converts hydrocarbons and tars into additional H2 and CO, increasing yield by 40+%
- HOT ensures all raw syngas is processed, preventing slip of tar and maximizing yield

- System 1000 and HOT are fully integrated
  - Mechanical – Syngas island package offered by SunGas begins with biomass and produces syngas ready for FT
  - Process – From startup to normal operation to shutdown – fully integrated technologies ensure smooth operation
  - Safety – Unplanned events in any unit operation impacts the other operations, must be ready to respond

- Today – Walk through normal operation and transient process changes for gasifier and HOT POx

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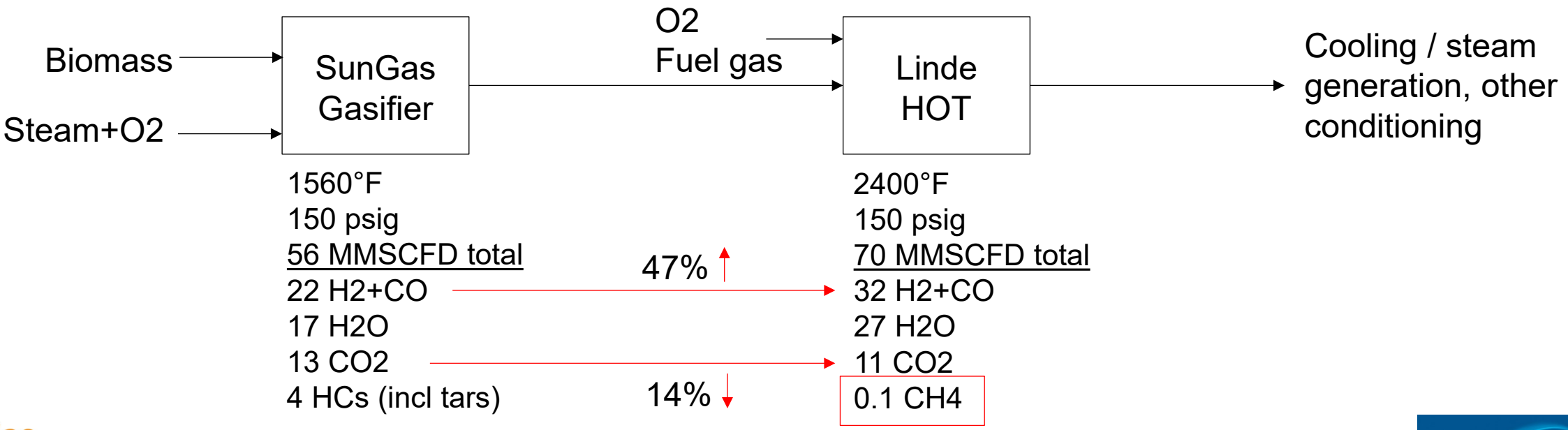
Linde

Integrated System – Normal Operation

Basic description of normal operation:

- SunGas produces a raw syngas containing tars and CH4
- Linde upgrades with tar/CH4 conversion to syngas components (H2+CO)
- The upgraded gas is sent to further processing (removal of particulates, halides, ammonia, etc.)

Any deviations during normal operation will be due primarily to feedstock variations such as moisture, carbon, etc.

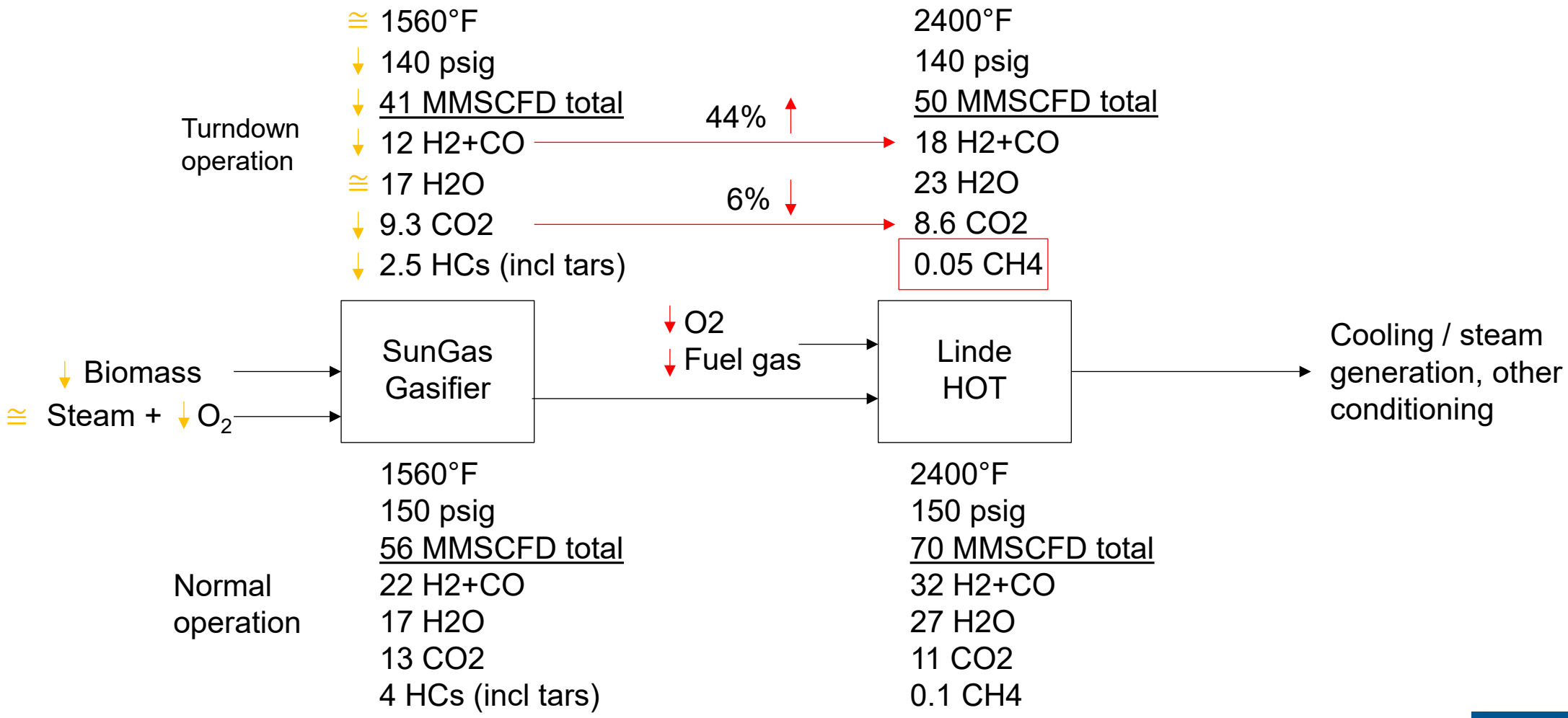


Integrated System – Turndown Steps

- S-1000 operates by maintaining bed fluidization
- SunGas high level steps to turn down operating rate:
  - Decrease biomass feeding rate
  - Adjust O2 flow to maintain gasifier temperature
  - Adjust flow conditions (Flow rate or Pressure) to maintain velocity
  - Maintain steam/O2 to ensure reactivity and fluidization

- HOT operates by maintaining temperature
- Linde high level steps to respond to SunGas actions:
  - Reducing mass flow will reduce HOT firing rate
  - Reducing raw syngas will reduce HOT firing rate
  - Changing operating pressure requires large flow control range (valve selection is important)
  - Relative increase in H2O requires relative increase in overall stoichiometry

Integrated System – Gasifier Turndown & HOT Response



Integrated System – Adjustment Back to Normal Operation

- Incremental changes in gasifier while maintaining bed properties and chemistry

  → Incremental responses in POx to maintain temperature
- Operators can select operating rate up to 120% of Normal Operation

Conclusion

- System 1000 and HOT are fully integrated at all layers:
  - **Mechanical** – Syngas island package offered by SunGas begins with biomass and produces syngas ready for FT
  - **Process** – From startup to normal operation to shutdown – fully integrated technologies ensure smooth operation
  - **Safety** – Unplanned events in any unit operation impacts the other operations, must be ready to respond
- Operating changes in one part of the process requires adjustments in all other parts of the process

Thank You