

FreeSpin[®] In-Line Turboexpander

Waste pressure to energy

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Sapphire Technologies Background



Baker Hughes (Italy, 2019)

- Joint development for NG pressure letdown application
- Proof of concept for FIT's magnetic bearings, 300-kW generator, & variable speed drive
- 10,000+ operating hours



Toho Gas (Japan, 2021)

- Two FIT (125-kW & 300-kW) installed at LNG regasification facility
- Japan's third largest NG provider
- Commissioned & certified by Japan's Ministry of the Environment as a clean energy project eligible for government incentive

Technology background

- Calnetix invests US\$30M since 2006 to develop expander technology
- 400+ Organic Rankine Cycle refrigerant expanders installed worldwide
- Millions of operating hours

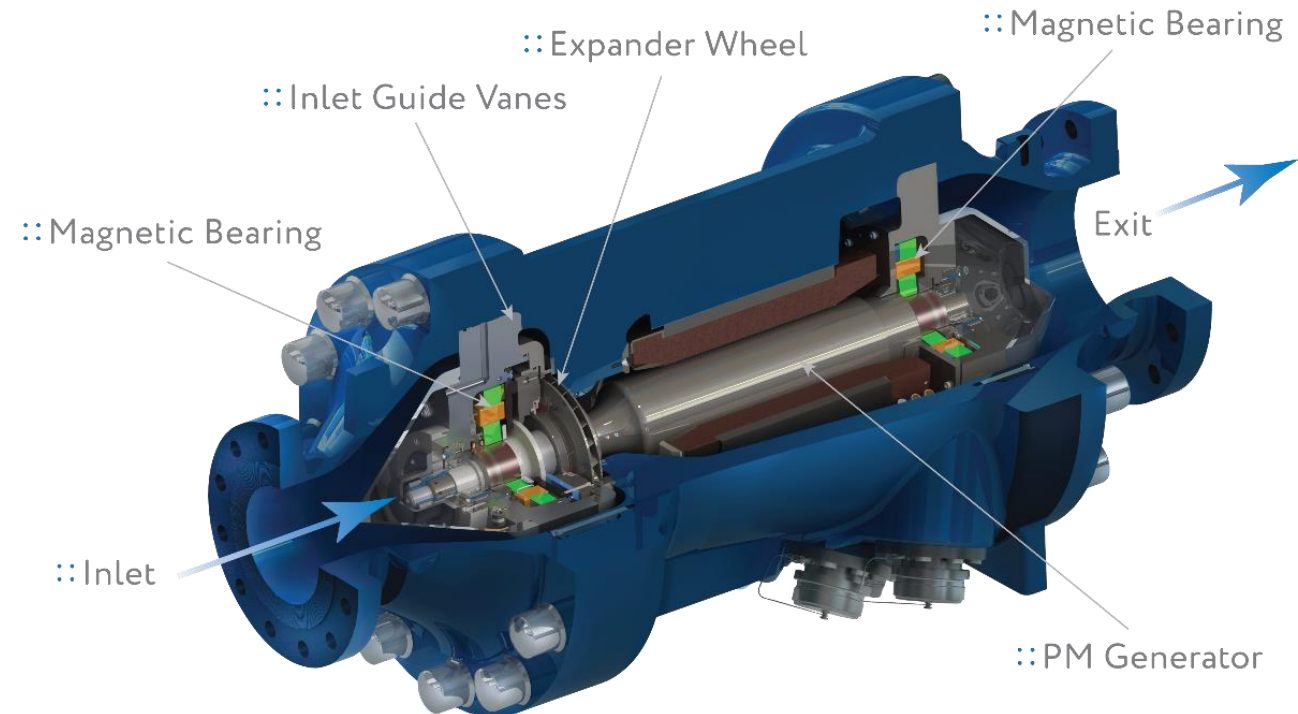


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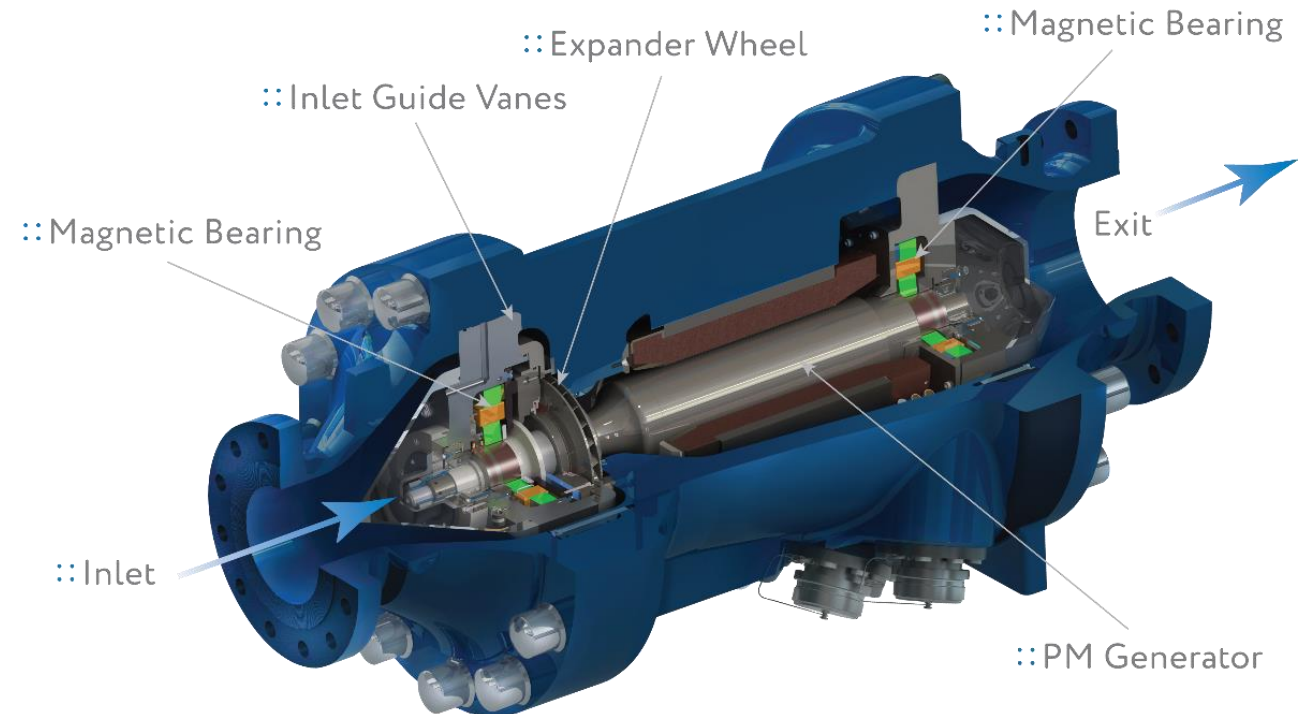
Conversion of wasted pressure energy into clean electric power

1. High-pressure gas enters FIT
2. Kinetic energy is converted to rotational energy in the wheel
3. The wheel spins a PM generator, creating voltage in a stator
4. Current is transmitted from the stator to a variable speed drive (VSD) via power cabling
5. Conditioned power is sent from the VSD to the load

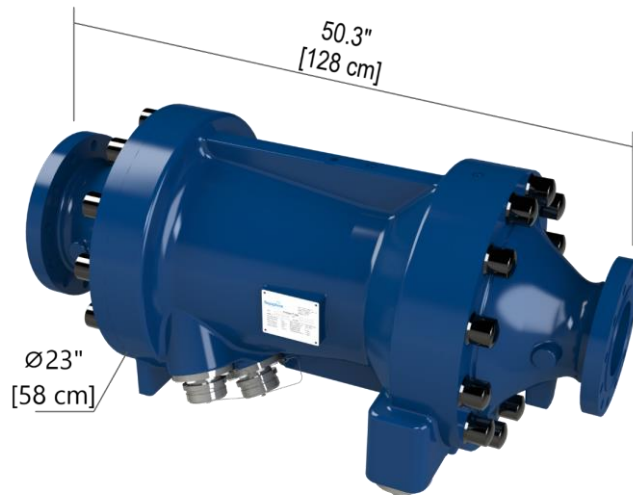


FreeSpin[®] In-Line Turboexpander (FIT)

- Active magnetic bearings levitate rotor during operation
 - No friction
 - Low life cycle cost with 20-yr design life
- Expanded (cooled) gas exits wheel and flows-through generator section
 - No additional cooling required
- Hermetically sealed, no-leak housing
 - Flange-connected into pipeline
 - No penetrations for lubrication or cooling



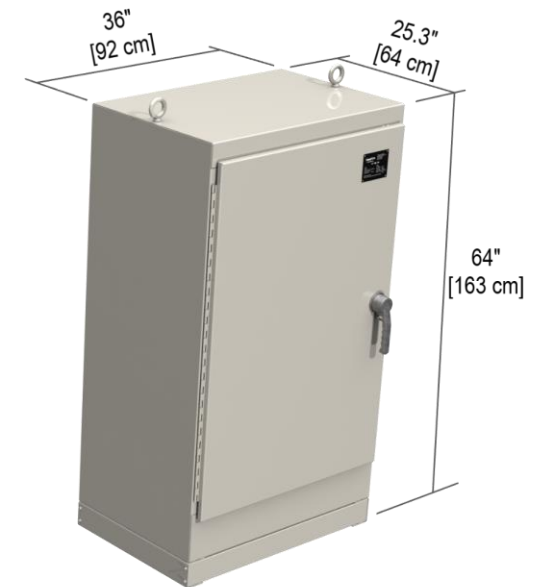
Scope of Supply



Turboexpander



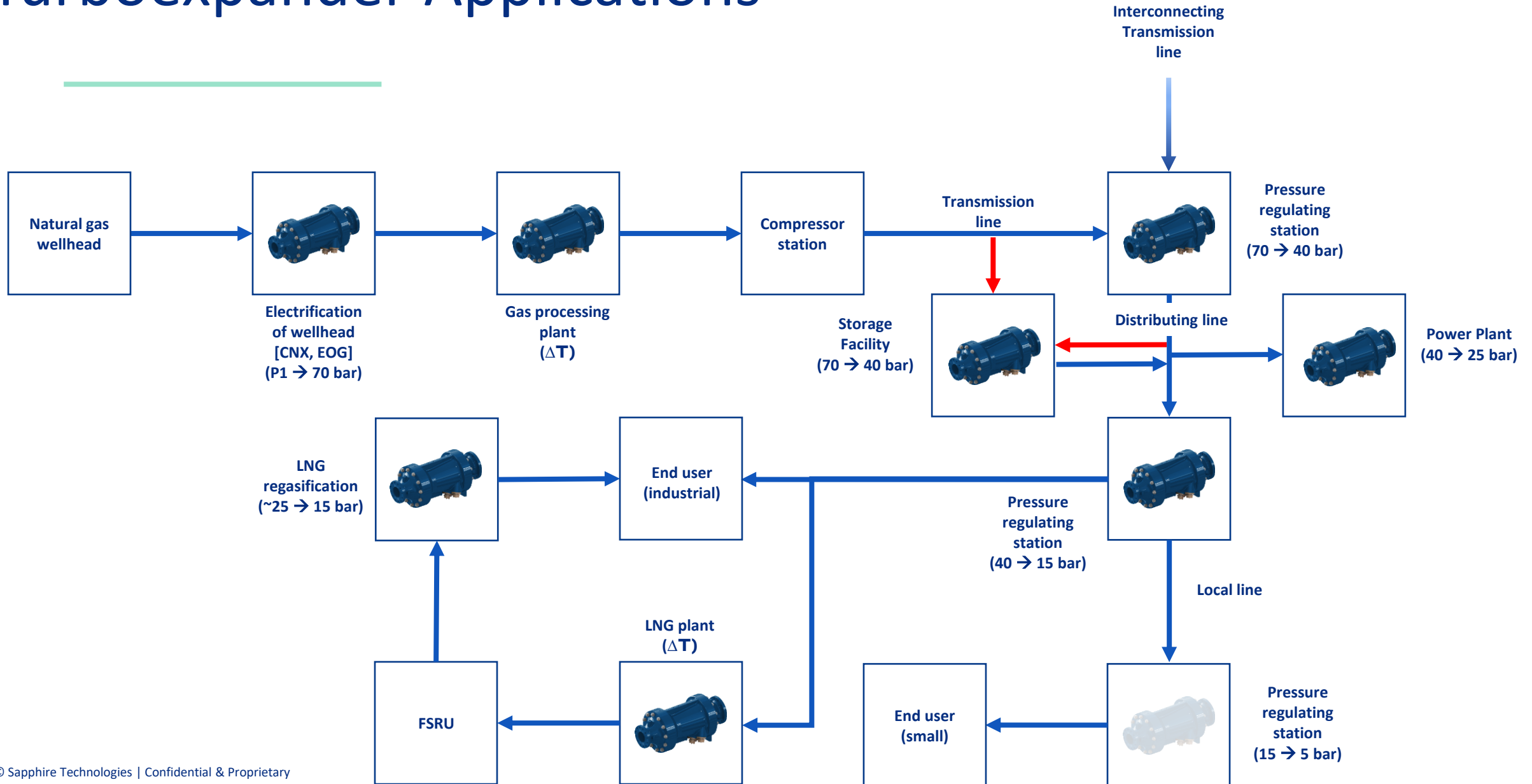
VSD Cabinet



Brake Resistor

Natural Gas Pressure Letdown

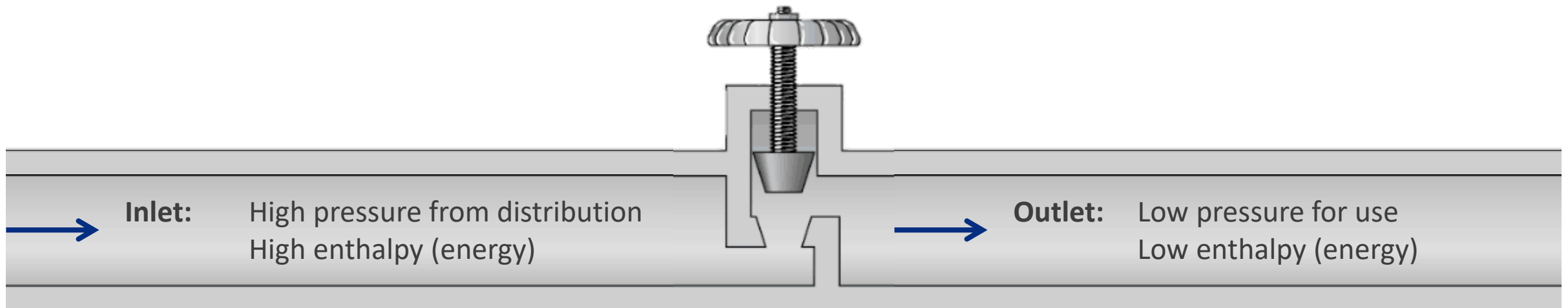
Turboexpander Applications



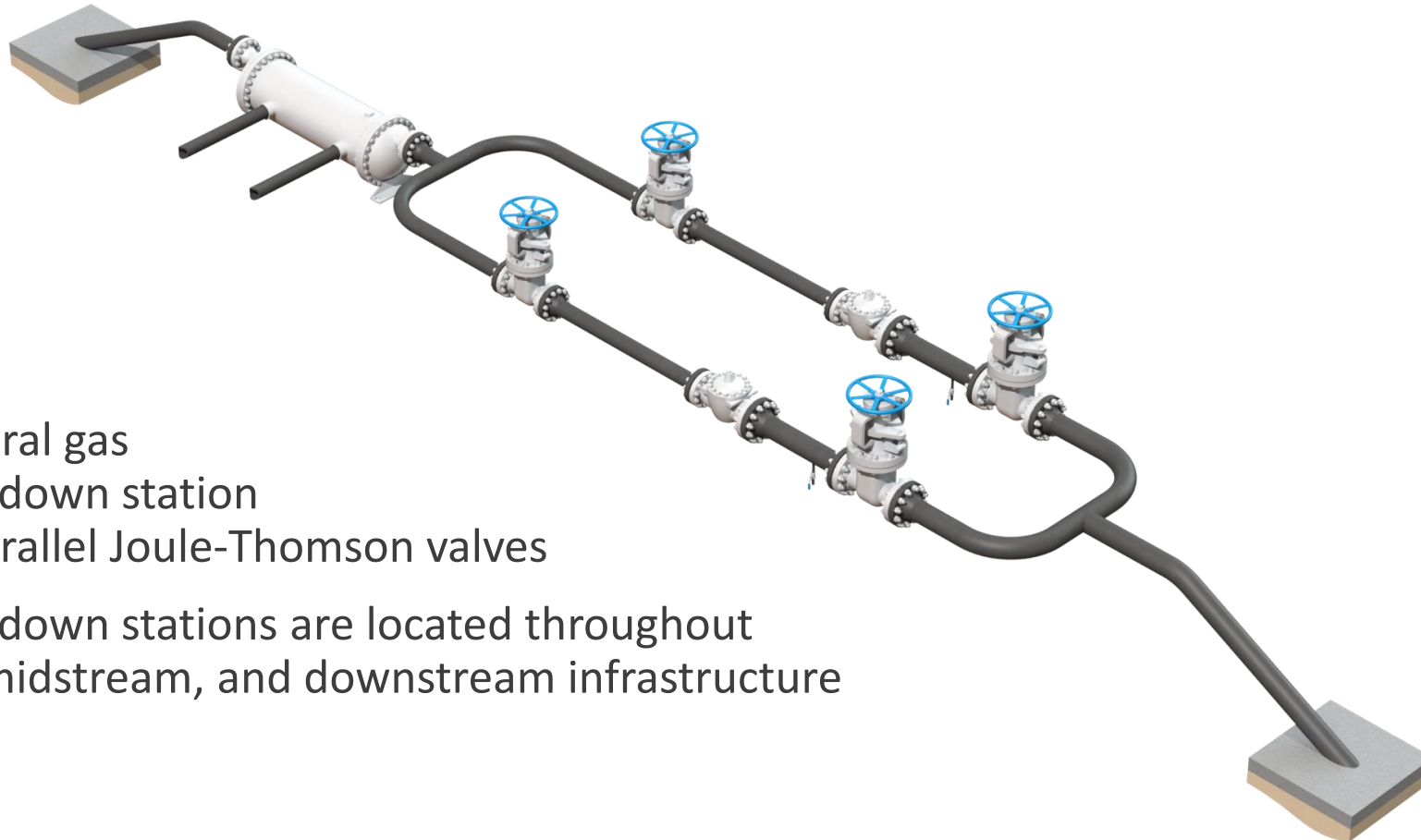
Natural Gas Pressure Letdown

Existing Process (Wasted Pressure Energy)

- Pressure energy is wasted at over 300,000 natural gas pressure letdown stations globally
 - Joule-Thomson valves (incumbent) cannot recover this energy

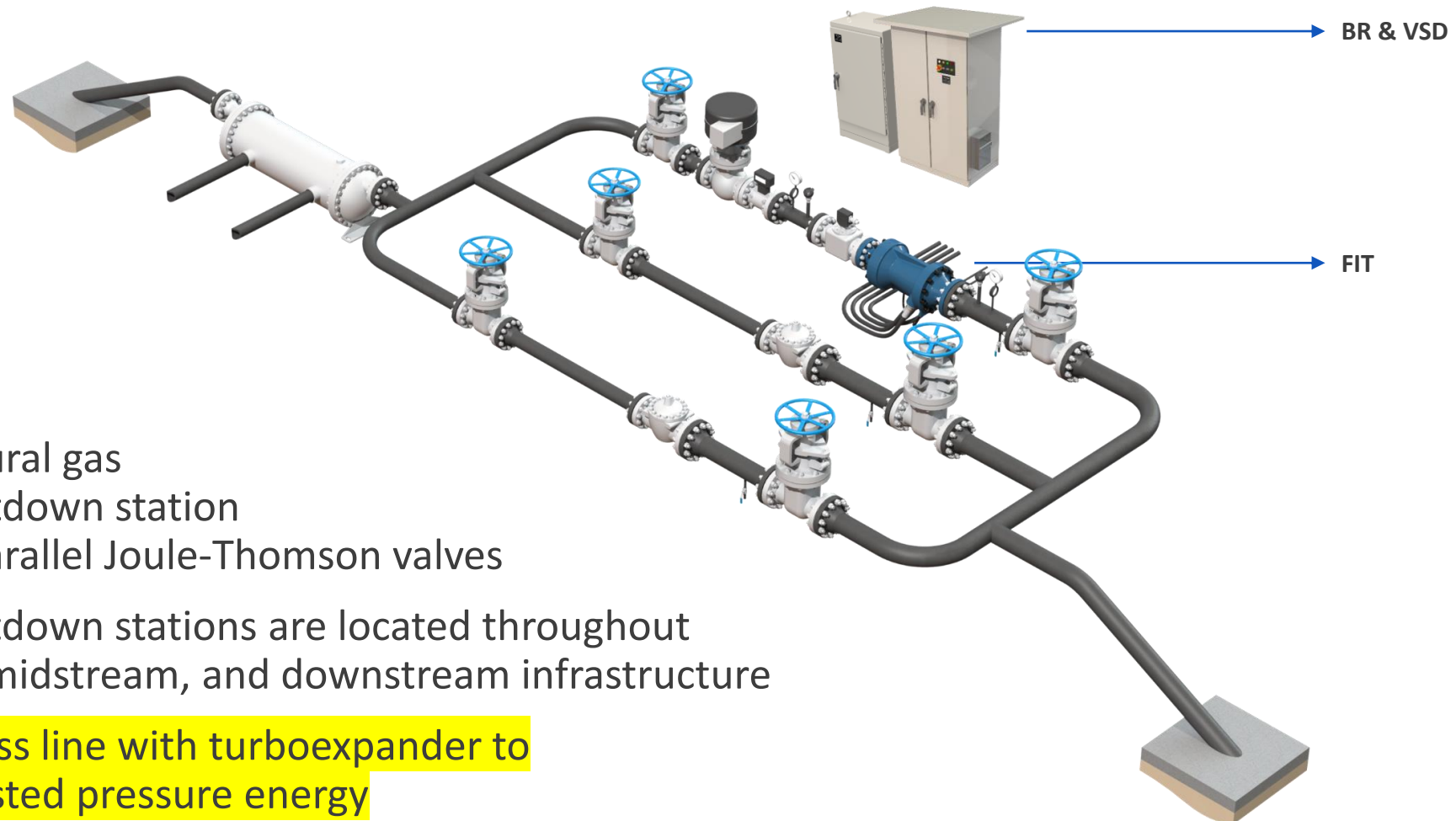


Natural Gas Pressure Letdown Existing Process (Wasted Pressure Energy)



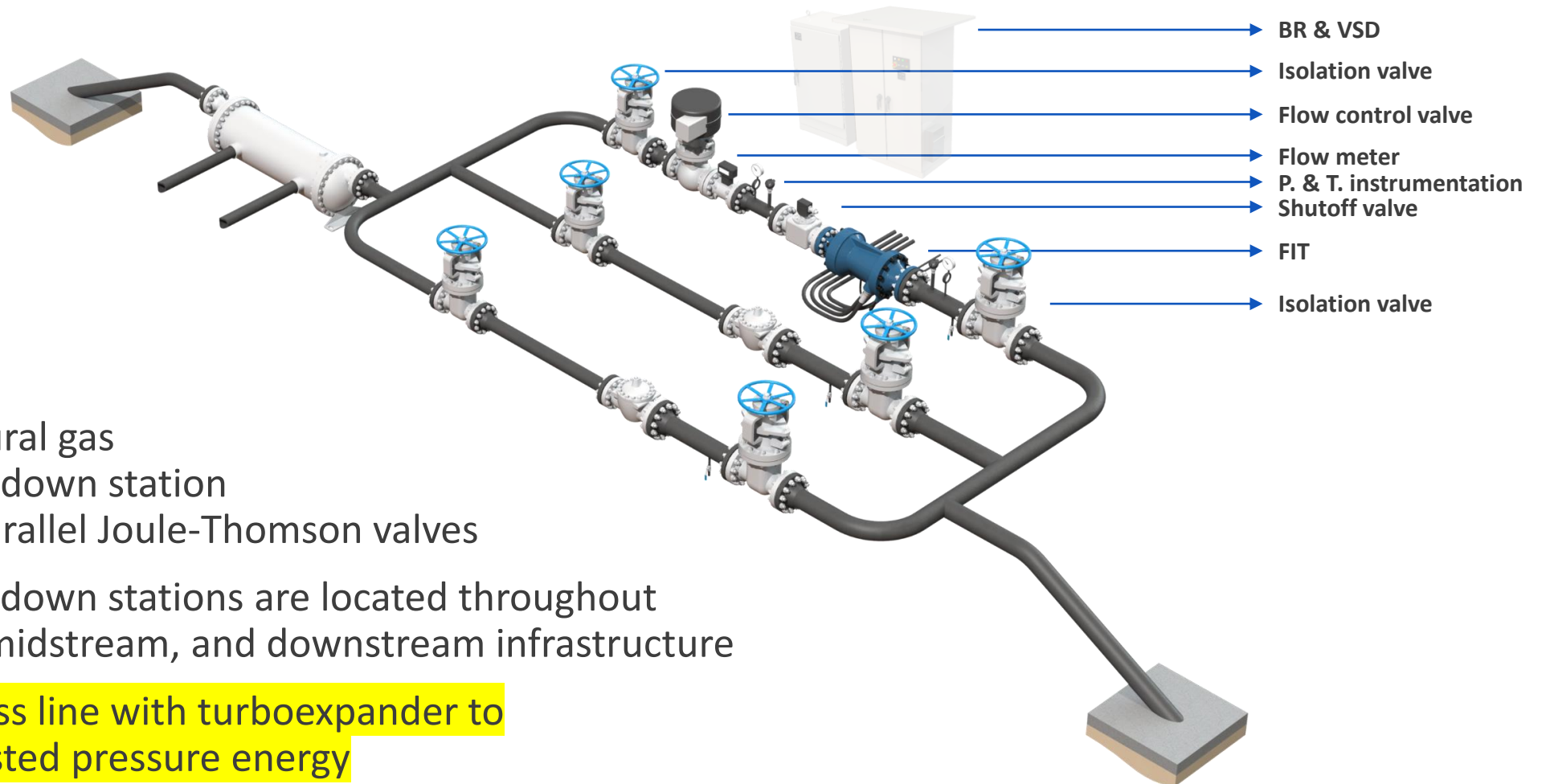
- Typical natural gas pressure letdown station with two parallel Joule-Thomson valves
- Pressure letdown stations are located throughout upstream, midstream, and downstream infrastructure

Natural Gas Pressure Letdown FreeSpin® In-line Turboexpander



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- Install bypass line with turboexpander to recover wasted pressure energy

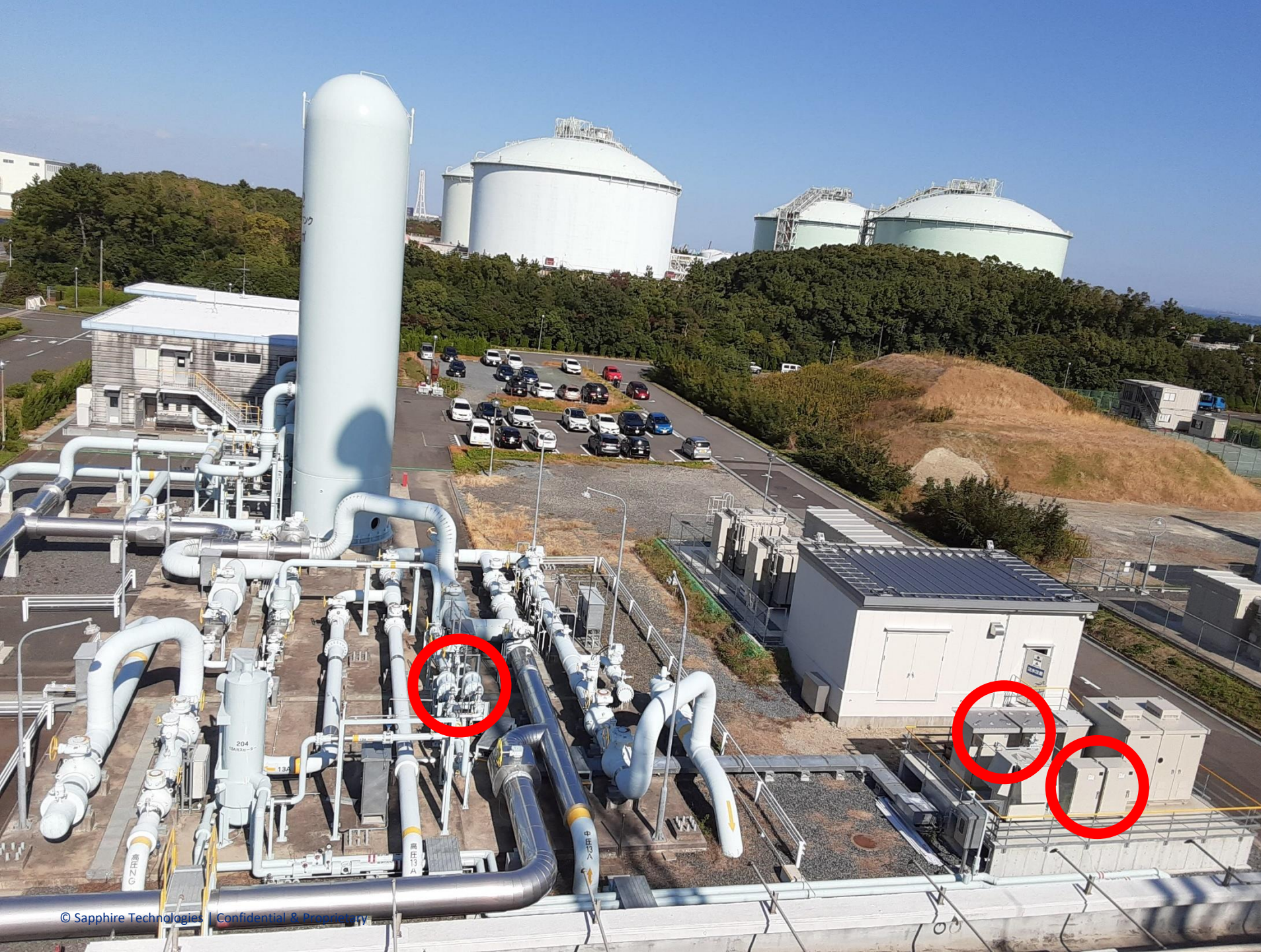
Natural Gas Pressure Letdown FreeSpin® In-line Turboexpander



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Facility



Facility



FIT 300 & FIT 125



FIT 300 & FIT 125



FIT 300 Cabling



Variable Speed Drives



Brake Resistors

Application Offerings



LNG Regasification

- Regasification process is relatively standard
- 2 units operated at full power in Japan
- Replicate Toho Gas application globally



Natural Gas Midstream

- Agreement signed with Tallgrass – in production
- Replicate with other majors (i.e. TC Energy, Enbridge)
- Leverage Evolve datacenter strategy
- CO2 sequestration



Upstream

- Install pilot projects for onshore clean, dry gas (CNX Resources & EOG)
- Launch development project with Schlumberger
- Develop high pressure system for sour, wet gas operation



Gas Processing

- Integrate system into onshore gas processing facilities
- Complete FEED study with Eni for initial order

FUTURE MARKET



Hydrogen

- Develop 1-10 tons/day liquefaction application (i.e., Plug Power)

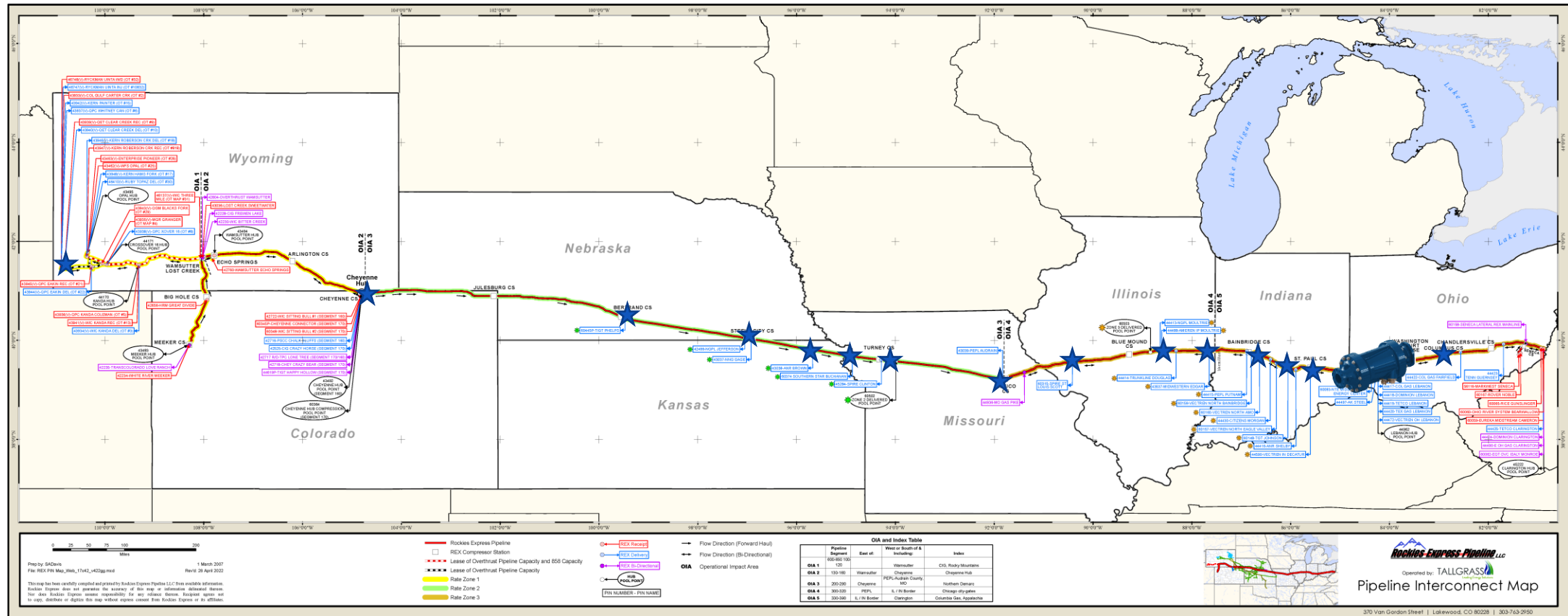
FUTURE MARKET

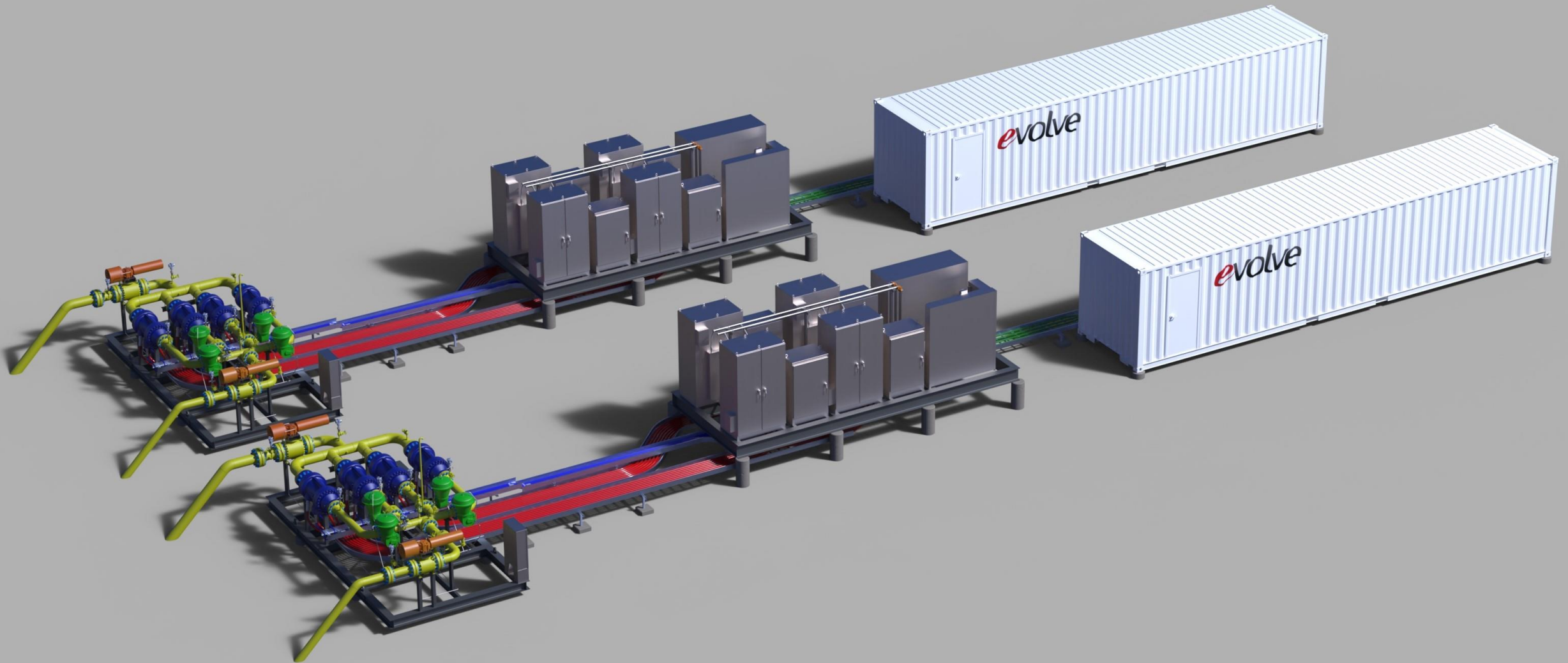


Refining

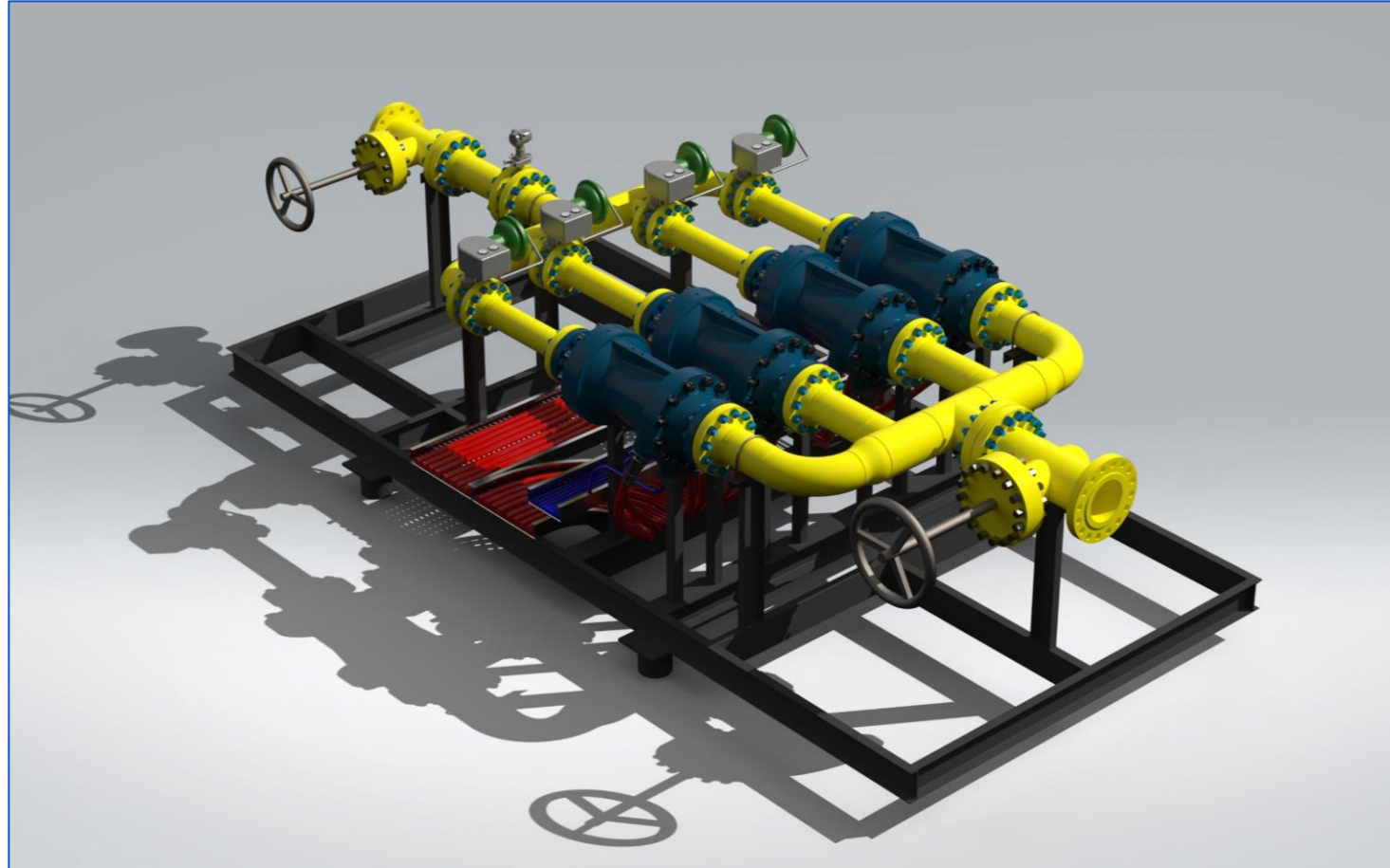
- Short term: Main natural gas header into refinery
- Long term: High-hydrogen "process gas" within refinery
- Honeywell UOP as trusted advisor / channel partner

Tallgrass Energy, Rockies Express Pipeline

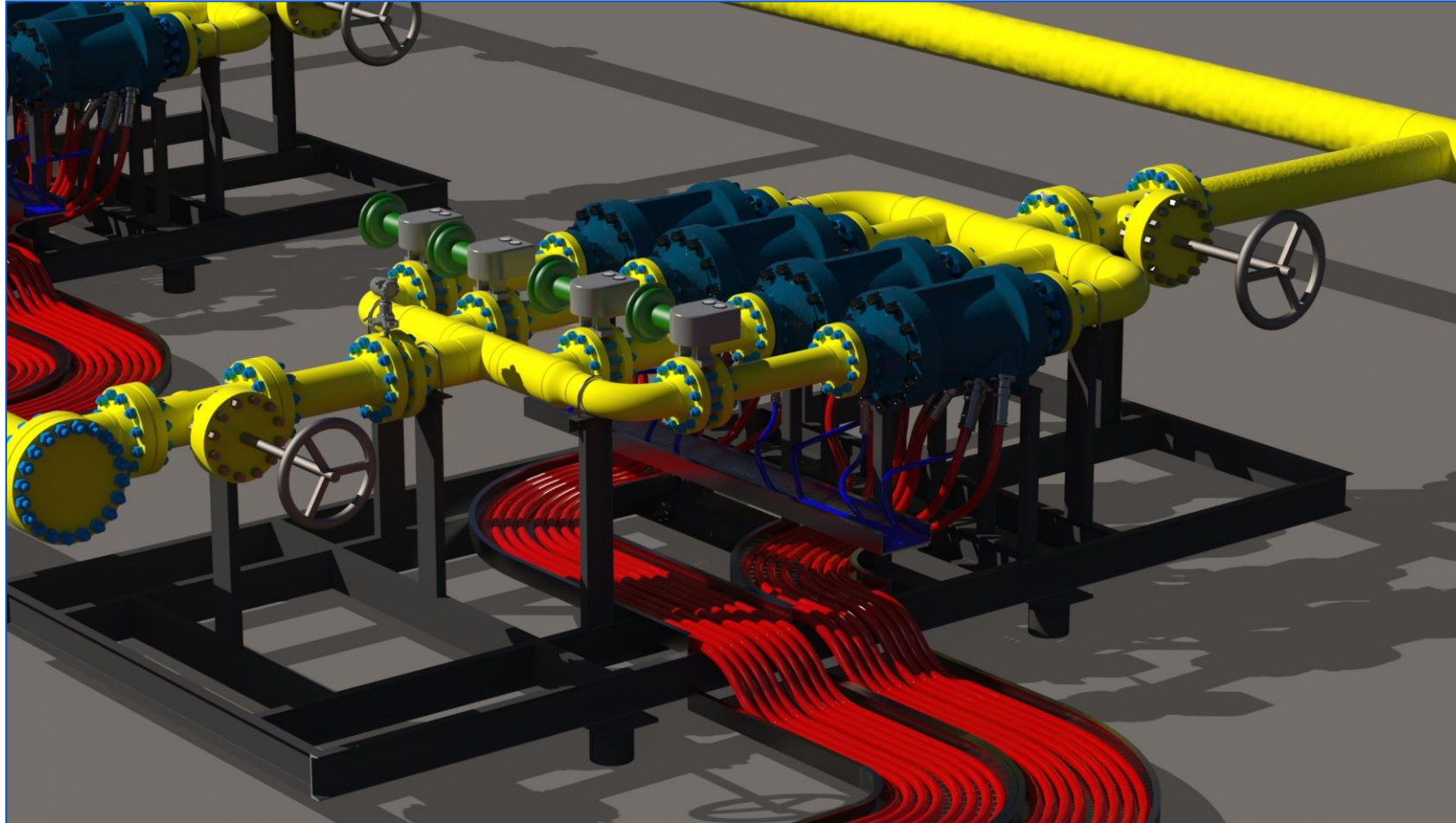




Manifold Turboexpander Design



Manifold Turboexpander Design



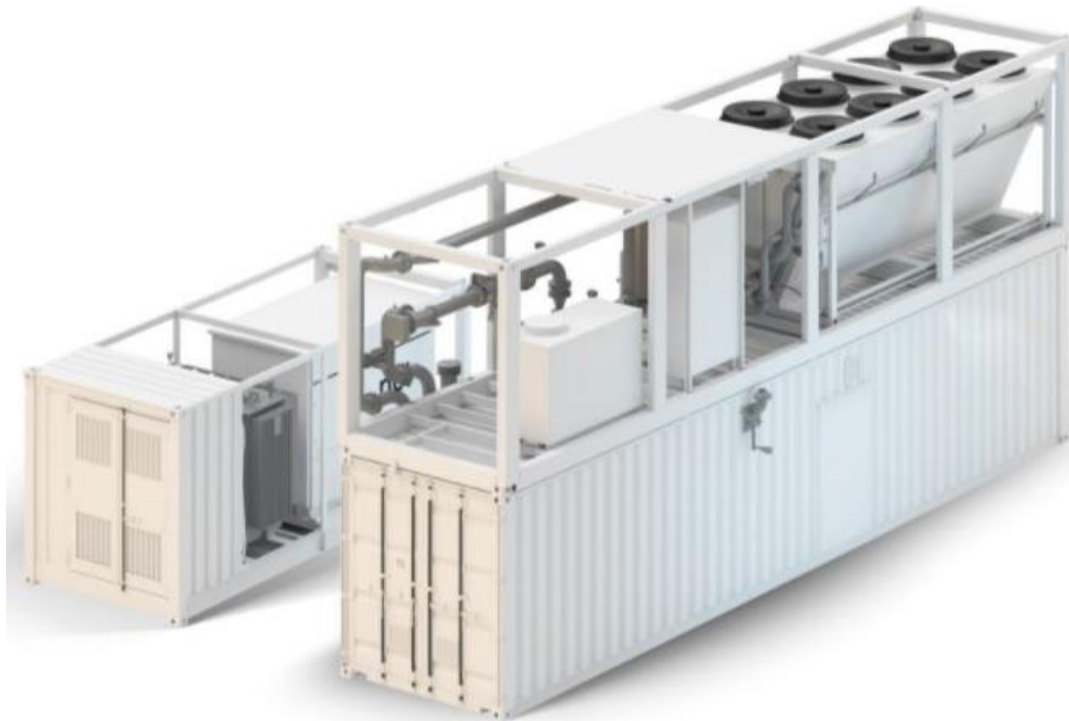
Skid-Mounted Power Electronics





Hydrogen Applications and Considerations

Hydrogen Blending



- Electrolyzer modules available in 1.25- & 2.5-megawatt sizes
 - 531- or 1062-kilogram hydrogen per day
- Nominal outlet pressure of 40 bar-g
- Injection into the natural gas grid possible

Hydrogen Operation in Europe

- Current focus for hydrogen space
 - Use produced power to run electrolyzer
 - Reinject hydrogen to grid / Unbundling in the EU
- Future product for hydrogen
 - We are here as a technology supplier
 - Want to develop a future product as soon as the infrastructure is ready for it - 100% hydrogen network

Supplemental Information

Recommended Parameters

Parameter	Value	Units	Comments
Flow Rates	>7,500	Nm ³ /hr	Higher flow rates preferable
Pressure Ratio	>1.2:1	-	Upstream-to-Downstream pressure ratio. Higher ratio is preferable
Absolute Pressure Drop	>7	Bar-g	In most applications, Pressure Ratio will be a more important consideration
Inlet Temperature	~25	°C	Inlet T dependent on target pressure reduction and gas composition
Outlet Temperature	Varies	°C	Usually specified by operator. Constrained by avoidance of icing and/or liquid drop-out after gas expansion
Gas Composition	-	-	Sales Gas is ideal. No sour gas or corrosive components