The Role of Steam-Generating Heat Pumps in Boosting Energy Efficiency While Reducing Operating Costs in Industrial Manufacturing

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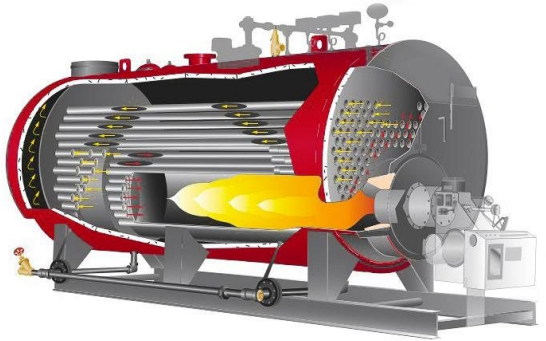
FACT
20% of global carbon emissions are caused by industrial heat
half of that is steam

Manufacturers are committed to decreasing factory emissions, but

99% of industrial steam comes from fuel -fired boilers



Fuel-fired boilers: technology from 1867

Historically the only cost -effective option

WHY?

ELECTRIC BOILERS AND RNG

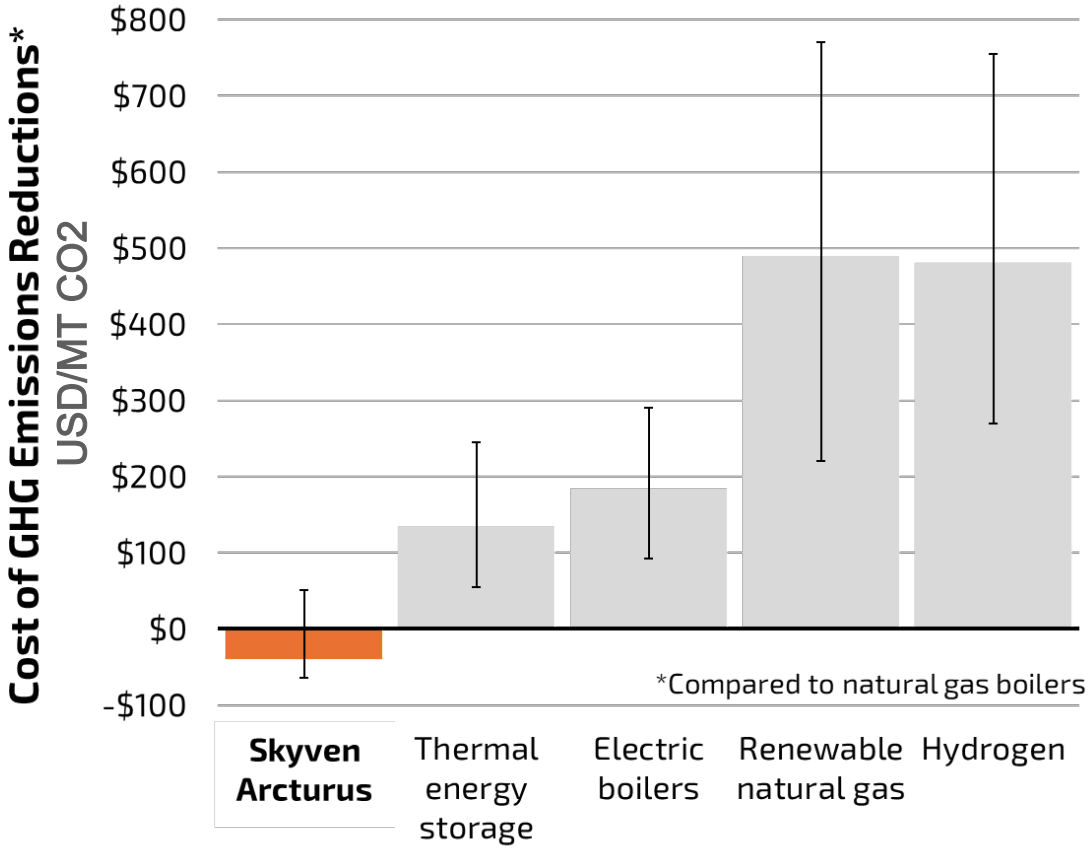
cost 3-5x more than natural gas

EXISTING HEAT PUMPS

cannot produce steam at high enough temps and pressures

Source: https://www.nrel.gov/docs/fy22osti/81721.pdf
Source: www.siemens-energy.com/global/en/offerings/power -generation/heat -pumps.html
Source: www.edf.org/sites/default/files/documents/MACC_2.0%20report_Evolved_EDF.pdf

Best economics of any steam generation technology



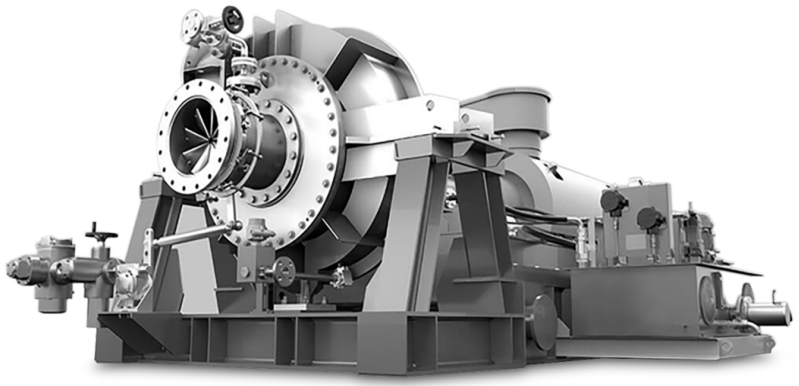
WHAT WE DO

Skyven delivers emissions - free industrial steam at the lowest cost possible, with no CAPEX required.

The Skyven Arcturus Steam -Generating Heat Pump

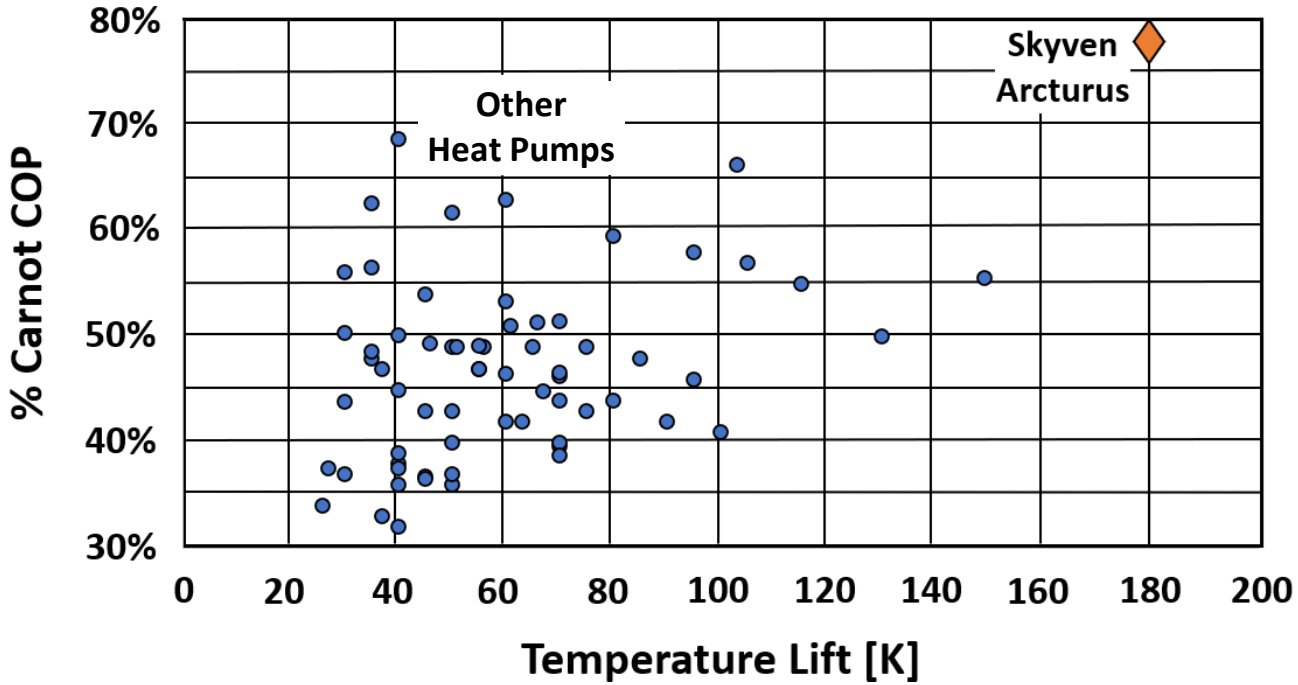
Steam at the lowest cost and lowest emissions, always

- ✓ **Emissions -free** steam production using electricity instead of natural gas
- ✓ **High COP** counteracts electricity-to-gas price differentials
- ✓ **Steam temperatures and pressures** up to **420F (215C)** and **300 psig (20.7 barg)**
- ✓ **Steam flows** of **20-200 klbs /hr (10 -100 tons/hr)**
- ✓ **Waste heat recovery** at temperatures as low as **85F (30C)**
- ✓ **Redundant,** hybrid configuration with existing boilers, improving reliability and reducing cost



Highest COP possible

Best coefficient of performance (COP) means the lowest energy consumption of any steam -generating tech

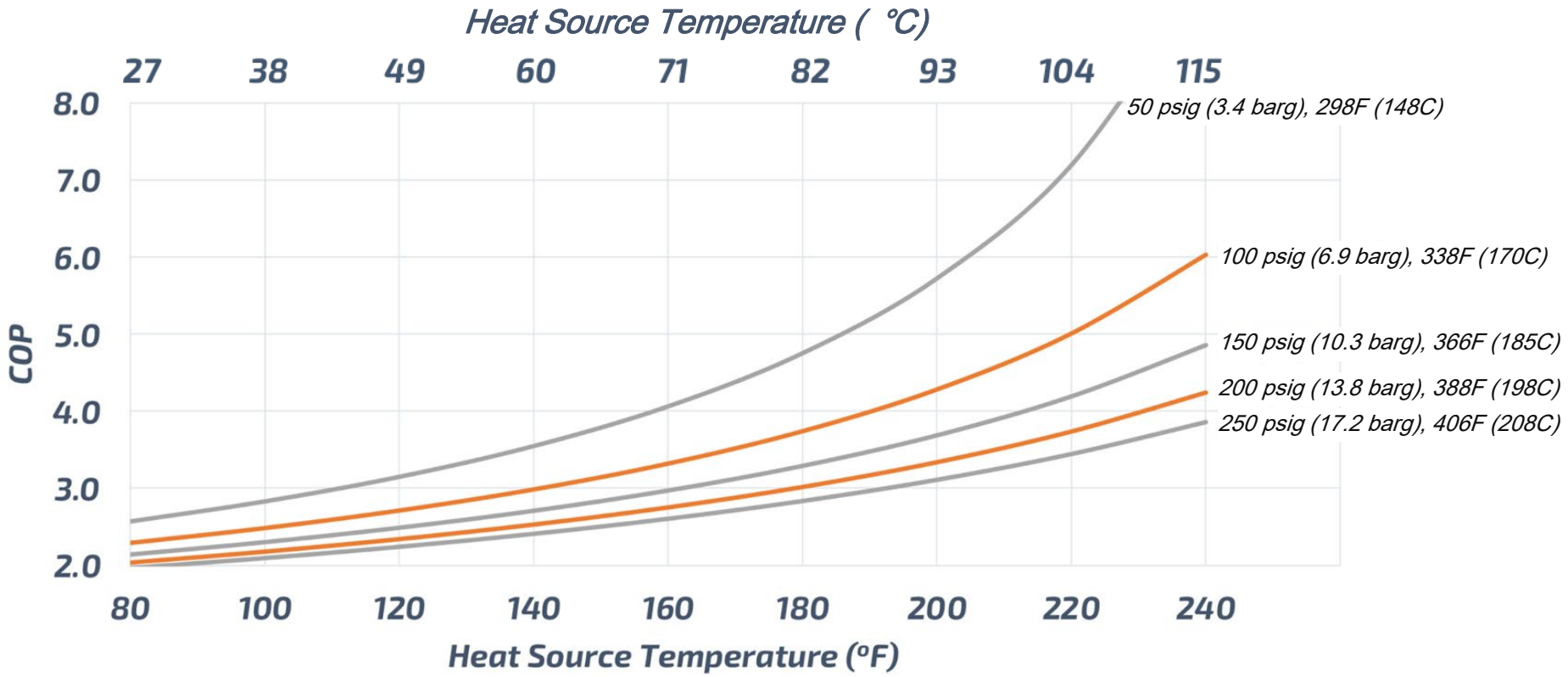


"% Carnot COP" is % of max allowed by the laws of physics.

We achieve 78% thanks to our multistage open -cycle MVR architecture with low impeller speeds and in-situ desuperheating.

High COPs across operating conditions

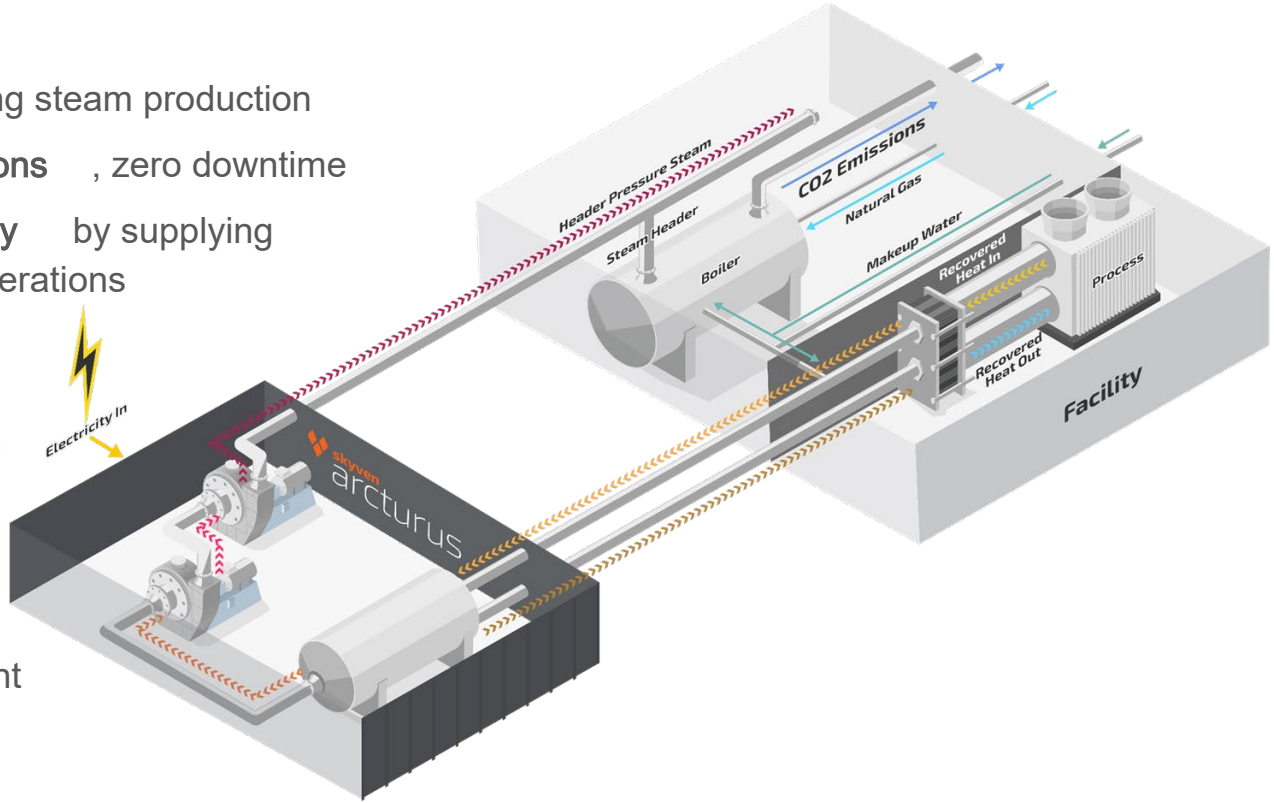
COP depends on heat source temperature and steam pressure/temperature.



Redundant, hybrid configuration

Skyven Arcturus

- **Installed in parallel** with existing steam production
- **No impact to production operations** , zero downtime
- **Increases plant's steam reliability** by supplying additional steam at baseload operations (up to 80% of facility demand)
- **Lowest -cost steam at all times** through fuel -switching between electricity and natural gas
- **Water** is the only refrigerant
- **Siting flexibility** up to half a mile (0.8 km) away from the plant



ALIGN + FUND

our financial goals with your emissions reduction.

the project with no capital expenditure.

Three Implementation Models

Skyven Ownership
(Energy-as-a-Service)

1. Shared Savings Model
- Skyven funds, installs, and operates Arcturus.
- Skyven procures electricity.
- Skyven and Customer share net economic benefits.

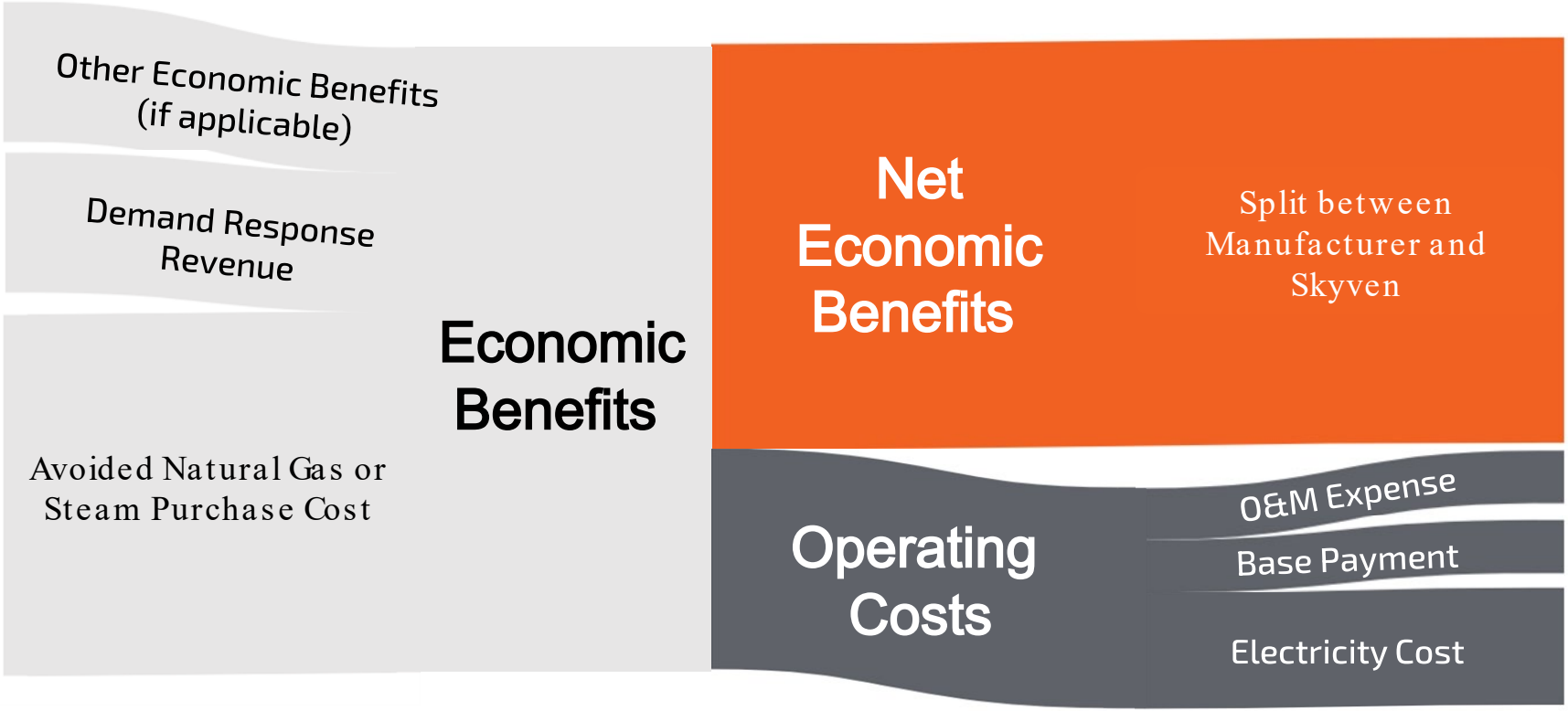
2. Tolling Model
- Skyven funds, installs, and operates Arcturus.
- Skyven or Customer procures electricity.
- Customer purchases emissions-free steam from Skyven.

Customer Ownership

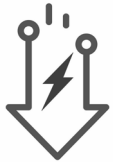
3. CAPEX Approach
- Customer funds the Arcturus project.
- Skyven installs and commissions Arcturus.
- Skyven available for O&M.

Skyven's Shared Savings Model

Skyven covers all CapEx; Skyven and Customer share economic benefits



Skyven's approach to electricity procurement



Step 1: Eliminate demand charges

Avoid coincident peak periods by switching heat pump off and operating the existing steam production systems (i.e. hybrid mode)

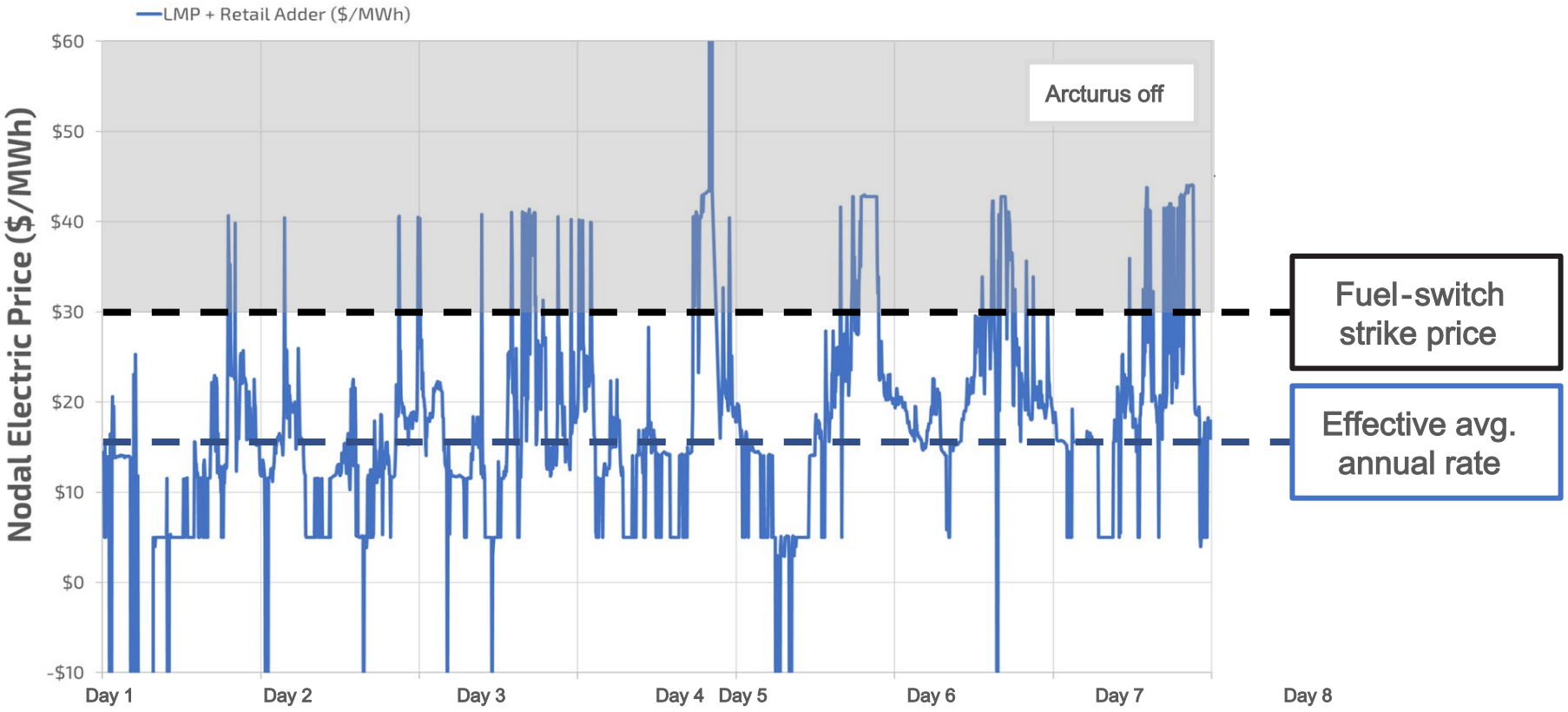
Step 2: Negotiate index pricing

Secure a rate structure based on locational marginal pricing (LMP), where we pay what the utility pays plus a fixed adder

Step 3: Operate Arcturus in hybrid mode

Switch heat pump off and operate in boiler -only mode when electricity prices rise above the fuel-switch strike price

Hybrid operations utilizing fuel -switch strike price



*Representative data

Why our model proves value

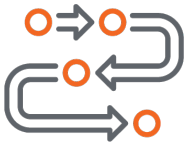
Profitable, low-risk decarbonization

Proven Technology

- **Proven Mechanical Vapor Recompression (MVR)** technology
- **In-situ Guarantee** : Skyven's capital investment serves as a multi-million-dollar guarantee that the system will perform

Financially Attractive

- **Zero CapEx**: Skyven covers 100% of capital costs
- **High COP** to counteract electrification expense
- **Aligned Incentives** : Skyven only makes money if the customer cuts carbon and saves money



No Impact to Operations

- **Very Low Risk:** Fully redundant system with existing natural boilers, drastically reducing risk
- **No downtime, easy integration:** Arcturus can be installed up to half-mile from the plant and ties in only at three standard and straightforward points.

In Action | Industrial Facilities and Projected Results

Eastern U.S. Pulp & Paper Facility

Technical Overview	
Heat Source Conditions:	
Source Type:	Paper Machine Exhaust
Source Temp:	168°F (76°C)
Source Heat Available:	48 MMBtu/hr
Arcturus Steam Generation:	
Steam Pressure:	60 psig (4 barg)
Steam Temp:	307°F (153°C)
Steam Capacity:	60.9 klb/hr (30 t/h)
Electric Power:	6.3 MW
COP:	3.3

With Skyven Arcturus:	
Annual CO2 Emissions Avoidance:	36,330 MT
Avg Annual Savings:	$1.9M

German Chemical Facility

Technical Overview	
Heat Source Conditions:	
Source Type:	Vapor Condenser
Source Temp:	185°F (85°C)
Source Heat Available:	30.7 MMBtu/hr
Arcturus Steam Generation:	
Steam Pressure:	46 psig (3.2 barg)
Steam Temp:	294°F (145°C)
Steam Capacity:	152.25 klb/hr (75 t/h)
Electric Power:	15.1 MW
COP:	3.54

With Skyven Arcturus:	
Annual CO2 Emissions Avoidance:	42,877 MT
Avg Annual Savings:	$3.1M

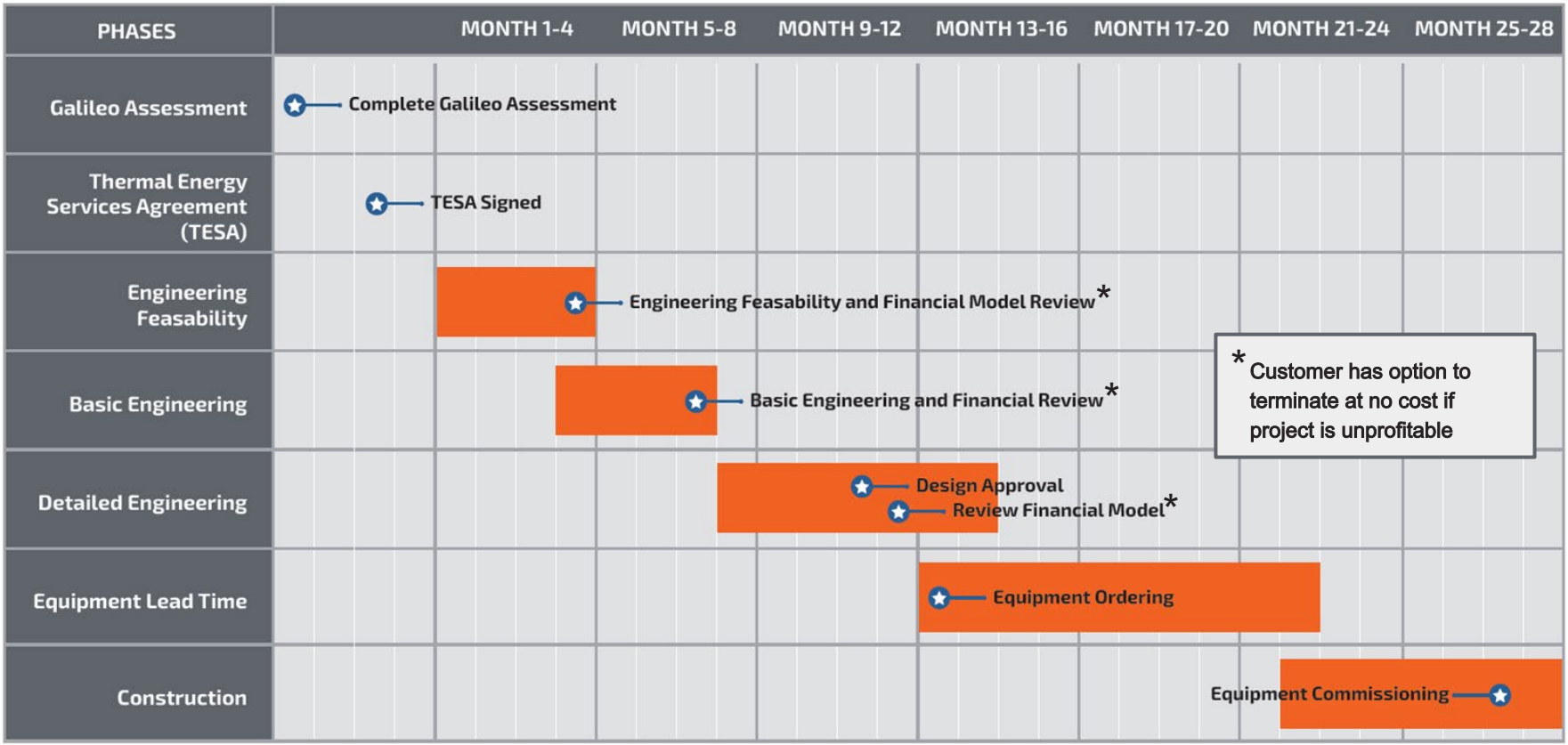
Canadian Ethanol Facility

Technical Overview	
Heat Source Conditions:	
Source Type:	Dryer Exhaust
Source Temp:	205°F (96°C)
Source Heat Available:	38 MMBtu/hr
Arcturus Steam Generation:	
Steam Pressure:	150 psig (10 barg)
Steam Temp:	366°F (185°C)
Steam Capacity:	49.6 klb/hr (24 t/h)
Electric Power:	4.4 MW
COP:	3.42

With Skyven Arcturus:	
Annual CO2 Emissions Avoidance:	29,164 MT
Avg Annual Savings:	$1.1M

Project Timeline

Project timeline and milestones



The timeline provided is an estimate.

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