Integrated Resource Planning Schedule

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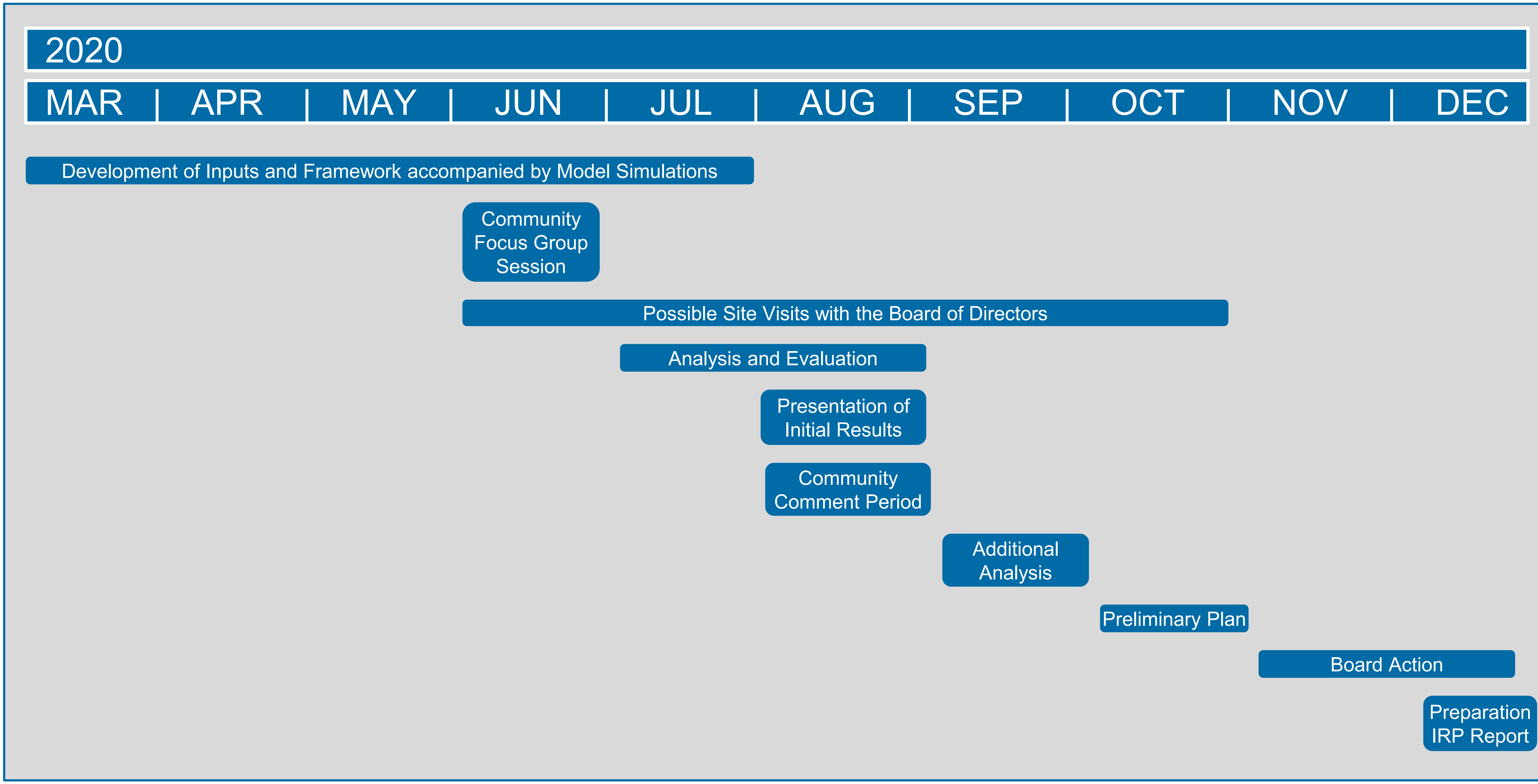
April 23, 2020

IRP Process - Key Tasks

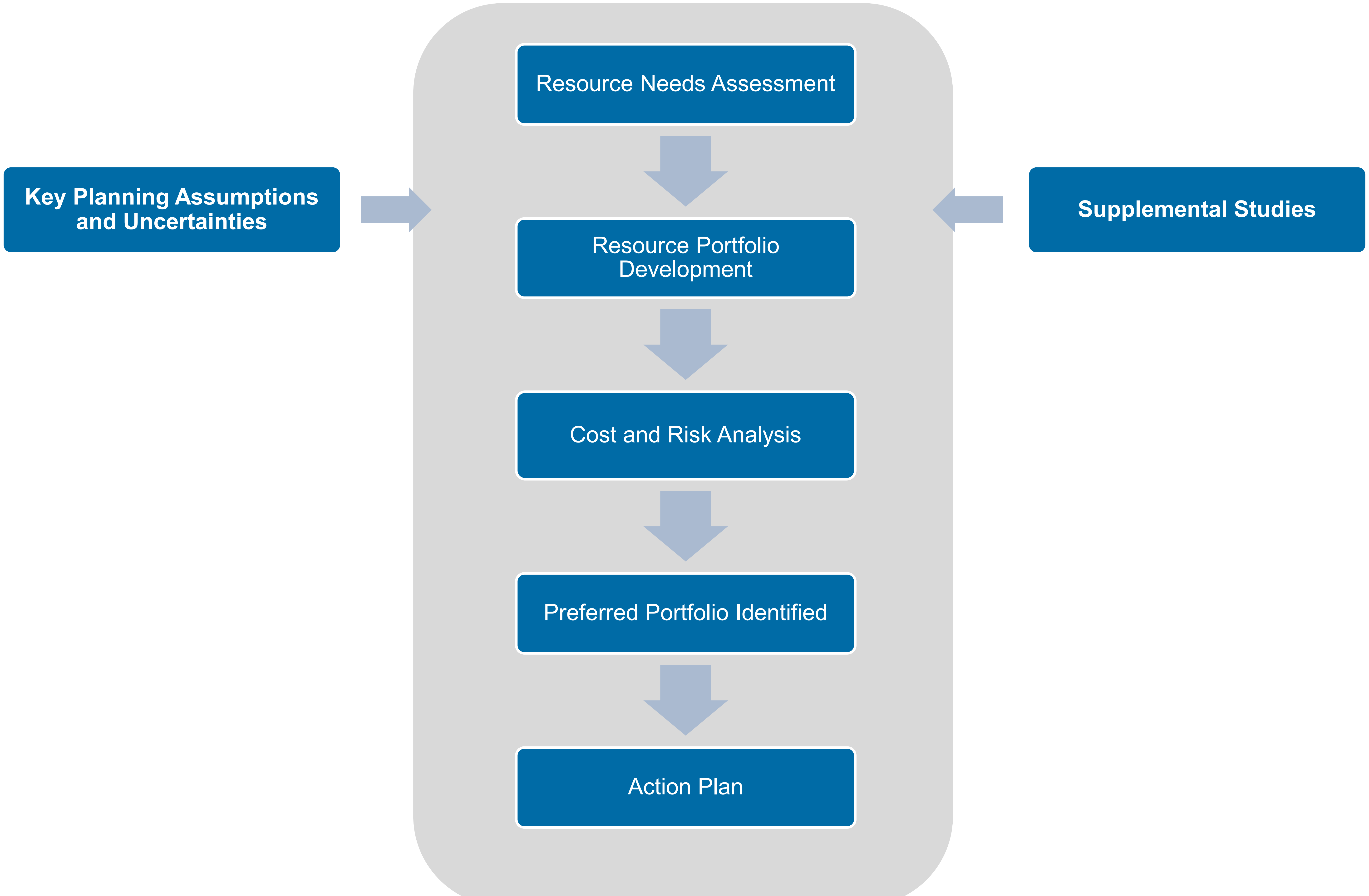
Integrated Resource Plan: (9-Month Key Tasks)

1. **Development of Inputs and Framework, to identify and develop scenarios, resource options and business strategies to evaluate how a future portfolio might change under different conditions accompanied by detailed model simulations. (Mar - Jul)**
2. **Community Focus Group meeting to identify issues important to the public and develop possible scenarios to broadly address those issues. (Jun 2020)**
3. **Possible site visits with the Board of Directors. (Summer - Fall 2020)**
4. **Analysis and evaluation, to include developing and evaluating the performance of multiple resource portfolios. (Jul - Aug 2020)**
5. **Presentation of Initial Results. (Aug 2020)**
6. **Community Comment Period (Aug 2020)**
7. **Additional Analysis, to be completed in response to the KYMEA Board and other stakeholder comments. (Sep 2020)**
8. **Preliminary Plan, to include the IRP preferred plan, near-term actions and key elements. (Oct 2020)**
9. **Expected Request for Approval of the IRP Preferred Plan from the KYMEA Board. (Nov - Dec 2020)**
10. **Publication of the Final IRP Report by July 2021, on KYMEA's website. (Dec 2020 - Jul 2021)**

Key Tasks Timeline - 2020



IRP Process Key Elements



Key Decision Points through 2029

Near-Term Actions

2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029

Vistra PPA Expires – May 31, 2022

Ashwood Solar I PPA Begins – December 1, 2022

PPS PPA Nomination - May 31, 2029

MISO Point-to-Point Path Expires – May 31, 2027

BREC PPA Expires – May 31, 2029

PPS PPA Expires – May 31, 2029

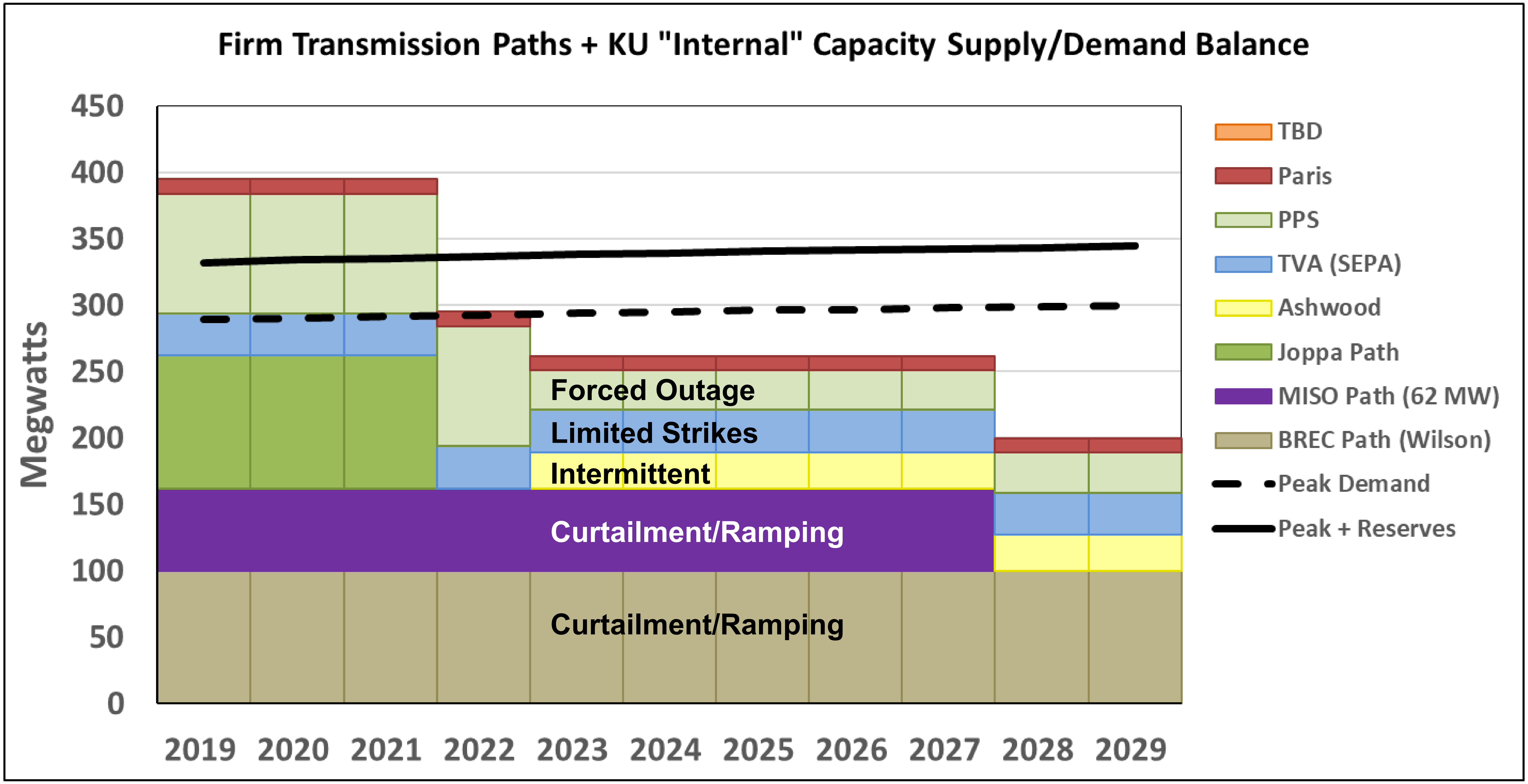
Paris Member Generation Expires – May 31, 2029

MISO Point-to-Point Path Expires – May 31, 2029

Hedging Strategies

20 Year Study: Planning Year from Jun 2022 – May 2042

Deliverability/Reliability



Supply-Side Alternatives

1. Market Purchases with Firm Transmission
2. Steam-Coal Generation
3. Simple Cycle Gas Turbine Natural Gas Generation
4. Combined Cycle Natural Gas Generation
5. Reciprocating Engine Natural Gas Generation
6. Cogeneration Natural Gas Generation
7. Solar Array
8. Battery Storage
9. TBD

New Hydro, New Wind, and New Nuclear are not available to KYMEA

Steam-Coal Generation

KYMEA options include participation in an existing coal unit.

Simple Cycle Gas Turbine

GE Power

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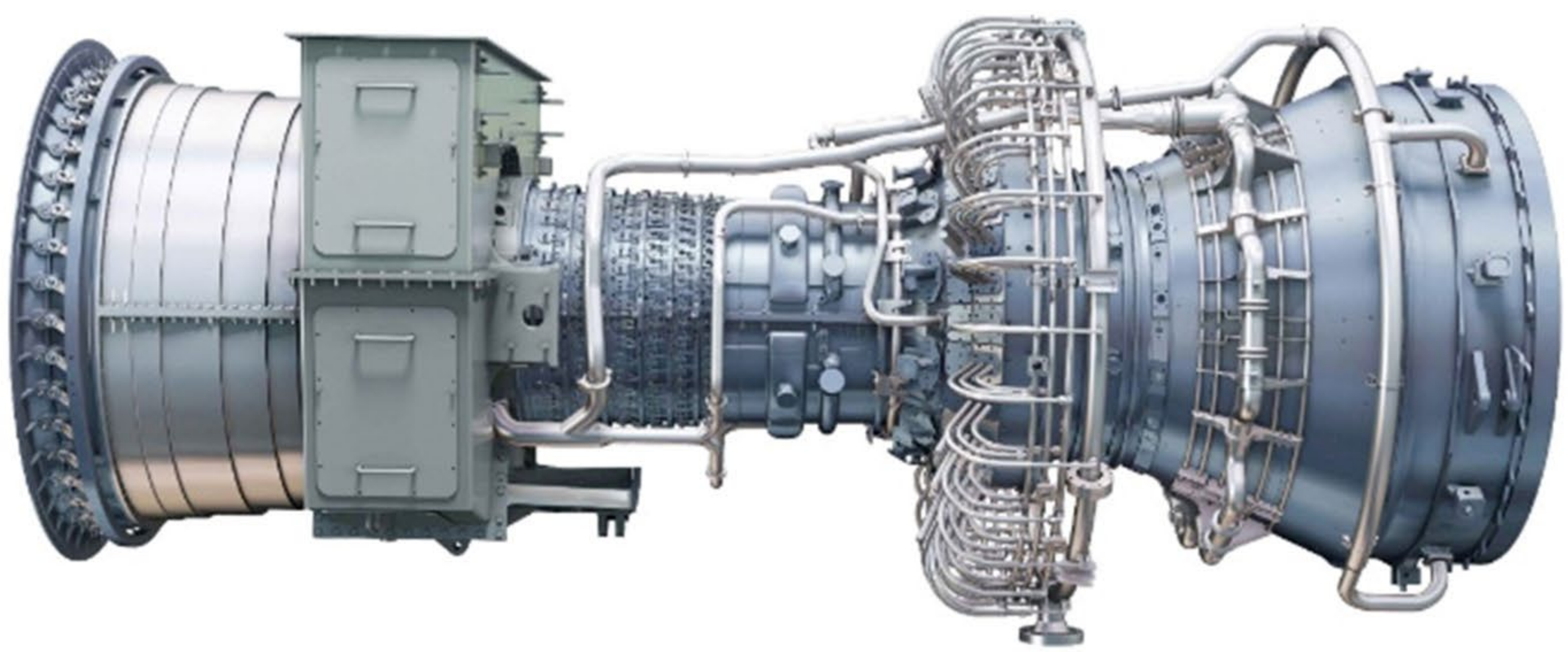
AERODERIVATIVE GAS TURBINE

LM6000

VIEW PRODUCT SPECIFICATIONS >



45-58 MW	Up to 41.3%	99.8%/98.7%	5 min.	50 MW/min.
Net output	Net efficiency	Reliability/Availability	Start time	Ramp rate

KYMEA options include ownership in smaller CT or participation in larger CT

Combined Cycle Natural Gas Turbine

GE Power

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HOME • GAS • HEAT RECOVERY STEAM GENERATORS

HEAT RECOVERY STEAM GENERATORS (HRSG)

The heat recovery steam generator (HRSG) provides the thermodynamic link between the gas turbines and steam turbines in a combined-cycle power plant. Each HRSG solution is custom-engineered to meet your desired operating flexibility and performance requirements. With more than 750 HRSGs installed worldwide, GE is a world leader in supplying HRSGs behind all major OEM's gas turbines.

DESIGNED FOR YOUR NEEDS

GE's HRSG units are cost-effectively designed for heavy cycling operations that allow owners to reduce the cost of electricity, boost performance, increase reliability, and enhance flexibility. Numerous options are available, such as supplementary firing, SCR for NOx abatement, CO catalyst for emissions reduction, and exhaust gas bypass systems for simple-cycle gas turbine operation in a combined-cycle installation.

KYMEA options include ownership in smaller CC or participation in larger CC

Reciprocating Engines

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Combined Heat and Power Technology Fact Sheet Series

Reciprocating Engines

Reciprocating internal combustion engines are a mature technology used for power generation, transportation, and many other purposes. Worldwide production of reciprocating internal combustion engines exceeds 200 million units per year.[1] For CHP installations, reciprocating engines have capacities that range from 10 kW to 10 MW. Multiple engines can be integrated to deliver capacities exceeding 10 MW in a single plant. Several manufacturers offer reciprocating engines for distributed power generation, and these engines, which are most often fueled with natural gas, are well suited for CHP service (see Table 1 for summary of attributes).

Reciprocating engine CHP installation at an industrial facility.
Photo courtesy of Caterpillar.

Applications

Reciprocating engines are well suited to a variety of distributed generation applications and are used throughout industrial, commercial, and institutional facilities for power generation and CHP. There are nearly 2,400 reciprocating engine CHP installations in the U.S., representing 54% of the entire population of installed CHP systems.[2] These reciprocating engines have a combined capacity of nearly 2.4 gigawatts (GW), with spark ignited engines fueled by natural gas and other gas fuels accounting for 83% of this capacity. Thermal loads most amenable to engine-driven CHP systems in commercial/institutional buildings are space heating and hot water requirements. The primary applications for CHP in the commercial/institutional and residential sectors are those with relatively high and coincident electric and hot water demand. Common applications for reciprocating engine CHP systems include universities, hospitals, water treatment facilities, industrial facilities, commercial buildings, and multi-family dwellings.

Table 1. Summary of Reciprocating Engine Attributes

Size range	Reciprocating engines for CHP are available in sizes from 10 kW to 10 MW. Multiple engines can be combined to deliver higher capacities. The majority of CHP installations with reciprocating engine are below 5 MW.[2]
Thermal output	Thermal energy can be recovered from the engine exhaust, cooling water, and lubricating oil, and then used to produce hot water, low pressure steam, or chilled water (with an absorption chiller).
Part-load operation	Reciprocating engines perform well at part-load and are well suited for both baseload and load following applications.
Fuel	Reciprocating engines can be operated with a wide range of gas and liquid fuels. For CHP, natural gas is the most common fuel.
Reliability	Reciprocating engines are a mature technology with high reliability.
Other	Reciprocating engines have relatively low installed costs and are widely used in CHP applications. Reciprocating engines start quickly and operate on typical natural gas delivery pressures with no additional gas compression required.

1 Power Systems Research, EnginLink™, 2013.
2 U.S. DOE *Combined Heat and Power Installation Database*, data compiled through December 31, 2015

Technology Description

There are two primary reciprocating engine designs relevant to stationary power generation applications – the spark ignition Otto-cycle engine and the compression ignition Diesel-cycle engine. The essential mechanical components of the Otto-cycle and Diesel-cycle are the same. Both use a cylindrical combustion chamber in which a close fitting piston travels the length of the cylinder. The piston connects to a crankshaft that transforms the linear motion of the piston into the rotary motion of the crankshaft. Most engines have multiple cylinders that power a single crankshaft.

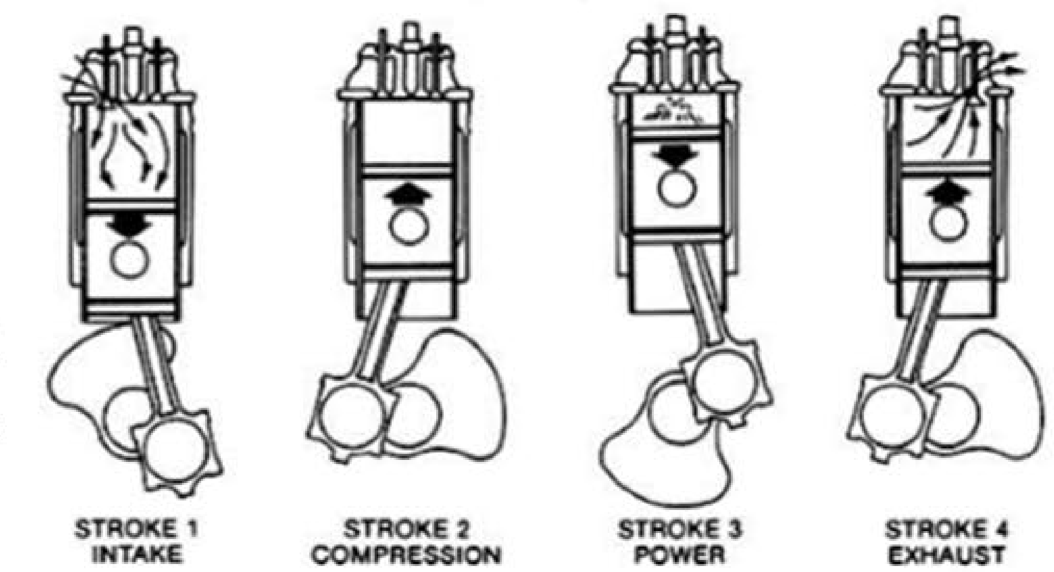


Figure 1. Four-stroke spark ignition reciprocating engine.
Graphic credit IHS Engineering.

The main difference between the two cycles is the method of igniting the fuel. Spark ignition engines (Otto-cycle) use a spark plug to ignite a pre-mixed air fuel mixture introduced into the cylinder. Compression ignition engines (Diesel-cycle) compress the air introduced into the cylinder to a high pressure, raising its temperature to the auto-ignition temperature of the fuel that is injected at high pressure. For CHP, most installations utilize 4-stroke spark ignition engines (see **Figure 1**).

Reciprocating engines are characterized as either rich-burn or lean-burn. Rich-burn engines are operated near the stoichiometric air/fuel ratio, which means the air and fuel quantities are matched for complete combustion, with little or no excess air. In contrast, lean-burn engines are operated at air levels significantly higher than the stoichiometric ratio. In lean-burn engines, engine-out NOx emissions are reduced as a result of lower combustion chamber temperatures compared to rich-burn engines. Most spark ignition and diesel engines relevant to stationary power generation applications complete a power cycle in four strokes of the piston within the cylinder, as shown in Figure 1:

1. Intake stroke - introduction of air (diesel) or air-fuel mixture (spark ignition) into the cylinder.
2. Compression stroke - compression of air or an air-fuel mixture within the cylinder. In diesel engines, the fuel is injected at or near the end of the compression stroke (top dead center, or TDC) and ignited by the elevated temperature of the compressed air in the cylinder. In spark ignition engines, the compressed air-fuel mixture is ignited by an ignition source at or near TDC.
3. Power stroke - acceleration of the piston by the expansion of the hot, high pressure combustion gases.
4. Exhaust stroke - expulsion of combustion products from the cylinder through the exhaust port.

Performance Characteristics

Performance characteristics for five representative natural gas reciprocating engines used in CHP applications are summarized in **Table 2**.

The five systems shown in **Table 2** range from 100 kW to 9.3 MW, which covers most CHP installations that use reciprocating engines. Electric efficiencies generally increase with size, and the electric efficiencies for the five systems range from approximately 30% (System #1) to 42% (System #5). Overall CHP efficiencies are near 80%, ranging from approximately 77% (System #5) to 83% (System #1). As electrical efficiency increases, the quantity of thermal energy available to produce useful heat decreases per unit of power output, and the power to heat ratio generally increases. A changing ratio of power to heat impacts project economics and may affect the decisions that customers make in terms of CHP acceptance, sizing, and the desirability of selling power. For the representative systems in **Table 2**, the power to heat ratio ranges from 0.56 to 1.20. In power generation and CHP applications, reciprocating engines generally drive synchronous generators at constant speed to produce stead alternating current (AC) power. As load is reduced, the heat rate of spark ignition engines increases and efficiency decreases. While gas engines compare favorably to gas turbines—which typically experience efficiency decreases of 15 to 25 percent at half load conditions—multiple engines may be preferable to a single large unit to avoid efficiency penalties where significant load reductions are expected on a regular basis.

Reciprocating Engines (continued)

Table 2. Reciprocating Engine Performance Characteristics

Description	System				
	1	2	3	4	5
Net Electric Power (kW)[3]	100	633	1,141	3,325	9,341
Fuel Input (MMBtu/hr, HHV)[4]	1.15	6.26	10.37	27.73	76.06
Useful Thermal (MMBtu/hr)	0.61	2.84	4.46	10.69	26.60
Power to Heat Ratio[5]	0.56	0.76	0.87	1.06	1.20
Electric Efficiency (%, HHV)	29.6%	34.5%	37.6%	40.9%	41.9%
Thermal Efficiency (%, HHV)	53.2%	45.3%	43.0%	38.6%	35.0%
Overall Efficiency (%, HHV)	82.8%	79.8%	80.6%	79.5%	76.9%

Note: Performance characteristics are average values and are not intended to represent a specific product.

Capital and O&M Costs

Table 3 shows representative capital costs for natural gas reciprocating engines used in CHP applications. The costs are average values based on data collected from multiple manufacturers. Installed costs can vary significantly depending on the scope of the plant equipment, geographical area, competitive market conditions, special site requirements, emissions control hardware, and prevailing labor rates.

Capital costs for generator set packages shown in **Table 3** include all expenses for a complete CHP system, including heat recovery hardware and emission control equipment. The CHP systems shown in **Table 3** are assumed to produce hot water, although reciprocating engines are also capable of producing low pressure steam. With construction and installation included, installed costs range from $2,900 to $1,430 per kW. As indicated, capital costs decline on a per kW basis as size increases. Non-fuel operation and maintenance (O&M) costs are also shown in **Table 3**. As indicated, these costs range from 2.4 to 0.9 ¢/kWh. Like capital costs, O&M costs decline as capacity increases. Maintenance costs vary with type, speed, size, and number of cylinders of an engine. These costs typically include:

- Maintenance labor
- Engine parts and materials (e.g., oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc.) and consumables, such as oil
- Minor and major overhauls

Maintenance can either be done by in-house personnel or contracted out to manufacturers, distributors, or dealers under service contracts.

Table 3. Reciprocating Engine Capital and O&M Costs

Description	System				
	1	2	3	4	5
Net Electric Power (kW)	100	633	1,141	3,325	9,341
Engine Type	Rich-burn	Lean-burn	Lean-burn	Lean-burn	Lean-burn
Engine and Generator ($/kW, including heat recovery and emission control)	$1,650	$1,650	$1,380	$1,080	$900
Construction and Installation	$1,250	$1,190	$990	$720	$530
Total Installed Cost	$2,900	$2,840	$2,370	$1,800	$1,430
Total O&M Cost (¢/kWh)	2.4	2.1	1.9	1.6	0.9

Note: Costs are average values and are not intended to represent a specific product.

3 Parasitic electric loads for reciprocating engines are typically small. In this fact sheet, parasitic loads are assumed to be negligible, resulting in no difference between gross and net power.

4 Values in this fact sheet are based on the higher heating value (HHV) of natural gas unless noted otherwise.

5 Power to heat ratio is the electric power output divided by the useful thermal output.

Emissions

Emissions of criteria pollutants—oxides of nitrogen (NOx), carbon monoxide (CO), and volatile organic compounds (unburned, non-methane hydrocarbons, or VOCs)—are the primary environmental concern with reciprocating engines operating on natural gas. **Table 4** shows representative emissions for reciprocating engines operating on natural gas in CHP applications. Emissions can vary significantly between different engine models and manufacturers and can also vary significantly with small changes in operating conditions (e.g., air/fuel ratio). Rich-burn engines have higher uncontrolled NOx emissions compared to lean-burn engines and are almost always supplied with a three-way catalyst to control NOx, CO, and VOC emissions. For lean-burn engines, selective catalytic reduction (SCR) can be used to reduce NOx emissions if needed, and an oxidation catalyst can be used to reduce CO and VOC emissions.

Table 4 shows CO_2 emissions for CHP systems based on the power output of the complete CHP system. For the complete CHP system, CO_2 emissions are calculated with a thermal credit for natural gas fuel that would otherwise be used by an on-site boiler. With this thermal credit, CO_2 emissions range from 452-536 lbs/MWh. For comparison, a typical natural gas combined cycle power plant will have emissions of 800-900 lbs/MWh, and a coal plant will have CO_2 emissions near 2,000 lbs/MWh. ■

Table 4. Reciprocating Engine Emission Characteristics

Description	System				
	1	2	3	4	5
Electric Capacity (kW)	100	633	1,141	3,325	9,341
Engine Combustion	Rich-burn	Lean-burn	Lean-burn	Lean-burn	Lean-burn
Emissions before Exhaust Treatment (g/bhp-hr)[6,7,8]					
NOx	N/A[9]	< 1.0	< 1.0	< 1.0	< 1.5
CO		< 1.5	< 1.5	< 1.5	< 1.5
VOC		< 1.0	< 1.0	< 1.0	< 1.0
Emissions after Exhaust Treatment (g/bhp-hr)[10]					
NOx	0.05	0.05	0.05	0.05	0.08
CO	0.14	0.08	0.08	0.08	0.08
VOC	0.07	0.05	0.05	0.05	0.05
Emissions after Exhaust Treatment (lbs/MWh)[11,12]					
NOx	0.14	0.15	0.15	0.15	0.22
CO	0.41	0.22	0.22	0.22	0.22
VOC	0.20	0.15	0.15	0.15	0.15
CO_2 Emissions (lbs/MWh)					
Electricity only	1,348	1,157	1,062	975	952
CHP with thermal credit[13]	452	502	491	505	536

Note: Emissions are average values and are not intended to represent a specific product.

6 Manufacturers often express an upper limit for emissions performance (e.g., NOx < 1.0 g/bhp-hr). This format is used for emissions data prior to exhaust treatment (also referred to as "engine-out" emissions).

7 CO and VOC emissions for Systems #2, #3, and #4 were not available from product specification sheets, and the values shown are estimates.

8 NOx, CO, and VOC emissions for System #5 were not available from product specification sheets, and the values shown are estimates.

9 Rich-burn engines are typically supplied with a three-way catalyst. Hence, uncontrolled emissions are not reported.

10 For lean-burn engines, exhaust treatment is assumed to reduce emissions by 95%.

11 To convert between g/bhp-hr and lbs/MWh, multiply value in g/bhp-hr by 2.956 to get result in lbs/MWh.

12 NOx, CO, and VOC emissions are based on electric output and do not include a thermal credit.

13 The CHP CO_2 emissions include a thermal credit for avoided fuel that would otherwise be used in an onsite boiler. The boiler is assumed to operate on natural gas with an efficiency of 80%.

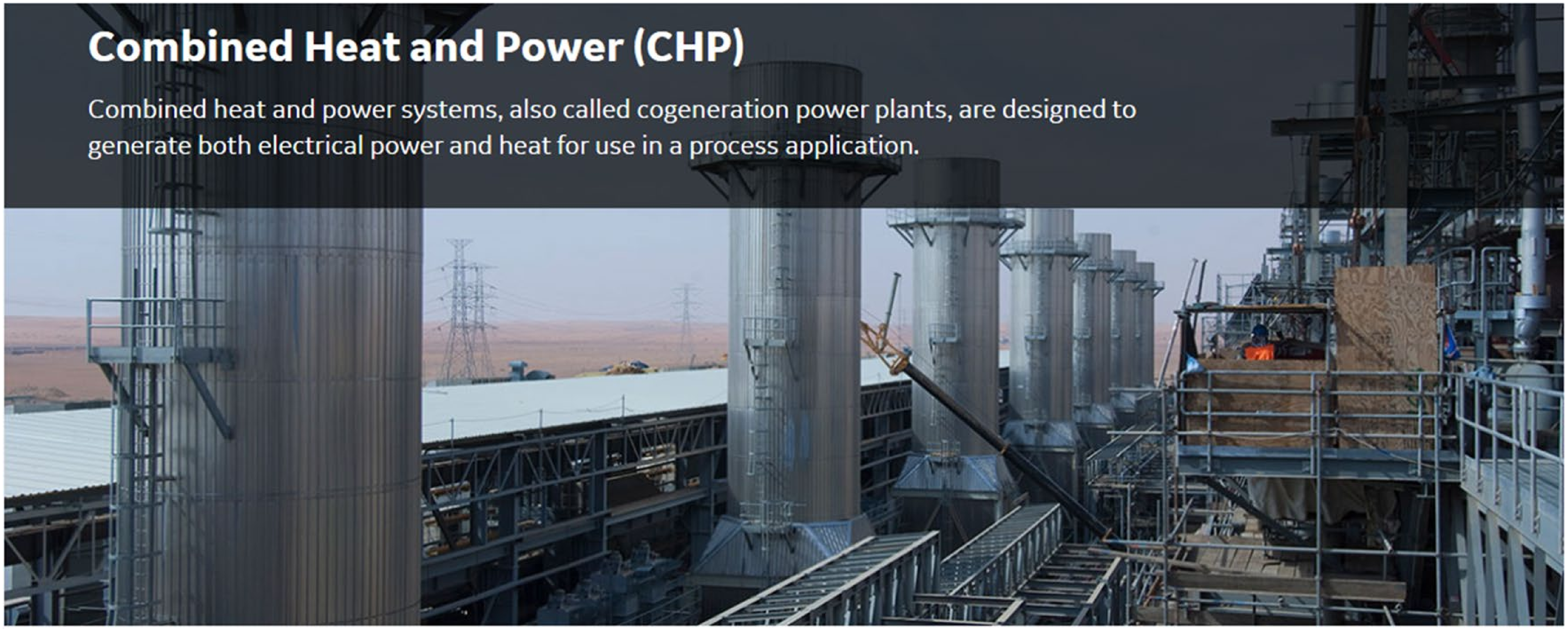
U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

For more information, visit the CHP Deployment Program at energy.gov/chp or email us at CHP@ee.doe.gov

DOE/EE-1331 • July 2016

Cogeneration



WHAT IS COGENERATION?

Cogeneration, also known as combined heat and power (CHP), is a highly efficient process that generates electricity and heat simultaneously. By utilizing the exhaust energy from gas turbines, useful steam can be generated in a heat exchanger which can then be used in any number of applications, all with no additional fuel consumption. As a result, the overall efficiency of CHP systems can exceed 80%, making CHP one of the most energy-efficient methods of power generation. With the broadest **gas turbine product portfolio** in the industry, GE is uniquely positioned to provide its customers with the right products to provide the required ratio of power to heat for their CHP systems. For more information on combined heat and power applications, view our **webinar here**.

Cogeneration (continued)

THE BENEFITS OF COGENERATION

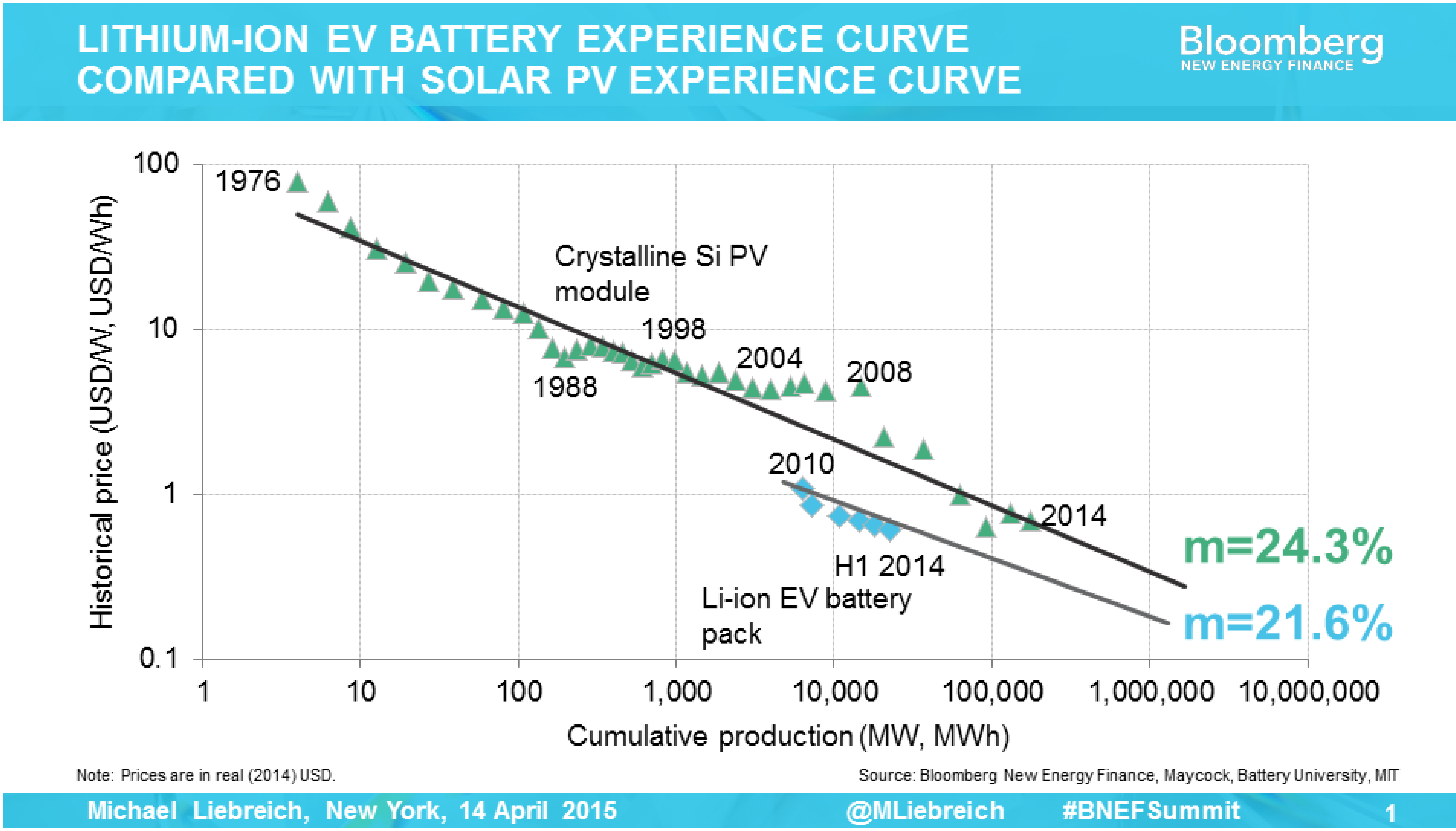
By using one fuel source to produce both heat and electricity simultaneously, cogeneration – or combined heat and power - is significantly more efficient and cost effective than traditional power generation. Why? With traditional power generation, electricity and thermal energy are produced separately using two different processes and fuel sources—conventional fossil fuels are used to generate the electricity and, in most cases, the heat produced as a byproduct to this process is lost to the atmosphere. Then an on-site boiler or furnace is used to generate heat.

Cogeneration solutions use a single fuel in a combustion engine, like a gas turbine, to generate electricity. The heat that is created as a result of the process is captured and recycled to provide hot water or steam for other uses—like heating or cooling for the facility. In addition to eliminating waste and increasing energy production efficiency, cogeneration solutions have many advantages.

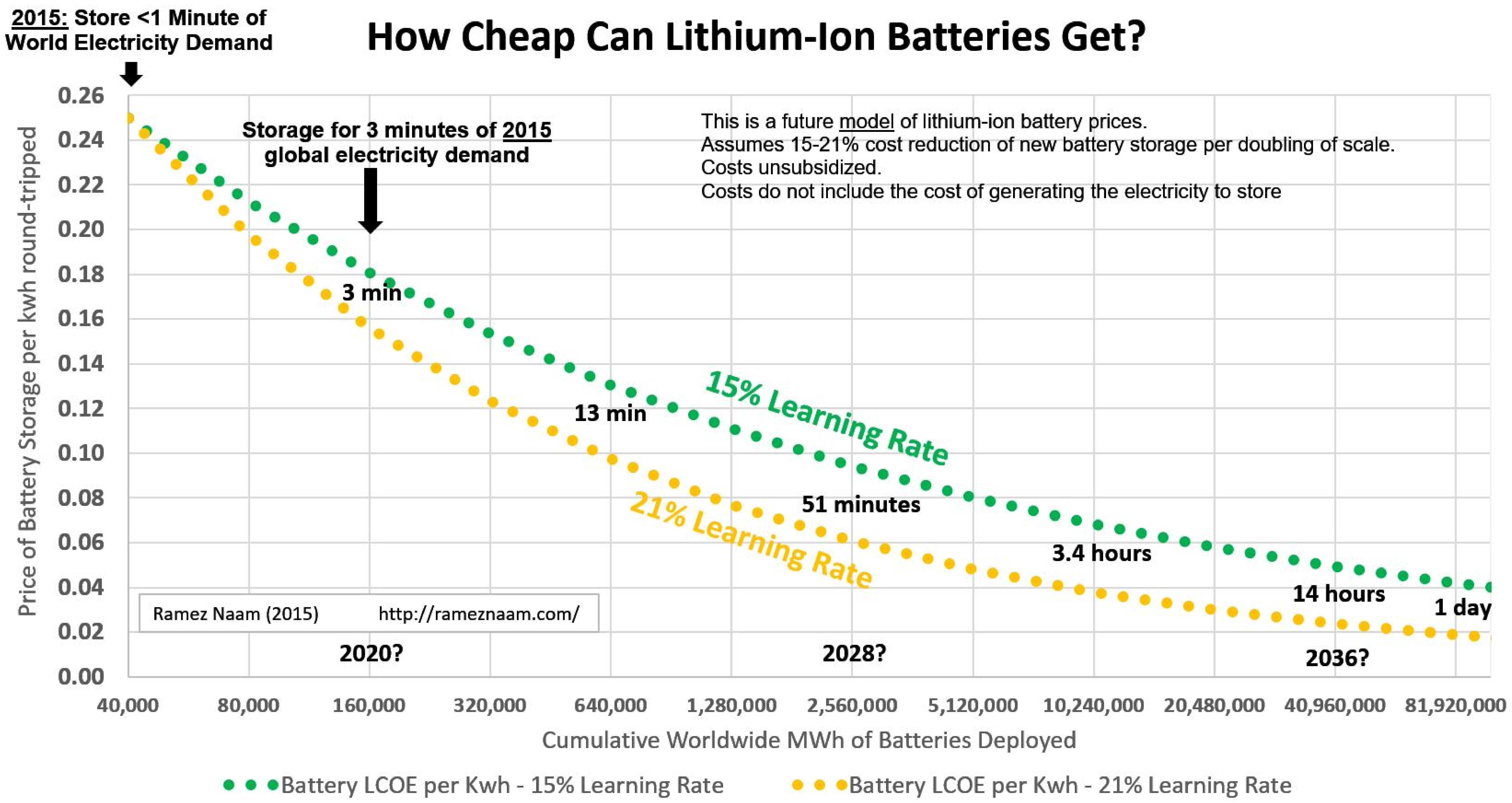
ADVANTAGES OF COGENERATION:

- *Save money* - Achieve up to 95% percent total efficiency, burn less fuel for the energy you need, and reduce thermal and electrical costs creating a payback in as little as 2 years.
- *Save energy* - Realize energy savings of up to 40% using the energy from your turbine's waste heat.
- *Increase predictability* – Predict against grid power price volatility and supply uncertainty for more accurate financial planning.
- *Increase reliability* - Achieve 98% reliability or more with the proven technology of GE's aeroderivative gas turbines.
- *Energy reform benefits* - Benefit from government energy reforms and associated incentives (green certificates and "efficient cogeneration") promoting self power generation.
- *Reduce emissions* - With combined heat and power, you can make sure you're meeting government regulations by reducing your greenhouse gas emissions by up to 30%.

Solar and Battery Experience Curve



Battery Learning Rate Projection



Demand-Side Management Alternatives

1. Peak Clipping
2. Energy Efficiency Programs
3. Distributed Energy Resources
4. TBD

EnCompass Modeling

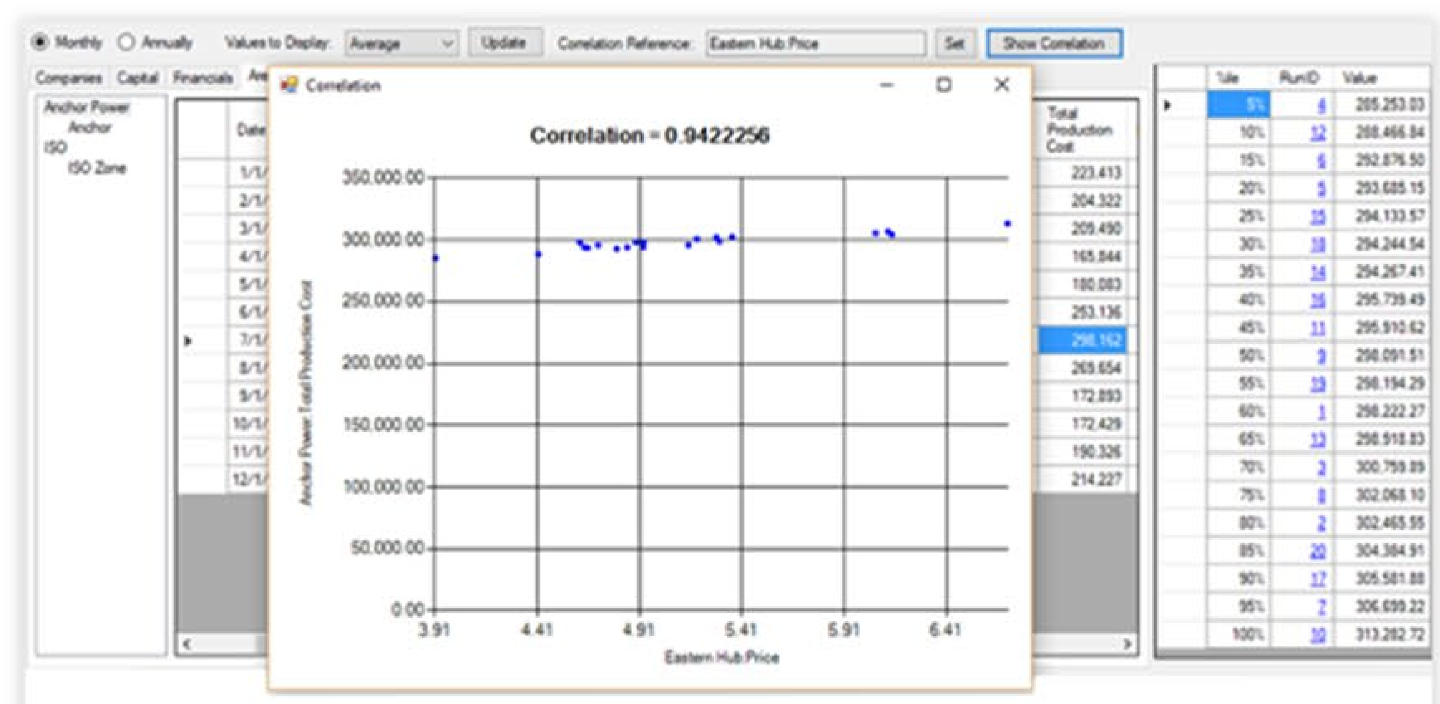
Integrated Resource Planning

We help electric utilities face the complexity in power supply planning, as well as balancing requirements for reliability and environmental compliance in the most cost-effective manner. EnCompass determines not only the best way to utilize resources, but also which technologies should be added in the future, or existing resources that should be converted or retired.

Integrated Resource Planning

Valuation and Risk Assessment

Projecting future operations and cash flows of either a single power project or a portfolio of energy assets requires a detailed commitment and dispatch optimization model to capture all operating constraints. Valuations produced by Anchor Power can be used for project finance, tax assessments, budgeting, rate cases, and developing hedging strategies.



Valuation & Risk Assessment

Progress to date: The EnCompass database has been built and staff is currently running simulations and analyzing preliminary results.