How Generators Make Money: Introduction and Grid Operations

Handout | Reference materials

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Welcome/What we'll cover

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Hi, I'm Tanvi and I'm a director at Grizzly Power. We are an independent power producer, or an IPP. We own power plants and run them to sell electric supply services. I'll help you learn about how power plants make, and unfortunately sometimes lose, money.

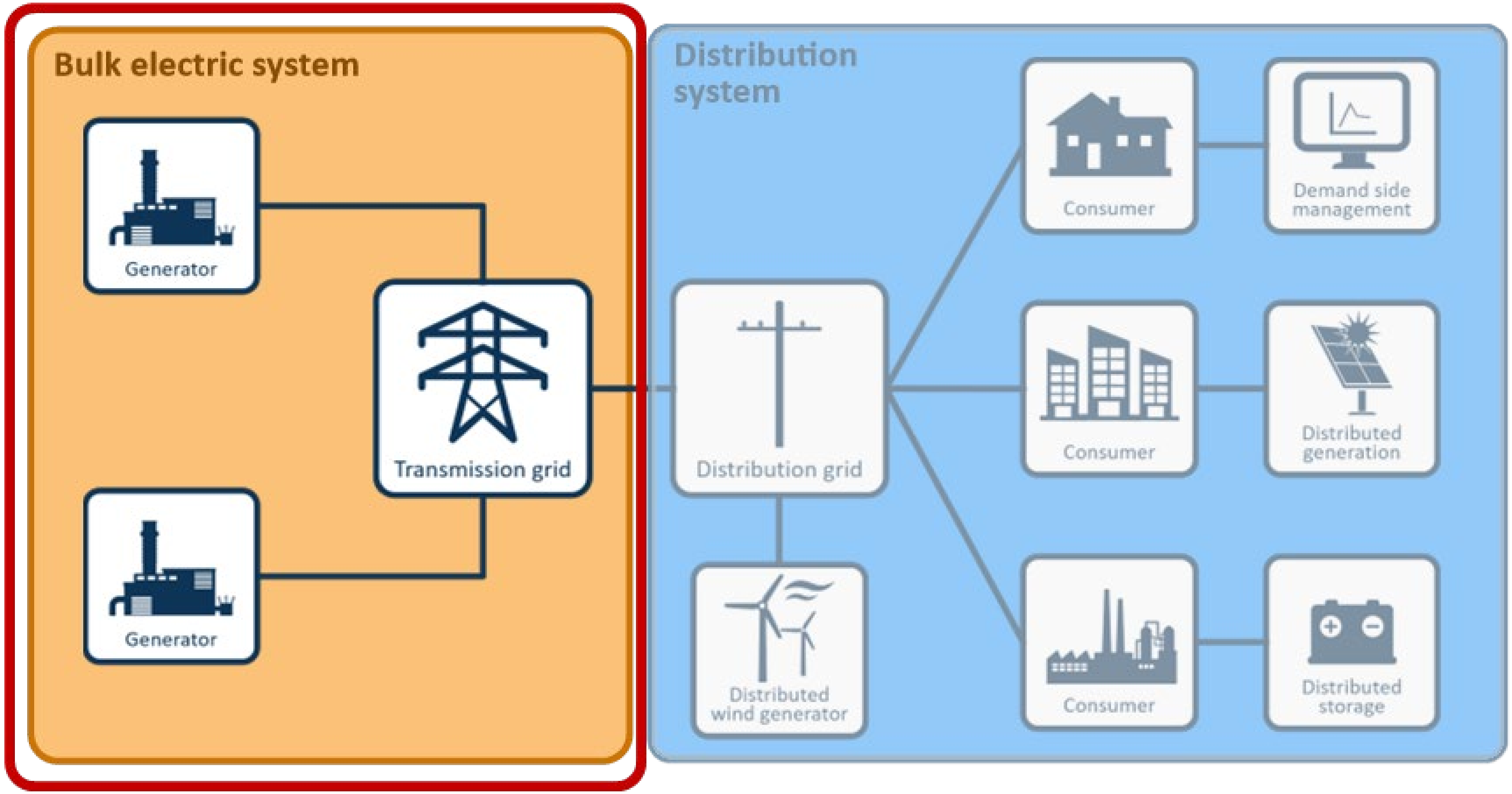
The ongoing transition in the electricity industry requires investors, regulators, planners, and asset operators to increasingly make decisions under uncertain conditions.

The uncertainty strongly impacts power generators who find that technology developments, market fluctuations, decarbonization initiatives, and numerous other factors can make an investment in power generation assets valuable one day and money losers the next.

To help you sort this all out, we will consider how the grid operates; how services are traded in markets; key generation technologies and their characteristics; the services that generation owners can provide to obtain revenues; how units are dispatched; and how prices for services are determined. Then we'll conclude by considering how all these factors result in earnings or losses for power plants.

Bulk electric system

In this course we'll discuss only those power plants connected to the transmission system, not distributed energy resources connected to the distribution system. This part of the electric grid is called the bulk electric system or the BES.



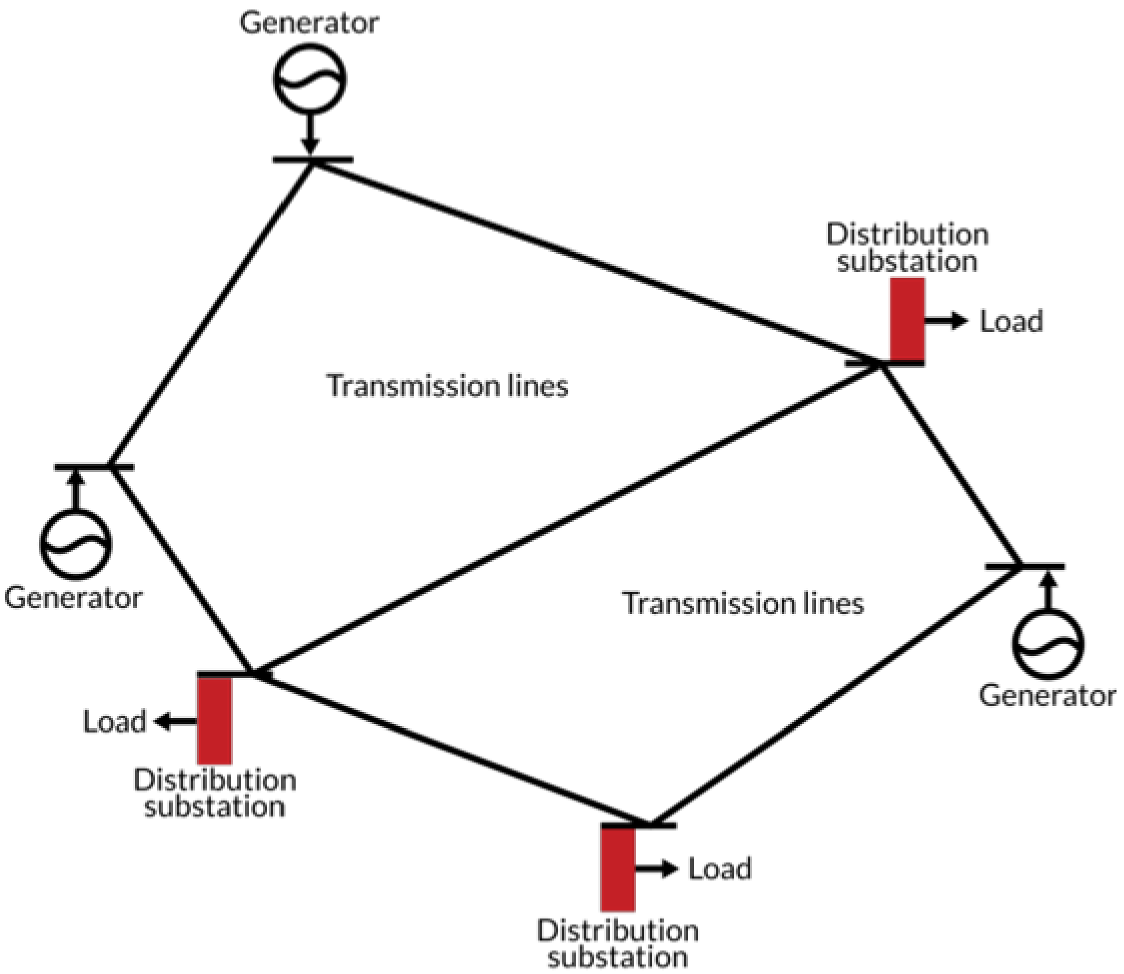
Electric grid operations

How are electric grids operated to ensure reliability?

We'll start by looking at how the electric grid is operated and the role of power plants in ensuring supply meets customer demand. Understanding how transmission system operators balance supply and demand given transmission constraints is important since this process determines when our power plants operate.

A simple electric grid

Let's look at a simple bulk electric grid. The transmission system connects multiple generators to distribution substations. To ensure system reliability, total supply from the generators must continuously match the total demand from the distribution system. There must also be adequate transmission capacity to move the supply from the generators to the distribution substations.



Bulk electric system operators

Given the unique physical characteristics of the electrical system, it is critical that a single entity takes charge of the regional bulk electrical grid.

Organizations called transmission system operators, control area operators, or balancing authorities take on this responsibility.

Transmission system operators schedule and dispatch power plants and operate the transmission system for a specific region of the electric grid.

In regions with an independent system operator, or ISO, they also facilitate markets that identify which power plants are most economic to dispatch and set market prices.

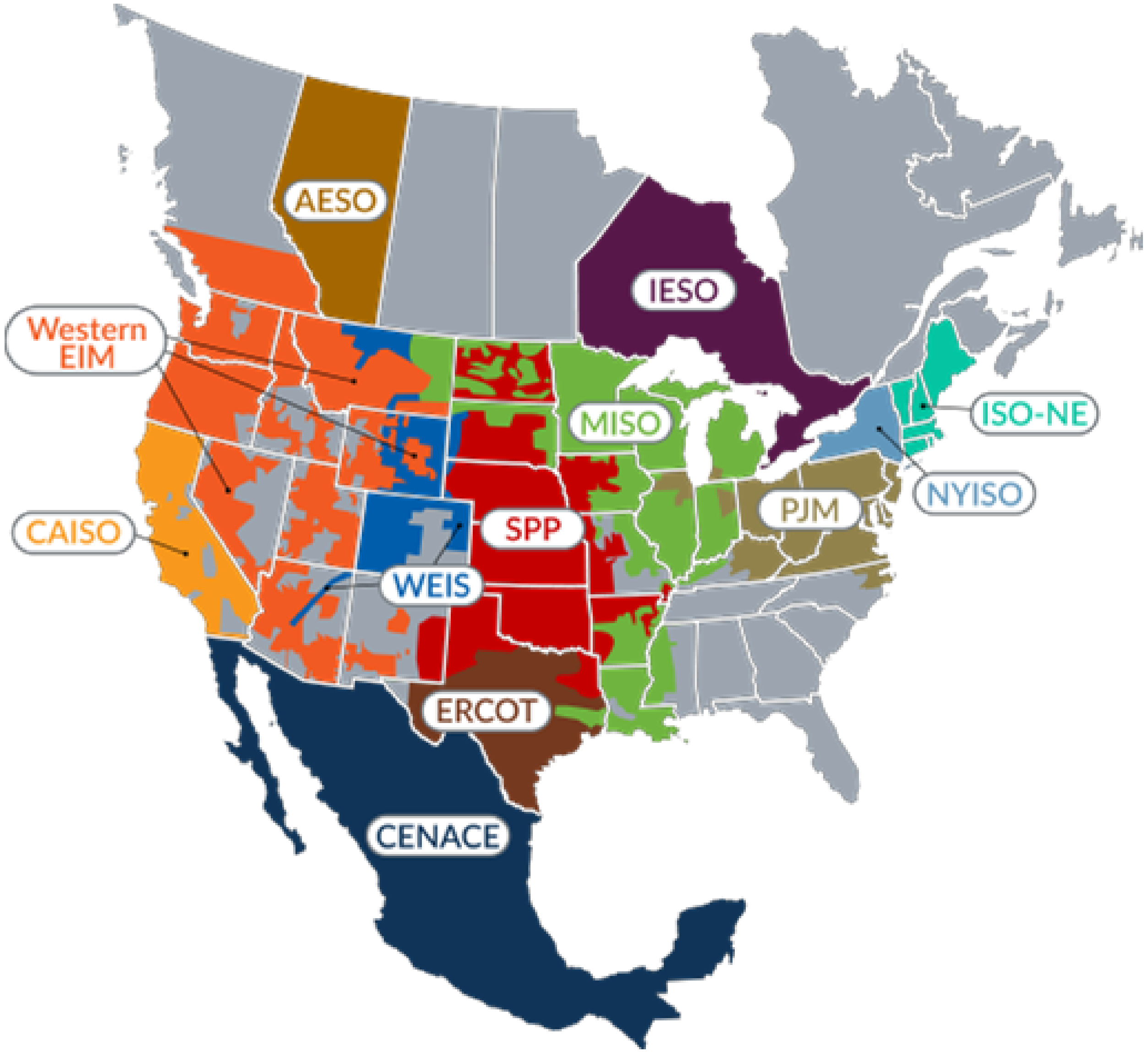
Types of transmission system operators

If you are new to the business, it can be hard to tell who is the transmission system operator for any given power plant. It depends on where the plant is located, and it may be different for two plants located in the same state.

There are two types of transmission system operators - those in organized wholesale markets facilitated by ISOs, and those in markets without an ISO.

Grids in markets without an ISO are operated by large utilities or power authorities while grids in organized markets are operated by the ISO.

This map shows areas in North America operated by utilities or power authorities in gray, and areas operated by ISOs in color.



Maintaining frequency

Transmission system operators maintain reliability by ensuring frequency and voltage are kept within required limits.

The balance of supply and demand determines the grid's frequency. While system frequency is the same in all locations of the BES, this varies over time. Maintaining the frequency is a key task of transmission system operators. They call on our power plants to adjust output to help maintain the right balance.

If supply equals demand, including system losses, the system is balanced. But if supply is larger than demand, system frequency increases. Or if demand is larger than supply, system frequency decreases.

The system frequency is 60 hertz in most of the Americas and 50 hertz in much of the rest of the world.

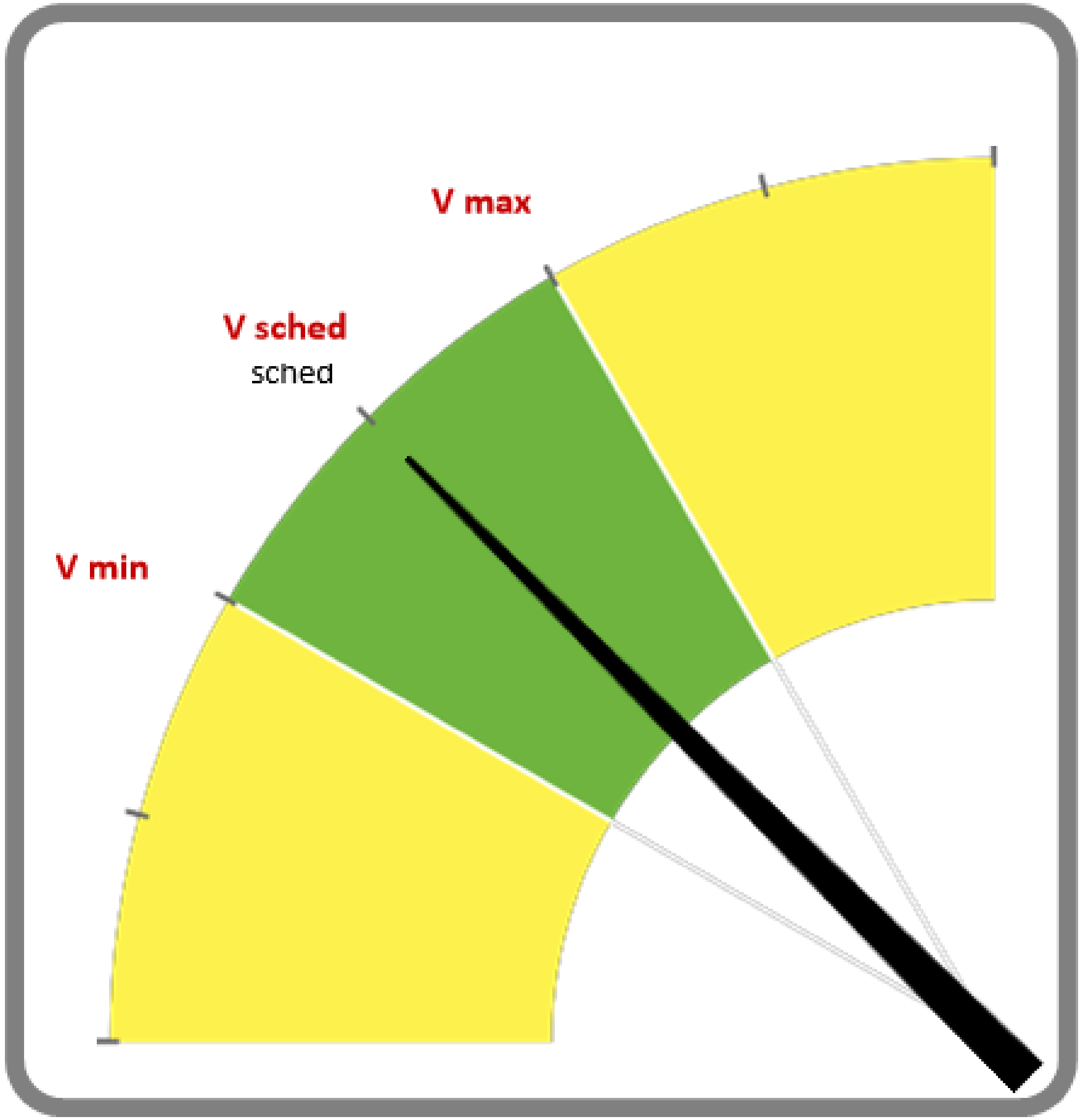
Operators primarily balance supply and demand by adjusting energy output from power plants. Grizzly's plants receive signals from the transmission system operator and either automatically or manually adjust output as needed to balance the grid. Although ramping power plants up or down is by far the most common way to balance the system, operators sometimes balance by controlling battery storage or reducing loads.

Maintaining voltage

Unlike frequency, voltages vary across the bulk electric system.

Voltage also must be maintained within acceptable values. Each key point along the grid has desired voltage called V scheduled, and maximum and minimum voltages called V max and V min.

Transmission system operators control voltage by injecting or withdrawing reactive power from the grid. Certain types of generators, including many of Grizzly's units, can provide reactive power. It can also be injected or withdrawn by battery storage, equipment in substations, devices on the distribution grid, and by distributed energy resources.



The role of transmission system operators

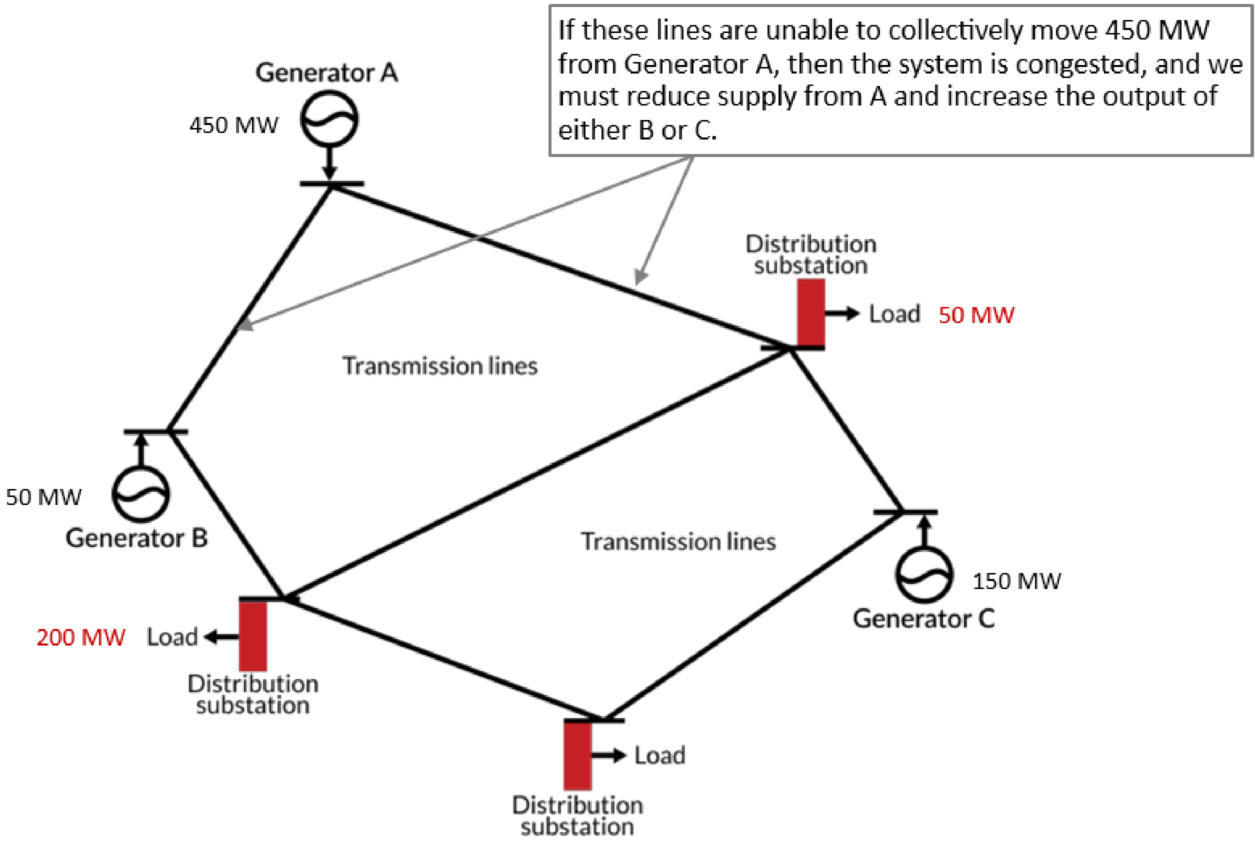
To ensure safe and reliable supply, transmission system operators must forecast needs and then schedule, control, and coordinate the dispatch of power plants and the flow of electricity.

This function is performed across a complex integrated grid that transmits power from generating units over large geographical areas to distribution companies serving a diverse group of customers.

Transmission system operators must consider the unique physical characteristics of the bulk electric system. They must avoid causing major electric outages. Because these operators determine when Grizzly Power units must turn on and off, we try to learn as much as we can about how each transmission system operator performs the balancing and scheduling functions.

Transmission system operators don't just schedule power plants they also make sure there's enough transmission to move power from generators to distribution substations. Each transmission path has a specific operational limit that varies based on the line equipment, the outside temperature, and various operational characteristics.

When a path's capacity is lower than the desired flow across that path, we say the path is congested. Congested lines result in power plants being scheduled for less than their capacity. In some cases, previously scheduled output or load may be curtailed.



Why grid operations matters

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As the transmission system operators manage frequency and voltage, they depend on services provided by power plants to perform their functions. Grizzly's power plants often provide these services. The transmission system operators also take actions that impact our plant operations. Next, we'll discuss how our units provide these services, how the services are bought and sold, and when transmission system operations affect our units.

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Generation Markets

Welcome to the Generation Markets section of How Generators Make Money. In this section we will discuss types of trading, types of power plant owners, and market structures.

Types of trading in electric markets

Bilateral contracts

Electronic exchange trades

Organized wholesale market transactions

I want to tell you about the ways that Grizzly Power sells its services, which we call trading.

We will look at three types of trading.

Bilateral contracts

Under bilateral trading, two market participants agree to a private arrangement. For example, Grizzly Power often signs contracts with a utility to sell energy or other services for a period of one year or more in a supply contract called a power purchase agreement or a PPA. We also sell renewable energy credits, or RECs, from our solar plants to various buyers in bilateral transactions. Details of the transactions such as price and terms are negotiated between us and the buyer either by phone, email, text, or in person.

Electronic exchange trades

In addition to personal negotiation, we sometimes enter bilateral agreements using a proprietary electronic exchange called a power exchange or PX. In an exchange, buyers and sellers are matched based on price offers and bids. Terms are standardized and not negotiated. We often use electronic exchanges to sell forward energy that has not been committed in other contracts.

ISO market transactions

ISOs facilitate markets and set specific auction rules. Prices are based on market clearing prices. Unlike electronic exchanges, participants are not matched with a specific counterparty. The ISO buys power from generators and sells to utilities and retail marketers. Transaction terms are standardized.

Grizzly Power sells capacity, energy, and ancillary services in ISO markets.

Types of power plant owners

Vertically Integrated utilities in non-ISO markets

Vertically integrated utilities in ISO markets

Independent power producers (IPPs)

To understand power markets and the types of entities Grizzly competes against, you need to understand the different types of generation owners. The ownership model impacts the financial motivation behind power plant behavior.

We will look at three types of power plant owners.

Utilities in non-ISO markets

In regions outside of ISOs, markets are dominated by vertically integrated utilities. These may be investor-owned utilities, municipal utilities, or co-ops.

In this case, power plants are primarily scheduled to serve the utility's own load. If power in the market is cheaper than the cost of running utility-owned generation, the utilities may reduce their unit output and buy from the market. They also buy from the market when they are short supply and may sell to the market when they are long.

Any excess wholesale revenues may be used to reduce customer rates or may be shared between customers and utility shareholders as profit. But these revenues are typically small relative to the utility's overall revenue.

- Units are owned by a utility
- Units are used to serve the utility's own load
- Participation in markets is less important than service to end-use customers

Utilities in an ISO market

- Units are owned by a utility
- Units are used to serve the utility's own load + participate in markets
- Revenues may go to customers, utility profit, or a mix of both
- Participation in markets may be important to the utility

In regions with an ISO, units may be owned by vertically integrated utilities.

In this case, the power plants serve a dual purpose. They provide capacity needed to serve the utility's own load, but they also participate in wholesale markets to attain market-based revenues.

When revenues are achieved, they may be returned to utility customers through a rate discount, may be retained by the utility as additional profit, or may be shared between customers and the utility. Although the utility remains highly regulated, its regulator may now expect the utility to compete in markets to attain revenues that will reduce utility customer rates.

Independent power producer

In regions with an ISO or where utilities are required or prefer to buy supply from non-utility generators, there are units owned by non-utility, for-profit companies. These are called independent power producers, or IPPs. They may also be called merchant generators.

IPPs make revenues through bilateral contracts or spot sales into organized wholesale markets.

When revenues are achieved, they are used to cover owner costs and for owner profits.

Grizzly Power is an independent power producer, and our goal is to make profits for our shareholders by providing electric services. We carry significantly more risk than utility generators since we cannot recover any of our costs through regulated rates.

- Units are owned by non-utility independent power producers (IPPs)
- Units sell output through bilateral contracts or organized markets
- Revenues cover costs plus generator profit
- Higher risk than regulated utilities

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Market structures

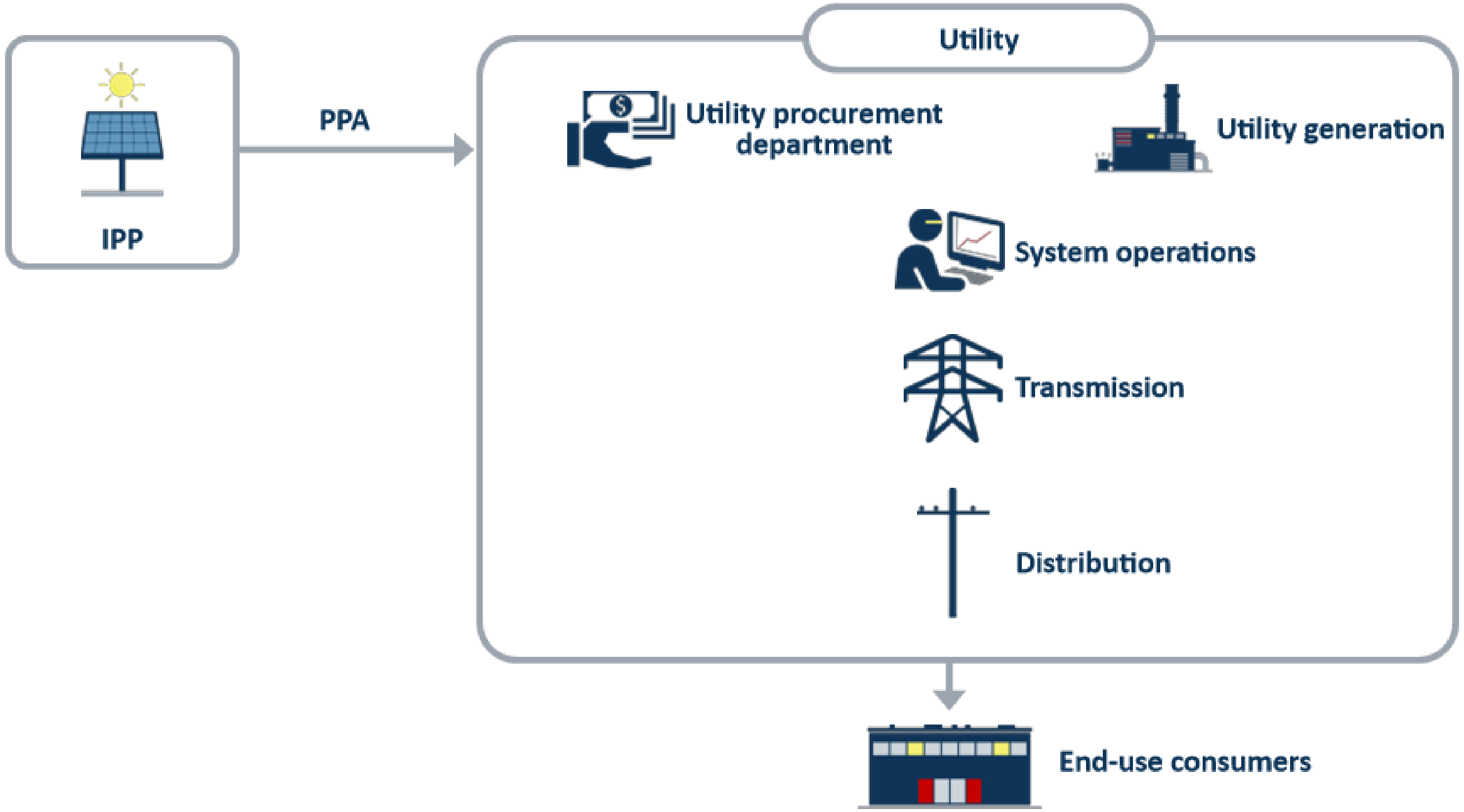
Who can we sell to under different market structures?

Since Grizzly Power has assets in various regions, we need to explore the different market structures that exist in different regions. Understanding market structures allows us to understand our opportunities for selling services as an IPP. It also helps us understand our competition.

Non-ISO markets

Units in regions without an ISO usually sell only to the local utility. In some cases, they can sell to remote utilities, marketers, or large end users using utility open-access transmission tariffs to move the power.

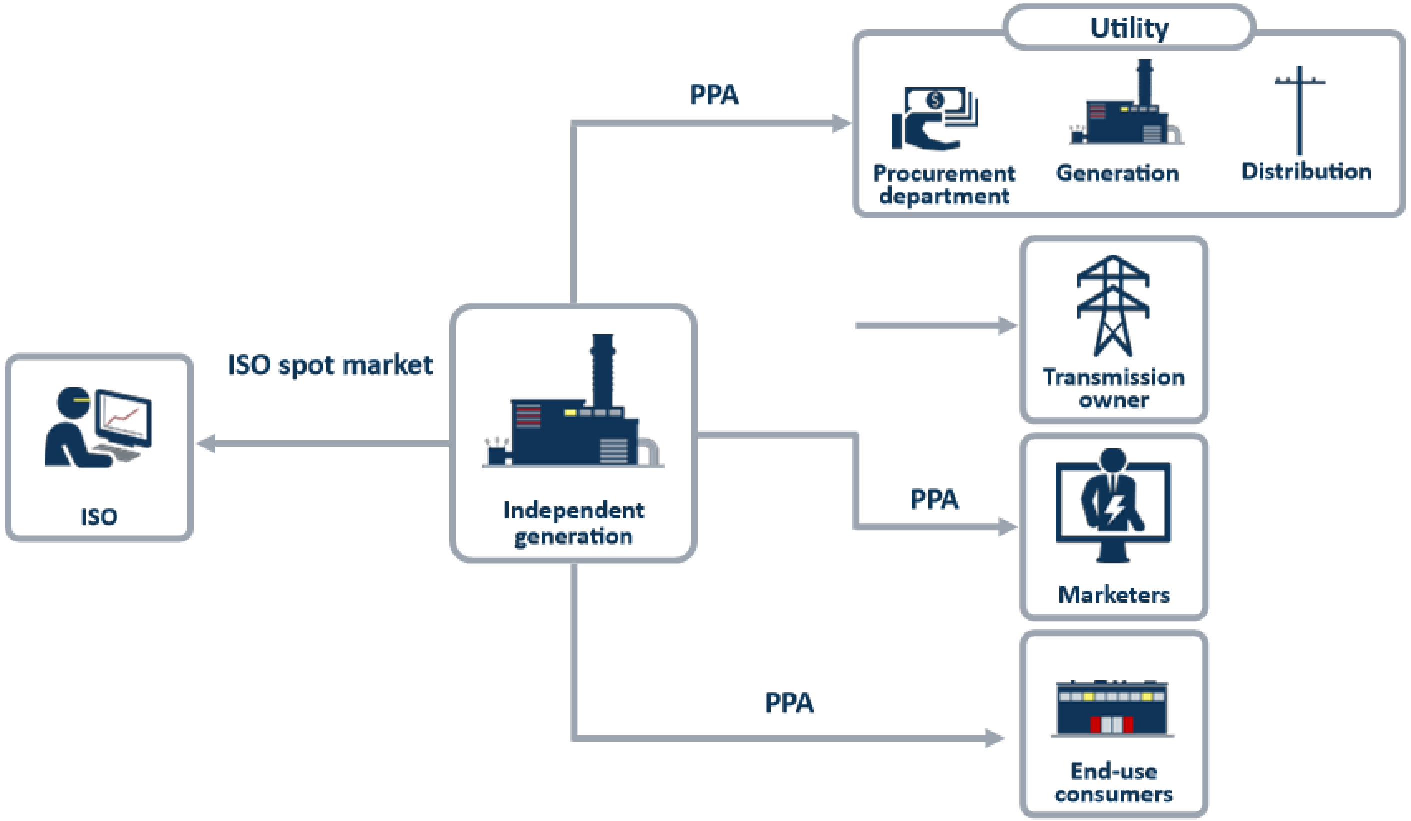
Grizzly Power invests in a power plant in these regions only if we can get a long-term power purchase agreement. This is common with our solar power plants.



ISO markets

Within ISO markets is the opportunity to sell capacity or energy to many market participants through bilateral power purchase agreements, or PPAs. There is also an opportunity to sell energy and ancillary services to the ISO in day-ahead and real-time markets. Some ISOs also run capacity markets, which creates an additional opportunity to sell capacity services.

Most of Grizzly Power's units are in organized wholesale markets. We try to contract at least half of our energy output in longer-term PPAs for our gas units and at least 75% of our energy output for our solar units. The remaining output is sold in the ISO day-ahead or real-time markets. Depending on the region, we may also contract capacity in bilateral agreements or through ISO auctions.



Power Plant Characteristics

Welcome to the Power Plant Characteristics section of How Generators Make Money. In this section we will discuss operational, environmental, and cost characteristics of our power plants and the other power plants that Grizzly competes with in the marketplace.

Power plant characteristics that impact opportunities

Operational

Emissions

Costs

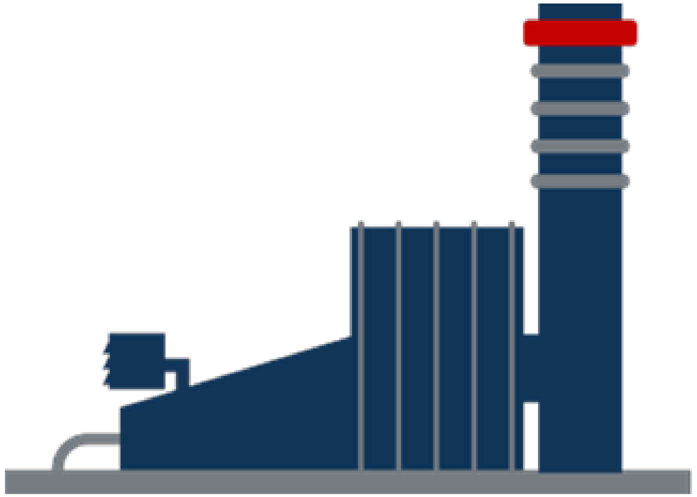
Understanding power plant characteristics is key to understanding revenue opportunities and how revenues translate into earnings.

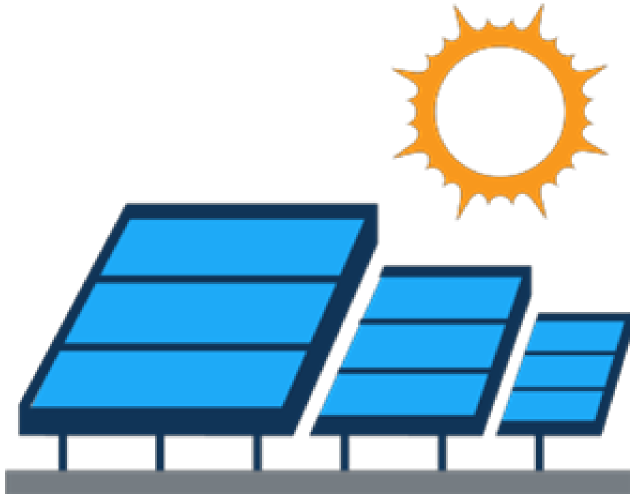
Key factors we need to understand include operational, emissions, and cost characteristics.

Operational characteristics

A plant's operational characteristics determine which services it can provide and when its services are expected to be available.

Characteristics determine the services offered and when they can be offered





Operational characteristics

Characteristic	Key questions
Variability	How much does the resource output vary over time based on uncontrollable factors?
Predictability	If the resource is variable, how easy is it for operators to predict the output in the day ahead and during the operating day?
Dispatchability	Can the resource be controlled locally and/or remotely? Can it be dispatched by a transmission system operator?
Ramp rate	How quickly can the resource's output ramp up or down during operation?
Grid support	Under what conditions is the resource capable of providing grid support services including frequency support, operational reserves, voltage support, and black start?

Operational characteristics

Characteristic	Pronghorn gas combined-cycle	Bluesky solar
Variability	As long as gas supply is available and there is no unexpected maintenance outage, output is controlled by the amount dispatched	Output is variable based on available solar radiation
Predictability	Output is predictable except during unexpected maintenance outages or inability to acquire fuel supply	Output is fairly predictable over long periods of times such as a year, and highly predictable in the day-ahead and real-time.
Dispatchability	Unit can be dispatched directly by the transmission system operator	Panels can be dispatched down by the transmission system operator through curtailment, cannot be dispatched up
Ramp rate	Unit has a ramp rate of 40 MW/minute	Plant output ramps up or down almost instantly based on the amount of sunlight
Grid support	Unit can provide inertia, frequency support, operational reserves, voltage support, and blackstart	Plant is not currently configured to provide grid support, but has the potential to provide synthetic inertia, frequency support, and voltage support through inverter-based electronics

Operational characteristics

Characteristic	Operational characteristics
Fuel cost	How much it costs to run the unit as determined by the heat rate and fuel price. This includes how fuel costs vary depending on plant loading.
Start-up costs	How much it costs each time the unit is started.
Start-up time	How long it takes to start the unit.
Shutdown time	How long it takes to shut down the unit.
Number of starts per day	The maximum number of times the unit can be started in a day.

Emission characteristics

How do emissions characteristics impact revenue opportunities?

Regulations concerning power plant emissions impact operations of certain units.

Units that have to pay emission taxes or buy RECs have higher variable costs and are less likely to be selected.

But units with zero carbon emissions that receive tax benefits or earn green credits have lower costs and are more likely to be selected to run.

Emissions characteristics

Our power plants have very different emissions profiles.

This unit emits nitrous oxides (NO_x) and carbon dioxide (CO_2). In some markets we must control NO_x output either through operational practices, installation of technology, or limiting run hours. In some markets we must acquire carbon credits to offset CO_2 emissions.

This plant has no emissions. When it runs, it generates renewable energy credits (RECs), which have a financial value. If we contract with a utility to buy the plant's output, they may dispatch it regardless of the purchase agreement price to achieve renewable goals.

Cost characteristics

Having a solid grasp of the various costs associated with our units is crucial to understanding how we create earnings. This can also help us understand when a specific generator is competitive with other units in the market.

How much does it cost to provide services?

Cost characteristics

Having a solid grasp of the various costs associated with our units is crucial to understanding how we create earnings. This can also help us understand when a specific generator is competitive with other units in the market.

Capital	Upfront costs to build, acquire, or upgrade the facility. These costs impact the debt service and return on equity that must be collected through revenues each year to make the unit profitable.
Fixed	Expenditures required on a periodic basis such as annual plant maintenance and overheads such as staffing. These costs are incurred regardless of how much the plant runs.
Variable	Costs incurred when the unit runs including fuel, variable operations and maintenance (O&M), start-up, and emission costs. Variable costs may be offset by environmental credits for renewables and nuclear.

Cost characteristics

Bluesky solar example

Plant capacity: 200 MW

Capital

Debt service: $11.9 million per year

Expected return on equity: $9.6 million per year

Fixed

Total fixed: $2.2 million per year

Variable

Zero cost

Pronghorn gas combined-cycle example

Plant capacity: 400 MW

Capital

Debt service: $26.4 million per year

Expected return on equity: $19.2 million per year

Fixed

Total fixed: $5.6 million per year

Variable

Fuel: 7 x cost of gas in $/MMBtu x MWh generated

O&M: $3/MWh generated

Carbon credits: 0.4 x carbon cost x MWh generated

Summary of Characteristics

Grizzly Power competes with other power plants in our region. Whether our units get dispatched at any given point in time depends on our characteristics relative to our competitors. It is important for us to understand all types of power plants, whether or not we own that technology.

Operational

Technology	Variable	Predictable	Dispatchable	Ramp Rate	Grid Support
Hydro	Partially	Yes	Yes	Fast	Yes
Coal steam turbine	No	Yes	Yes	Medium	Yes
Nuclear steam turbine	No	Yes	No	Slow	Partially
Gas combined-cycle	No	Yes	Yes	Fast	Yes
Gas combustion turbine	No	Yes	Yes	Fast	Yes
Gas reciprocating engine	No	Yes	Yes	Fast	Yes
Solar PV	Yes	Somewhat	No	Fast	Partially
Solar PV with battery	Partially	Yes	Partially	Fast	Yes
Onshore wind	Yes	Somewhat	No	Fast	Partially
Offshore wind	Yes	Somewhat	No	Fast	Partially

Environmental

Technology	Carbon emissions	Other emissions
Hydro	None	None
Coal steam turbine		
Nuclear steam turbine	None	None
Gas combined-cycle		
Gas combustion turbine		
Gas reciprocating engine		
Solar PV	None	None
Solar PV with battery	None	None
Onshore wind	None	None
Offshore wind	None	None

Cost

Technology	Capital	Fixed	Variable
Hydro	$$	$	$
Coal steam turbine	$$	$$	$$
Nuclear steam turbine	$$$	$$$	$
Gas combined-cycle	$	$	$$
Gas combustion turbine	$	$	$$$
Gas reciprocating engine	$	$	$$$
Solar PV	$	$	$
Solar PV with battery	$$	$	$$
Onshore wind	$	$$	$
Offshore wind	$$	$$	$

Services and Revenue Streams

Welcome to the Services and Revenue Streams section of How Generators Make Money. In this section we will discuss the various services that power plants sell in power markets and how this results in revenue streams.

Services and revenue streams

- Capacity
- Energy
- Environmental credits
- Ancillary services

Grizzly's power plants attain revenues by selling services in various markets. In this section, I'll explain these services and how we get revenues from each of them.

These four services are how we generate revenue from our power plants.

Capacity services

When we sell capacity from a power plant, we agree to provide energy if called upon. The definition of what we are selling is slightly different in an ISO and non-ISO market as shown here.

- **Non-ISO market:** Generation available if called upon by the buyer
- **ISO market:** Generation committed to offer energy into markets

Capacity services

Capacity deals are structured differently in vertically integrated versus organized wholesale markets. Given what you've learned about the different market structures, how do you think each market type may provide for sufficient capacity?

ISO market capacity

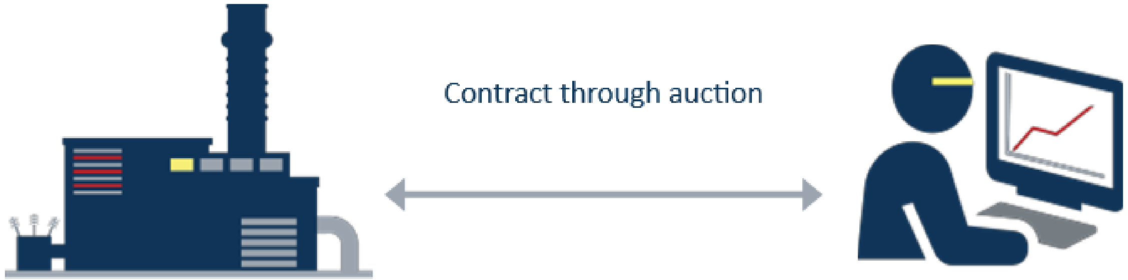
Structured as a contract providing an amount of generation available if the buyer calls for energy

- Typically between a generator and a utility or other load-serving entity that needs capacity for reliability purposes
- Arrangements are through bilateral contracts

Non-ISO market capacity

Structured as an agreement committing an amount of generation to offer energy into the ISO markets

- In regions with a capacity auction, capacity is sold in a contract between the generator and the ISO with the price set through an auction
- In regions without a capacity auction, bilateral contracts between generators and load-serving entities (utilities or retail marketers) are used



Capacity revenues

A unit's capacity revenue is the capacity price times the capacity amount provided times the number of days over which it is provided. Note that most contracts or tariffs contain a clause that penalizes a unit for failure to perform.

$/MW-day x MW of capacity x number of days

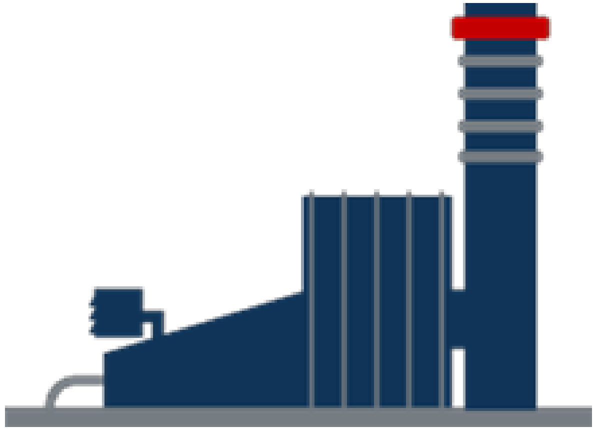
Pronghorn gas combined-cycle capacity revenue example

Details:

Pronghorn is in an organized market and has an annual contract for 400 MW of capacity priced at $190/MW-day

For the month of January, Pronghorn performed as required by contract

Monthly revenue for January:
$190/MW-day x 400 MW x 31 days = $2,356,000



Bluesky solar capacity revenue example

Details:

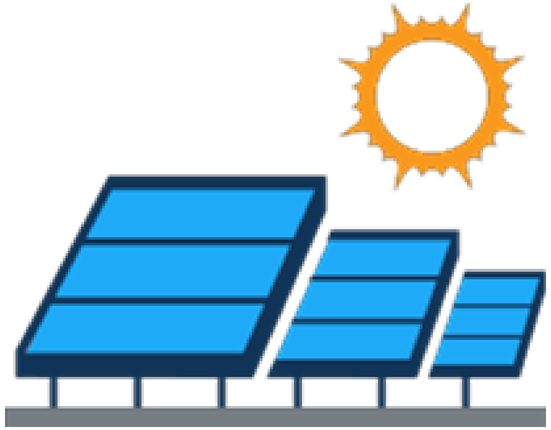
Bluesky is in an organized market and has an annual contract for 50 MW of capacity priced at $190/MW-day

Only 50 MW of Bluesky's nameplate capacity of 200 MW was certified as reliable capacity due to it being a variable resource

For the month of January Bluesky performed as required by contract

Monthly revenue for January:

$190/MW-day x 50 MW x 31 days = $294,500



Energy services

Energy is the actual electrons generated and delivered onto the grid. Grizzly sells energy in three time frames: forward, day-ahead, and real-time.

Forward energy

Structured as an agreement committing the generator to provide:

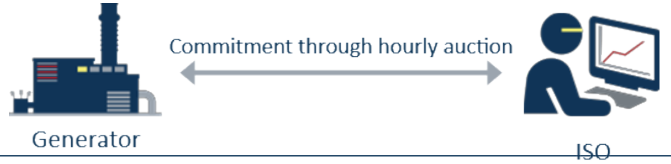
- A specified number of MWh
- Over a specified time period
- At a specified location
- At a specified price

Day-ahead energy

In a vertical market, structured as a bilateral agreement like forward energy.

In an organized market, sold into the ISO hourly market:

- Generators scheduled by the ISO are committed to deliver the scheduled amount and are paid the hourly day-ahead price for their location for the amount scheduled

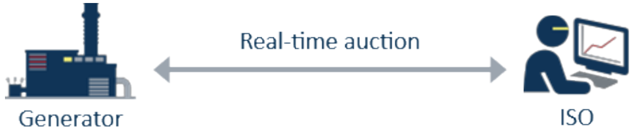


Real-time energy

In a vertical market, structured as a bilateral agreement like forward energy.

In an organized market, sold into the ISO real-time market:

- Generators whose actual output varies from their day-ahead schedule buy or sell real-time energy to make-up the difference
- Actual output varies due to instructions from the ISO or due to uninstructed deviations due to power plant operational issues
- Uninstructed deviations may result in penalties from the ISO
- The real-time price is the 5-or 15-minute price for the generator's location



Environmental credit services

Energy from a renewable or zero-emission generator is often eligible for additional compensation through a mechanism called an environmental credit. These credits allow buyers wishing to control environmental impacts to pay for the environmental attribute associated with the output from a clean generator. Credits include renewable energy credits called RECs, and zero emission credits called ZECs. The sale of these credits is usually structured as a bilateral deal.

Environmental credit

Structured as a bilateral transaction selling the environmental attribute associated with 1 MWh of output

- RECs are typically associated with wind, solar, biopower, geothermal, and small hydro
- ZECs are typically associated with nuclear power
- Credits may be traded separately or may be embedded in the energy price

Energy and environmental credit revenues

A unit's energy revenues equal the sum of the various energy market revenues, plus any environmental credit revenues.

A unit's energy revenue is the sum of:

- Forward energy: MWh delivered x $/MWh forward energy price
- Day-ahead energy: MWh scheduled x $/MWh day-ahead energy price
- Real-time energy: (MWh delivered – MWh bought) x $/MWh real-time energy price
- Energy credits: MWh delivered x $/MWh price for RECs or ZECs

Pronghorn gas combined-cycle energy and environmental credit revenue example

January revenues

Forward energy:	148,800 MWh x $40/MWh = $5, 952,000
Day-ahead energy:	50,000 MWh x $43/MWh = $2,150,000
Real-time energy:	8,000 MWh x $56/MWh = $448,000
Environmental credits:	$0.00
Total	8,550,000

Bluesky solar energy and environmental credit revenue example

January revenues

Forward energy:	8,000 MWh x $70/MWh = $5,952,000
Day-ahead energy:	$0.00
Real-time energy:	$0.00
Environmental credits:	$0.00
Total	$560,000

In this example Bluesky included RECs in the forward energy price, and all energy output was committed under the bilateral forward contract.

Ancillary services

The transmission system operator requires these ancillary services to maintain system reliability.

Frequency regulation	Capacity in MW available for the transmission system operator to automatically ramp unit output up or down within seconds to support system frequency.
Spinning reserve	Capacity in MW that is synchronized to the frequency of the system available for the transmission system operator to ramp up within 10 minutes.
Non-spinning reserve	Capacity in MW that is not synchronized to the frequency of the system available for the transmission system operator to ramp up within a specified time frame. Also called replacement reserve.
Voltage support	Reactive power in MVar available to the transmission system operator.
Blackstart	Capacity in MW that can start without power from the grid available to the transmission system operator to restore the grid after an outage.

Ancillary services

Ancillary services trade bilaterally in regions without an organized market and are acquired by the ISO in organized markets.

In a vertically integrated market, ancillary services are most commonly provided by utility-owned generation but may be acquired through bilateral contracts.

In an organized market, ancillary services are acquired by the ISO either through auctions (frequency support, spinning, and non-spinning reserve) or through annual contracts (voltage support and blackstart).

Ancillary services revenue

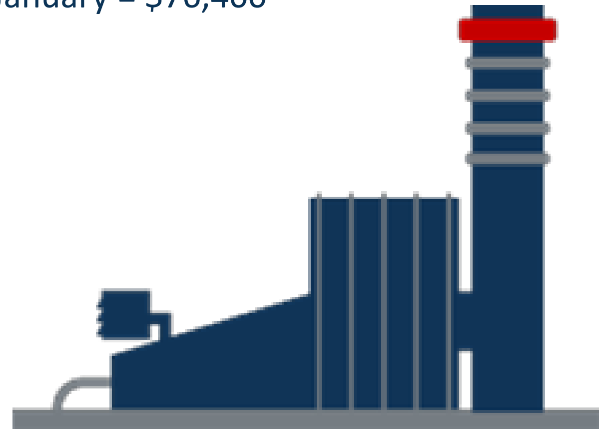
Monthly payment:
Sum of payments for the various services in either $/MW or $/MVar multiplied by the appropriate amount of the service provided

Pronghorn gas combined-cycle capacity revenue example

Here is an example of Pronghorn's January ancillary services revenue:

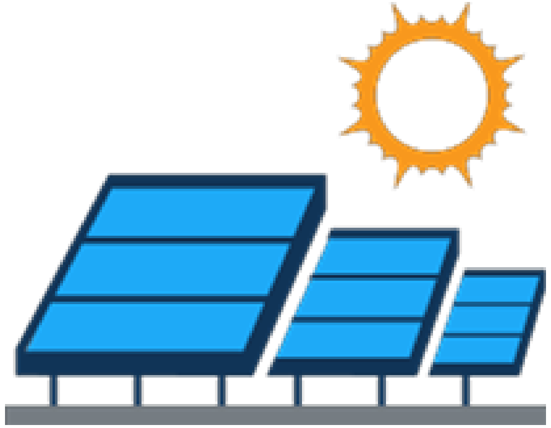
- Pronghorn is capable of providing AGC, reserves, voltage support, and blackstart
- 5,400 MW of spinning reserve provided at an average price of $12/MW
  Spinning reserve revenue = 5,400 MW x $12/MW = $64,800
- 950 MVars of voltage support at a price of $8/Mvar
  Voltage support revenue = 950 MVars x $8/MVar = $7,600
- 400 MW of blackstart provided at a monthly price of $100/MW
  Blackstart revenue = 400 MW x $10/MW = $4,000

Total revenues for January = $76,400



Bluesky solar capacity revenue example

Due to the nature of its resource, Bluesky does not provide ancillary services



Power plant revenues

By adding the revenues from the various services, we can determine the total revenue for a power plant over a specified period. At Grizzly Power we carefully track revenues so that we can see if our units are profitable and how we might boost revenues by focusing on different services. We also use this equation to forecast future revenues by using market models to forecast prices and market needs for each of the services.

Capacity

+

Energy

+

Environmental credits

+

Ancillary services

Total revenues

Monthly revenues

	Pronghorn January revenues	Bluesky January revenues
Capacity	$2,356,000	$294,500
Energy	$8,550,000	$560,000
Environmental credits	$0	Bundled in energy price
Ancillary services	$75,450	$0
Total	$10,981,450	$854,500

Here is an example of the total revenues for our two power plants. Within our company, we study the monthly revenues for each plant carefully to understand what actions we might take to improve each unit's earnings. As you continue through this course, think about actions Grizzly might take to improve each unit's revenues.

Services units can provide

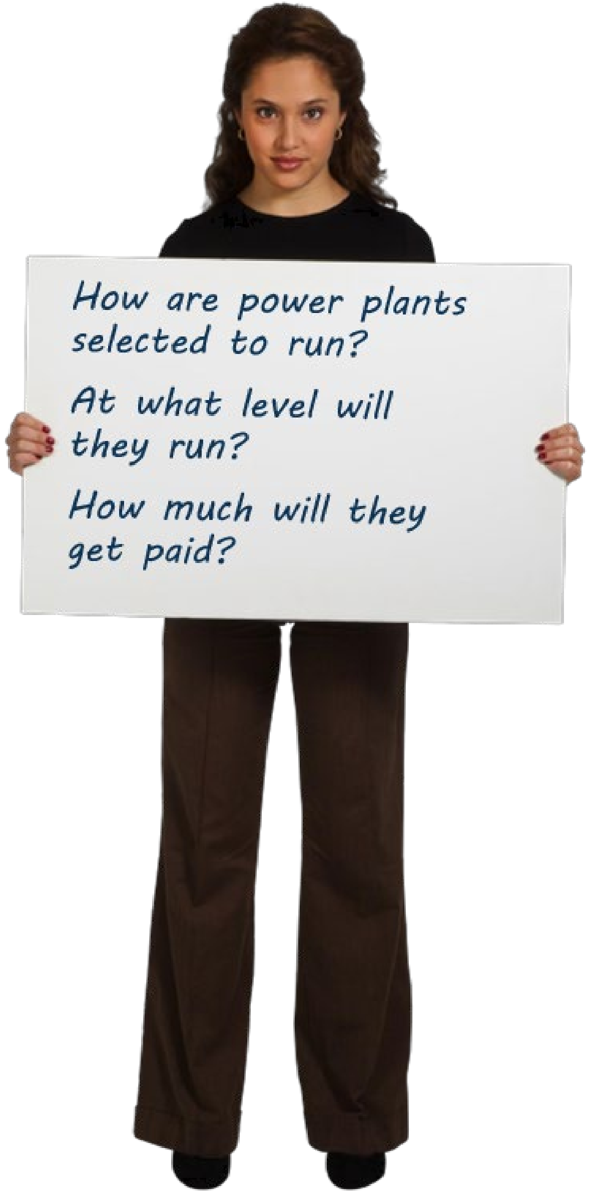
Since we must compete with other power plants, it is important to know not only which services our units can provide, but also how other power plant types stack up. Here is an overview.

Technology	Capacity	Energy	Environmental credits	Frequency response	Reserves	Voltage support	Blackstart
Hydro	X	X	Only small hydro	X	X	X	X
Coal steam turbine	X	X		X	X	X	
Nuclear steam turbine	X	X	ZECs			X	
Gas combined-cycle	X	X		X	X	X	X
Gas combustion turbine	X	X		X	X	X	X
Gas reciprocating engine	X	X		X	X	X	X
Solar PV	Partial	X	RECs			X	
Solar PV with battery	X	X	RECs	X	X	X	X
Onshore wind	Partial	X	RECs			X	
Offshore wind	Partial	X	RECs			X	

Unit Selection and Pricing

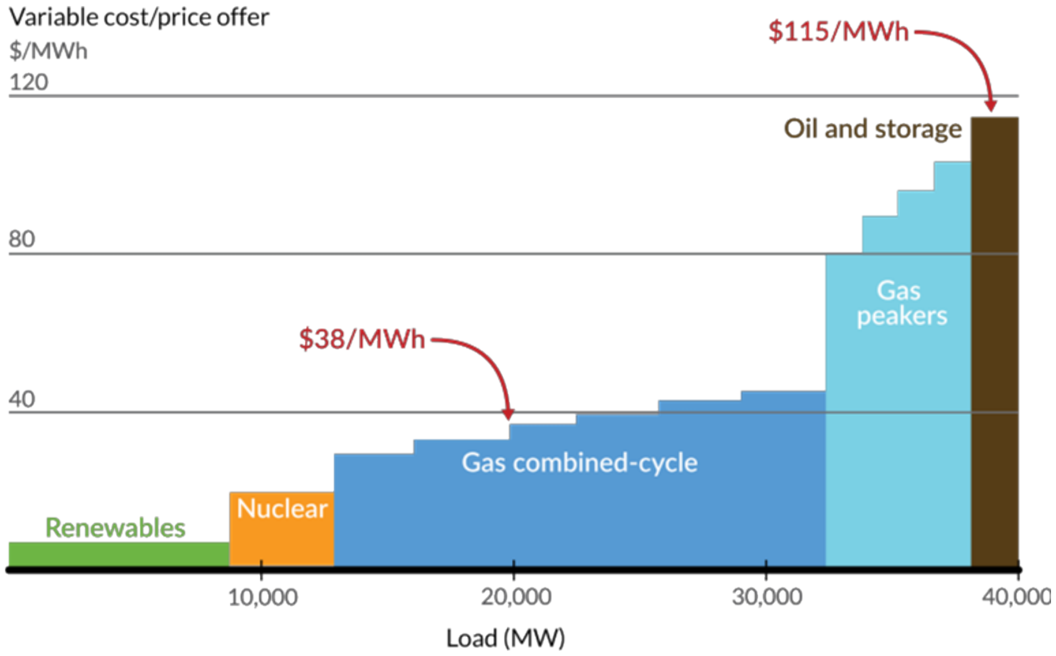
Welcome to the Unit Selection and Pricing section of How Generators Make Money. In this section we will describe how units are scheduled and dispatched, and how prices are set for the services these units provide.

Unit selection



To determine revenue opportunities for our power plants, we need to understand three key factors: when our units will be selected to run, the percentage of potential capacity that will actually be used, and how much they will be paid.

Least-cost dispatch subject to constraints



Let's consider how transmission system operators decide which units are run at any point in time and at what percentage of capacity they are run. The key criterion a transmission system operator follows in scheduling and dispatching units is choosing the lowest cost units capable of serving the system load given any operating constraints.

The constraints include the operational flexibility of generation, maintenance needs, regulatory requirements, and transmission limitations. Key constraints that are influenced by plant operations and that Grizzly's personnel has some control over include unit startup costs, minimum run limits, maximum start-stops, and ramp rates.

Let's look at a system dispatch curve. Here we show a graph of the various units with their available capacity to serve load stacked by variable price. This stack tells the order in which the resources would be dispatched. For instance, if loads are 20,000 MW, the operator will dispatch all renewable and nuclear units available plus the lower-cost gas combined-cycle units. The marginal cost unit dispatched will cost about $38/MWh. But if load increases to 40,000 MW, the operator will require all the renewable, nuclear, and gas units, plus some of the oil or storage resources. The resulting marginal cost is $115/MWh.

The transmission system operator uses an optimization model to develop the dispatch stack for any given period. Typically, the system is optimized across all 24 hours of the day. This results in an hourly power plant schedule prepared the day before. For our solar units, the schedule is usually based on forecast availability of sunlight. The schedule for our gas plants is based on system needs and our unit price offer. A similar analysis is used during real-time operations to determine which units should be ramped up or down to keep the system in balance within each hour.

Unit selection by utilities

For power plants in regions without an organized wholesale market, each utility or group of utilities within a power pool schedules and dispatches power plants based on the unit variable operating cost or the bilateral contract price for purchased power. Variable operating costs include fuel costs plus other variable operating and maintenance costs.

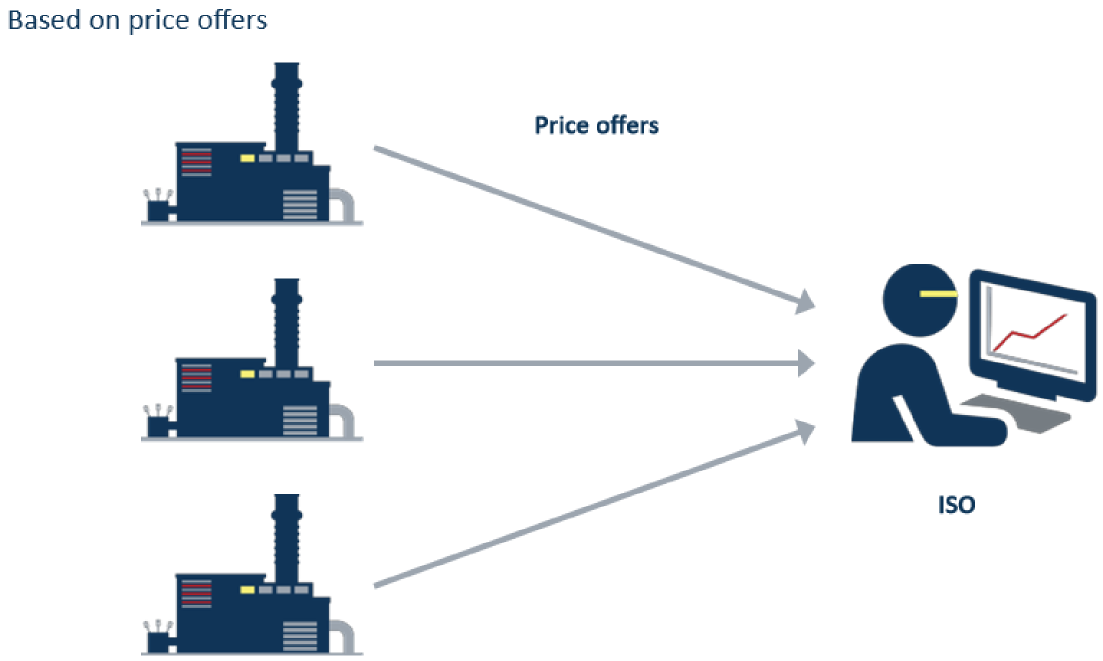
Here you can see variable cost information and how it results in a schedule for one hour for a utility with forecast loads of 1,820 MW if no constraints exist. Note that the units with higher operating costs are not scheduled to run at all or are scheduled to run at partial loading.

Based on variable operating cost or bilateral purchase price
Forecast load = 1,820 MW

Unit	Capacity (MW)	Variable cost ($MWh)	Scheduled output (MW)
Laporte Wind	250	0	250
Mead Solar	150	0	150
Estes Hydro	200	12	200
Wellington CCGT	400	38	400
Beals PPA	200	40	200
Severance CCGT	500	42	500
Waverly Recip	150	65	20
Windsor CT	100	90	0
Erie CT	50	120	0

Fixed costs are not considered

Unit selection by an ISO



For power plants in an ISO, units provide the ISO with an offer that specifies the price the unit requires to run. They may also include minimum run times, maximum start-stops, ramp rates, and other operational requirements. Generation owners can also specify if they want their unit to run regardless of price in which case it will be dispatched unless its use will result in operational issues.

Unit selection by an ISO

The ISO evaluates the various price offers and operational constraints and determines the optimal schedule resulting in the lowest overall cost to the market.

Here you can see price offers and how they result in a schedule when forecast loads are 1,600 MW and assuming no operational constraints. Note that even if the Green Valley and Bisbee units have bilateral contracts at a price such as $70/MWh, they still offer $0 since this is their variable cost.

Forecast load = 1,600 MW

Unit	Capacity (MW)	Price offer ($MWh)	Scheduled output (MW)
Green Valley Solar	100	0	100
Bisbee Solar	150	0	150
Holbrook Hydro	150	15	150
Imperial Geothermal	200	28	200
Grizzly Oracle CCGT	400	41	400
Catalina CCGT	500	43	500
Sonoita CCGT	300	44	100
Douglas CT	100	90	0
Rodeo CT	50	120	0

Price determination

Bilateral contracts

Electronic exchange trades

Organized wholesale market transactions

Now we are ready to discuss how the energy price paid to units is determined.

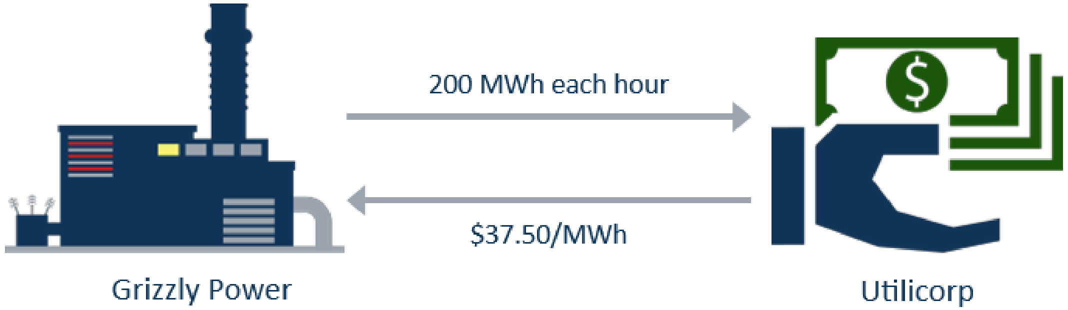
Let's look at the pricing mechanism for each of these three transaction types.

Bilateral pricing

Prices for bilateral transactions are set by negotiation between the buyer and seller.

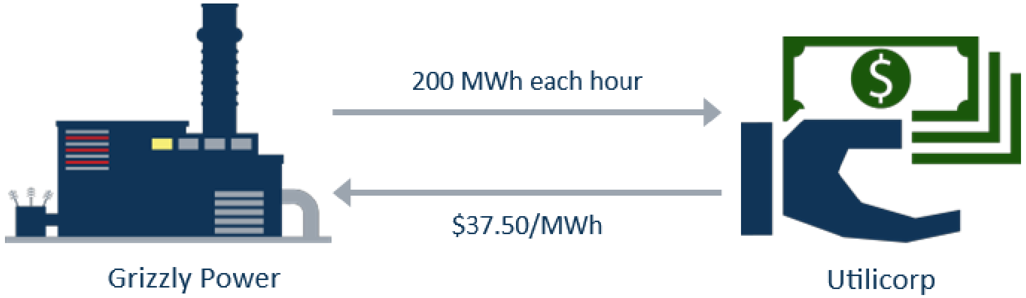
Bilateral transactions are commonly priced as fixed or indexed at a specified delivery point.

Indexed price example



- Grizzly and Utilicorp have agreed to an indexed bilateral agreement
- Grizzly sells Utilicorp 200 MWh each hour for the period January to March
- Grizzly is paid based on the agreed price that is calculated monthly using the formula:
  Price = (7.0 x the monthly natural gas index for our region as reported by Inside FERC)/MWh where 7.0 represents the contractual heat rate

Fixed price example

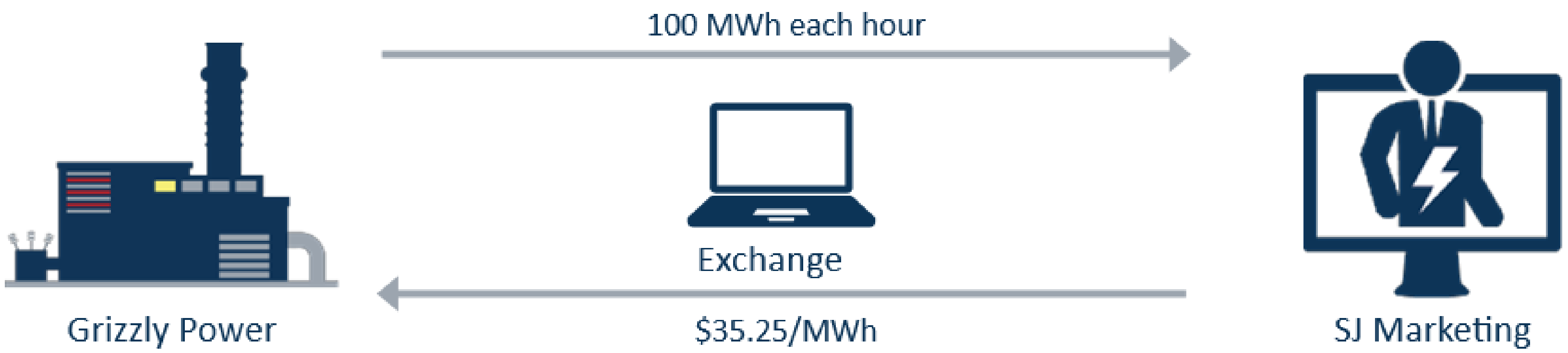


- Grizzly and Utilicorp have agreed to an indexed bilateral agreement
- Grizzly power sells Utilicorp 200 MWh each hour for the period January to March
- Grizzly is paid the agreed upon fixed price of $37.50/MWh

Exchange pricing

Exchanges match buy and sell offers at a specific grid location. Transactions are implemented using a standardized bilateral contract.

Indexed price example



- Grizzly and SJ Marketing are matched on the exchange for a volume of 100 MWh, with the resulting fixed price bilateral agreement priced at $35.25/MWh
- Grizzly sells SJ Marketing 100 MWh each hour for the period January to March
- Grizzly is paid the agreed upon fixed price of $35.25/MWh

ISO pricing

In an organized wholesale market, the ISO buys and sells energy. It does this by facilitating day-ahead and real-time markets. The outcome is clearing prices at each node. If a generator's price offer is at or below the clearing price, the unit will be scheduled. If it is above, it will not be scheduled.

Buyers of energy are charged the clearing price for their consumption of energy at the node where it is delivered.

Clearing price example

Forecast load = 1,600 MW

Unit	Capacity (MW)	Price offer ($MWh)	Scheduled output (MW)
Green Valley Solar	100	0	100
Bisbee Solar	150	0	150
Holbrook Hydro	150	15	150
Imperial Geothermal	200	28	200
Grizzly Power CCGT	400	41	400
Catalina CCGT	500	43	500
Sonoita CCGT	300	44	100
Douglas CT	100	90	0
Rodeo CT	50	120	0

Clearing price

Grizzly Power submitted an offer to sell 400 MW at a price of $41/MWh for the hour of 1100-1159 in the day-ahead market for the date of January 15.
The market clearing price for that hour based on an optimization of all seller offers and all buyer bids was $44/MWh.
Grizzly Power sells 400 MWh into the ISO day-ahead market at a price of $44/MWh.

Organized market outcome

- For this hour, Grizzly Power offered 400 MWh to the ISO at a price of $41/MWh
- Because the clearing price for the hour was $44/MWh, Grizzly's unit was scheduled
- Grizzly is scheduled to provide 400 MWh to the ISO
- The ISO will pay Grizzly the clearing price of $44/MWh

Day-ahead vs. real-time pricing

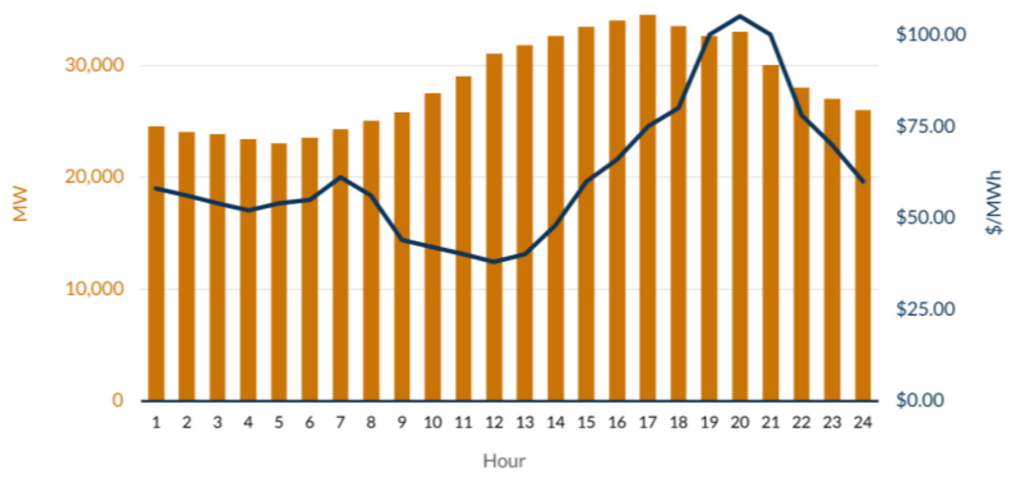
Day-ahead

Real-time

In an ISO market, two sets of energy prices are determined: day-ahead prices and real-time prices.

Day-ahead prices

Day-ahead scheduling matches forecast load with a sufficient amount of energy at the lowest cost possible.

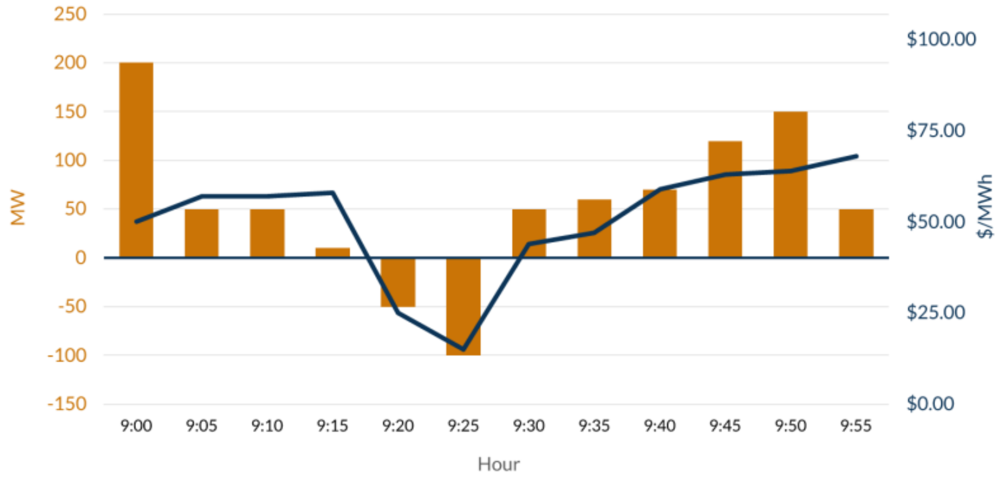


The ISO day-ahead scheduling process chooses generation units to provide enough supply to match forecast load at the least cost possible. Generators are scheduled hour by hour based on the load forecast for that hour and the generators' price offers. A result of this process is the determination of a market-clearing day-ahead price for each hour at each grid pricing point based on the marginal cost of supplying power at that location. The applicable locational price is paid to each generator scheduled in the day-ahead market.

Let's suppose that our Oracle unit cleared the ISO's day-ahead auction and was scheduled to provide 200 MW at this location for this hour. In this case, we will be paid for 200 MWh priced at $44 per MWh. If we fail to deliver this, we are obligated to buy makeup power in the real-time market.

Real-time prices

Real-time dispatch ramps supply up or down to balance changes in load or variable supply at the lowest cost possible.



As the ISO balances load minute by minute through each operating hour, it must ramp units up and down to match changes in loads and variable supply sources. The ISO sets a real-time price each 5 or 15 minutes based on the marginal price offer of units ramped in each time period.

At 200 MW of output, we are indifferent to real-time prices

At 220 MW of output, we are paid the real-time price for the extra 20 MW

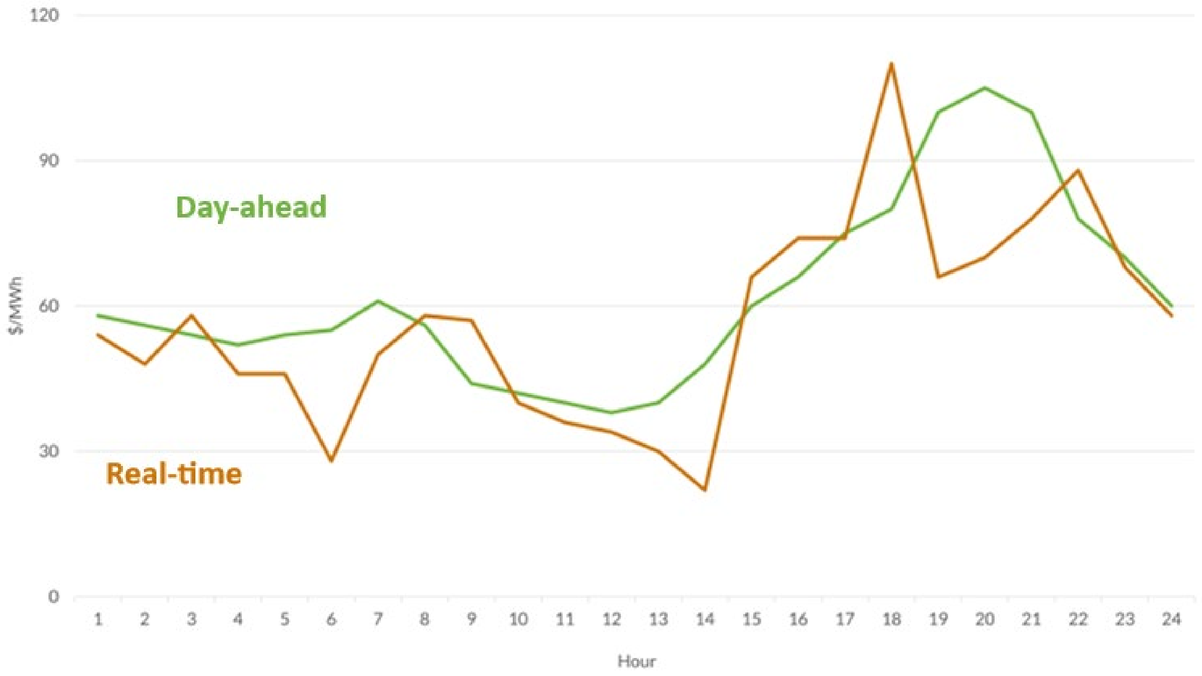
At 180 MW of output, we are paid the real-time price of the extra 20 MW

Since our Oracle unit cleared the day-ahead market at 200 MW for the hour beginning at 9 a.m., we will be indifferent to the real-time price as long as we continue to run at 200 MW.

Let's suppose that our Oracle unit cleared the ISO's day-ahead auction and was scheduled to provide 200 MW at this location for this hour. In this case, we will be paid for 200 MWh priced at $44 per MWh. If we fail to deliver this, we are obligated to buy makeup power in the real-time market.

On the other hand, let’s suppose that our unit output falls to 180 MW. In this case we must pay the ISO the real-time price for the missing 20 MW during the periods we are generating at 180 MW.

How day-ahead and real-time prices compare



While there tends to be some correlation between day-ahead and real-time prices, they are rarely the same. Over time, it is expected that real-time prices will be more volatile than day-ahead prices but will average a bit lower. Note that while the real-time price varies each 5- or 15-minute period, we have shown an hourly average real-time price on this graph for simplicity.

Time price variance

Prices vary across the day based on the amount of demand and the price offers of the various power plants. Day-ahead prices vary hourly, while real-time prices vary every five or fifteen minutes depending on the particular ISO rules.

Day-ahead

Vary every hour

Real-time

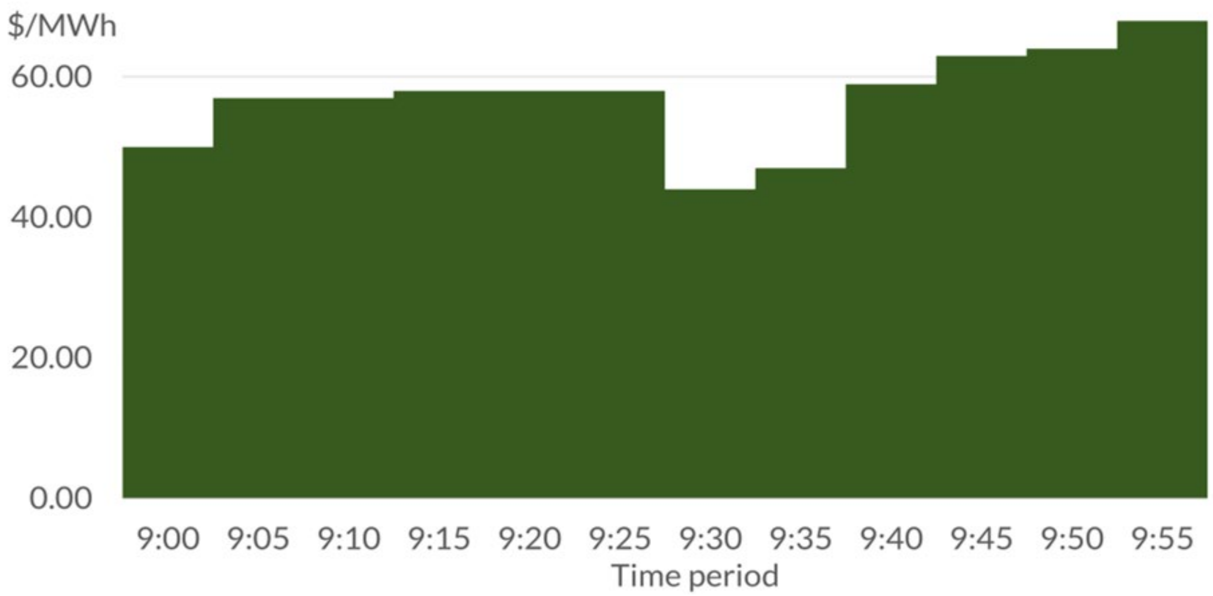
Vary every 5 or 15 minutes

Time variance in day-ahead prices

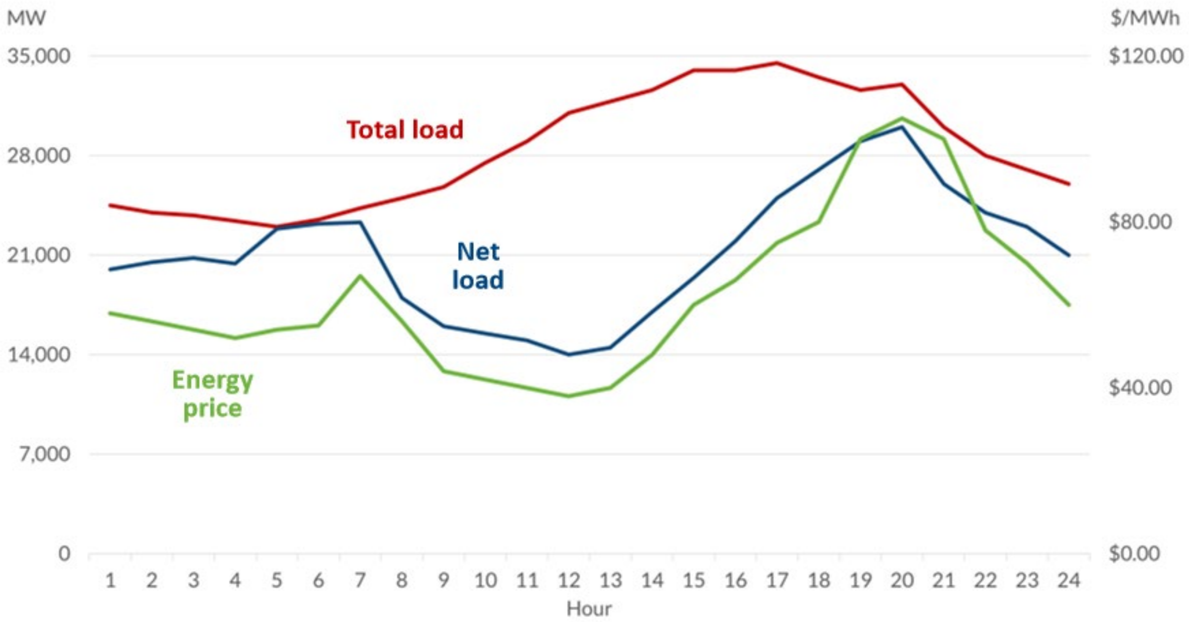
Here is an example of day-ahead prices across one day. Note there are different prices for each hour and the price stays the same across each hour. This graph shows that for the hour starting at 9 a.m., the price is $44.

Real-time prices

Here is an example of real-time prices across the hour beginning at 9 a.m. in a five-minute market.



Factors affecting prices

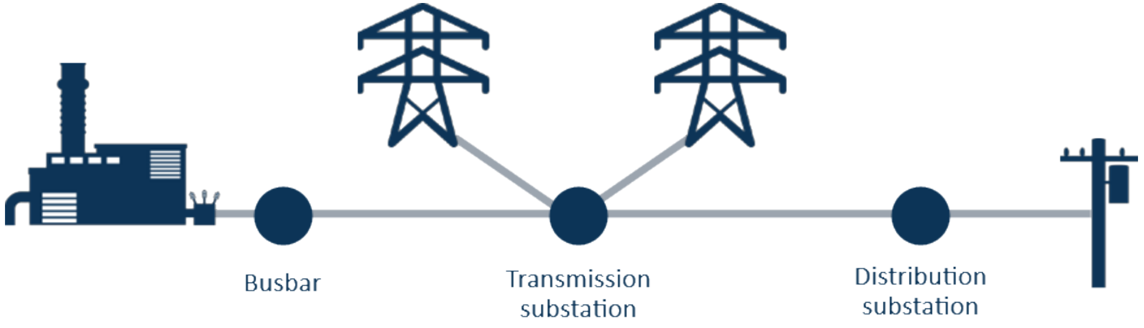


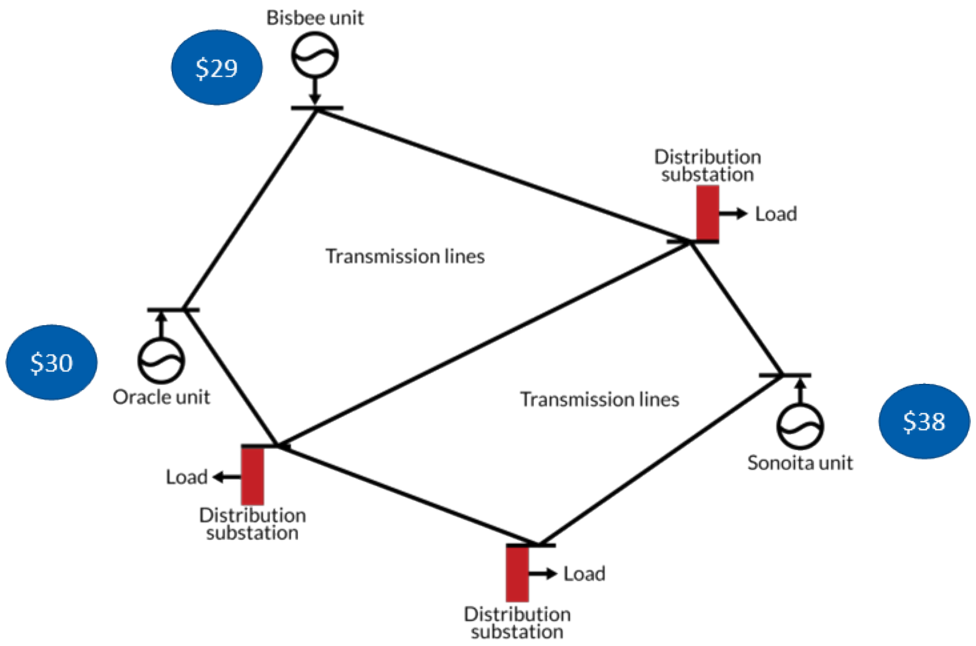
Prices in competitive wholesale markets vary due to multiple factors including the total load to be served, the availability of transmission to move energy from supply to load, and the price for marginal supply at each location.

As amounts of renewable generation grow, much of the load is served by renewable supply that has a variable cost near zero. However, the marginal clearing price, which is paid to all generators, is set by a smaller set of gas or coal units that are required to serve the net load.

Net load is the difference between total load and renewable generation output. Transmission availability also becomes increasingly important since renewable supply is often located in regions without sufficient take-away transmission capacity,

Locational price variance



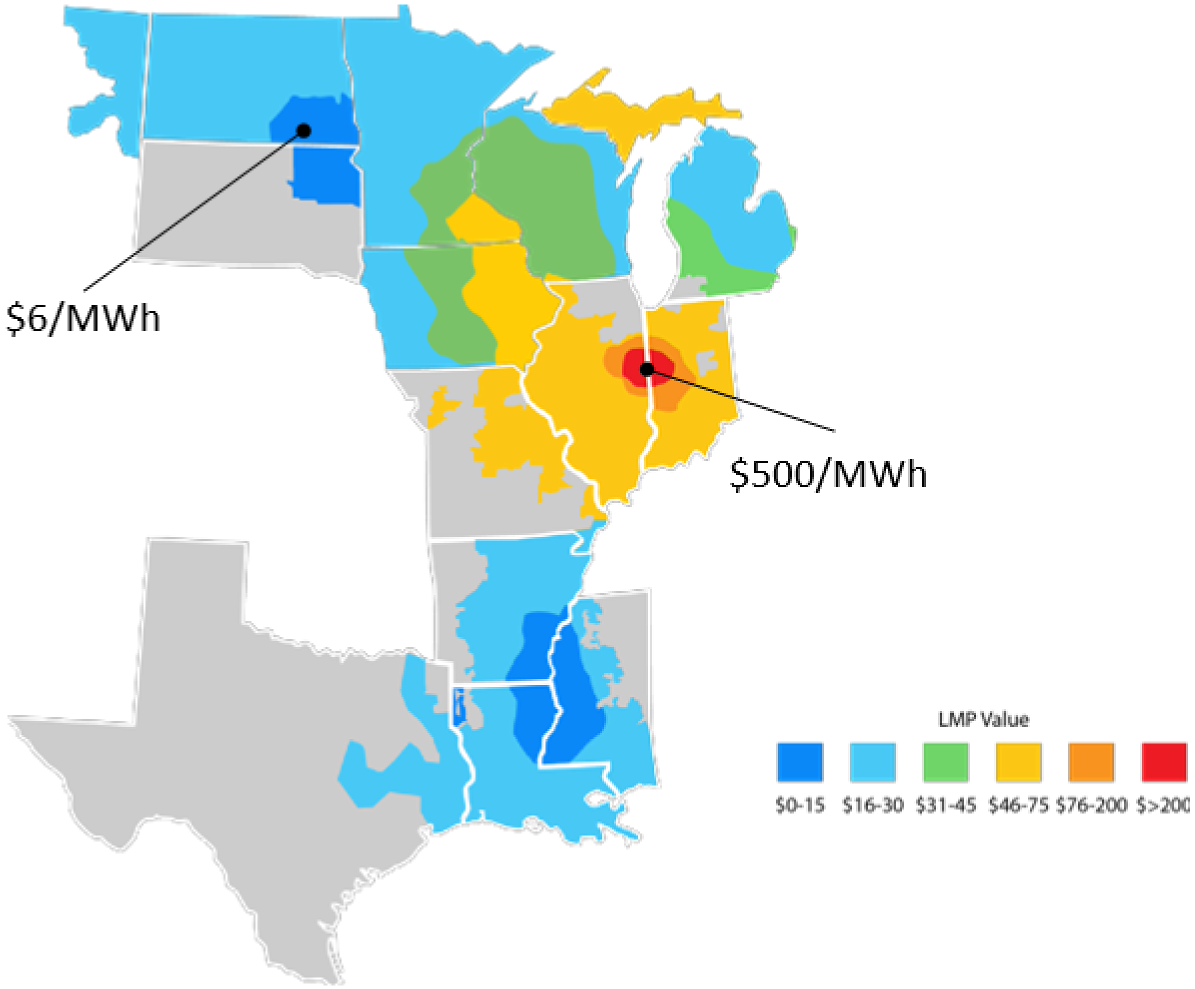


In an organized market, prices vary by location based on system conditions. These prices are called LMPs, which stands for locational marginal prices. The locations where prices are set are called nodes. These include generation busbars, which are the points where power plants connect to the transmission system; transmission substations which are points where two transmission lines connect; and distribution substations which are where distribution utilities connect to the transmission system. Organized wholesale markets typically have thousands of nodes.

The LMP set at the generation busbar determines how much the power plant is paid when it sells energy into an ISO market. In this case the Bisbee unit is paid $29/MWh, the Oracle unit is paid $30/MWh, and the Sonoita unit is paid $38/MWh.

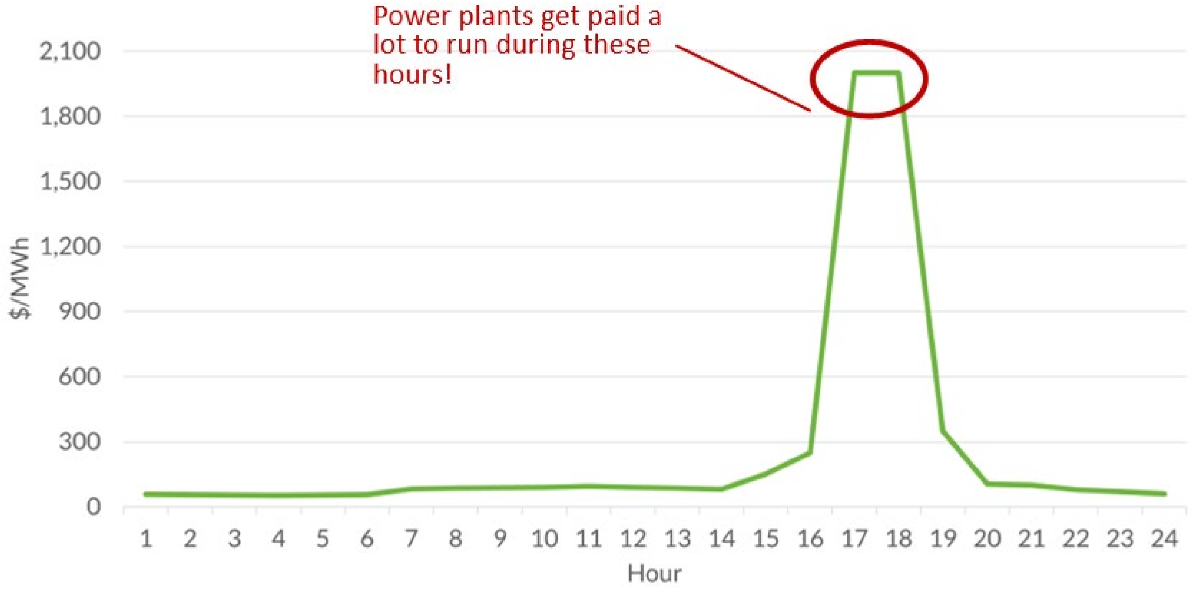
The LMP prices are different due to different system losses associated with various locations and/or due to transmission congestion at different points in the system

LMPs across an ISO



This map shows the range of LMPs across an ISO for a specific hour. The lowest price for this hour is $6/MWh at a node in North Dakota. The highest price is $500/MWh at a node in Illinois. Clearly it is important for us at Grizzly Power to understand the locational price dynamics for each of our power plants!

Prices can go very high



When supply is tight relative to demand, prices can get very high. This is because high-cost units or demand response programs set the marginal clearing price. In other cases it is due to administrative scarcity prices set by the ISO when certain supply/demand conditions are forecast.

While high prices are designed to motivate generators to run at locations where supply is short, these prices are hard on consumers who ultimately pay for the expensive energy. To help protect consumers, most ISOs have price offer caps, energy price caps, or both.

During times of tight supply, it is important for Grizzly Power to have all our units available to run because failure to do so results in loss of significant earnings opportunity.

Prices can go negative

Prices can go below zero due to a combination of factors including low loads, lots of renewable output, non-renewable plants unable to ramp down due to operational reasons, and/or lack of transmission capacity out of an area with lots of supply. Negative prices mean that power plants pay money to put power on the grid!

Running our power plants during hours with negative pricing causes us to lose money unless we have locked in a price earlier through a bilateral deal or we are receiving REC payments or tax credits that exceed the negative price.

Generator Earnings

Welcome to the Generator Earnings section of How Generators Make Money. In this section we consider the various factors that impact a power plant's earnings.

Making or losing money

Margin

Return on equity

Examples

Our understanding of grid operations, markets, unit selection, services, pricing, and unit characteristics allows us to determine whether each of our power plants is likely to make or lose money in each market. It also allows us to understand why a unit has or has not been financially successful in the past.

We'll start with a discussion of margin and return on equity. And then we'll explore the factors that affect whether a power plant is financially successful.

Margin

$$\text{Operating profit margin} = (\text{sum of revenues}) - (\text{sum of fixed and variable costs})$$

This is how we calculate the operating profit margin for a power plant. It lets us know if a power plant has created any money after operating costs have been paid.

$$\text{Net profit margin} = \text{Operating profit margin} - \text{Debt costs} - \text{Taxes}$$

Next we calculate the net profit margin, which tells us if we have any money left over after paying debt costs and taxes.

Assuming a unit creates a net profit, the profit results in return for shareholders of independent power producers such as Grizzly Power. For regulated utilities, net profit may be used to reduce rates for the utility's customers, for shareholder return, or may be a combination of both.

$$\text{Negative profit margin} = \text{Loss}$$

If the net profit margin is negative, the power plant shows a loss for that period, and both management and our shareholders are not happy!

Return on investment

$$\text{Return on investment (ROI)} = \frac{\text{Net profit margin}}{\text{Capital}}$$

Suppose that Pronghorn had the following results:

- Revenue: $131.7 million
- Costs: $90 million
- Debt payment: $19.4 million
- Taxes: $15 million
- Capital: $324 million

Earnings = Revenue – Costs – Debt = $22.3 million

ROI = 22.3 / 324 = 6.9%

For our units, we review their performance monthly and annually by calculating the plant's return on investment, commonly called the ROI. This is the net profit margin divided by the amount of capital we have invested in a specific power plant.

Here is an example of calculating the annual ROI for our Pronghorn unit. Note that we are using annual revenues, cost, and debt payments, which are the sum of the monthly values across the twelve months of the year.

Base scenario

Here are a few scenarios to help you understand how various factors impact our earnings.
First let's look at a base ROI scenario for our Pronghorn and Bluesky power plants.

Pronghorn gas combined-cycle

- All 400 MW contracted as capacity
- Half of expected energy output contracted as forward energy at an indexed price
- We will attempt to sell the uncontracted energy into day-ahead or real-time markets
- We will also offer to provide AGC, reserves, and blackstart in the ancillary services markets
- Capital $324 million

Bluesky solar

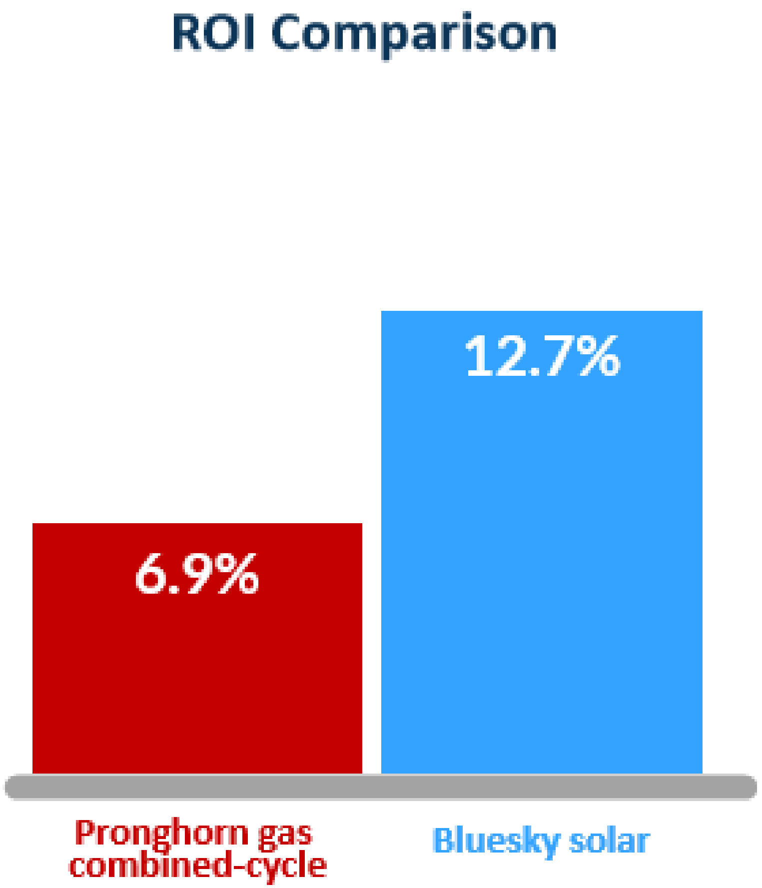
- 50 MW contracted as capacity
- 60% of expected energy output contracted as forward energy at a fixed price that includes REC value
- We will attempt to sell the uncontracted energy into day-ahead or real-time markets
- We will not participate in ancillary services markets
- Capital $175 million

Expected ROI = 6.9%

Expected results	$
Revenues	
Capacity	27,740,000
Energy	102,132,000
RECs	0
Ancillary services	1,905,600
Total revenue	131,777,600
Costs	
Fixed costs	4,600,000
Fuel costs	64,112,000
Variable O&M costs	6,334,000
Total Costs	75,046,000
Capital	324,000,000
ROI calculation	
Margin	56,731,600
Debt and taxes	34,440,000
Remaining margin	22,291,600
ROI	6.9%

Expected ROI = 12.7%

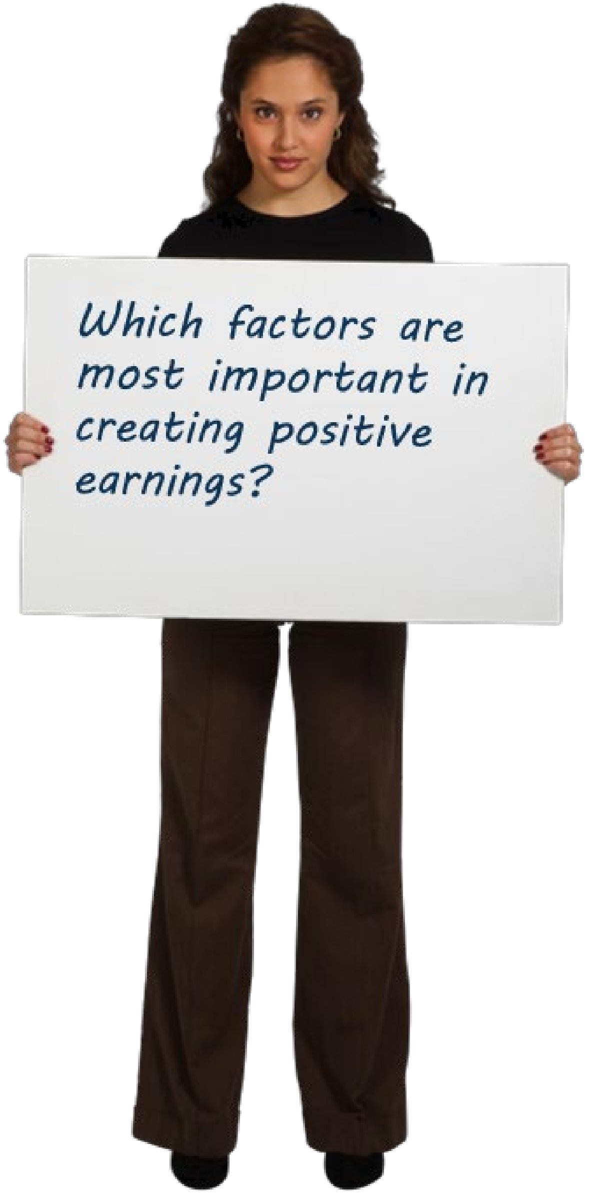
Expected results	$
Revenues	
Capacity	3,467,500
Energy	29,233,872
RECs	5,676,480
Ancillary services	0
Total revenue	38,377,852
Costs	
Fixed costs	2,200,000
Fuel costs	0
Variable O&M costs	0
Total costs	2,200,000
Capital	175,000,000
ROI calculation	
Margin	36,177,852
Debt and taxes	14,000,000
Remaining margin	22,177,852
ROI	12.7%



Notice how the Pronghorn unit, even though it has more capacity and four times the revenue of the Bluesky unit, has a much lower ROI. This is because Pronghorn has fuel costs and higher O&M costs.

So if we think that this scenario will continue, we'd prefer to invest in new solar capacity instead of a similar gas unit.

ROI examples

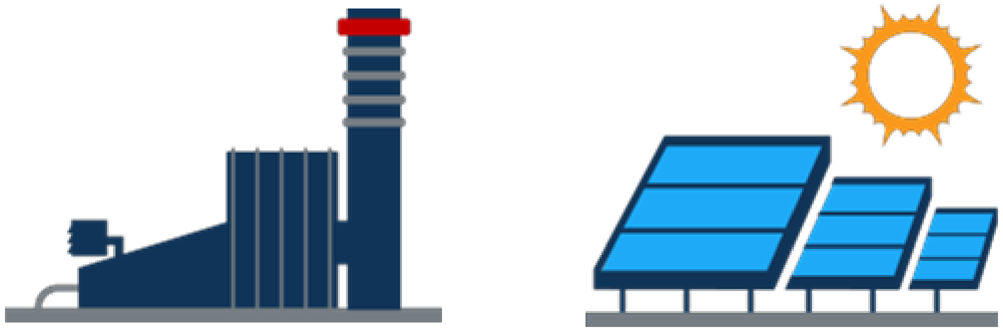


It is important to understand the risk profile for each unit since actual outcomes will inevitably differ from our base expectation. To get a sense of how revenues may vary, let's look at several scenarios.

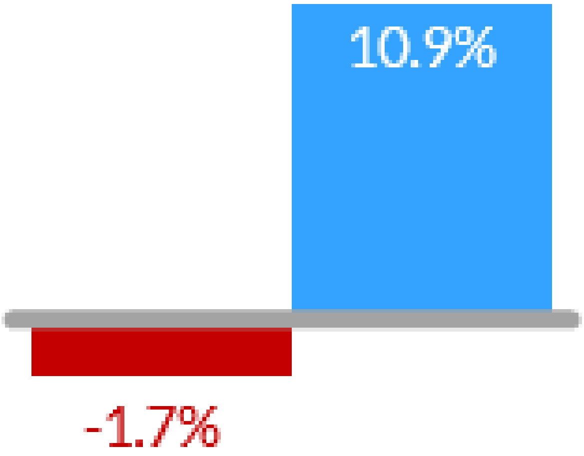
For each scenario, we keep all variables consistent with the base scenario except for changes in the factors noted on the screen. By changing limited factors at a time, we can get a sense of what is most important in creating earnings.

Scenario 1

Both units were unsuccessful in the capacity auction for the year, and so they lost their capacity revenues.

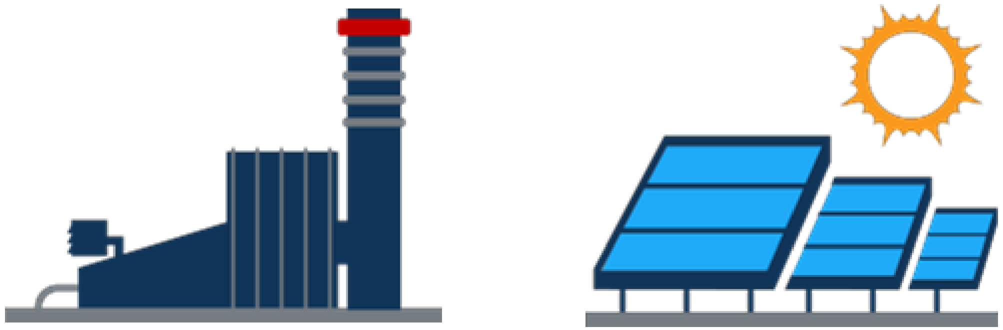


- Because Bluesky's capacity is already derated for purposes of the capacity market, loss of capacity revenues is proportionately less important than for Pronghorn.
- Pronghorn is unable to make enough energy and ancillary services revenue to cover its costs, so the loss of capacity revenues causes ROI to go negative.

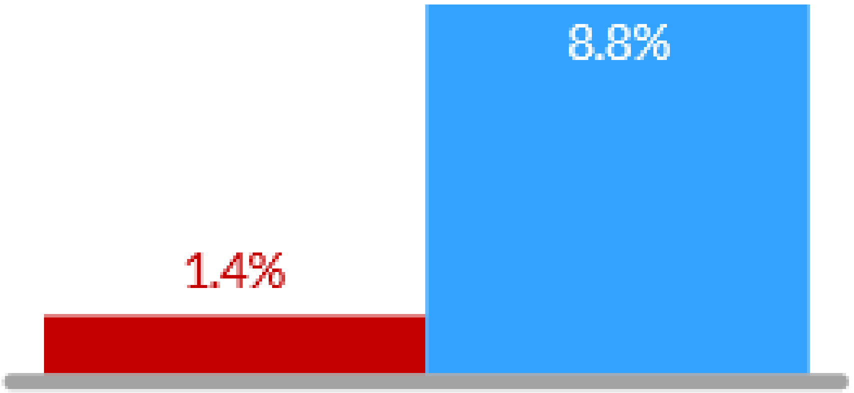


Scenario 2

Lots of new renewable capacity has been built in the same region as our two plants. Because of constraints on transmission to move the energy out of our region, local marginal prices are now depressed.

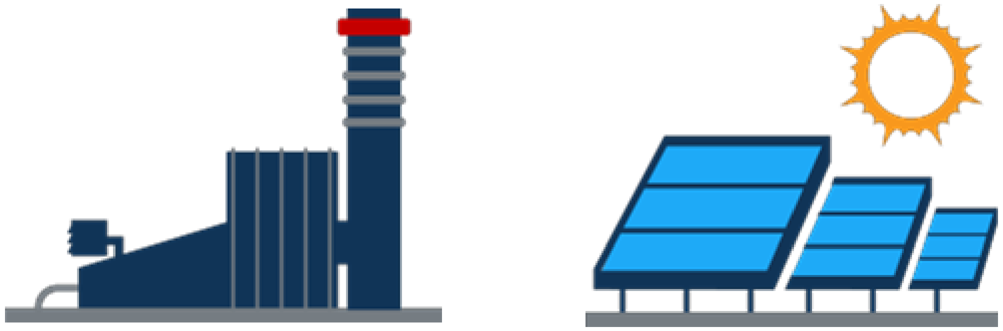


- Both units see a decline in earnings due to lower day-ahead and real-time energy prices.
- Because Bluesky sells more of its capacity in forward energy sales than Pronghorn, Bluesky is less affected than is Pronghorn.
- Also, due to the new low-cost capacity, Pronghorn's sales will likely drop.

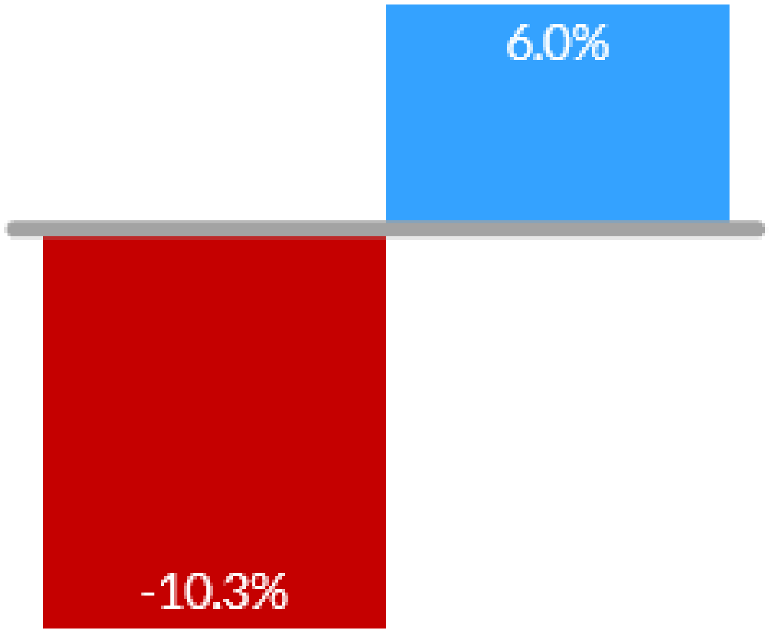


Scenario 3

Both units' forward energy sales expire, and due to a drop in prices in their region (due to the same reasons as presented in Scenario 2) revenues in the day-ahead and real-time energy markets do not make up for the loss in forward sales.

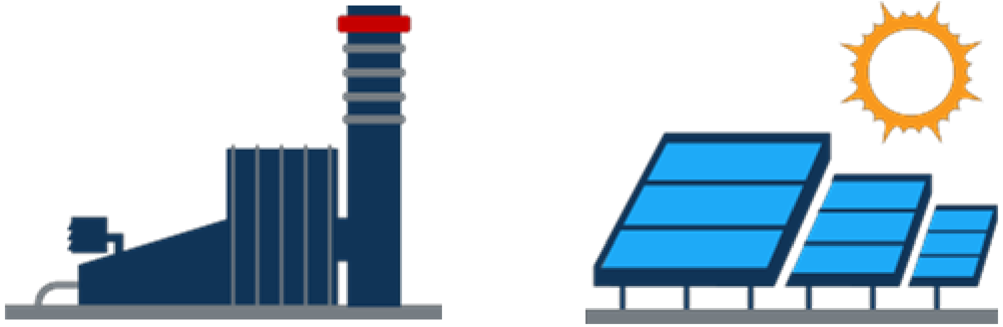


- Both units see a significant drop in revenues due to loss of forward sales. Replacement sales in the day-ahead and real-time markets are for a much lower price.
- Bluesky is less affected because it continues to receive significant revenue from REC sales and it does not have variable costs to cover.
- Also, Bluesky's volumes are more likely to remain steady since they have a $0 variable cost compared to a much higher variable cost for Pronghorn.

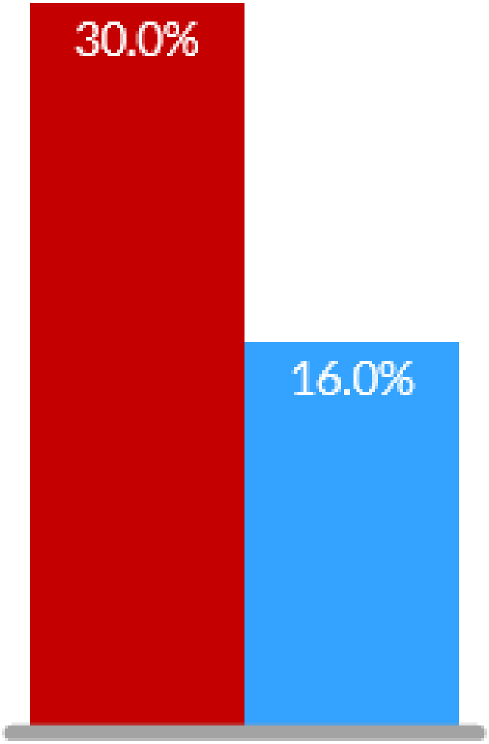


Scenario 4

Both units maintain their capacity revenues and forward sales, while day-ahead and real-time market prices rise due to increased demand.

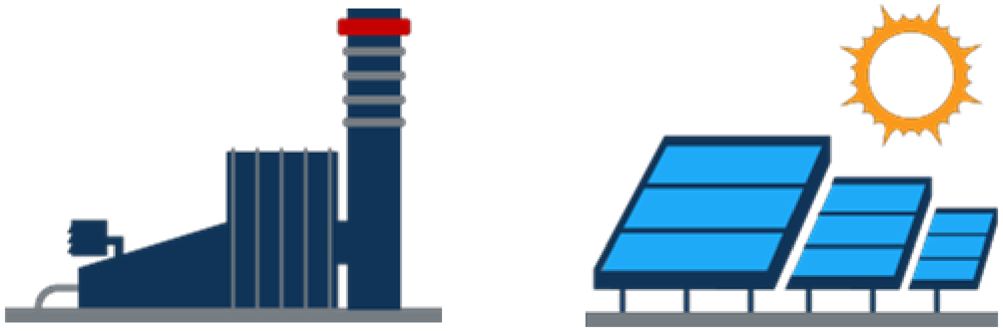


- Because less of Pronghorn's energy is sold forward, it benefits more than Bluesky when spot prices rise.

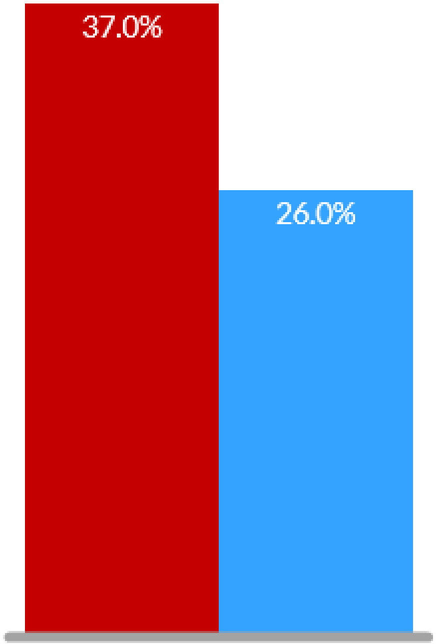


Scenario 5

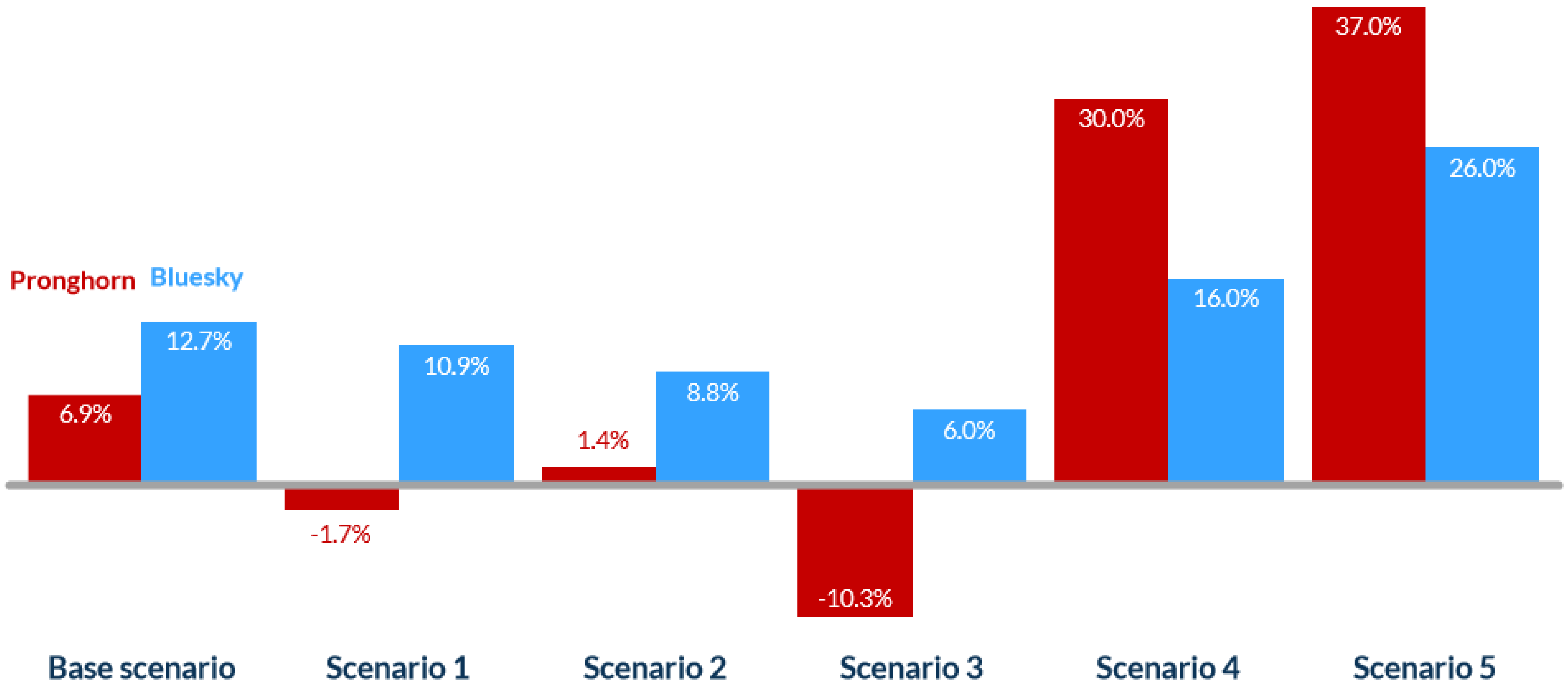
Both units' forward energy sales expire, but the units benefit from the change as day-ahead and real-time market prices rise due to increased demand.



- Both units are now selling all energy output in day-ahead and real-time markets.
- Because previously they were both selling at a lower price in forward markets, earnings rise.
- Pronghorn benefits more because Bluesky was already receiving a high forward price due to RECs, causing the price increase to be much higher for Pronghorn than for Bluesky.



ROI exercise summary



Key factors driving earnings

- Market structure
- Capability to provide services
- Operational flexibility and other operational capabilities
- Fixed and variable (including fuel and O&M) costs
- Debt costs
- Capital investment required
- Competitiveness relative to other units in the same market
- Forecast run hours
- Forecast prices including locational marginal prices
- Whether unit generates environmental credits
- Transmission capacity to move power to market
- Ability to keep the unit in service and to perform to schedule

In our examples you may notice numerous factors that impact a power plant's financial outcomes. As we wrap up, study this list of key factors we consider at Grizzly Power Think of which factors we can control and which are out of our control. As you can see, we have lots to evaluate in determining the earnings potential of existing or future power plants.

Energy units and conversions

Mcf	Thousand cubic feet
MMcf	Million cubic feet
bbl	Barrel
gal	Gallon
Btu	British thermal unit
MMBtu	Million btu
GJ	Gigajoule (metric measure of energy)
Dth	Decatherm
kW	Kilowatt
kWh	Kilowatt-hour
MW	Megawatt
MWh	Megawatt-hour
toe	Tons of oil equivalent

1 therm	=	100,000 Btu
1 Dth	=	10 therms
10 therms	=	1 MMBtu
1,000,000 Btu	=	1 MMBtu
1 Dth	=	1 MMBtu
1,000 Mcf	=	1 MMcf
1,000 MMcf	=	1 Bcf
1 MMcf	=	1,015 MMBtu (varies with energy content of the gas)
1 GJ	=	0.95 MMBtu
1 bbl	=	42 U.S. gal
1 bbl	=	34.97 Imperial gal
1 bbl	=	0.136 toe
1,000 kWh	=	1 MWh
1,000 kW	=	1 MW