How to create an energy budget

This document consists of a three-step guide to implementing energy budget modelling.

1 Analyze historical data
Examine past energy use, operations and weather for a baseline understanding.

2 Input future projections
Enter forecasted operations and weather to predict future energy requirements.

3 Incorporate cost data
Include past and projected energy prices to calculate financial implications.

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1 Collect and analyze historical data

Why develop an energy model?

This guide focuses on electricity and natural gas use in energy modelling. A good model is a powerful tool to help you understand how your facility uses energy over time and under changing conditions. It's crucial to develop a statistically valid model, as this is often required by energy-efficiency incentive programs, such as those offered by the Independent Electricity System Operator (IESO) and Save on Energy.[1]

Match data granularity with needs

Monthly consumption and cost data are usually sufficient for budgeting purposes. However, if daily data are available, they can create more accurate models, especially when billing periods and process volumes or product mixes vary. For small and medium-sized operations, useful energy models can often be developed with data from the main utility meter. Larger or more complex facilities may benefit from using sub meters[2] that closely correlate with energy consumption associated with specific processes.

Source and retrieve data

In recent years, utility companies have installed interval sub meter electricity and natural gas meters[3] on industrial customer sites throughout Ontario. Customers can download these interval sub meter energy data from their electricity and natural gas accounts, often through a "Green Button"[4] download service. Data from customer-owned energy sub meters are usually retrievable from building automation systems or other on-site energy management information systems. If historical data are only available on paper bills, manual entry may be time-consuming but necessary.

Identify independent variables

When developing a model, data on factors influencing energy consumption (independent variables) must be collected. These may include:

- Production or processing volumes by category (daily if possible)
- Facility operating hours, occupancy levels and number of events held (daily if possible)
- Outdoor temperatures, hours of daylight and other relevant environmental data (from Environment Canada)

Specify models for each fuel

Models of daily or monthly energy consumption for each fuel can be developed in various ways. Some processes can be modeled effectively with one independent variable (e.g., tonnes of ore milled), but using two or more variables often results in models with better statistical correlations.[5] This is especially true when energy consumption is affected by both throughput and outdoor temperatures (e.g., kWh/tonne/cooling degree day).

Use the right software

While models can be developed with simple spreadsheets, specialty software such as RETScreen®, a specialized tool for energy analysis developed by CanmetENERGY (Natural Resources Canada)[6], can provide additional value and analytical possibilities.

Collaborate on model development

It's beneficial to review the models with your team to identify events that have influenced energy consumption over recent historical periods. Adjustments may be necessary to account for unusual events or production changes.

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[1] Inaccurate or misleading energy models can lead to significant financial implications for facility owners, incentive programs and stakeholders. There are several recognized authorities (e.g., ASHRAE, CalTrack, IPMVP, etc.) on the statistical requirements of data used to assess facility energy performance. Save on Energy's Performance Program requirements available at saveonenergy.ca/For-Business-and-Industry/Programs-and-incentives/Energy-Performance-Program describe acceptable data testing methods.

[2] A sub meter (e.g., electricity, natural gas, water) is used within a building or facility to measure the amount of energy for a specific purpose or area at a level below the "whole facility" utility meter or main meter. It can be installed permanently or on a temporary/portable basis.

[3] An interval or smart meter (e.g., electricity, natural gas, water) is used to measure and transmit or record consumption over certain periods of time to enable time-of-use billing and demand profiling.

[4] Green Button is a standardized data format that gives residential and business energy customers an option to easily access and securely transfer their energy usage data directly from their utility provider. The Green Button initiative was created by the U.S. Department of Energy and partners in 2011. The Ontario Ministry of Energy began to advance their Green Button initiative in Ontario in 2012 and can be found at oeb.ca/consumer-information-and-protection/green-button.

[5] The correlation between energy consumption of equipment and industrial throughput (e.g., kWh/tonne) is often improved when combined with correlation of energy consumption and outdoor air temperature, especially for unconditioned areas or when meter data include both general facility air conditioning and process heating/cooling.

[6] RETScreen is a comprehensive software platform managed by CanmetENERGY Varennes Research Centre of Natural Resources Canada and can be found at natural-resources.canada.ca/maps-tools-and-publications/tools/modelling-tools/retscreen/746

2 Input future projections and forecast business operations

Gather internal data

Collect your monthly business forecast data (e.g., product mix and volumes) from internal sources, as available.

Analyze forecast vs. historical data

If the forecasted monthly product mix and volumes are similar to past values, the energy consumption prediction model should respond accordingly with expected trendlines.

Adjust for significant changes

If forecasted volumes and mix are significantly different, it may be necessary to make some assumptions and adjustments to the model. For example, if your plant is adding a second or third shift of production to the winter months for the first time, you will likely be using far more natural gas and electricity than in the past.

3 Incorporate cost data

Understand energy pricing

The foundation of energy costing is inputting data on recent, current and forecasted energy prices for the budget period. While this information is easily accessible in some jurisdictions, in Ontario there are unique challenges to obtaining accurate pricing data.

Electricity

Ontario electricity prices can vary widely even with relatively fixed operations, volumes and occupancies. Understanding how you are charged for electricity is crucial. Your bill includes the following charges:

- Fixed customer charges
- Commodity charges (in $/kWh)
- Global adjustment charges
- Power factor charges
- Demand charges
- Distribution and delivery charges
- Transformer charges

Fortunately, many resources are available to help you understand and manage these costs. These include the Ontario Energy Board's "Understanding your electricity bill," the IESO's "Electricity Pricing Explained" and "Interval meter sample bill" from Toronto Hydro.

Natural gas

Ontario natural gas costs are much simpler to understand and predict. Unless you are a very large natural gas customer, the customer charges, commodity charges, delivery charges, transmission, storage and other charges are generally highly regulated and subject to approvals and notifications that you can use to adjust your budgets. Ontario's system for electricity pricing is dynamic and based on actual daily and hourly system supply and demand. Natural gas pricing is set by the Ontario Energy Board every three months with natural gas utility companies. Any adjustments to transmission, delivery or storage charges or other rates are communicated in advance to all customers. Any fluctuations in commodity (producer) natural gas prices are made through adjustments after the fact and are a relatively small part of most monthly bills. Some users, especially large ones, buy natural gas through commodity contracts from suppliers at fixed prices and are only charged for delivery and other fixed costs.

In general, natural gas does not involve the same complex market factors as electricity, but large users may pay special rates for periods of higher demand or lower rates if they can be interrupted for demand response purposes. For more information, see the Ontario Energy Board's "Understanding your natural gas bill" and Enbridge Gas' "Large volume services & rates".

Finalize your energy model and budget

Components of a successful model

A successful model typically requires the following key elements:

1. A statistically valid historical baseline model.
2. Relatively accurate operations and weather data.
3. Precise energy consumption and cost data.

Plan future energy use and costs

By inputting operations forecasts and estimated energy costing data (with assumptions), you can project future consumption and costs.

Next steps

- Review projections with key stakeholders.
- Identify potential areas for energy optimization.
- Update the model regularly with new data to maintain accuracy.

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Case study

How one large Ontario mine mapped its energy future

This case study demonstrates the process of creating a comprehensive energy budget for a large mining operation in Ontario.[7]

Scope

Focus
Electricity and natural gas consumption

Historical data
2018-2022

Budget projection
2023-2030

Key components

1. **Energy management budget**
   The budget formed a crucial part of the site's overall energy strategy.
2. **Bottom-up approach**
   Energy drivers were analyzed in underground mining areas and the mill.
3. **Data sources**
   - Daily production metrics from various operational sources
   - Historical energy consumption and billing data from utility revenue meters and invoices
   - Additional data from numerous sub meters (2018-2022)

Other considerations

A complete budget should include all significant delivered fuels, as well as water use and cost data.

Water use and cost data are often valuable to collect for budgeting purposes.

Electricity consumption

Electricity accounted for the bulk of the site's energy use. There were several utility meters and numerous sub meters that covered about 80% of the site's consumption.

Natural gas

About 80% of the natural gas used was for direct-fired burners for heating incoming ventilation air. Again, there were utility meters and several sub meters that measured consumption.

Diesel and other fuels

Diesel, propane and other fuels accounted for less than 10% of the total energy needs and were used mainly to power some of the mining equipment and were not included in the study. For the purposes of the case study, we focused on electricity and natural gas.

Case study

Key production and energy data tables 2018-2022

The table below shows mine production and energy data for the 2018-2022 time period. Indicators (KPI) were developed, including:

Key production and energy data	2018	2019	2020	2021	2022
Total tonnes hoisted (tonnes)	1,540,000	1,340,000	1,348,000	1,551,000	1,851,000
Total tonnes milled (tonnes)	1,153,000	945,000	869,000	1,123,000	1,355,000
Total energy (eMWh)	1,235,000	893,000	1,062,000	1,085,000	1,295,000
Site-wide electric consumption (MWh)	822,000	735,000	682,500	728,000	826,000
Total milling electricity (MWh)	235,000	175,000	156,000	187,000	209,000
Total underground electricity (MWh)	419,000	337,000	307,000	256,000	288,000
Site-wide natural gas usage (eMWh)	353,000	350,000	319,000	297,000	409,000
Heating degree day (10°C)	5,300	5,200	4,800	4,500	5,300

Key performance indicators for energy

By analyzing groupings of processes and process boundaries with installed and supplementary logging[8] and spot metering,[9] key performance indicators (KPI) were developed, including:

KPI	Description	Unit
Total site electricity	Total site electricity per (ore/waste/total) tonnes hoisted	kWh/tonne hoisted
Underground electricity	Total U/G electricity per (ore/waste/total) tonnes hoisted	kWh/tonne
Underground development	Metres of development (tunnels)	metres
Milling electricity	Total milling electricity per tonne milled	kWh/tonne milled
Natural gas	Natural gas per HDD (at 10°C balance point)	ekWh/HDD

Case study

Develop models and baselines

Collect tab

Data from 2018–2022 was entered into RETScreen Expert. This dataset included key variables such as daily and monthly tonnes of ore and waste rock, metres of development and degree days from a local weather station. The dependent variables focused on electricity and natural gas consumption.

Separate energy modelling

To gain a deeper understanding of energy usage patterns, it was essential to model electricity and fuel-driven processes separately. This approach allows for more accurate analysis of performance and costs.

Leverage RETScreen Expert

Data analysis was conducted using RETScreen Expert, leveraging its optimization features to correlate independent data with electricity consumption. The primary tool used was regression analysis,[10] which results in a best-fit equation and statistical measures. One key measure is the coefficient of determination or R2, which indicates how well the model fits the data. An R2 value ranges from 0.0 to 1.0, with 0.75 or higher being desirable for energy modelling. A high R2 value signifies a strong goodness of fit, meaning the model accurately predicts energy consumption based on the input variables.

Adopting best practices

Best practices for energy analysis, such as ISO 50001 and IPMVP, require at least 12 months of energy data with an R2 of 0.75. Ideally, 24 months or more of data are preferred, although this can be challenging in dynamic business environments with changing product mixes.

Additional resources

For more details on detailed energy consumption statistics see the Save on Energy Energy Performance Program, International Performance Measurement and Verification Protocol (IPMVP) and the ISO 50000 series of energy management standards.

[7] While based on real data, all information has been anonymized to protect the site's privacy.

[8] Logging is the use of temporary interval meters to collect interval data from variable processes for many hours, days or weeks. An example is a power logger on a rock crusher.

[9] Spot metering is the use of portable devices such as a clamp meter to get a quick reading of a process that is fairly constant, like a simple lighting circuit or open fan.

[10] Regression analysis is a mathematical function used to establish a relationship between the dependent variable and the independent variables. The fit of the regression line in a graph indicates how well the independent variables explain the outcome of the dependent variable. Modelling this relationship may only require one independent variable (e.g., tonnes of ore milled) but generally two or more coincident variables influence energy usage or production.

Case study

Electricity use baseline

In this case, combinations of up to four production variables were analyzed across different timeframes. It was determined that the two key production variables—tonnes hoisted and development metres—along with heating degree days, produced an acceptable regression analysis with electricity consumption over the 24-month period from January 2020 to December 2021.

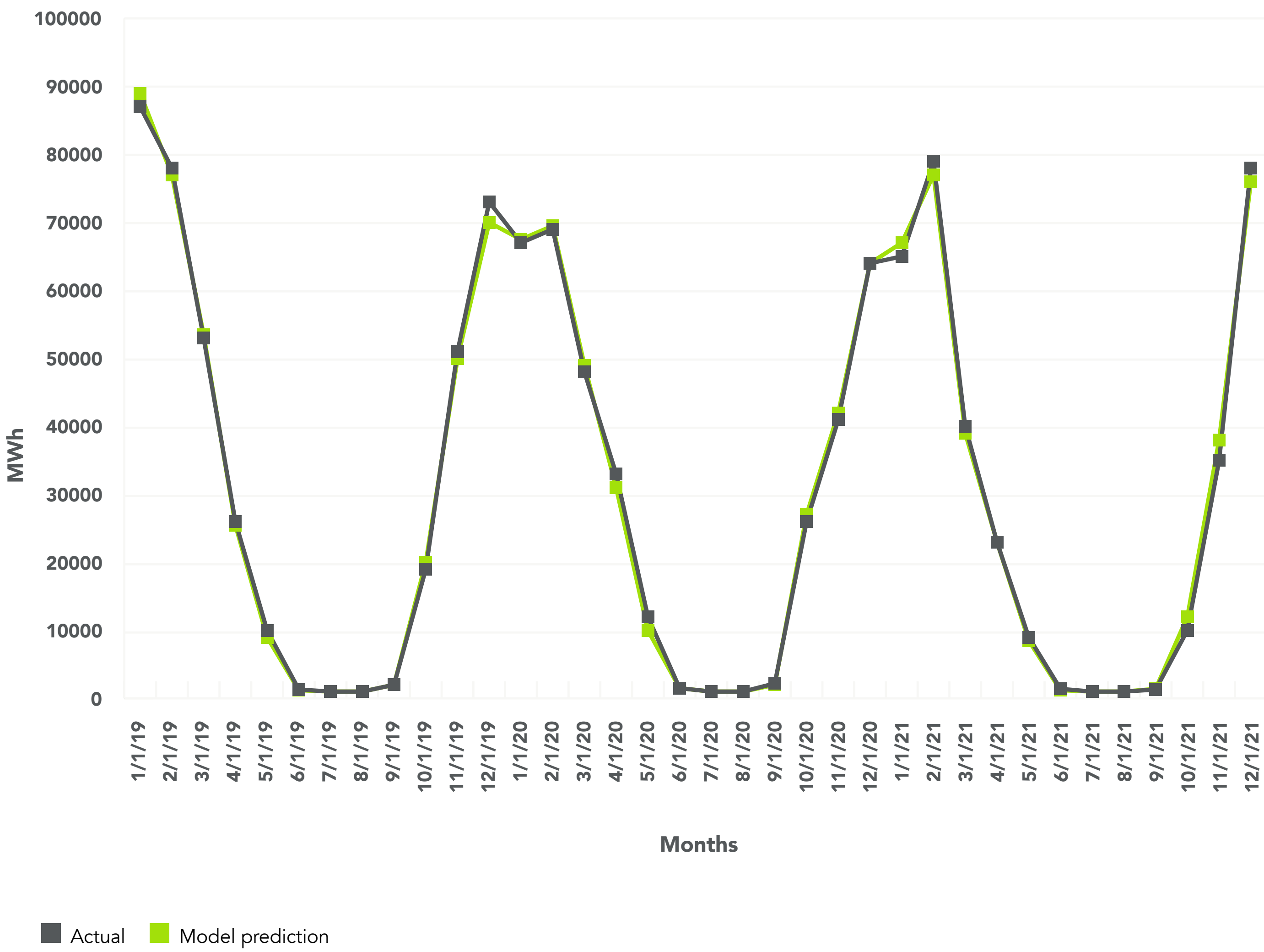
Monthly electricity consumption in baseline period

Case study

Natural gas use baseline

Heating degree days produced a very high R^2 correlation over the entire period with natural gas consumption over the 36-month period of January 2019 to December 2021.

Monthly natural gas consumption in baseline period



Case study

Production and energy consumption forecast

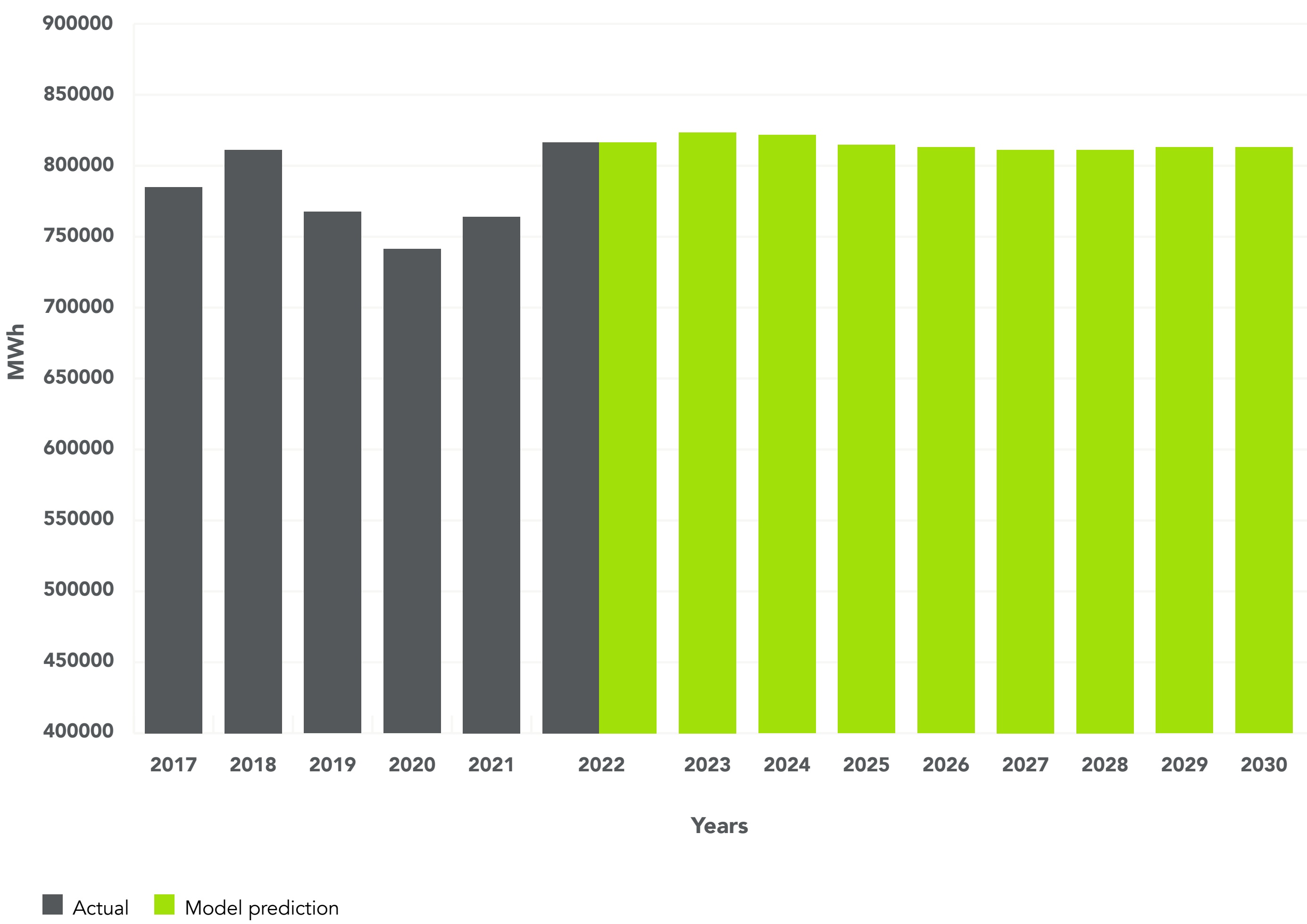
Production forecast

A production forecast, detailing tonnes of ore milled, was derived from the mine plan. This forecast was used to estimate tonnes of ore and waste hoisted and milled. It also provided estimates for planned development metres based on other mine plan information.

Energy forecasts

The regression equation from the baseline model, developed using historical data, was extrapolated using forecasted production values (ore and waste hoisted and milled), estimated development metres and historical average heating degree days. RETScreen Expert was used to create to a forecast.

Electricity consumption forecast



Case study

Energy budget development

The energy budget was developed by combining natural gas and electricity consumption estimates, derived from mine plan production estimates, with forecasted commodity pricing data.

Natural gas pricing

Forecasting natural gas costs was relatively straightforward, as natural gas pricing is typically based on contract-fixed prices or pre-announced/published regulated prices.

Electricity pricing in Ontario

Forecasting electricity costs in Ontario is more complex. Large business electricity customers in Ontario pay the hourly Ontario energy price (HOEP)[11] and/or alternative pricing set by contracts with third parties. HOEP is determined in Ontario's wholesale commodity electricity market and fluctuates throughout the day. Businesses that can shift their energy use to times of low HOEP will see significant reductions in their electricity bills. Alternative pricing with third parties is based on bilateral contracts,e.g., purchased power agreements.

Global adjustment (GA)

All electricity customers in Ontario pay the global adjustment,[12] which covers base costs for running the electricity system, including new infrastructure; regulated rates to suppliers under contract; and energy-efficiency programs. Class A customers,[13] comprising medium and large businesses participating in the Industrial Conservation Initiative (ICI),[14] have their global adjustment costs determined by their share of total demand during Ontario's top five peak demand hours annually. For example, if a Class A customer accounts for an average of two percent of Ontario's peak demand during these hours, they will be billed for two percent of the province's total global adjustment costs.

Forecasting and resources

The IESO provides forecasts to help customers predict energy costs. By analyzing past performance and using these forecasts, businesses can gain insights into how future usage may affect their global adjustment costs. While this process can be challenging, tools like the IESO's "Peak tracker" and specialized energy consultants familiar with the Ontario electricity system can offer valuable assistance.

[11] HOEP details are available at ieso.ca/power-data/price-overview/hourly-ontario-energy-price.

[12] Global adjustment details are available at ieso.ca/Power-Data/Price-Overview/Global-Adjustment.

[13] Class A details are available at ieso.ca/en/Sector-Participants/Settlements/Global-Adjustment-Class-A-Eligibility.

[14] ICI details are available at ieso.ca/-/media/Files/IESO/Document-Library/global-adjustment/ICI-Backgrounder.ashx.

Case study

Energy budget sample

Below is a sample electricity budget that includes key information.

Electricity consumption forecast 2023

	Units	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Total consumption from the model	MWh	66,000	75,000	71,000	62,000	61,000	69,000	73,000	76,000	81,000	71,000	72,000	81,000
HOEP (with IESO et al)	$ per MWh	38	39	41	38	38	38	53	53	51	53	53	53
HOEP-based payment (row 1 x row 2)	$ (thousand)	2,508	2,925	2,911	2,356	2,318	2,622	3,869	4,028	4,131	3,763	3,816	4,293
Ontario total demand (5 GA peaks from IESO)	MW	110,455	110,455	110,455	110,455	110,455	110,455	107,104	107,104	107,104	107,104	107,104	107,104
Site demand (avg. at 5 peaks used for GA calc)	MW	270	270	270	270	270	270	290	290	290	290	290	290
Site GA demand factor (of Ontario total)	Fraction of 1.00	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0027	0.0027	0.0027	0.0027	0.0027	0.0027
Total GA cost for all Ontario (from IESO)	$ (million)	587	587	587	587	587	587	406	406	406	406	406	406
GA-based payment (row 6 x row 7)	$ (thousand)	1,435	1,435	1,435	1,435	1,435	1,435	1,099	1,099	1,099	1,099	1,099	1,099
Other electricity-related charges	$ (thousand)	492	492	492	492	492	492	492	492	492	492	492	492
Total HOEP + GA + other payments (rows 3 + 8 + 9)	$ (thousand)	4,435	4,852	4,838	4,283	4,245	4,549	5,460	5,619	5,722	5,354	5,407	5,884
Total HOEP+GA+other cost per MWh (row 10/row 11)	$ per MWh	67	65	68	69	70	66	75	74	71	75	75	73

Glossary

1. **Total consumption:** The estimated megawatt-hours of electricity use for a month, as predicted by the energy model.

2. **Hourly Ontario energy price (HOEP):** The commodity-only cost from the IESO.

3. **HOEP payment calculation:** HOEP × consumption.

4. **Ontario total system demand:** The average of the top five one-hour peak demands recorded by the IESO, used for global adjustment calculations. Actual values are used for January to June, and estimated values from history/forecasts are used for July to December.

5. **Site peak demand:** The average of five coincident one-hour peak demands at the site, recorded by the IESO and used for global adjustment calculations. Actual values are used for January to June, and estimated values for July to December.

6. **Global adjustment demand factor:** Calculated by dividing the coincident site one-hour demand. Actual values are used for January to June, and estimated values for July to December.

7. **Total system-wide global adjustment cost:** Obtained from the IESO. Actual values are used for January to June, and estimated values for July to December.

8. **Site demand factor:** The proportion of a site's peak demand relative to the total system-wide peak demand during the top five coincident peak hours. It is used to determine the site's share of global adjustment costs.

9. **Site global adjustment payment calculation:** Total global adjustment × site demand factor.

10. **Other charges:** IESO, local utility and regulatory charges, as well as miscellaneous electricity charges (losses, account fees, distribution charges, etc.).

11. **Total monthly payments:** The sum of HOEP, global adjustment and other charges.

12. **Cost per MWh:** Total monthly payments divided by monthly consumption.

Key takeaways

How to use the energy budget and model

Building a bottom-up energy budget from an energy model helps companies gain a deeper understanding of their facilities' and processes' energy usage under various conditions. It also highlights the importance of understanding their relationship with their energy providers. Like all budgets, an energy budget is crucial for a management reporting system. Actual energy consumption and costs should be measured against the budget on a monthly basis (at minimum), followed by timely management reviews, corrective actions and budget revisions as necessary.

These are some key use cases for an energy budget and model.

Communication and understanding

Fosters a common understanding of the relationships between planning, costing and operations, providing vital inputs and feedback for comprehensive operational and financial budgets.

Forecasting costs

Offers a roadmap of forecasted energy costs and cash flow requirements.

Costing insights

Provides costing information that may prompt investigations into alternative energy supplies or technologies.

Operational visibility

Gives managers the visibility needed to implement energy-efficiency projects and demand-reduction initiatives.

Data for incentives and reporting

Supplies data for incentive programs, sustainability initiatives and reporting needs.

Enhanced energy management

By providing a better understanding of energy usage patterns, companies can manage their energy consumption more effectively. Monitoring energy usage helps identify areas of high consumption, allowing for targeted reductions.

Energy management for sectors with high energy intensity

For facilities with high energy intensity, such as those in the pulp and paper, metals, minerals, refineries, chemicals, lumber and food industries, it is advisable to refine monthly budgets into more frequent intervals—weekly, daily, or even shorter periods—for enhanced performance monitoring and corrective action. This approach requires adequate training and resources for effective data collection and management. For additional information on strategic energy management, energy management information systems and ISO 50001, please visit the IESO, Save on Energy and Natural Resources Canada.

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