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Optimization of PGE Power Generation

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Abstract

This paper outlines a study of the optimization of methods by which Portland General Electric (PGE) generates the power that it sells to customers. Specifically, we looked at 16 proposed and hypothetical generation projects, and used a variety of parameters to determine which projects optimized profit, while adhering to constraints concerning the required overall capacity, government regulations regarding environmental standards, reliability, and desired level of diversity in its generation methods. Our results showed that, based on a grouping of 4 potential projects for each generation type, that the optimal solution involves funding 2 hydro projects, 1 wind project, and 1 natural gas project. This confirms in some ways our original hypothesis, which was that hydroelectricity would be the cheapest in our region, and yet the model showed that due to diversity of generation requirements, other methods were chosen with nearly equal funding. Overall, the information and analysis provided in this study should be beneficial to policy makers and project planners not as a definitive plan for investment, but as a demonstration of an optimization technique that, given greater access to more accurate proprietary data, could provide a sound argument in support of a particular course of action when determining the optimal investment strategy for a utility company such as PGE.

Contents

1 Introduction

Electric power in the United States - and other countries for that matter - is a precious commodity. The methods of generation are always under great scrutiny to make sure they are economically efficient, environmentally friendly, and provide reliable sources of energy. Power generation companies must stay current on all aspects of their business in order to keep their operation running smoothly while supporting the dynamic regulatory and political requirements placed on them.

A primary concern involves how much power any particular company asset generates, by what method they generate it in, what the current and future reliability/availability rates are, and will facility changes be required. The answers to these questions then spawn additional concerns for how much power a must be purchase from others in order to meet both current and future demands. The same concerns of power type, reliability/availability, and anticipated facility changes apply to the volume of power purchased from other companies to fulfill their client's power demand needs. To properly evaluate the purchasing decisions and make a make-vs-buy decision, additional information company with available power, the contract types they prefer, minimum/maximum commitment durations, and other situation specific details must be gathered. Our model has been constructed to be flexible with specialty variables that will enable quick evaluation of several scenarios with little or no adjustment to the model prior to activation of the optimization engine.

A secondary but major concern involves regulation of power generation itself. Government regulations on power generation seem to be increasing every year. These regulations require better efficiency and a more focused use of renewable energy sources. Resulting in the need to acquire and process the large amounts of information that are required to keep their business successful while ensuring appropriate compliance.

Our project goal is to help a power generation company have the ability to evaluate multiple make-vs-buy scenarios to enable them to make major project decisions regarding anticipated future demands. Our model has been designed to enable both the planning department and the brokerage department to input key pieces of information into the model structure to get scenario results that can answer a variety of 'what if' situations to either maximize revenues and/or minimize purchasing power from other companies to support these make-vs-buy decisions.

1.1 Background of Problem and Prior Research

The project team was first introduced to the problem through a former colleague who suggested the team focused on using Federal Energy Regulatory Commission (FERC) data and see if a model could be based on it in regards to "buyback" of energy. "Buyback" happens when a company has to buy back energy, it simply means that more power was transferred than that customer required. In the past, energy surpluses have caused other companies to shut down power generation stations because the level of demand and revenue involved did not support the cost of keeping the plant running. Such closures that take place before the expected life of the plant is reached drastically change the financial, operating, and strategic plans of the company. This makes it essential to be able to evaluate numerous scenarios and analyze the pros and cons of each before making a final decision to add additional generating capacity. They must determine if the current demand is stable, increasing, decreasing, or subject to abnormal environmental conditions (e.g., excessively heavy or light snow/rain and flood conditions that affect they hydro facilities).

The team dived right into the FERC data to determine what was available. We found that the FERC transactional data, financial filings, and information about available power suppliers was just a small piece of the available information. We found an abundance of information available on the Northwest including more transactional information, market averages for revenue, rates, and regional demand level.[3] We found that the FERC had lots of raw data we downloaded into Excel sheets for evaluation. Unfortunately it was at such a low transactional level that it did not adequately support the type of optimization model we were looking for. After pursuing the NW (need the site name), it became clear that we needed to select a single company to evaluate. The market has so many companies of varying sizes from extremely large with multiple type of power plants to very small companies with only a single unit low MW generating unit. We wanted a company that had several different types of power plants (e.g., hydroelectric, natural gas, fuel oil or coal, and some wind facilities). This meant we needed at least a medium and probably a large company. Next we wanted a company that was in our Northwest vicinity, preferably that served all or some of the Portland area. After several down select cycles, we decided to choose Portland General Electric (PGE).

PGE is a recognized leader in the utility industry and has safely and dependably powered northwest Oregon since 1889. Currently PGE generates energy in several formats. We anticipate that they need to know what the optimal mix of power plan resources would best support the energy demand of their clients to maximize overall profit for their existing and future market share. PGE using the following assets to generates energy for their clients:

- 7 hydroelectric facilities
- 5 natural gas facilities
- 4 fuel oil facilities
- 3 wind facilities

PGE also has a track record of obtaining/generating a certain percentage of their power from "Other" sources. We speculate that these may include micro-generation facilities of most any type. PGE has a policy to purchase additional power from others to ensure that their demand base has adequate access to power. Currently PGE purchases 43% of their current demand from other power generating companies. They are conservative and want to make smart decisions regarding whether or not to expand their asset base with additional power plant facilities.[5]

Once we decided on PGE as our target company, the team divided up the research to enable the widest coverage for obtaining meaningful information that will support our optimization model. The next section describes the variety of information we targeted and used to develop our model and complete this paper.

1.2 Outline of Data Sources

As mentioned before, Portland General Electric is a progressive company in the Energy industry servicing the needs of the public demand via hydroelectric, natural gas, fuel oil and wind power. As the population of Portland continues to grow, PGE will have to increase energy production in order to meet future demand increases. They are evaluating what the best allocation of their investment funds is in order to maximize their profit and meet these future demands.

Hydroelectric Energy involves the conversion of the power of water from rivers into electricity by energizing turbines that create this Energy. In the North West this is a readily available source of Energy production due to the Willamette and Columbia rivers. Portland General Electrics 7 hydroelectric facilities account for up to 10% of PGEs Energy. There are advantages and disadvantages to investing in hydroelectric power. On the positive side, upfront investments in hydroelectric power tend to be minimal as the main raw material needed for this process is naturally occurring, have a low environmental impact and water is easily accessible.

As a result of this low form of investment, new hydroelectric energy plant constructions are being considered as a future method of energy production to invest in. The downside of investing in hydroelectric energy is that, while its a small upfront investment, the energy generation is not as efficient as some of the other forms of energy production and if you have a bad year with little runoff that energy figure will decrease drastically. Unlike Hydroelectric Energy production, natural gas generates high amounts of energy.

Natural gas is an energy source often used for heating, cooking, and generating electricity. It involves extracting it from deep underground natural rock formations or hydrocarbon reservoirs. Once extracted, a purification process must ensue to remove impurities and generate the gas that meets natural gas standards. Portland General Electrics 5 Natural Gas facilities account for up to 24% of PGEs Energy. There are advantages and disadvantages to investing in natural gas power. On the positive side, natural gas generates a profitable amount of energy.

On the flipside, while natural gas and coal are available, the process of extracting and converting into an available source of energy is very involved, requires a higher upfront investment, and has a high environmental impact. The process of extracting natural gas is the same process used to generate fuel oil. Its a distillation process that generates different forms of energy as the byproducts cool. But each of these processes involve further purification steps to remove impurities before it can be used for energy.

Fuel oil is a pre-energy source generated from the processing of crude oil. This oil can be further converted into various forms of energy energy-rich fuel sources (i.e. petrol, diesel, jet, heating, etc.). This is a highly intensive purification process that demands a higher investment but can yield very profitable gains. General Electrics 4 fuel oil facilities account for up to 10% of PGEs Energy. The positive and negative aspects of this form of energy production are the same as natural gas. Unlike these last two forms of energy production, wind energy has differing pros and cons.

Wind Energy involves the conversion of the wind power into electricity by energizing generators that create this Energy. PGE has three (3) wind energy plants that account for up to 9% of PGEs Energy. Investments in wind energy tend to be larger as the process of establishing wind facilities for converting wind into a usable form of energy is very expensive. Once established, like hydroelectric power, the raw material is free and constantly available- allowing for a quick return on investment. As a result of this, PGE is also evaluating wind energy farms as a possible method to allocate its investments.

The team evaluated data from the different models for PGE energy production as well as related data from other sources. In analyzing all the sources, and making correlations, it was found that for 2010 there were reports for each of the models reviewed. This data established a starting point for collaboration and analysis. Some of the data is specific to PGE (FERC, PGE Corp.) while some is related to power generation in general. Putting data in the same units was one of the biggest tasks of this project as many information databases carried energy use in Mega-Watt Hour (MWH) while some did listings in Mega-Watts (MW). Of those that listed in just MW, they also provided a time of transfer which allowed the team to convert from MW to MWH thereby ensuring correct analysis and evaluation. Most databases, however, already had revenue figures in dollars per MWH, so the conversion helped in that regard as well.

The team also evaluated the amount of total energy purchased from other sources. 2010 proved to be a difficult year for hydroelectric power generation due to decreased runoff. This forced PGE to purchase energy from other sources which presented a challenge for profit. In 2010 PGE generated a total of 2766 MW of energy- which represented 57% of Portland General Electrics Energy. The other 43% or 2,074 MW came from total purchased power from other sources. As a result of this information, the team evaluated increased demand over the ensuing 10 years due to growth and decreasing the total purchased to 25%. This increase capacity provides the driving force for the model engendered by the team.

As part of this project, the team used the future energy demands to determine what the most profitable allocation of investments and resources would be (natural Gas, fuel oil, hydroelectric, or wind). The model evaluates available resource capacity over time and determines via binary format whether a project would be worth investing in. There are certain constraints the system takes into consideration in evaluating the data. Section 2.0 of this report discusses in greater detail these factors.

1.3 Assumptions

Throughout the generation of the energy model and evaluation of the existing data, some project assumptions had to be made. These assumptions were made for simplicitys sake, but were always based on information from other sources not necessarily specific to Portland General Electric but associated with energy data collected from other sources (i.e. FERC, NW, etc.). For the purpose of this project and its overall goal of learning the modeling and optimization process, simplifying was necessary. Some of the data which was simplified included the cost of construction throughout many years of the project.

1.4 Data

Operating costs of generation plants were taken as national average numbers from report data at *http://www.eia.gov/electricity/annual/html/epa_08_04.html*. Output of new generation plants were extracted from the data of average sized plants. Income data (revenue) was taken from an average reported in the FERC filing of PGE in 2010. Cost of Purchase from Others energy was taken as averages of MWh purchased by PGE for each month of 2010.

2 Structure of Model

2.1 Key Elements

The model is designed to help the user choose between 16 power generation projects. Each project carries with it an initial cost, revenue from generation, and added capacity to the overall generation portfolio of PGE. Each project also has a focus of generation that can be used in future constraints or even decision variables. These focuses already align with what PGE has for generation capabilities, namely Hydro, Wind, Natural Gas, and Diesel (Fossil) Fuel.

To make a truly educated decision on which projects to choose a few bits of information from the user must be known:

- Cash on hand for initial investment in projects
- Time frame for return on investment
- Generation capacity needed at the end of the time frame
- Revenue from sale of power generated

The cash on hand will be the amount that is available for initial, up-front, investment into any of the constructions projects. This cash may be liquid or from bank loans, however if loans are to be utilized then the total amortized loan amount should be used for the initial cost data. The model assumes a 10% down payment on the capital project from cash reserves. This is in line with the majority of banking practices for such construction projects. In many cases that can be higher, but a current indicator of 10% is used.

The Time Frame is the target time, in years, for completion of the projects to meet a certain generation command. For instance, we can place this time frame at 10 years and set the Generation Capacity to be the amount of megawatts needed at the end of that 10 hear span. This number can be set to any year interval greater than 0 for purposes of the model. However, it must be noted that it will then calculate everything based on this parameter so one must take great care in ensuring that the demand requirement is proper for the time frame.

The Generation Capacity is the capacity needed at the end of the time frame. However, there is more to it that just the maximum amount. Currently PGE generates from owned plants and also purchases power from others to complete its total capacity requirements. As part of the model we have chosen to calculate a Capacity Shortfall that takes into account owned generation stations and purchases from others. However, in line with PGEs business plan we wish to reduce the amount purchased from others to be limited to 25% of overall capacity.

For instance, at this time PGE generates 2766MW of their own power and purchases 2074MW from others. This means they purchase 43% of their power from others. As part of the model, we reduce the purchase from others to 25% of total. If the capacity demand at the end of the time frame is 5319MW it is known that the total amount from others cannot exceed 1329.75 or 1330MW. PGE already generates 2766MW so the total Generation Shortfall would be 5319MW-2766MW-1330MW = 1223MW.

For the purpose of the model it is known that additional generation needed, including the reduction in purchasing from others, is 1396MW. That gives us an overall generation capacity requirement including owned generation stations and purchases from others of 5549MW. The revenue that comes from the generation of power is one of the main factors in the optimization model. The amount listed for MWhr/yr is an average taken from PGE financial records for the year 2010. The average gives us a suitable value to use for the revenue from the generation amount utilizing the plants at 100% - of MWhr that the plants will give in a year. The other 90% of the capital investment cost will be subtracted from revenue as part of the model.

Operating costs of a generation plant are an important factor. These have already been calculated into the revenue costs as directed in the data from PGE. In other words, this revenue profit is truly that, profit with all the operating expenses taken out. Therefore, for out model we only need to account for the initial construction investment.

There are five main constraints that the model has:

- The Decision Variables must be binary

- The Available Cash (for initial investment) must be greater than or equal to the Cash Used
- The New Capacity added must be less than or equal to the max capacity needed
- The New Capacity added must be greater than or equal to the Shortfall capacity
- Non-Negativity for all variables

This model is a Binary Choice Model much like those outlined in Chapter 6 of Baker. Therefor the decision variables themselves are binary. A 1 in the variable means that the project is built; while a 0 means that it is not.

The Available Cash, as stated above, is what is available for initial investment in projects. This constraint means that PGE cannot go in the red to invest in projects. This variable can be changed to match what is available at the time of running this model.

The next two constraints are in regards to the New Capacity added amount. The new projects capacity, in total, should be equal to or more than what is required due to the Generation Shortfall. However, if them model were left to calculate maximum revenue while just having a lower bound of additional generation amount then it is likely that it will create much more than is needed. Therefore a Max additional generation variable has been added. This can either be input by the user or have a standard buffer. In the current case, the standard buffer is 600MW.

The last constraint means that no negative decision variables (which are binary and cant be negative anyway) can be negative.

The mathematical representation of the model is as follows:

$$y_i = \begin{cases} 1 & \text{if project } i \text{ is selected,} \\ 0 & \text{otherwise.} \end{cases} \tag{1}$$

Our secondary iterative variables are defined as:

$$\begin{aligned} I_i &= \text{Initial investment cost of project} \\ R_i &= \text{Overall Revenue of Project per time frame} \\ C_i &= \text{Capacity of Project [MW]} \\ M_i &= \text{MWh/yr @ 100\% availability} \end{aligned} \tag{2}$$

Our secondary general variables are defined as:

$$
\begin{aligned}
&CapNeed = \text{Needed capacity after time frame}\\
&CapCur = \text{Current capacity generated and 25\% purchased from others}\\
&MaxCap = \text{Maximumm Capacity Needed}\\
&G = \text{Revenue generated per 1 MWh/yr}\\
&Invest = \text{Total funds available for investment}
\end{aligned} \tag{3}
$$

Our Objective Function is defined as:

$$
\begin{aligned}
&\text{Maximize } p = \sum_{i=1}^{n} y_i(R_i - .9I_i)\\
&\text{where } R_i = M_i G
\end{aligned} \tag{4}
$$

subject to the constraints:

$$
\begin{aligned}
&y_i = binary\\
&\sum_{i=1}^{n} .1(y_i I_i) \leq Invest\\
&\sum_{i=1}^{n} y_i C_i \geq CapNeed - CapCur\\
&\sum_{i=1}^{n} y_i C_i \leq MaxCap
\end{aligned} \tag{5}
$$

3 Implementation in Excel

Refer to Figure 1 for the implementation of the model in Excel. The descriptions of cells are as follows:

C10:C25 These cells contain the project identifiers (1-16). These are merely convenience of use items and not used in any calculations. (Input non model use)

D10:D25 This is the project capital cost in $millions.

E10:E25 The Decision Variables for them model. Constrained to be Binary: 1 if the project is chosen, otherwise 0. (D.V)

F10:F25 The down payment required for starting the project. This is set at 10% of the capital cost for the project. (Calculated in excel provided to model)

G10:G25 This is the remaining capital that must be paid off in the time span. For this model it is 90% of the capital cost of the project. It will be subtracted from the revenue. (Calculated in excel provided to model)

Portland General Electric Project Selection Optimization Model

	Project	in $M Capital Cost	Select? (1=yes, 0=no)	in $M Down Payment	In $M Remaining Cap. Cost	10 Revenue In Millions	Years Additional Capacity	MWhr/year at 100% Availability	In $M Avg $ Revenue/ MWhr/yr
Hydro Rehab	1	$ 110.00	1	$ 11.00	$ 99.00	$947	44	385704	$0.000246
Hydro Rehab	2	$ 72.70	0	$ 7.27	$ 65.43	$0	5	43830	$0.000246
Hydro Rehab	3	$ 110.00	1	$ 11.00	$ 99.00	$882	41	359406	$0.000246
Hydro Rehab	4	$ 72.70	1	$ 7.27	$ 65.43	$258	12	105192	$0.000246
Wind New	5	$ 911.00	0	$ 91.10	$ 819.90	$0	246	2156436	$0.000246
Wind New	6	$ 385.00	0	$ 38.50	$ 346.50	$0	175	1534050	$0.000246
Wind New	7	$ 911.00	0	$ 91.10	$ 819.90	$0	210	1840860	$0.000246
Wind New	8	$ 385.00	1	$ 38.50	$ 346.50	$4,025	187	1639242	$0.000246
Diesel New	9	$ 1,900.00	0	$ 190.00	$ 1,710.00	$0	800	7012800	$0.000246
Diesel Conversion	10	$ 725.00	0	$ 72.50	$ 652.50	$0	735	6443010	$0.000246
Diesel New	11	$ 1,900.00	0	$ 190.00	$ 1,710.00	$0	820	7188120	$0.000246
Diesel Conversion	12	$ 725.00	0	$ 72.50	$ 652.50	$0	670	5873220	$0.000246
Natural Gas Rehab	13	$ 250.00	0	$ 25.00	$ 225.00	$0	100	876600	$0.000246
Natural Gas New	14	$ 400.00	1	$ 40.00	$ 360.00	$15,497	720	6311520	$0.000246
Natural Gas Rehab	15	$ 250.00	1	$ 25.00	$ 225.00	$6,457	300	2629800	$0.000246
Natural Gas New	16	$ 400.00	1	$ 40.00	$ 360.00	$14,852	690	6048540	$0.000246
			Used	$ 172.77					
			Available	$ 500.00					

1,994	MW of new Capacity from Projects
$41,364	Total Revenue

Max Cap.
1996

10 yr Capacity Need	
	MW
	5549

Capacity Shortfall	
	MW
	1396

Current Capacity	
	MW
Generated	2766
Purchased	2,074
Total	4840

Future Demand Capacity	
	MW
Generated	4162
Purchased	1,387
Total	5549

Figure 1: Implementation in Excel of our model to optimize project investment for PGE

H10:H25 Revenue realized from the project when running at 100% availability in $million. This is calculated from items in column H multiplied by I. e.g. H10=J10*K10*years. (Calculated in excel provided to model)

I10:I25 This is the additional total MW capacity given by the corresponding project. This information is input from the Nameplate Capacity listed for the model. (Input - used in model)

J10:J25 MWhr/yr available at 100% operation of the generation plant in that project. Calculated from its name plate capacity and converted to MWhr/yr. (Calculated in model)

K10:K25 Average revenue per MWhr/yr. As listed in previous section, this is the average revenue accounting for operational costs. (Input used by model)

H6 Time frame for model to target. In most cases this is 10 years as the data for demand and pricing are related to such. However, it can be modified to gain more flexibility from the model to look at different time frames. (Input used by model)

F26 Investment dollars spent on projects in $millions. This is the total down payment amount needed for the projects selected. (Calculated by model)

F27 Total investment money available in $millions. (Input used by model)

H28 The total of new capacity added to PGE generation portfolio with the selected projects. (Calculated by model)

H29 Total revenue realized at the end of the time frame with projects selected. (Calculated by model)

H33 Total capacity needed at end of the time frame. (Input used by model)

K33 Capacity Shortfall to be filled by projects. (Calculated by Excel, result used by model)

L30 Maximum additional capacity needed. (Calculated by excel used by model)

The Current Capacity and Future Demand boxes utilize known data about PGE to help calculate the Generation Shortfall amount used in J33.

In Excel terms, the model looks like this:

$$Objective: \ G29 \ (maximize) \tag{6}$$
$$Variables: \ D10 : D25 \tag{7}$$
$$Constraints: \ D10 : D25 = binary \tag{8}$$
$$E27 \geq E26 \tag{9}$$
$$G28 \leq K30 \tag{10}$$
$$G28 \geq J33 \tag{11}$$

After populating the model with all data, it is ok to run the solver. The model itself is linear.

4 Results and Analysis

After properly constructing the model, setting the variables appropriately and running the solver tool to optimize the model, we began to look at the results that the model gave us. The first thing that we noticed was the spectrum of projects of each type that were chosen. As can be seen in Figure 1, the model chose all four of the hydroelectric projects, three of the four natural gas projects, one of the wind projects, and none of the diesel projects. For the most part, this was to be expected. Because of the amount of needed capacity, the amount of available investment funds, and the given potential capacity of the prospective projects, there Solver required a relatively wide margin to successfully find an optimum.

Because of the nature of the power grid, the desired capacity for the date ten years in the future had to be considered a concrete minimum. This is because this value was arrived at only *after* considered what the market could reliably be depended on the provide, and so having a capacity less than what they were projected to need by even a few megawatts could result in blackout conditions if demand peaked at the point that they predicted it would. However, since electricity is not a storable commodity in the sense that other manufactured goods may be, and it cannot be stored to be sold later, having a capacity any greater than what would be required would be wasteful, and this would thus need to be minimized. Because we could not simultaneously maximize profit and minimize capacity overage, we simply set an arbitrary limit for the capacity that could be built into their system. In deciding the value of this constraint it became clear that it would be difficult to build exactly the right plant at exactly the right time. If PGE had the ability to commission a built-to-order facility with exactly the nameplate capacity required, they would not experience this issue. However, if a situation was encountered like the one that we modeled, where they solicited proposals from independent contractors and companies to build their "stock" model facilities, then they would have to find a way to optimize the scenario in a very similar way to this, to figure out the right balance of profit and capacity overage. We found that our initial estimate of an arbitrary maximum of a few hundred MW over the desired increase in capacity created too small of a feasible region for the Solver tool, and it would not return a solution. Only after increasing this maximum to 2000 MW—or about 40% higher than the originally desired increase—could the Solver tool return a feasible solution. This, of course, depended on the values of the projects capacity and cost variables, which in some cases were hypothetical, but it still illustrates how difficult it can be to make these kinds of decisions—even if only programmatically.

5 Conclusions

Ultimately we felt that this was a fairly realistic example of a way that someone in an upper-level decision making role at PGE might begin to approach a problem such as this, where there are several different potential projects, each with its own costs and benefits. Overall, our expectations and original assumptions were mostly proven correct—in that facilities that are cheap to build and cheap to operate on a per megawatt basis will be the first that are chosen for funding. What was surprising, (or simply not intuitively obvious), about the outcome of our model was the fact that in some cases the decision to go ahead on a project may be driven more by a combination of convenience and necessity in terms of the project providing the right capacity at the right time than about any higher notions of environmental concerns, or overall diversification.

These last two measures, while important, are notoriously difficult to quantify. This is likely why regulatory efforts to enforce measures of the environment, and those of reliability, (which often is influenced by diversity of generation methods), are sometimes fraught with conflict. In any case, no matter how arbitrary these measures are, they are an important way, if not one of the only ways, to safeguard the nations power grid against the dangers of dirty production methods, or the dangers of "putting all the eggs in one basket", so to speak.

We hope that this study will serve as a type of exploratory venture into optimization of power generation project funding using one of the most basic tools available in the industry: the Solver function in Microsoft Excel. Using this otherwise commonplace piece of software, we are able to fine-tune the direction that our company desires to go in, and analyze several different routes forward by adjusting a few simple variables.

6 Opportunities for Further Research

There were many different components that were not added to our model or topics that were not addressed because of various reasons—most often related to time constraints or to a conscious desire to maintain the focus of the study on the core components of this type of decision-making process. Throughout the term, however, our group discussed and explored several other ideas for ways to go with the model, and we'd like to discuss those here.

A common theme of essentially all of the omitted components is that of access to data. Because PGE is a for-profit company, they have very good reasons to not willfully distribute their operational data. In any case, were we able to access data regarding the operating costs of their existing projects of each type, or were we in a position at PGE, we would be able to populate the model with more accurate data, as well as data with greater granularity, which would yield results with the same qualities. For example, the investment costs of funding a new hydroelectric facility for PGE may be more or less than is estimated in this paper because of situations that only PGE is aware of, such as their existing logistics network in the hydroelectric industry, their corporate relationships with other industrial entities on the major river ways where the hydro facilities would be built, and other such factors.

Operational costs, although present indirectly in the cost structure of our model, are not listed with much specificity and granularity because these figures could not be reliably had from the data we were able to procure. It would improve the model substantially to not only include cost data for the next ten years in one year increments, but to also include cost data for the duration of the life of the project. This would be the primary way that renewable projects such as hydro and wind would gain favor over cheaper to build, but finite resource based projects such as natural gas and diesel. This would of course depend largely on the ability to accurately forecast the price of such energy commodities for decades into the future, which is not possible. However, even if one were to make the highly conservative assumption that the price of all kinds of petroleum were to remain the same for the next 50 years, the relative advantage of wind and hydro power would be greatly enhanced, or rather the degree to which that advantage is able to be seen.

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7 Data

PGE Generation Projects:						
Project	**Resouce Type**	**Nameplate Capacity (MW)**	**Status**	**Owner**	**2010 Energy (MWa)**	**Avg. Energy (Mwa)**
Beaver 1 - 7	Natural gas	586.2	Operating	Portland General Electric	17.9	
Beaver 8	Natural gas	24.5	Operating	Portland General Electric	0	
Biglow Canyon I	Wind	125.4	Operating	Portland General Electric	35.61	41.8
Biglow Canyon II	Wind	149.5	Operating	Portland General Electric	42.45370813	49.8333333
Biglow Canyon III	Wind	174.8	Operating	Portland General Electric	51.88155502	60.9
Coyote Springs 1	Natural gas	266.4	Operating	Portland General Electric	177.74	
Faraday 1 - 6	Hydro	36.6	Operating	Portland General Electric	20.8	26
North Fork 1 & 2	Hydro	40.8	Operating	Portland General Electric	23.7	23
Oak Grove (Three Lynx) 1 &	Hydro	51	Operating	Portland General Electric	27.6	30
Port Westward CC 1A & 1B	Natural gas	399	Operating	Portland General Electric	313.4	
River Mill 1 - 5	Hydro	19.1	Operating	Portland General Electric	12.9	14
T.W. Sullivan 1 - 13	Hydro	15.4	Operating	Portland General Electric	15.5	
Pelton 1- 3	Hydro	109.8	Operating	Portland General Electric (2/3), Warm Spring	48.4	51
Round Butte 1 - 3	Hydro	300	Operating	Portland General Electric (2/3), Warm Spring	114.22	114
Total Energy Produced:		2298.5			902.1052632	

Cost:

From SEC Annual Report:

	Capacity	**%**
Thermal (NG):	1,157	24
Thermal (Coal):	670	14
Hydro	489	10
Wind	450	9
Total Generation:	**2,766**	**57%**

Also of Note:

SEC filing indicates that (as of 11-5-09), PGE will need 873 Mwa of new resources by 2015, increasing to 1,396 Mwa by 2020, to meet expected customer demand.
It goes on to say this projected energy gap would increase by appx. 374 MW if Boardman were to cease operations
Page 18 of annual filing outlines their current plan to address these needs. Very informative.

Per 2010 Annual 10-K Filing

Project	**Resouce Type**	**Net Capacity in MWs***	**Ownership Share of Jointly-Owned**	**Wholly-Owned or Jointly-Owned**
Faraday	Hydro	46		Wholly-Owned
North Fork	Hydro	58		Wholly-Owned
Oak Grove	Hydro	44		Wholly-Owned
River Mill	Hydro	25		Wholly-Owned
T.W. Sullivan	Hydro	18		Wholly-Owned
Beaver	Natural Gas/Oil	516		Wholly-Owned
Port Westward	Natural Gas/Oil	410		Wholly-Owned
Coyote Springs	Natural Gas/Oil	231		Wholly-Owned
Biglow Canyon	Wind	450		Wholly-Owned
Boardman	Coal	374	65%	Jointly-Owned PGE Operates
Colstrip	Coal	296	20%	Jointly-Owned PPL Montana, LLC Operates
Pelton	Hydro	73	66.67%	Jointly-Owned PGE Operates
Round Butte	Hydro	225	66.67%	Jointly-Owned PGE Operates
Total Net Capacity		2766		

* NOTE: Net Capacity of generating unit as demonstrated by actual operating or test experience, net of electricity used in the operation of a given facility. For wind-powered generating facilities, nameplate ratings are used in place of net capacity. Angenerator's nameplate rating is its full-load capacity under normal operating conditions as defined by the manufacturer.

Power Operations in 2010:				
PGE Operaterated plants were ~95% availability in 2010, as compared with 89% in 2009 and 92% in 2008. The Colstrip (which is not operated by PGE) had ~95%, compared with 68% in 2009 and 97% in 2008.				
In 2009 both the Colstrip and Boardman coal-fired generating plants experienced extended maintenance and repair outages resulting in incremental replacement power costs of approx $16M.				

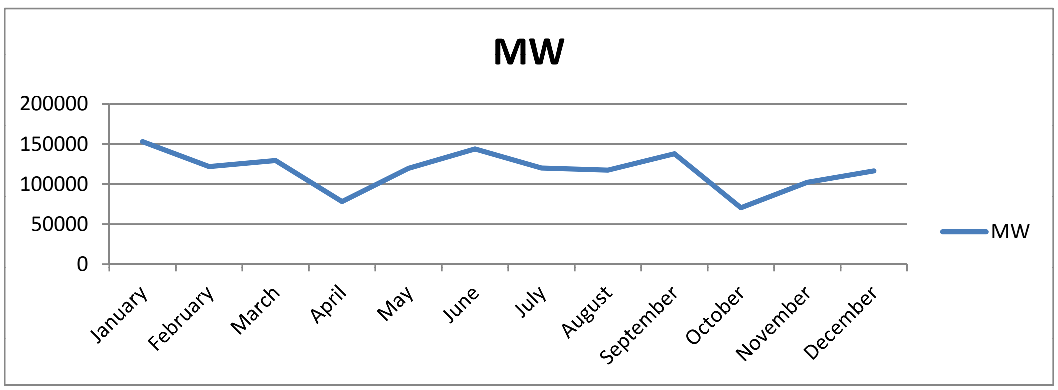
PGE Resource Capacity in MW		
	Capacity MW	%
Generation:		
Thermal:		
Natural gas	1,157	24
Coal	670	14
Total thermal	1,827	38
Hydro	489	10
Wind	450	9
Total generation	2,766	57
Purchased power:		
Long-term contracts:		
Capacity/exchange	540	11
Mid-Columbia hydro	507	10
Confederated Tribes hydro	150	3
Wind	44	1
Other	221	5
Total long-term contracts	1,462	30
Short-term contracts	612	13
Total purchased power	2,074	43
Total resource capacity	4,840	100

From 2010 PGE Annual Report SEC Filing:

Long-term contracts:		Capacity	%
	Capacity/exchange	540	11
	Mid-Columbia hydro	507	10
	Confederated Tribes hydro	150	3
	Wind	44	1
	Other	221	5
Long-term contracts total:		1,462	30%
Short-term contracts total:		612	13%
Total Energy Purchased:		2,074	43%

Cost:

Generated Capacity:	2,766	57%
Total Resource Capacity:	4,840	100%



Total MW Purchased from others per QTR and MWH price incurred.

2010 Q1		MW	Cost
January		152930	$ 208,640.41
February		121865	$ 170,272.55
March		129411	$ 182,234.91
2010 Q2			
April		78122	$ 93,821.82
May		119703	$ 144,739.46
June		143851	$ 185,006.12
2010 Q3			
July		120013	$ 151,579.06
August		117403	$ 145,122.34
September		137816	$ 174,537.54

2010 Q4			
October		70402	$ 83,789.03
November		102240	$ 127,244.46
December		116457	$ 152,925.41
Totals		1410213	$ 1,819,913.11

Per 2010 Annual 10-K Filing:

Future Energy Resource Strategy:

To meet the projected energy requirements, the IRP included energy efficiency measures, new renewable resources, new transmission capability, new generating plants, and improvements to existing generating plants, as follows:

- Acquisition of 214 MWa of energy efficiency through continuation of Energy Trust of Oregon programs, with funding to be provided from the existing public purpose charge and through enabling legislation included in Oregon's RPS;
- An additional 122 MWa of wind or other renewable resources necessary to meet requirements of Oregon's RPS by 2015;
- Transmission capacity additions to interconnect new and existing energy resources in eastern Oregon to PGE's services territory. For additional information on the Cascade Crossing Transmission Project (Cascade Crossing), see the Transmission and Distribution section in this Item 1;
- New natural gas generation facilities to help meet additional base load requirements estimated at 300 to 500 MW, which is expected to be in service in or around 2015;
- New natural gas generation facilities to help meet peak capacity requirements estimated at up to 200 MW, which is expected to be in service in or around 2013; and
- Future plans for the Boardman plant, including the addition of certain emissions controls and the continuation of coal-fired operation of the plant through 2020.

2010 PGE Sources of energy (MWh in thousands):		
Generation:		
Thermal:		
Coal	4,984	23
Natural gas	4,460	21
Total thermal	9,444	44
Hydro	1,830	9
Wind	833	4
Total generation	12,107	57
Purchased power:		
Term purchases	3,984	19
Purchased hydro	2,417	11
Purchased wind	297	1
Spot purchases	2,618	12
Total purchased power	9,316	43
Total system load	21,423	100
Less: wholesale sales	(2,580	
Retail load requirement	18,843	

From 2010 FERC EQRs:

Notes:			

Data goes from row 2 to 24530

There are 24 transactions listed in MW-MO that need to be converted to MWH

Their SEC annual report claims that they only earned $87 M from wholesale revenue. I'm not sure how to reconcile that with this data.

(NOTE: more than 1000 pages of data do not print but are available in the file.)

Total Energy Sold on Market:	7,524,294
Revenue:	$239,304,843.66

Total Energy Sold to Meet Demand:

Revenue:	

Per 2010 Annual 10-K Filing

DELIVERIES BY CUSTOMER CLASS

Customer Type	Avg # Customers	Energy Deliveries (thousands of MWh)
Residential	717,719	7,452
Commercial	102,282	7,277
Industrial	265	4,004
Total	820,266	18,733

The majority of the Company's service territory lies within the Portland/Salem Metropolitan Area

2010 PGE Energy Deliveries	MWh in thousands	As % of Total
Retail:		
Residential	7,452	35%
Commercial	7,277	34%
Industrial	4,004	19%
Total retail energy deliveries	18,733	88%
Wholesale energy deliveries	2,580	12%
Total energy deliveries	21,313	100%

	Heating Degree-Days	Cooling Degree-Days
2010	4,187	314
2009	4,391	627
2008	4,582	474
15-year average for 2010	4,192	473

The table above indicates that during 2010 , heating degree-days were down about 5% from the prior year, while in 2009 demand for heating was greater than the 15-year average, but less than what it was in 2008. Demand for electricity for air conditioning was down in 2010 due to the 50% decline in cooling degree-days from 2009, which saw an unusually warm summer, while 2008 was a near average cooling degree year.

PGE's all-time high net system load peak of 4,073 MW occurred in December 1998. The Company's all-time "summer peak" of 3,949 MW occurred in July 2009, driven by unusually warm weather, and exceeded the December 2009 "winter peak" of 3,851 MW. The following table shows the Company's average winter and summer loads for the periods indicated along with the corresponding peak load and month in which it occurred:

YEAR	SEASON	Average Load MW	Month	Peak Load MW
2010	Winter	2,445	November	3,582
2010	Summer	2,220	August	3,544
2009	Winter	2,658	December	3,851
2009	Summer	2,267	July	3,949
2008	Winter	2,691	December	4,031
2008	Summer	2,324	August	3,743

PGE Revenues for Year Ending December 31, 2010

	AMOUNT ($M)	%
Retail:		
Residential	803	45%
Commercial	601	34%
Industrial	221	12%
Subtotal	1,625	91%
Other accrued revenues, net	39	20%
Total retail revenues	1,664	93%
Wholesale revenues	87	50%
Other operating revenues	32	20%
Revenues, net	1,783	100%

2010 AVERAGE STATISTICS

Average Usage per Customer in kWh	
Residential	10,384
Commercial	68,040
Industrial	12,986,466
Avg Revenue per Cusomter in dollars	
Residential	$1,049
Commercial	$5,769
Industrial	$859,251
Avg Revenue per kWh in cents	
Residential	10.10 ¢
Commercial	8.48 ¢
Industrial	6.62 ¢

2010	Heating	Cooling Degree-Days
1st Quarter	1,629	—
2nd Quarter	861	18
3rd Quarter	117	296
4th Quarter	1,580	—
Full Year	4,187	314
15yr Full Year Avg	4,192	473

Per 2010 Annual 10-K Filing

Project Completed in Aug 2010			Total Project Cost	# Wind Turbines	In Service & Installed Capacity
Biglow Canyon Wind Farm			$960M	217	450 MW

	Completed	Phase Cost	# Wind Turbines	Installed Capacity
Phase 1	Dec-07	$256M	76	125 MW
Phase 2	Aug-09	$319M	65	150 MW
Phase 3	Aug-10	$385M	76	175 MW

Construction of Biglow Canyon Phase 3, the smart meter project, and ongoing capital expenditures for the upgrade, replacement, and expansion of transmission, distribution and generation infrastructure: were $450M in 2010 and are expected to by ~$310M in 2011

The following table indicates actual capital expenditures for 2010 and future debt maturities and projected cash requirements for 2011 through 2015 for projects that the Board of Directors has approved (in millions):

PGE CAPITAL EXPENDITURES AND FUTURE DEBT MATURITIES	For Year Ending December 31					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Ongoing capital expenditures	211	251	219	215	235	256
Biglow Canyon Phase III	166	—	—	—	—	—
Hydro licensing and construction	8	31	21	13	25	27
Smart meter project	45	4	—	—	—	—
Boardman emissions controls (1)	5	24	1	13	3	—
Total capital expenditures	435	310	241	241	263	283
Preliminary engineering	8	20	2	—	—	—
Long-term debt maturities	186	10	100	100	63	70