Executive Summary

Opportunities for the Smart Grid to Integrate With and Support EcoDistricts and District Energy Systems

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Introduction

Despite limited adoption in the United States, district scale energy production and distribution is well established the world over as an efficient means of supplying basic heating and cooling. District Energy systems are used to supply heating and cooling on a neighborhood scale. The emerging capabilities and infrastructure of the Smart Grid offer opportunities to increase the potential benefits of District Energy systems and provide necessary services to the electric grid. This "green paper" will explore two potential ways of leveraging the Smart Grid in District Energy applications.

The management of energy supply and demand on a neighborhood scale constitutes a significant opportunity for energy conservation and the reduction of greenhouse gas (GHG) emissions. New strategies can be used to overcome the economies of scale that have long benefitted large centralized electricity generation plants, which incur transmission losses. Distributing smaller power plants and capturing waste heat from electrical generation to meet the thermal needs of a district rather than separately burning fuel to do so further increases the net efficiency of combined heat and power systems. Emissions are reduced while still meeting the energy needs of a group of buildings.

Renewable portfolio standards (RPS) mandated by the State of Oregon require utilities to generate 20% of their power with renewable resources by 2020 and 25% by 2025, which is a significant increase compared to current levels. One of the obstacles to further scaling of renewable resources, particularly wind power generation, is the management of variability in the supply. Countries that have successfully managed the integration of greater percentages of renewable energy into their power generation portfolio have generally had fewer centralized sources of supply. For example, Denmark generates 20% of its electricity from wind. District Energy systems provide 46% of its heating demands. Distributed generation, augmented with energy storage and communications to support intelligent control of load and generation, can be the cornerstones of EcoDistricts now developing in the Portland area.

This paper evaluates two approaches to using District Energy systems. The capabilities of the Smart Grid are utilized to efficiently meet the energy requirements of a geographic area and to provide needed services to the grid while contributing toward emission reduction targets.

Technology Analysis

Using intermittent renewable generation requires increased flexibility of both generation and load. The operation of a District Energy network can be optimized to meet this goal. In the Pacific Northwest, wind energy is the fastest growing form of renewable power generation. Wind is a highly variable resource and the balancing of electricity on the grid is primarily executed by varying spinning reserve assets. Spinning reserve assets enable a utility to draw on responsive generation facilities to help supply meet demand at every instant. In the Pacific Northwest, this means reducing or increasing the flow through dam turbines or fluctuating simple cycle gas turbines. Of these two options, hydroelectric spinning reserves are favored for economic reasons. The use of these strategies to make a variable resource, such as wind, into a useful and reliable source of electricity is known as "firming." The capability of hydroelectric reserves for wind firming is capacity-limited by changing river operations. Wind generation is forecasted to increase significantly over the next decade. When the spinning reserve portfolio lacks the generation flexibility to compensate for spikes in wind generation, the excess power may be dissipated with no benefit or return.

Storing excess energy can be done in many ways. Methods include pumped water, compressed air storage, or utility-scale battery storage. We evaluated two alternative methods of storage: thermal storage and flexible combined heat and power generation.

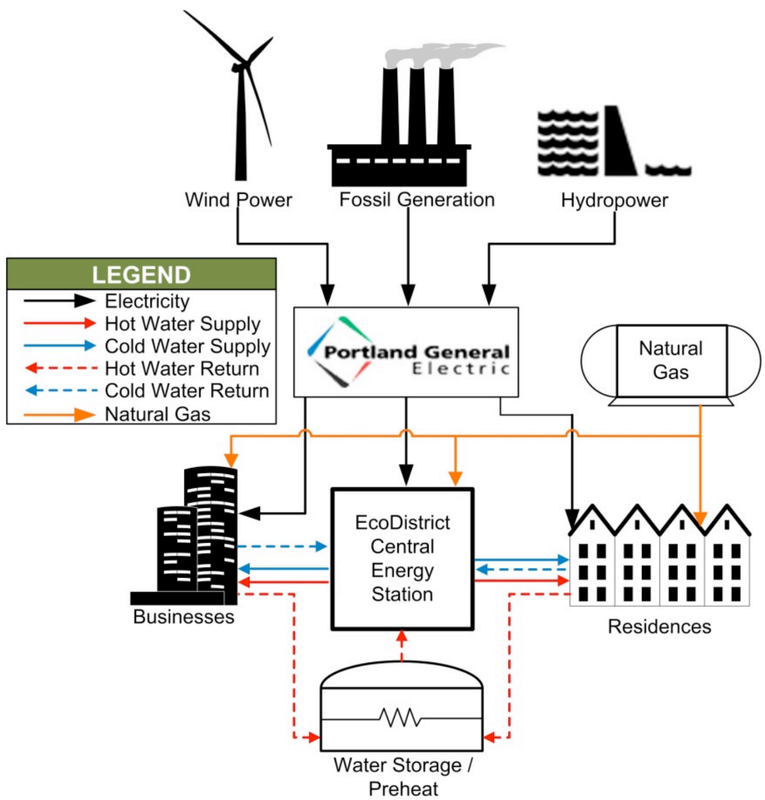

Figure 1 - Thermal Storage for Non-firm Wind Power

Technology Option 1: Natural Gas Boilers with Electric Resistance & Electric Chillers

Thermal storage uses excess electricity generated from wind farms within the region to heat water for use in the district (Figure 1). Signals from the wind generation asset owners would trigger the control of the heating elements. These activities would be coordinated with Portland General Electric (PGE) and the Bonneville Power Administration (BPA). BPA is responsible for the transmission of much of the wind generation in the region.

Heat in excess of demand on the District Energy system would be stored in one major tank. The temperatures of buildings within the district could be adjusted within limits to pre-heat or pre-cool based on the availability of excess energy. An electrical preheating strategy provides a service to help integrate wind generation into the grid. To maintain the balance between supply and demand, the heating elements serve the same function as reducing energy generation. This ability is called downward frequency regulation ancillary service, and holds value for PGE in that the utility can purchase this ancillary service to help integrate more wind in pursuit of renewable energy goals.

The thermal storage option makes use of the excess electricity by converting it to heat with the element inside a storage tank. Heating and hot water can then be distributed to neighborhood buildings. Making use of the renewable wind resource for heating will reduce consumption of natural gas in the boilers which will be used for the bulk of the District Heating needs. The amount of electricity used for heating is of central importance in determining both environmental benefits as well as financial viability.

Technology Option 2: Combined Heat and Power With Load Following Capabilities

A second option for District Energy generation is an advanced combined heat and power (CHP) system that provides heating and cooling to the North Pearl neighborhood (Figure 2). The CHP system incorporates the flexibility of providing both downward and upward regulation ancillary service.

CHP makes use of a natural gas fired combustion turbine. Efficiency and flexibility are increased by making use of very hot exhaust gas ordinarily wasted. The gases are used to operate chillers that produce cold water and a combined cycle generator that produces additional electricity. Heat from the combustion turbine is also used to provide hot water for distribution across the neighborhood energy district.
The CHP system could be used to provide both downward and upward regulation service because the turbine and generator can respond in either direction by ramping up or down for electricity generation as needed. This design provides flexibility as an ancillary service, allowing connection to PGE's distribution network for seamless integration into the exiting grid. When thermal and electricity loads are low, natural gas consumption will decrease, effectively saving the resource for use at a later time when demands are high and intermittent renewable resources may not be in operation.

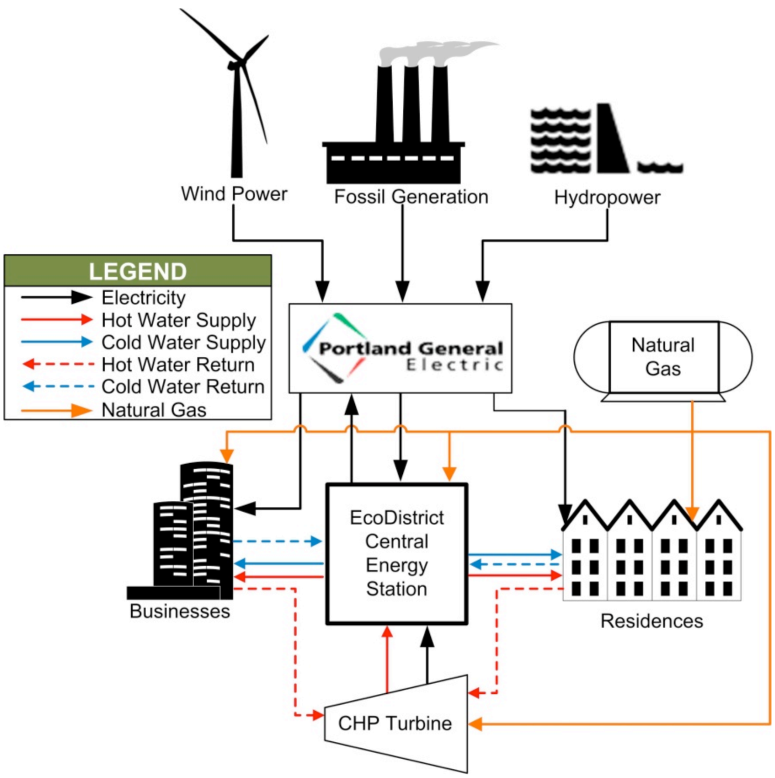

Figure 2 - Ancillary Service Providing Combined Heat and Power System

Business Analysis

We considered the economic viability of using a District Energy system in the same manner as that used by Compass[12]. Instead of internal rate of return (IRR), we used simple payback as our financial comparison metric. We calculated the operation time required to cover all capital and operating costs. We assumed a discount rate of 5%. Independent scenario analyses were performed for the thermal storage option and the CHP option. Capital costs and monthly net revenue streams were estimated.

Revenue streams for Option 1, in which the EcoDistrict buys electricity for return hot water preheating, incorporate estimates of natural gas price, operating and maintenance (O&M) costs, excess wind electricity purchasing rates ($/kWh) and capacity charges ($/kW-month). The latter two components are negotiated with PGE.

Inputs for monthly revenue streams for Option 2, in which the EcoDistrict sells electricity from CHP operations, incorporate natural gas price, O&M costs, electricity sales rates, and capacity charges. The latter two components are again negotiated with PGE, but are different than in Option 1. The tables below show simple paybacks periods for Option 1 and Option 2 under various scenarios defined by non-firm wind availability, natural gas price, electricity purchase price, and capacity charge.

Normal Non-Firm Wind Scenario	Capacity Charge	$5/MWh Energy Price	$20/MWh Energy Price
$5/MMBtu Natural Gas Price	$5/kW/Mo	11	17
	$15/kW/Mo	4	4
$10/MMBtu Natural Gas Price	$5/kW/Mo	4	9
	$15/kW/Mo	3	4

Table 1a

Low Non-Firm Wind Scenario	Capacity Charge	$5/MWh Energy Price	$20/MWh Energy Price
$5/MMBtu Natural Gas Price	$5/kW/Mo	15	20
	$15/kW/Mo	4	4
$10/MMBtu Natural Gas Price	$5/kW/Mo	15	14
	$15/kW/Mo	4	4

Table 1b

Simple Payback Periods for Normal and Low Non-Firm Wind Scenarios
Technology Option 1 Natural Gas Boilers with Electric Resistance & Electric Chillers

Note: Table 1a assumes that downward wind firming ancillary services are needed 15% of the time. Table 1b assumes that wind firming ancillary services are needed only 5% of the time. Sensitivity analysis was also performed under a normal ($5/MMBtu) and high ($10/MMBtu) gas price scenarios.

[12] Compass Resource Management, *Business Analysis for a Neighborhood Energy Utility in the North Pearl District*, March 31, 2009

	Capacity Charge	$67/MWh Energy Price	$100/MWh Energy Price
$5/MMBtu Natural Gas Price	$7.9/kW/Mo	8	4
	$20/kW/Mo	6	4
$10/MMBtu Natural Gas Price	$7.9/kW/Mo	*	9
	$20/kW/Mo	*	7

Table 2
Simple Payback Period Scenarios
Technology Option 2 Combined Heat and Power With Load Following Capabilities

Note: Starred (*) scenarios were not considered because with high natural gas prices the electricity sales price would likely increase substantially presenting significant risk to Option 2.

As can be seen from Tables 1 and 2, both technology options offer simple paybacks that could reasonably result in external project financing. Option 1 offers slightly less attractive simple paybacks but also more manageable risk. Option 2 generally offers more attractive simple payback values, but involves significantly more financial risk due to large initial investment and greater susceptibility to outside factors. In addition, Option 2 offsets significantly more carbon emissions than Option 1, which may have financial implications in the future if carbon pricing constraints become a reality.

Policy Analysis

There are a wide range of stakeholders for both the establishment of District Energy systems and the incorporation of Smart Grid functionalities within that system. Stakeholders include entities with economic interests, regulatory control mandates and enabling infrastructure. For the purposes of this study, we will classify these groups as essential, influential, or interested. We will also review some of the relevant regulations and consider the impact of policy mandates, with a gap analysis on enabling policy for Smart Grid integrated District Energy systems.

In many ways, the most important stakeholder for any Smart Grid enabled District Energy project is the electric utility already serving the district. For both of the technology options evaluated, the relevant utility is Portland General Electric (PGE). Obviously there needs to be a developer for any project and an operating entity. However, without a utility partnership for implementation and ongoing operations, a smart District Energy system cannot succeed technically or financially. In order to foster this partnership, any proposed solution must not compromise the safety of utility employees or the reliability of the broader grid. Additionally, prices for ancillary services provided to the utility and intermittent energy purchases from the utility must be market based and improve the profitability in the eyes of PGE's shareholders.

Organizations that exercise regulatory control over the Smart Grid aspects of the proposed technology options are also essential stakeholders. If the requirements of these groups are not met, no project can be pursued. The Federal Energy Regulatory Commission (FERC) and Oregon Department of Energy (ODOE) are the primary regulators for a prospective smart

District Energy project in Portland. The City of Portland's Office of Communications and Franchise Management would also have extensive control over the permit and franchise requirements. The City's role in a District Energy project would extend beyond permits in order to serve as a true partner in a successful implementation. The City of Portland specifically identified District Energy systems as a crucial component in the ability to meet the aggressive goals set forth in the city's Climate Action Plan. The City also identified that substantial financial incentives would be effective in making the economics more conducive to district development. Portland has positioned itself as a leader in global urban sustainability and can burnish these credentials further by supporting innovative and effective solutions.

Either of the technology options would need to comply with environmental regulations set forth by the U.S. Environmental Protection Agency and Oregon Department of Environmental Quality. The state government, and particularly the state legislature, would play a significant role. Systems that support the scaling of intermittent renewable resources are needed for Oregon to meet its Renewable Portfolio Standards. Incentives such as tax relief or debt-financing support from the state would be consistent with climate action goals.

Summary and Challenges

Both technology options, the thermal storage of non-firm wind energy and the ancillary service providing combined heat and power system, are economically feasible with simple payback periods between ten and twenty years. Furthermore, the options reviewed reduce greenhouse gas (GHG) emissions through more efficient energy conversion. Based on the more attractive financial metrics and substantially increased carbon emission offsets, our recommendation is the implementation of Option 2, the combined heat and power turbine with load following capabilities. The financial risk associated with Option 2, stemming from uncertainty in the price of natural gas, may result in more expensive financing. However, despite the greatly increased initial expenditure, the simple payback periods are likely to be more attractive than the payback periods of Option 1. Option 2 will be capable of meeting the thermal needs of the district while supplying a substantial portion of the district's electrical demand through low-carbon emissions. The implementation of such a system is enabled by responsive Smart Grid technology and high-speed interactive communications equipment. Installation of a load-following District Energy system of this sort in the North Pearl should provide a model for other District Energy systems.

The most significant obstacles for either of the technology options are the lack of established markets for the services they provide. As the need to firm excess variable wind power is tied to the scaling of the wind generation on the grid, the demand for this service is developing. However, a market for these services does not currently exist. Similarly, there is not a developed market for the ancillary services provided by the combined heat and power system in Option 2 on the scale considered in this analysis.

An additional challenge to the implementation of either of the technology options would be the identification or establishment of a qualified operating franchise. There is a dearth of domestic District Energy systems that extend beyond a single entity and the options discussed are novel, complex and based upon unknown and variable revenue sources and supplies. One way to overcome this would be to emulate the District Energy systems of St. Paul, Minnesota, and Vancouver, British Columbia, in the establishment of public or public/private entities to operate the system.