

Estimate of Mitigation Option Costs and Benefits for Washington Energy Supply GHG Analysis

ES-1 Grid-based renewable energy incentives and/or barrier removal

Date Last Modified:

11/04/2007

G. Powell

Key Data and Assumptions	2012	2020	Units
--------------------------	------	------	-------

Renewable requirements

20%	fraction of state sales
-----	-------------------------

From Option Goals:

- Add the maximum amount of feasible grid-based renewables, taking into account the economic, environmental impacts and system reliability
- I-937 requires 15% by 2020

Mix of new renewables

Wind
Solar Thermal
Biomass
Photovoltaic
Geothermal

91%	88%
2%	2%
7%	10%
0%	0%
0%	0%
100%	100%

Switch to check impact of key assumptions

Use alternative scenario (y/n)

n

Base scenario -- the following assumptions are currently in use

Wind capital costs

See note 1

1419	1179	\$/kW
------	------	-------

Wind Capacity Fraction of System Peak	Cost (\$/MWh of Wind Generation)
0%	0.0
5%	\$3
10%	\$6
20%	\$8
30%	\$12.50

*Source : calculations derived from Northwest Wind Integration Action Plan (March 2007)
<http://www.nwcouncil.org/energy/Wind/library/2007-1.htm>*

End-date for PTC

2010

Summary Results for ES-1				2012	2020	Units
--------------------------	--	--	--	------	------	-------

Economic Analysis - Additional Renewables 20% of sales by 2020, all utilities

Total Renewables Added based on generated rather than delivered energy	1,716	6,256	GWh
Avoided electricity emissions rate	0.500	0.500	tCO ₂ /MWh
Total Emissions Reductions	0.9	3.1	MMtCO ₂
Net Present Value (2006-2020)		\$630	\$million
Cumulative Emissions Reductions (2006-2020)		17.2	MMtCO ₂
Cost-Effectiveness		\$36.58	\$/tCO ₂ e

Other Data, Assumptions, Calculations				2012	2020	Units
---------------------------------------	--	--	--	------	------	-------

Electricity Sales

Reference case (accounts for conservation from I-937)	90,580	100,275	GWh
---	--------	---------	-----

Renewable electricity requirements

Targets, fraction of electricity sales -- all utilities included		20%	fraction of sales
<i>Note: this requirement now applies to all utilities, including co-ops, for this option, assume gradual ramp up from 2007 levels</i>			
Renewable generation in I-937 case	4,356	14,239	GWh
Renewable generation in I-937 reference case, as fraction of sales after	5%	14.2%	fraction of sales
<i>Note: does not account for T&D losses in generation</i>			
Feasible Renewables	7%	20%	fraction of sales
Feasible Renewables, delivered	5,947	20,055	GWh
Feasible renewables, generated	6,417	21,571	GWh
Additional renewables for ES1 (excluding reference case renewables)	1,716	6,256	GWh

Calculations in Constant Base Year \$

The following assumptions reflect the Scenario chosen above (top of page)

Production Tax Credit level	18.0	\$/MWh
PTC Period	10	years
PTC End Year	2010	year

Source: o Union of Concerned Scientists. The Washington Clean Average Wind integration Costs

Wind Capacity Fraction of System Peak	Cost (\$/MWh of Wind Generation)
0%	0.0
5%	\$3
10%	\$6
20%	\$8
30%	\$12.50

Wind

Capital Cost	1,419	1,179	\$/kW
Transmission	80	80	\$/kW
Lifetime	20	20	Years
Capital Recovery Factor	11.07%	11.07%	
Levitized Cost	165.91	139.33	\$/kW-yr
Fixed O&M	31.37	25.63	\$/kW-yr
Fixed Costs	197.28	164.96	\$/kW-yr
Capacity Factor	35%	35%	
LevCapCost	64.34	53.80	\$/MWh
Variable O&M	0.00	0.00	\$/MWh
Fixed+Variable Costs	64.34	53.80	\$/MWh

Solar

Capital Cost	2,527	2,309	\$/kW
Transmission	80	80	\$/kW
Lifetime	25	25	Years
Capital Recovery Factor	9.90%	9.90%	
Levitized Cost	257.99	236.42	\$/kW-yr
Fixed O&M	51.70	43.10	\$/kW-yr
Fixed Costs	309.69	279.52	\$/kW-yr
Capacity Factor	25%	25%	
LevCapCost	141.41	127.63	\$/MWh
Variable O&M	0.00	0.00	\$/MWh
Fixed+Variable Costs	141.41	127.63	\$/MWh
Production Tax Credit level		18.0	\$/MWh
PTC Period		10	years
PTC End Year		2010	year

Biomass

Capital Cost	2,155	2,066	\$/kW
Transmission	80	80	\$/kW
Lifetime	30	30	Years
Capital Recovery Factor	9.20%	9.20%	
Levitized Cost	205.64	197.39	\$/kW-yr
Fixed O&M	50.18	50.18	\$/kW-yr
Fixed Costs	255.82	247.57	\$/kW-yr
Capacity Factor	75%	75%	
LevCapCost	38.94	37.68	\$/MWh
Fuel Cost	2.84	2.84	\$/MBtu
Heat Rate	8,911	8,911	Btu/kWh
Fuel Gen Cost	25.31	25.31	\$/MWh
Variable O&M	2.96	2.96	\$/MWh
Fixed+Variable Costs	67.20	65.95	\$/MWh

Solar - Thermal

Capital Cost	2,959	2,784	\$/kW
Transmission	80	80	\$/kW
Lifetime	25	25	Years
Capital Recovery Factor	9.90%	9.20%	
Levitized Cost	300.78	263.50	\$/kW-yr
Fixed O&M	51.70	43.10	\$/kW-yr
Fixed Costs	352.48	306.60	\$/kW-yr
Capacity Factor	25%	25%	
LevCapCost	160.95	140.00	\$/MWh
Variable O&M	0.00	0.00	\$/MWh
Fixed+Variable Costs	160.95	140.00	\$/MWh

Solar - PV

Capital Cost	4,398	3,998	\$/kW
Transmission	80	80	\$/kW
Lifetime	20	20	Years
Capital Recovery Factor	9.90%	9.90%	
Levelized Cost	443.13	403.52	\$/kW-yr
Fixed O&M	10.60	8.90	\$/kW-yr
Fixed Costs	453.73	412.42	\$/kW-yr
Capacity Factor	25%	25%	
LevCapCost	207.18	188.32	\$/MWh
Variable O&M	0.00	0.00	\$/MWh
Fixed+Variable Costs	207.18	188.32	\$/MWh

Geothermal

Capital Cost	3,941	4,925	\$/kW
Transmission	80	80	\$/kW
Lifetime	30	30	Years
Capital Recovery Factor	9.20%	9.20%	
Levelized Cost	369.94	460.49	\$/kW-yr
Fixed O&M	75.00	68.20	\$/kW-yr
Fixed Costs	444.94	528.69	\$/kW-yr
Capacity Factor	85%	85%	
LevCapCost	59.76	71.00	\$/MWh
Variable O&M	0.00	0.00	\$/MWh
Fixed+Variable Costs	59.76	71.00	\$/MWh

Other Data, Assumptions, Calculations	2012	2020	Units
---------------------------------------	------	------	-------

BAU total generation	115,788	126,177	GWh
Renewable Energy to meet I-937	1,993	14,239	GWh
BAU Renewable Energy	4,356	4,805	GWh
Total renewable energy (BAU + I-937 requirements)	4,356	14,239	GWh
BAU %	0.0%	0.0%	%
Wind Fraction	0.0%	0.0%	%
BAU Renewables Generation	4,356	14,239	GWh
electricity sales after efficiency measures	90,580	100,275	GWh

New Renewable requirement	6.6%	20.0%	%
---------------------------	------	-------	---

Total Renewables (assuming ramp up starting in 2008)	5,947	20,055	GWh
Added Renewables Requirement	1,591	5,816	GWh
Incremental Additions	835	1,164	GWh

New RPS Fractions

Wind	91.0%	88.0%	Credit Mult
Solar Thermal	2.0%	2.0%	
Biomass	7.0%	10.0%	
Photovoltaic	0.0%	0.0%	
Geothermal	0.0%	0.0%	
RPS Extra Credit for Solar/Geothermal/Biomass			

RPS Annual Additions (adjusted for RPS factors)

Wind	760	1,024	GWh
Solar Thermal	17	23	GWh
Biomass	58	116	GWh
Photovoltaic	0	0	GWh
Geothermal	0	0	GWh
Total Additions	835	1,164	GWh

RPS Cumulative

Wind	1,447	5,214	GWh
Solar Thermal	32	116	GWh
Biomass	111	485	GWh
Photovoltaic	0	0	GWh
Geothermal	0	0	GWh

Total Washington Peak Generation	18,444	20,071	MW
----------------------------------	--------	--------	----

BAU Wind Generation	4,356	14,239	GWh
BAU Wind Capacity	1,421	4,644	MW
BAU Wind Capacity Fraction	7.7%	23.1%	%
BAU Integration Price	\$5	\$9	\$/MWh
BAU Integration Cost	\$20	\$134	\$million

Total Wind Generation	5,804	19,453	GWh
Total Wind Capacity	1,893	6,345	MW
Total Wind Capacity Fraction	10.3%	31.6%	%
Total Integration Price	\$6	\$13	\$/MWh
Total Integration Cost	\$35	\$257	\$million

Program Additional Wind Integration Costs	\$15	\$123	\$million
---	------	-------	-----------

New Capacity

Wind	472	1,701	MW
Solar Thermal	15	53	MW
Biomass	17	74	MW
Photovoltaic	0	0	MW
Geothermal	0	0	MW

Additions Levelized Price

Wind	\$61	\$54	\$/MWh
Solar Thermal	\$137	\$128	\$/MWh
Biomass	\$67	\$66	\$/MWh
Photovoltaic	\$201	\$188	\$/MWh
Geothermal	\$64	\$71	\$/MWh

First Year Levelized Cost

Wind	\$46	\$55	\$million
Solar Thermal	\$2	\$3	\$million
Biomass	\$4	\$8	\$million
Photovoltaic	\$0	\$0	\$million
Geothermal	\$0	\$0	\$million

PTC Payment

Wind	\$0	\$0	\$/MWh
Solar Thermal	\$0	\$0	\$/MWh
Biomass	\$0	\$0	\$/MWh
Photovoltaic	\$0	\$0	\$/MWh
Geothermal	\$0	\$0	\$/MWh

PTC Levelization Adjustment

Wind	\$0	\$0	\$million
Solar Thermal	\$0	\$0	\$million
Biomass	\$0	\$0	\$million
Photovoltaic	\$0	\$0	\$million
Geothermal	\$0	\$0	\$million

Annual Program Costs

Wind	\$104	\$425	\$million
Solar Thermal	\$4	\$15	\$million
Biomass	\$4	\$29	\$million
Photovoltaic	\$0	\$0	\$million
Geothermal	\$0	\$0	\$million
<u>Total</u>	\$112	\$469	\$million

Avg Program Cost

\$71	\$81	\$/MWh
------	------	--------

Avoided Generation Cost

\$43	\$43	\$/MWh
------	------	--------

Program Avoided Costs

Wind	\$63	\$227	\$million
Solar Thermal	\$1	\$5	\$million
Biomass	\$5	\$21	\$million
Photovoltaic	\$0	\$0	\$million
Geothermal	\$0	\$0	\$million

Net Program Costs

Wind	\$41	\$199	\$million
Solar Thermal	\$3	\$10	\$million
Biomass	-\$1	\$8	\$million
Photovoltaic	\$0	\$0	\$million
Geothermal	\$0	\$0	\$million
<u>Total</u>	\$43	\$217	\$million

Biomass Consumption

992,188	4,324,680	MMBTU
62,012	270,292	dry tons

NOTES AND DATA FROM SOURCES

Note 1:

Based on conversation with Ken Dragoon of Renewable Northwest Project and info from PSE and Avista. Previous estimate for 2008 was \$1557/kW; previous estimate for 2025 was \$1050/kW. New estimate for 2008 is \$2000/kW; the 2025 estimate is based on ratios from the previous estimate.

Estimate of Mitigation Option Costs and Benefits for Washington Energy Supply GHG Analysis

ES-2 Distributed renewable energy incentives and/or barrier removal

Date Last Modified: 11/05/2007

G. Powell

Key Data and Assumptions	2012	2020/all	Units
First Year Results Accrue		2009	
Option Design Elements:			
Target Year for Reaching Solar Hot Water (SHW) Implementation Level		2015	
Fraction of additional existing Washington Homes with Solar HW by Target Year		0.8%	
<i>Using the Western Governor's Association estimate of 500,000 systems installed by 2015 for entire region. The WA fraction was estimated using same fraction as used for WGA estimates of Solar PV by state (accounting for electricity use, solar insolation, and population growth).</i>			
Target Year for Reaching Distributed Wind Generation Implementation Level		2020	
Additional WA Distributed Wind Generation Achieved by Target Year		30.0	MW
<i>Placeholder for now (See Note 7 for WA specific information)</i>			
Target Year for Reaching Solar PV Implementation Level		2020	
Additional WA Solar PV Achieved by Target Year		20.0	MW
<i>Placeholder for now (See Note 9 for WA specific information)</i>			
Target Year for Reaching Biomass/Landfill Gas/Biogas Implementation Level		2020	
Additional WA Biomass/Landfill Gas/Biogas Achieved by Target Year		50.0	MW
<i>Placeholder for now</i>			
Avoided Electricity Cost		\$43	\$/MWh
<i>Weighted average over total 2007-2020 electricity savings for this policy in each sector. See common assumptions ("Common Factors" worksheet in this workbook).</i>			
Avoided Natural Gas Cost		\$11.4	\$/MMBtu
<i>See common assumptions ("Common Factors" worksheet in this workbook)</i>			
Avoided LPG Cost		\$8	\$/MMBtu
<i>See common assumptions ("Common Factors" worksheet in this workbook)</i>			

Results	2012	2020	Units
Savings due to Implementation of ES-2 Programs			
Electricity			
TOTAL Reduction in Electricity Sales (savings from SWH/CHP plus electricity output from CHP/Solar PV and landfill gas/biomass/biogas systems)	141	406	GWh (sales)
Reduction in Generation Requirements	152	436	GWh (generation)
Gross GHG Emission Savings	0	0.22	MMtCO ₂ e
Natural Gas			
Net Change in Gas Use (negative values denote increased use)	99	181	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.01	0.01	MMtCO ₂ e
Landfill Gas			
Net Change in Gas Use (negative values denote increased use)	-21	-125	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.0000	0.0000	MMtCO ₂ e
Biomass			
Net Change in Biomass Use (negative values denote increased use)	-475	-2,850	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.000	0.000	MMtCO ₂ e
Biogas			
Net Change in Gas Use (negative values denote increased use)	0	0	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.0000	0.0000	MMtCO ₂ e

Summary Results for ES-2 (DG)	2012	2020	Units
-------------------------------	------	------	-------

Total for Policy (Electricity, Natural gas, LPG, Oil, Landfill Gas, Biomass, Biogas)

GHG Emission Savings	0.13	0.31	MMtCO ₂ e
Net Present Value (2007-2020)		\$124	\$million
Cumulative Emissions Reductions (2007-2020)		2.3	MMtCO ₂ e
Cost-Effectiveness		\$54	\$/tCO ₂ e

Total for Solar Hot Water

GHG Emission Savings	0.06	0.11	MMtCO ₂ e
Net Present Value (2007-2020)		\$3	\$million
Cumulative Emissions Reductions (2007-2020)		1.0	MMtCO ₂ e
Cost-Effectiveness		\$3	\$/tCO ₂ e

Total for Distributed Wind Generation

GHG Emission Savings	0.02	0.05	MMtCO ₂ e
Net Present Value (2007-2020)		\$9	\$million
Cumulative Emissions Reductions (2007-2020)		0.3	MMtCO ₂ e
Cost-Effectiveness		\$29	\$/tCO ₂ e

Total for Solar PV

GHG Emission Savings	0.01	0.02	MMtCO ₂ e
Net Present Value (2007-2020)		\$86	\$million
Cumulative Emissions Reductions (2007-2020)		0.1	MMtCO ₂ e
Cost-Effectiveness		\$705	\$/tCO ₂ e

Total for Biomass/Landfill Gas/Biogas

GHG Emission Savings	0.04	0.13	MMtCO ₂ e
Net Present Value (2007-2020)		\$25	\$million
Cumulative Emissions Reductions (2007-2020)		0.9	MMtCO ₂ e
Cost-Effectiveness		\$29	\$/tCO ₂ e

Other Data, Assumptions, Calculations	2012	2020/all	Units
---------------------------------------	------	----------	-------

Residential Sector Water Heating

Number of Total Housing Units in Washington (thousand)	2,956,453	3,210,585	
Estimates of			
Source: Population Division, U.S. Census Bureau			
Release Date: August 15, 2007			

Assumes 2005 ratio of new homes to increase in population holds through 2020.

Fraction of Additional Housing Units Solar Water Heat through Program	0.4%	0.8%	
See assumptions above			

Fraction of Housing Units Using Non-Solar Water Heat In Absence of Program

Fraction Using Electricity	42.0%	42.0%
Fraction Using Natural Gas	58.0%	58.0%
Fraction Using LPG	0.0%	0.0%
Fraction Using Solar (alone or with back-up, before policy)	0.0%	0.0%

Rough Estimates using NW region mix for new houses, From NW Alliance Water Heater Market Study, nwalliance.org/research/reports/06-158.pdf

Use of Electricity and Other (non-solar) Energy Sources per (non-solar) Household in Absence of Program

Electricity	4,000	3,810	kWh
Natural Gas	17.96	17.27	MMBtu
LPG	17.96	17.27	MMBtu

Value for 2010 assumes 4000 kWh per HH using electricity for water heat, which is a rough estimate pending receipt of state-specific data. Estimates for gas and lpg base on average EF of .93 for Electricity, .7 for Natural Gas/LPG. Value in 2020 assumes a 5% reduction in energy intensity

Additional Households Using Solar HW Under Program (thousand)	12.7	24.1
---	------	------

Fraction of household hot water needs provided by solar HW units	75.0%	75.0%
--	-------	-------

Placeholder Assumption--Back-up fuels used for water heating in housing units with solar water heating are assumed to be distributed based on the pre-Policy fractions given above. (placeholder based on report for Environment Canada)

Savings of Electricity and Other (non-solar) Energy Sources Due to Program

Electricity	15.8	28.9	GWh
Natural Gas	0.099	0.181	TBtu
LPG	-	-	TBtu

Capital Cost of Solar Water Heater

\$2,534	\$2,200
----------------	----------------

Assumption used in EIA's Annual Energy Outlook 2007. <http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/residential.pdf>

Implied Cumulative Additional Annualized Capital Costs for Residential Solar Hot Waters Installed

as a Result of Policy (thousand 2005 dollars)	\$ 2,182	\$ 3,601
---	-----------------	-----------------

Factors for Annualizing Capital Costs (Residential Solar Hot Water Systems)

Interest Rate (real)	7%/yr
Economic Life of System	20 years
Implied Annualization Factor	9.44%/yr
Marginal Federal Tax Rate, Residential	28%

Intermediate Results: Residential SWH Program

Reduction in Electricity Sales from SWH Program: Residential	16	29	GWh (sales)
Reduction in Generation Requirements	17	31	GWh (generation)
GHG Emission Savings	0.01	0.02	MMtCO ₂ e

Economic Analysis (for Electricity Savings due to SWH Program)

Net Present Value (2007-2020)	2	\$million
Cumulative Emissions Reductions (2007-2020)	0.1	MMtCO ₂ e
Cost-Effectiveness	\$14.09	\$/tCO ₂ e

Natural Gas

Savings due to Implementation of SWH Program

Reduction in Gas Use	99	181	Billion BTU
GHG Emission Savings	0.05	0.10	MMtCO ₂ e

Economic Analysis (for Gas Savings due to SWH Program)

Net Present Value (2007-2020)	\$1.2	\$million
Cumulative Emissions Reductions (2007-2020)	0.84	MMtCO ₂ e
Cost-Effectiveness	\$1.46	\$/tCO ₂ e

LPG

Savings due to Implementation of SWH Program

Reduction in Gas Use	0	0	Billion BTU
GHG Emission Savings	0.00	0.00	MMtCO ₂ e

Economic Analysis (for LPG Savings due to SWH Program)

Net Present Value (2007-2020)	0	\$million
Cumulative Emissions Reductions (2007-2020)	0.000	MMtCO ₂ e
Cost-Effectiveness	#DIV/0!	\$/tCO ₂ e

Distributed Wind Generation

Washington Potential for Distributed Wind

30

 MW
Placeholder for now (See Note 7 for WA specific information)

Estimated Future Washington Potential for Distributed Wind

10	30
----	----

 MW
Potential assumed to scale with forecast commercial plus industrial electricity sales.

Fraction of Potential Installed Under Program (Cumulative)

100.0%	100.0%
--------	--------

MW Wind Installed Under Program (annual installations)

3	3
---	---

 MW

Average full-capacity-equivalent hours of operation for New CHP units:
(Assumption based on capacity factors of :)

3,066	3,066
35.0%	35.0%

Placeholder, from Energy Trust Oregon 2004 report by Wiser et al., based on 1.5MW system. See Note 4.

Implied Cumulative Distributed wind Electricity Output (GWh)
 Wind

31	92
----	----

Inputs to Cost Estimates for Distributed Wind Systems

Estimated Average Installed Capital Costs by System Type (\$2005/kW)
 Wind

\$ 2,388	\$ 1,194
----------	----------

 \$/kW
Placeholder, from Energy Trust Oregon 2004 report by Wiser et al., based on 1.5MW system. See Note 4.

Factors for Annualizing Capital Costs (all plant types)

Interest Rate	8%/yr
Economic Life of System	20 years
Implied Annualization Factor	10.19%/yr

Estimated Average Non-fuel Operating and Maintenance Costs by System Type (\$/MWh)
 Wind

\$ -	\$ -
------	------

Intermediate Results for Cost Estimates

Total Capital Costs for New Systems (thousand 2005 dollars)
 Wind

\$ 5,373	\$ 2,985
----------	----------

Annualized Capital Costs for All Systems (thousand 2005 dollars)
 Wind

\$ 2,341	\$ 5,625
----------	----------

Annual Non-Fuel Operating and Maintenance Costs for All Systems (thousand 2005 dollars)
 Wind

\$ -	\$ -
------	------

Total Non-Fuel Costs for All Systems (thousand 2005 dollars)
 Natural Gas

\$ 2,341	\$ 5,625
----------	----------

Intermediate Results: Distributed Wind Electricity

TOTAL Reduction in Electricity Sales (electricity output from wind generation)	31	92	GWh (sales)
Reduction in Generation Requirements	33	99	GWh (generation)
Gross GHG Emission Savings	0.02	0.05	MMtCO ₂ e

Total for Distributed Wind Program

Net Present Value (2007-2020)	\$9	\$million
Cumulative Emissions Reductions (2006-2020)	0.3	MMtCO ₂ e
Cost-Effectiveness	\$28.90	\$/tCO ₂ e

Solar Photovoltaics (PV)Total Additional Capacity of PV Built under Program

6.7	20.0
-----	------

 MWAnnual Additional Capacity of PV Built under Program

1.7	1.7
-----	-----

 MW

Fraction of Additional Capacity As

Residential PV Systems

20%	20%
-----	-----

Commercial PV Systems

80%	80%
-----	-----

Average Capacity of Solar PV System Installed on Homes (kW)

3.00	3.00
------	------

*Assumption, consistent with capacity assumption used in Source in Note 2.*Average Capacity of Solar PV System Installed on Commercial Buildings (kW)

20.00	20.00
-------	-------

*Assumption, roughly consistent, per square foot of floor area, with capacity assumptions for new and existing residential buildings used in Source in Note 2. See also Note 6 for calculation of average floor area of commercial buildings.*Number of Homes Installing Solar PV Systems Annually

111	111
-----	-----

Total Number of Homes with Solar PV Systems Installed under this Option,

2009 to 2020:

1,333

*Note that a cumulative ~4,300 solar PV systems by 2020 is considerably less, on a per-capita basis, than the 1.2 million solar homes by 2020 used in an estimate of solar PV contributions to GHG emissions reduction in California (see Note 2).*Implied number of Commercial Solar PV Systems Added Annually

67	67
----	----

*Calculated based on target capacity and capacity-per-building assumption above.*Total Annual Residential Solar PV Capacity Installed on Homes (MW)

0.33	0.33
------	------

 MWTotal Annual Commercial Solar PV Capacity Installed (all Buildings) (MW)

1.33	1.33
------	------

 MWEstimated Annual Total Solar PV Installed Under Policy by Year (MW)

1.67	1.67
------	------

 MWEstimated Cumulative Total Solar PV Installed Under Policy by Year (MW)

6.67	20.00
------	-------

 MWAverage full-capacity-equivalent hours of operation for Solar PV Systems:

1,752	1,752
-------	-------

*Based on WGA report for Solar--See Note 4.**(Assumption based on capacity factors of :)*Implied New Solar PV Output, Cumulative Systems (GWh)

11.68	35
-------	----

 GWh**Inputs to Cost Estimates for Solar PV Systems (Data from Source in Note 3)**

Capital Costs for PV Systems for Homes

Total System - \$/kW

\$ 4,904	\$ 3,265
----------	----------

Total System - \$

\$ 14,712	\$ 9,795
-----------	----------

WGA report, See Note 1, assume additional decrease in cost after 2015 at half the rate of decrease from 2010 to 2015

Commercial System Capital costs/kW Relative to New Residential

Total System - \$/kW

\$ 2,464	\$ 1,870
----------	----------

Total System - \$

\$ 49,280	\$ 37,400
-----------	-----------

*WGA report, includes Federal incentives, See Note 1, assume additional decrease in cost after 2015 at half the rate of decrease from 2010 to 2015*Solar PV Operating and Maintenance (O&M) Costs (\$/MWh)

\$ 10.00	\$ 5.00
----------	---------

*WGA report,*Federal Solar Tax Credits: Residential Sector--See Note 3

0%	0%
----	----

Federal Solar Tax Credits: Commercial and Industrial Sectors--See Note 3

0%	0%
----	----

already accounted for in capital costs

Factors for Annualizing Capital Costs (Residential PV Systems)

Interest Rate

7%

/yrEconomic Life of System

20

 yearsImplied Annualization Factor

9.44%

/yrMarginal Federal Tax Rate, Residential

28%

Factors for Annualizing Capital Costs (Commercial PV Systems)

Interest Rate

8%

/yrEconomic Life of System

20

 yearsImplied Annualization Factor

10.19%

/yrReduce Capital Costs for Solar Tax Credits and Federal Mortgage Deductions?

NO

Intermediate Results for Solar PV System Cost Estimates

Total Capital Costs for New Systems (thousand 2005 dollars) Before Tax Credits

Systems for Residences	\$ 1,635	\$ 1,088
Systems for Commercial Installations	\$ 3,285	\$ 2,493

Annualized Capital Costs for All Systems (thousand 2005 dollars)

Systems for Residences	\$ 680	\$ 1,647
Systems for Commercial Installations	\$ 1,440	\$ 3,699

Annual Operating and Maintenance Costs for All Systems (thousand 2005 \$)

\$ 93	\$ 175
-------	--------

Intermediate Summary Results for Solar PV Generation Program

Total Electricity Output	11.7	35.0	GWh (sales)
Reduction in Generation Requirements	13	38	GWh (generation)
Gross GHG Emission Savings	0.01	0.02	MMtCO ₂ e
Total Cost (net of value of electricity output)	\$ 8	\$ 21	\$million
Net Present Value (2007-2020)		\$86	\$million
Cumulative Emissions Reductions (2006-2020)		0.1	MMtCO ₂ e
Cost-Effectiveness		\$704.62	\$/tCO ₂ e

Biomass/Landfill Gas/Biogas-fueled Systems

Total Additional Capacity of Biomass/LFG/Biogas Built under Program

16.7	50.0
------	------

 MW

Annual Additional Capacity of Biomass/LFG/Biogas Built under Program

4.2	4.2
-----	-----

 MW

Fraction of Additional Capacity as

Landfill Gas	5%	5%
Biomass	95%	95%
Biogas	0%	0%

The Agriculture, Forestry, and Waste TWG will account for biogas

Implied Annual New Biomass/Landfill Gas/Biogas-fueled Capacity by Fuel (MW)

Landfill Gas	0.21	0.21
Biomass	3.96	3.96
Biogas	-	-

Implied Cumulative New Biomass/Landfill Gas/Biogas-fueled Capacity by Fuel (MW)

Landfill Gas	0.42	2.50
Biomass	7.92	47.50
Biogas	-	-

Average Full-capacity-equivalent Hours of Operation for Systems Above:

Placeholder Assumptions	5,000	5,000
-------------------------	-------	-------

Inputs to Cost Estimates for Biomass/Landfill Gas/Biogas-fueled Systems

Estimated Average Installed Capital Costs by System Type (\$2005/kW)

Landfill Gas	\$ 2,000	\$ 1,500
Biomass	\$ 2,500	\$ 2,200
Biogas	\$ 2,500	\$ 2,200

Placeholder Assumptions

Factors for Annualizing Capital Costs (all plant types)

Interest Rate	8%/yr
Economic Life of System	20 years
Implied Annualization Factor	10.19%/yr

Estimated Average Non-fuel Operating and Maintenance Costs by System Type (\$/MWh)

Landfill Gas	\$ 20.00	\$ 20.00
Biomass	\$ 20.00	\$ 20.00
Biogas	\$ 20.00	\$ 20.00

Placeholder Assumptions

Implied Cumulative New Biomass/Landfill Gas/Biogas-fueled Electricity Output by Fuel (GWh)

Landfill Gas	2.1	12.5
Biomass	39.6	237.5
Biogas	-	-

Average Net Heat Rate by Fuel (Btu Fuel Input/kWh Electricity Output)

Landfill Gas	10,000	10,000
Biomass	12,000	12,000
Biogas	10,000	10,000

Placeholder Assumptions

Implied Fuel Input by Fuel (Billion Btu)

Landfill Gas	21	125
Biomass	475	2,850
Biogas	-	-

Intermediate Results for Biomass/Landfill Gas/Biogas-fueled Cost Estimates

Total Capital Costs for New Systems (thousand 2005 dollars)

Landfill Gas	\$ 417	\$ 313
Biomass	\$ 9,896	\$ 8,708
Biogas	\$ -	\$ -

Annualized Capital Costs for All Systems (thousand 2005 dollars)

Landfill Gas	\$ 85	\$ 454
Biomass	\$ 2,016	\$ 11,466
Biogas	\$ -	\$ -

Annual Non-Fuel Operating and Maintenance Costs for All Systems (thousand 2005 dollars)

Landfill Gas	\$ 42	\$ 250
Biomass	\$ 792	\$ 4,750
Biogas	\$ -	\$ -

Total Non-Fuel Costs for All Systems (thousand 2005 dollars)

Landfill Gas	\$ 127	\$ 704
Biomass	\$ 2,807	\$ 16,216
Biogas	\$ -	\$ -

Total Fuel Costs for All Systems (thousand 2005 dollars)

Landfill Gas	\$ -	\$ -
Biomass	\$ -	\$ -
Biogas	\$ -	\$ -

Intermediate Summary Results for Biomass/LFG/Biogas Generation Program

Total Electricity Output	83.3	250.0	GWh (sales)
Reduction in Generation Requirements	90	269	GWh (generation)
Gross GHG Emission Savings	0.04	0.13	MMtCO ₂ e
Total Cost (net of value of electricity output)	\$ 2	\$ 6	\$million
Net Present Value (2007-2020)		\$25	\$million
Cumulative Emissions Reductions (2006-2020)		0.9	MMtCO ₂ e
Cost-Effectiveness		\$28.96	\$/tCO ₂ e

NOTES AND DATA FROM SOURCES

Note 1:

From Western Governor's Association, Clean and Diversified Energy Initiative
Solar Task Force report <http://www.westgov.org/wga/initiatives/cdeac/index.htm>

Table 1. Current and Projected Levelized Cost of Energy for PV Systems

Year	Residential Systems (no incentives)			Commercial Systems (w/ ITC and MACRS)		
	2005	2010	2015	2005	2010	2015
Interest Rate (real) (i) *	4.0%	4.0%	4.0%	5.0%	5.0%	5.0%
System Lifetime (n)	25	30	30	25	30	30
Capital Recovery Factor (CRF)	0.064	0.058	0.058	0.071	0.065	0.065
System Selling Price (\$/Wdc)	7.30	5.17	3.89	6.00	4.41	3.60
AC-DC Conversion Efficiency (%)	91%	94%	97%	93%	95%	97%
AC Equiv. System Price (\$/Wac)	8.02	5.50	4.01	6.45	4.64	3.71
Fed ITC Rate (at permanent 10% level)	-	-	-	10%	10%	10%
Value of Fed ITC	-	-	-	0.65	0.46	0.37
Sys Cost after Fed ITC	-	-	-	5.81	4.18	3.34
Fed Accelerated Depreciation (Net Present Value)**	-	-	-	34%	34%	34%
Value of Fed Acc Dep. (basis = .95*system cost)	-	-	-	2.08	1.50	1.20
Final Cost (\$/Wac) (ICC)	8.02	5.50	4.01	3.72	2.68	2.14
Capacity Factor (CF)	21%	21%	21%	18.5%	18.5%	18.5%
O&M	0.02	0.01	0.005	0.02	0.01	0.005
Levelized Cost of Energy (LCOE) (cents/kWh)***	29.9	18.3	13.1	18.3	11.8	9.1

* These are real interest rates (i.e., adjusted for inflation and tax benefits) not nominal interest rates.
 ** Based on MACRS rates from IRS Publication 946, Table A-2 (assuming investment is made in 1st quarter of the year).
 *** The LCOE values were calculated using the standard formula for amortization of cost over time, assuming the system is financed through a loan matched to the lifetime of the system.
 $LEC = (ICC \times 1000 \times CRF) / (CF \times 8760) + O\&M$, where
 $ICC = \text{Installed Capacity Cost } (\$/Wp)$,
 $CRF = \text{Capital Recovery Factor} = (i^n(i+1)^n) / ((i+1)^n - 1)$,
 $CF = \text{Capacity Factor}$,
 $O\&M = \text{Operation and Maintenance } (\$/kWh)$,
 $i = \text{interest rate}$,
 $n = \text{system lifetime (i.e., how many years to amortize cost of system over)}$.

Note 2:

Source: Worksheet "Solar Homes Summary table.xls", with calculations in support of the California Million Solar Homes Initiative, authored by XENERGY, Inc., and provided by M. Lazarus. Selected annual data provided.

Note 3:

A description of the new Federal Solar Tax Credits for businesses and residences as contained in the Energy Policy Act of 2005 (EPA 2005) (see, for example, <http://www.seia.org/getpdf.php?id=21>) provides for 30% (of system cost) tax credits for solar PV investments by businesses in 2006 and 2007, reverting to 10% thereafter. For residences, the credit in 2006 and 2007 is 30% with a "cap" of \$2000, reverting to zero after 2007. See also, for Example, <http://www.sdenenergy.org/uploads/PV-Federal%20Tax%20Credits%20Summary%206-01-04%20FINAL.pdf>.

Note 4:

Information from a report prepared for the Energy Trust of Oregon, prepared by Mark Bolinger, Ryan Wiser, Tom Wind, Dan Juhl, and Robert Grace (2004)
A Comparative Analysis of Community Wind Power Development Options in Oregon
<http://www.oregon.gov/ENERGY/RENEW/Wind/docs/CommunityWindReportLBLforETO.pdf>

Note 5:

Source: International Energy Agency (IEA), TRENDS IN PHOTOVOLTAIC APPLICATIONS
Survey report of selected IEA countries between 1992 and 2004. Report #IEA-PVPS T1-14:2005.
 Page 18.

"Indicative costs" in 2004 in USD per kWp (assumedly DC output) for on-grid PV systems in the US:

<10 kW	7000 to 10,000
>10 kW	6300 to 8500

In EIA Projections of Renewable Energy Costs, presented in "Forum on the Economic Impact Analysis of NJ's Proposed 20% RPS" by Chris Namovicz of the USDOE EIA (Energy Information Administration), dated February 22, 2005, and available as <http://www.eia.doe.gov/oiaf/pdf/rec.pdf>, a wind power average cost of

6000	dollars/kW is provided for a 25 kW Commercial system, or
8200	dollars/kW for a 2 kW Residential system, with

"Large potential for cost reduction".

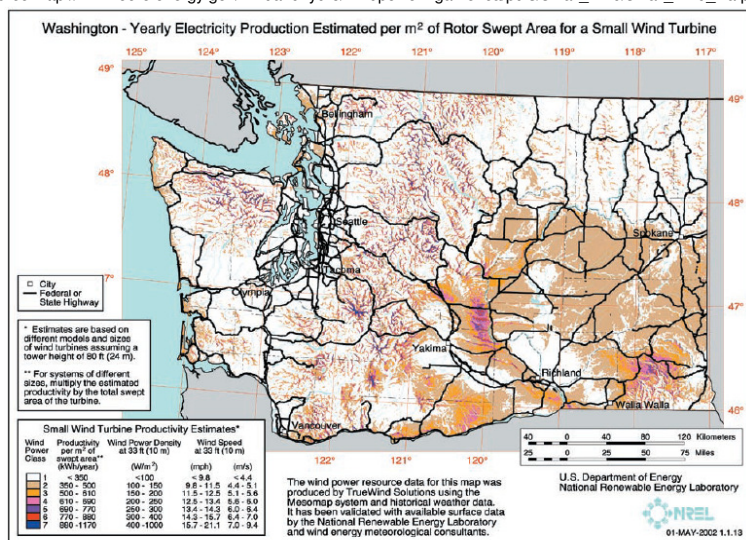
Note 6:

An older (1997) US DOE document OVERVIEW OF PHOTOVOLTAIC TECHNOLOGIES (available as http://www.eere.energy.gov/ba/pdfs/pv_overview.pdf) suggests that even early solar PV systems had O&M costs of under \$ 0.005 per kWh, which in 2005 dollars would be: \$ 0.0059 per kWh.

Note 7:

Small Wind Potential in WA:

Source: http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/small_wind/small_wind_wa.pdf



Source: http://www.awea.org/smallwind/documents/AWEA_SWT_Market_Study_6-05.pdf
 Home and Farm Wind Energy Systems: Reaching the Next Level
 AWEA Global Small Wind Industry Market Study Confirms Need for Level Playing Field: June 2005

30 MW of small wind capacity installed in US between 1990 - 2004.
 Small wind companies project growth targets of 18-21% by 2010, 107 MW by 2010.

Source: Renewable Energy Atlas of the West: http://www.energyatlas.org/PDFs/LowRes/atlas_state_WA.pdf
 Total WA wind potential: 62 million MWh/yr

Source: WA Governor's Report: Wind Supply Task Force <http://www.westgov.org/wga/initiatives/cdeac/Wind-full.pdf>
 240 MW wind capacity installed in WA as of 2004

Wind Potential in WA: 1,050 MW by 2015 under scenario 1

Scenario 1. Wind development that is either in progress or can be reasonably assumed to occur based on existing plans with minimal new transmission additions. Evidence from prior work on the ability of new transmission tariffs and related policy implementation was assumed to help stimulate wind additions. This represents a near-term goal.

Note 8:

Water Heater Fuel Sources

DOE, AEO 2007:

Residential Fuel Source for Water Heaters in the West:

- Electricity: 15 million homes: 64%
- Natural Gas: 7.9 million homes: 33%
- LPG: 0.7 million homes: 3%

Source: <http://nwalliance.org/research/reports/06-158.pdf>

Northwest Energy Efficiency Alliance Proprietary

Water Heater Market Study

Retrofit water heaters: 57% electric and 43% natural gas

New construction water heaters: 48% electric and 52% natural gas

Note 9:

Distributed Solar PV

Source: <http://www.westgov.org/wga/initiatives/cdeac/Solar-full.pdf>

Western Governor's Report:

By 2015:

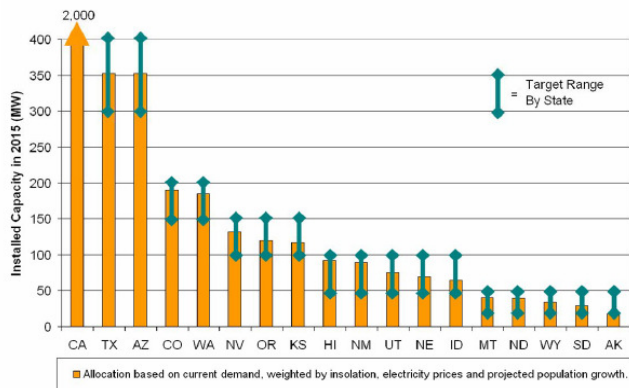
4,000 MW of distributed solar PV

WA potential:

Based on current demand, weighted by the amount of sunshine, electricity prices and projected population growth

WA installed capacity in 2015 184 MW +/- 10 MW

Figure II-1. Weighted Allocation of Installed Capacity in WGA States (Total = 4GW in 2015)



Source: NREL

State	Electricity Demand (TWh) ¹	Initial Share	Solar Insolation (kWh/kW) ²	Insolation Multiplier	Average Electricity Price 2003 (¢/kWh) ³	Electricity Price Multiplier 2003	Population 2005 (million) ⁴	Population 2015 (million) ⁴	10 Year Population Growth Index	Population Growth Multiplier	Final Share ⁵	Final Allocation (MW)
WA	79.7	17.3%	1139	0.72	5.9	0.94	6.205	6.951	1.12	1.03	11%	184

Source: PV Grid Connected Market Potential under a Cost Breakthrough Scenario: The Energy Foundation: Sept 2004

<http://www.ef.org/documents/EF-Final-Final2.pdf>

State	2025 Technical Ultimate Potential (MWp)		Total	% share of U.S Total	% share of Residential
	Residential Total	Commercial Total			
Washington	13,337	11,297	24,633	2%	54%

Note 10

Solar Hot Water

Source: <http://www.westgov.org/wga/initiatives/cdeac/Solar-full.pdf>
Western Governor's Report:

By 2015:

500,000 solar hot water systems could be installed providing the equivalent of 2,000 MW generating capacity and 15 billion ft³ of natural gas

As an example, Hawaiian Electric Company's Energy Solutions Solar Water Heating Program has grown to over 3,000 systems per year since its inception in 1996

European countries have also instituted a series of very successful incentive programs for solar water and space heating systems, enabling them to make significant progress and poising them for continued growth. Incentive programs are quite modest in countries with the most active solar water heating programs with rebates ranging from \$300 to \$1400 per system depending on size. Many of these countries have substantially less solar resource than that available in the Western US, yet they have more aggressive solar thermal programs. A subset of seven European Union countries⁴⁰ together installed approximately 250,000 solar thermal systems in 2003, or 875 MW_{th} equivalent.⁴¹ Austria alone (population of 8.1 million) has an existing installed solar thermal generating capacity of 1,469 MW_{th}, equal to all of the installed solar thermal capacity in the entire US (population 294 million). Israel, with the population roughly equivalent to Arizona, is home to 5 percent of the world's solar water heating deployments. By contrast, the US solar thermal market for water heating has been stagnant for a number of years at around 8,000 systems.

WGA goal
500000 systems for entire WGA region

scale this goal to Washington based on the ratio used for PV in WGA report, see Note 9

WGA goals for Solar PV

WGA region 4000 MW
WA 184 MW
WA's fraction 5%

WA Solar Hot wa 23000 systems
3,066,505 number of WA households in 2015
0.8% Fraction of homes in 2015

Note 11

Biomass/LFG/Biogass

Source: NW Council's Fifth Power Plan

			Capacity
Wood residue	1000-1700	aMW	1588 MW
Landfill gas	100-200	aMW	176 MW
Animal manure		50 aMW	59 MW
Pulping chemical recovery		280 aMW	329 MW
Biomass			1918 MW
Biogas			59 MW
Washington % of population			51.20%
Biomass in Washington (estimated based on population)			982 MW
Landfill gas in Washington (based on EPA LMOP numbers)			48 MW
<i>Source: EPA's LMOP http://www.epa.gov/lmop/proj/index.htm#2</i>			
Biomass/LFG/Biogass in Washington			1030 MW
Target implementation		5%	51.5 MW

Estimate of Mitigation Option Costs and Benefits for Washington Energy Supply GHG Analysis

ES-7 Combined Heat and Power (CHP) and thermal energy recovery and use

Date Last Modified:

11/01/2007

G. Powell

Key Data and Assumptions	2012	2020/all	Units
--------------------------	------	----------	-------

Total Remaining Estimated CHP Potential in WA as of 2004

2,847	MW	(See Note 1)
-------	----	--------------

From the Combined Heat and Power in the Pacific Northwest: Market Assessment, dated August 2004, to the Oak Ridge National Laboratory (http://www.chpcenternw.org/NwChpDocs/Chp_Market-Assessment_In_PNW_EEA_08_2004.pdf)

First Year Results Accrue

2009

Fuel Costs

2012	2020/all	Units
------	----------	-------

Natural Gas (Commercial and Industrial, Delivered)

\$6.8	\$/MMBtu
-------	----------

Based on 2006 projections

Biomass

\$2.8	\$/MMBtu
-------	----------

Estimate based on national study of state-by-state biomass resource resource assessments (Biomass Feedstock Availability in the United States: 1999 State Level Analysis, M Walsh et al 1999, with 2000update). Price equivalent of \$51/dry ton at 16 MMBtu/dry ton.

Oil

\$9.5	\$/MMBtu
-------	----------

From Seattle Steam comments

Coal

\$2.2	\$/MMBtu
-------	----------

Average coal heat content of 26.75 MMBTU/ton, based on 2001 USDOE/EIA data. USDOE/EIA figures for 2005 "other industrial users" are withheld for WA. www.eia.doe.gov/cneaf/coal/page/acr/table34.html

Avoided Electricity Cost

\$43	\$/MWh
------	--------

Estimate derived from NWPC data from RTF analysis, same source as marginal CO2 emission rate for electricity reductions, this is the simple average (not levelized value) of the marginal dispatch costs for 2010, 2015, and 2020

Avoided electricity emissions rate

0.50	0.50	tCO ₂ /MWh
------	------	-----------------------

Placeholder for now

Summary Results	2012	2020	Units
-----------------	------	------	-------

Total for Policy (All Fuels)

Total Net GHG Emission Savings

0.42	1.6	MMtCO ₂ e
------	-----	----------------------

Net Present Value (2007-2020)

\$82	\$million
------	-----------

Cumulative Emissions Reductions (2007-2020)

9.5	MMtCO ₂ e
-----	----------------------

Cost-Effectiveness

\$9	\$/tCO ₂ e
-----	-----------------------

Other Data, Assumptions, Calculations	2012	2020/all	Units
---------------------------------------	------	----------	-------

Fraction of Washington's Remaining Existing CHP Potential Tapped per Year

2.0%	3.0%
------	------

Rough estimate to be refined in consultation with TWG. Fractions of remaining potential tapped in each year are assumed to be beyond "baseline plus existing policies" levels, and thus due to CAT policies.

Annual Growth in CHP Potential

1.6%	1.6%
------	------

Rough estimate based on consideration of growth in electricity use in the commercial and industrial sectors.

Estimated CHP Potential by Year (MW)

3,182	3,612	MW
-------	-------	----

Potential shown above grows at the rate shown above.

Estimated CHP Installed Under Policy by Year (MW)

64	108	MW
----	-----	----

Average full-capacity-equivalent hours of operation for New CHP units:
assumption

4,000	4,000
-------	-------

Fraction of New CHP Capacity/Energy Fueled With:

Natural Gas
Biomass
Oil
Coal

94%	94%
6%	6%
0%	0%
0%	0%

Assumptions - see Note 3

Implied Annual New CHP Capacity by Fuel (MW)

Natural Gas
Biomass
Oil
Coal

60	102
4	7
-	-
-	-

Implied Cumulative New CHP Capacity by Fuel (MW)

Natural Gas
Biomass
Oil
Coal

234	917
15	59
-	-
-	-

Implied Cumulative New CHP Electricity Output by Fuel (GWh)

Natural Gas
Biomass
Oil
Coal

935	3,669
60	234
-	-
-	-

Average Net Heat Rate by Fuel (Btu Fuel Input/kWh Electricity Output)

Natural Gas
Biomass
Oil
Coal

7,000	7,000
14,000	14,000
13,000	13,000
12,000	12,000

Implied Fuel Input by Fuel (Billion Btu)

Natural Gas
Biomass
Oil
Coal

6,543	25,682
835	3,279
-	-
-	-

Usable Cogenerated Heat Output as a Fraction of Fuel Energy Input

Natural Gas
Biomass
Oil
Coal

40%	40%
40%	40%
40%	40%
40%	40%

Implied Usable Heat Output by Fuel (Billion Btu)

Natural Gas
Biomass
Oil
Coal

2,617	10,273
334	1,311
-	-
-	-

Fraction of New CHP Capacity/Energy by Size:

<1 MW	14%	14%
1-4.9 MW	24%	24%
5-24.9 MW	19%	19%
25-39.9 MW	13%	13%
40-259.9 MW	15%	15%
>259.9 MW	16%	16%

Implied Annual New CHP Capacity by Size (MW)

<1 MW	9	15
1-4.9 MW	15	26
5-24.9 MW	12	21
25-39.9 MW	28	47
40-259.9 MW	9	15
>259.9 MW	15	26

Implied Cumulative New CHP Capacity by Size (MW)

<1 MW	35	137
1-4.9 MW	59	232
5-24.9 MW	47	185
25-39.9 MW	107	422
40-259.9 MW	35	137
>259.9 MW	59	232

Implied Cumulative New CHP Electricity Output by Size (GWh)

<1 MW	139	547
1-4.9 MW	237	930
5-24.9 MW	188	739
25-39.9 MW	430	1,688
40-259.9 MW	139	547
>259.9 MW	237	930

Average Net Heat Rate by Size (Btu Fuel Input/kWh Electricity Output)

<1 MW	11,234	10,343
1-4.9 MW	9,868	8,480
5-24.9 MW	9,213	7,935
25-39.9 MW	9,945	8,865
40-259.9 MW	9,220	8,595
>259.9 MW	7,937	7,300

Implied Fuel Input by Size (Billion Btu)

<1 MW	1,541	5,657
1-4.9 MW	2,271	7,882
5-24.9 MW	1,686	5,864
25-39.9 MW	4,183	14,961
40-259.9 MW	1,267	4,702
>259.9 MW	1,849	6,785

Usable Cogenerated Heat Output as a Fraction of Fuel Energy Input

<1 MW	40%	40%
1-4.9 MW	40%	40%
5-24.9 MW	40%	40%
25-39.9 MW	40%	40%
40-259.9 MW	40%	40%
>259.9 MW	40%	40%

Implied Usable Heat Output by Fuel (Billion Btu)

<1 MW	616	2,263
1-4.9 MW	908	3,153
5-24.9 MW	674	2,345
25-39.9 MW	1,673	5,984
40-259.9 MW	507	1,881
>259.9 MW	740	2,714

Other Data, Assumptions, Calculations	2012	2020/all	Units
---------------------------------------	------	----------	-------

Fraction of Usable Heat Output Replacing Space/Water/Process Heat Use <i>(Assumption from Seattle Steam)</i>	94%	94%	
---	-----	-----	--

Fraction of CHP Heat Output Displacing Thermal Energy Produced Using

Natural Gas	90%	90%
Biomass	0%	0%
Coal	0%	0%
Electricity	10%	10%
Oil	0%	0%

Based on input from TWG

Net Efficiency of Displaced Boiler/Heater Thermal Energy Produced Using

Natural Gas	75%	75%
Biomass	75%	75%
Coal	75%	75%
Electricity	85%	85%
Oil	75%	75%

Assumptions

Net Displaced Fuel Use (Billion Btu)

Natural Gas	3,329	13,067
Biomass	-	-
Coal	-	-
Electricity	326	1,281
Oil	-	-

Inputs to Cost Estimates for CHP Systems

Factors for Annualizing Capital Costs (all plant types)

Interest Rate	8%/yr
Economic Life of System	20 years
Implied Annualization Factor	10.19%/yr

Estimated Average Installed Capital Costs by System Type (\$2005/kW)

Natural Gas	\$ 964	\$ 839
Biomass	\$ 1,214	\$ 1,089
Oil	\$ 964	\$ 839
Coal	\$ 964	\$ 839

Source: Combined Heat and Power in the Pacific Northwest: Market Assessment, based on a weighted average of various sizes of turbine systems; Biomass system assumed \$250 higher than gas turbine; Coal system assumed equal to gas turbine

Estimated Average Non-fuel Operating and Maintenance Costs by System Type (\$/MWh)

Natural Gas	\$ 5.00	\$ 6.00
Biomass	\$ 3.00	\$ 4.00
Coal	\$ 12.00	\$ 14.00

Estimated Average Installed Capital Costs by Size (\$2005/kW)

<1 MW	\$ 1,396	\$ 1,073
1-4.9 MW	\$ 1,046	\$ 929
5-24.9 MW	\$ 990	\$ 879
25-39.9 MW	\$ 890	\$ 784
40-259.9 MW	\$ 781	\$ 734
>259.9 MW	\$ 656	\$ 589

Estimated Average Non-fuel Operating and Maintenance Costs by Size (\$/MWh)

<1 MW	\$ 16.35	\$ 11.60
1-4.9 MW	\$ 9.49	\$ 8.44
5-24.9 MW	\$ 8.44	\$ 8.44
25-39.9 MW	\$ 5.27	\$ 4.22
40-259.9 MW	\$ 4.22	\$ 4.22
>259.9 MW	\$ 4.22	\$ 4.22

Intermediate Results for Cost Estimates

Total Capital Costs for New Systems by Fuel (thousand 2005 dollars)

Natural Gas	\$ 56,162	\$ 85,479
Biomass	\$ 4,539	\$ 7,082
Oil	\$ -	\$ -
Coal	\$ -	\$ -

Annualized Capital Costs for All Systems by Fuel (thousand 2005 dollars)

Natural Gas	\$ 22,713	\$ 83,931
Biomass	\$ 1,830	\$ 6,848
Oil	\$ -	\$ -
Coal	\$ -	\$ -

Annual Non-Fuel Operating and Maintenance Costs for All Systems (thousand 2005 dollars)

Natural Gas	\$ 4,673	\$ 22,013
Biomass	\$ 179	\$ 937
Oil	\$ -	\$ -
Coal	\$ -	\$ -

Total Non-Fuel Costs for All Systems (thousand 2005 dollars)

Natural Gas	\$ 27,387	\$ 105,945
Biomass	\$ 2,009	\$ 7,785
Oil	\$ -	\$ -
Coal	\$ -	\$ -

Total Gross Fuel Costs for All Systems (thousand 2005 dollars)

Natural Gas	\$ 44,489	\$ 174,640
Biomass	\$ 2,372	\$ 9,311
Oil	\$ -	\$ -
Coal	\$ -	\$ -

Total Fuel Cost Savings from Displaced Heating Fuels for All Systems (thousand 2005 dollars)

Natural Gas	\$ 22,636	\$ 88,857
Biomass	\$ -	\$ -
Coal	\$ -	\$ -
Electricity	\$ 718	\$ 2,818
Oil	\$ -	\$ -

Total Capital Costs for New Systems by Fuel (thousand 2005 dollars)

<1 MW	\$ 11,873	\$ 16,302
1-4.9 MW	\$ 15,489	\$ 23,969
5-24.9 MW	\$ 11,657	\$ 18,028
25-39.9 MW	\$ 23,900	\$ 36,743
40-259.9 MW	\$ 6,880	\$ 11,149
>259.9 MW	\$ 9,742	\$ 15,214

Annualized Capital Costs for All Systems by Fuel (thousand 2005 dollars)

<1 MW	\$ 4,866	\$ 17,085
1-4.9 MW	\$ 6,250	\$ 23,295
5-24.9 MW	\$ 4,704	\$ 17,528
25-39.9 MW	\$ 9,652	\$ 35,854
40-259.9 MW	\$ 2,758	\$ 10,534
>259.9 MW	\$ 3,926	\$ 14,703

Annual Non-Fuel Operating and Maintenance Costs for All Systems (thousand 2005 dollars)

<1 MW	\$ 2,278	\$ 6,346
1-4.9 MW	\$ 2,248	\$ 7,842
5-24.9 MW	\$ 1,588	\$ 6,235
25-39.9 MW	\$ 2,267	\$ 7,119
40-259.9 MW	\$ 588	\$ 2,308
>259.9 MW	\$ 999	\$ 3,921

Total Non-Fuel Costs for All Systems (thousand 2005 dollars)

<1 MW	\$ 7,143	\$ 23,431
1-4.9 MW	\$ 8,498	\$ 31,137
5-24.9 MW	\$ 6,292	\$ 23,762
25-39.9 MW	\$ 11,920	\$ 42,974
40-259.9 MW	\$ 3,346	\$ 12,842
>259.9 MW	\$ 4,925	\$ 18,624

Total Gross Fuel Costs for All Systems (thousand 2005 dollars)

<1 MW	\$ 6,568	\$ 25,780
1-4.9 MW	\$ 11,160	\$ 43,807
5-24.9 MW	\$ 8,872	\$ 34,826
25-39.9 MW	\$ 20,262	\$ 79,538
40-259.9 MW	\$ 6,568	\$ 25,780
>259.9 MW	\$ 11,160	\$ 43,807

Total Fuel Cost Savings from Displaced Heating Fuels for All Systems (thousand 2005 dollars)

<1 MW	\$ 3,273	\$ 12,848
1-4.9 MW	\$ 5,562	\$ 21,832
5-24.9 MW	\$ 4,421	\$ 17,356
25-39.9 MW	\$ 10,098	\$ 39,639
40-259.9 MW	\$ 3,273	\$ 12,848
>259.9 MW	\$ 5,562	\$ 21,832

Results	2012	2020	Units
Electricity			
TOTAL Reduction in Electricity Sales (electricity output from CHP plus avoided electricity use in boilers/space heaters/water heaters)	1,090	4,279	GWh (sales)
Reduction in Generation Requirements	1,175	4,602	GWh (generation)
Gross GHG Emission Savings	0.59	2.30	MMtCO ₂ e
Natural Gas			
Net Change in Gas Use (negative values denote increased use)	-3,214	-12,615	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	-0.17	-0.67	MMtCO ₂ e
Biomass			
Net Change in Biomass Use (negative values denote increased use)	-835	-3,279	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.00	-0.01	MMtCO ₂ e
		-204912	dry tons
Coal			
Net Change in Coal Use (negative values denote increased use)	0	0	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.00	0.00	MMtCO ₂ e
Oil			
Net Change in Oil Use (negative values denote increased use)	0	0	Billion BTU
Net GHG Emissions (negative values denote increased emissions)	0.00	0.00	MMtCO ₂ e

NOTES AND DATA FROM SOURCES

Note 1:

From *Combined Heat and Power in the Pacific Northwest: Market Assessment*

Task 1 - Final Report. Submitted to Oak Ridge National Laboratory

This report can be found at:

http://www.chpcenternw.org/NwChpDocs/Chp_Market-Assessment_In_PNW_EEA_08_2004.pdf

Accelerated Case assumptions – 2020 cost and performance specs, no stand-by charges, financial incentives equal to about 15% of capital costs

Note 2:

Natural gas - cell AJ53 of SEDS workbook

Coal - cell AQ53 of SEDS workbook

Electricity - to be confirmed

Oil - pet. coke, pentanes plus, residential fuel, still gas, naphthas, unfinished oils - cells AK53 to AP53 of SEDS workbook

Note 3:

From *Combined Heat and Power in the Pacific Northwest: Market Assessment*

Large industrial

From Table 4-1 (Washington only)		From Table 4-1 (Washington only)	
On-site CHP Technical Potential		CHP Export Potential	
Food	27	Food	24
Lumber and Wood	33	Lumber and Wood	28
Paper	122	Paper	229
Chemicals	25	Chemicals	11
Petroleum Refining	81	Petroleum Refining	568
Primary Metals	28	Primary Metals	9
Electronic Equipment	0	Electronic Equipment	0
Transportation Equipment	45	Transportation Equipment	0
Instrumentation	0	Instrumentation	0
	<u>361</u>		<u>869</u>
CHP Technical Potential	1,230		

Technical Potential

Existing facilities	
Large Industrial - On-site	360
Large Industrial - Export	870
Resource Recovery	27
Small Industrial	745
Commercial	2,885
New facilities	
Large Industrial - On-site	57
Small Industrial	304
Commercial	2,473
	<hr/>
	7,721

Food	51 MW
Lumber and Wood	61 MW
Paper	351 MW
	<hr/>
Total	463 MW

Biomass as percentage of total technical potential 6.0%

Amount of CHP economic potential from biomass 171 MW

Source: NW Council's Fifth Power Plan

Landfill gas	100-200	aMW	Capacity	176 MW
Washington % of population				51.20%
Landfill gas in Washington				90 MW

Assume landfill gas is included in "Technical Potential" in CHP in the Pacific Northwest: Market Assessment

Landfill gas as percentage of total technical potential 1.2%

Amount of CHP economic potential from landfill gas 33 MW

Note 4:

Economic Potential - Accelerated Case		
Upper limit of system size range	Potential (MW)	
500 kW	399	14.0%
1,000 kW	678	23.8%
5,000 kW	539	18.9%
20,000 kW	358	12.6%
50,000 kW	429	15.1%
260,000 kW	444	15.6%
	<hr/>	
	2,847	