Industrial Use Roadmap to 2020

Report to the Oregon Global Warming Commission

The following report, *Oregon Industrial Use Roadmap to 2020*, was developed by the Industrial Technical Committee of the Oregon Global Warming Commission (OGWC). Technical Committee members are listed in Appendix A of this report.

I. PURPOSE AND CONCLUSIONS

The Industrial Technical Committee of the Oregon Global Warming Commission is to identify technologies, practices and policies required to achieve Oregon industrial greenhouse gas emission (GhG) reductions of 10% below 1990 levels by 2020 and 75% below 1990 levels by 2050. The committee's short duration did not allow for a more comprehensive development of a roadmap. Next steps recommended include: establishing intermediary goals, timeline, prioritization of strategies based on impact (emission reductions), implementation strategies, identification of implementing parties, establish follow up date to report progress. It is further recommended that environmental interests be represented on subsequent industrial committees.

The recommendations in this report will be considered by the Oregon Global Warming Commission for inclusion in the Interim Roadmap to 2020/Report to the new Governor and Legislature, to state agencies, and to Oregon's Congressional delegation. Recommendations may also guide private sector investments and university research agendas.

A summary of the key recommendations is below with a more detailed discussion in Section III. Key Actions for 2020:

1. Accelerate use of energy efficient technology and practice.
2. Establish GhG leadership recognition program.
3. Improve access to financing and incentives.
4. Build human capacity to innovate and execute industry process improvements.

Background

In 2005, Oregon industrial greenhouse gas emissions of 19.96 million metric tons represented 27% of all Oregon emissions in carbon dioxide equivalents. Those emissions include direct combustion, electricity consumption, industrial processes, methane from wastewater, nitrous oxide from waste incineration, high global warming potential gasses such as ozone-depleting substance substitutes and other CO_2 equivalent emissions from semiconductor and other manufacturing processes. The two largest categories are 1) direct combustion of petroleum and natural gas and 2) consumption of electricity. These two categories totaled 13.2 $MMTCO_2e$ in 2005, roughly 66% of industrial emissions. In 1990, overall emissions were 16.3 $MMTCO_2e$. Reduction to 10% below 1990 levels by 2020 will require a 27% reduction of 5.3 $MMTCO_2e$ from the 2005 emissions level of 19.96 $MMTCO_2e$.

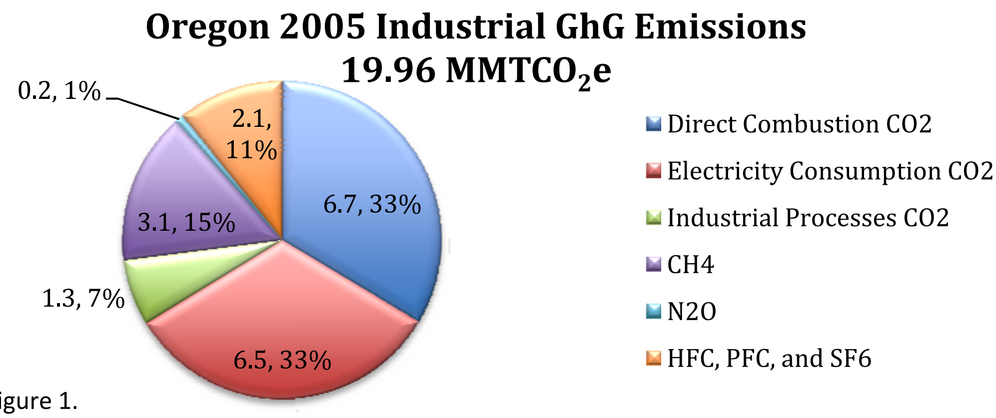

Figure 1.

Reduction of overall Oregon industry emissions to 75% below 1990 levels by 2050 would result in a reduction of 15.9 $MMTCO_2e$ or total industry emissions of 4.06 $MMTCO_2e$, which is the equivalent of more than half the emissions from direct combustion alone. Discussion with industry indicates that reduction of emission intensity per unit of production provides a manageable metric, encourages dramatic improvement, and addresses site or commodity specific processes, while positioning Oregon industry to compete globally based on environmental attributes.

Metrics of $MMTCO_2e$ intensity per unit of product from all Oregon industrial processes are not entirely known at this time. $MMTCO_2e$ benchmarking in industry, by unit of production, is nascent. Northwest Food Processors Association (NWFPA) has begun benchmarking products for energy intensity and $MMTCO_2e$, with product energy intensity as the metric for a commitment to its industry-wide energy reduction efforts.

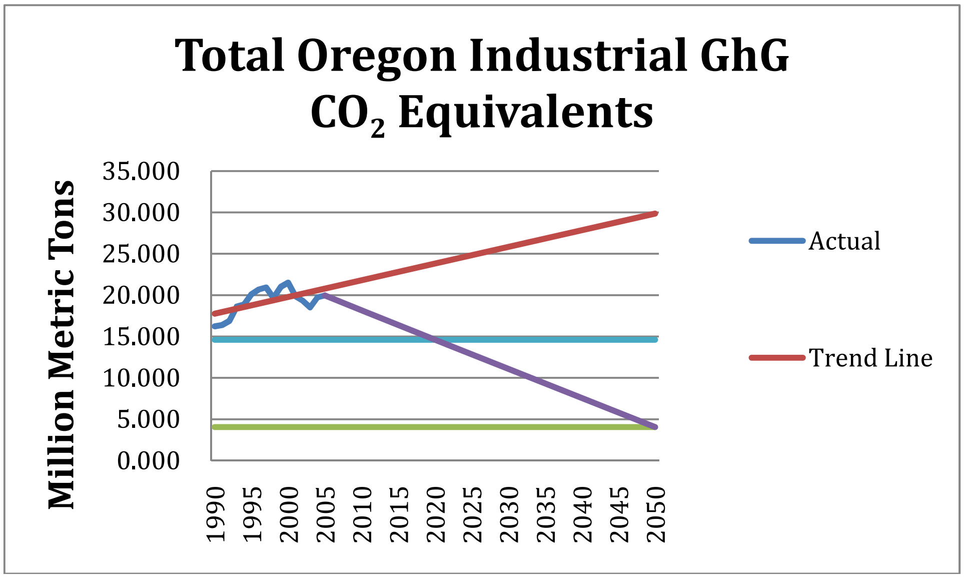

Figure 2. *Oregon Gross Greenhouse Gas Emissions Report,* Oregon Department of Energy, 2006

II. FUTURE STATEMENTS

In order to guide the recommendations, the group defined what the state of industry could be in 2020 and 2050 if Oregon Greenhouse goals were met. The following are visions and projections of the future for such a case.

Industrial Practices in 2050

Oregon industry is a zero waste, zero defect and 100% on-time producer of the most globally advanced products and industry services which have the lowest energy and raw materials intensity on the planet. For those reasons, Oregon industry products are sought-after worldwide. Comprehensive industry enterprise management systems enable production whereby each product is labeled with its carbon and all materials content from raw material extraction through delivery to the end-user. GhG emissions from natural gas and petroleum combustion, semiconductor manufacturing gasses, cement manufacturing, iron and steel processes, ammonia and urea production, and other industrial emissions, in intensity per unit of production, is 75% of 1990 levels. Continuous improvement management is measured in real-time, on a commodity-by-commodity basis, in all industry with quality and safety control fully integrated.

Industrial Practices in 2020

In 2020 Oregon industry is a national leader in applying and sharing best practices in energy efficiency, waste reduction and by-product utilization. In 2020, primary GhG emission reductions are being accomplished through stringent management, upgrade and replacement of direct natural gas using equipment. Other emissions reductions strategies from substitutes for greenhouse gas depleting refrigeration gases and process gasses are being developed. Lean manufacturing processes are being implemented and reduce overall energy use per unit of production.

The marketplace in 2020 shows substantial progress towards addressing these market barriers. The following conditions are accelerating industries GhG reductions. Industry is sharing best practices in ways that do not threaten their competitiveness. Third parties are vetting technologies and identifying successful applications with thorough case studies, workshops and technology transfer forums readily available to industry. Industry confidence in vetted technologies is high and the characteristics of plant specific applications are readily understood and communicated. Industry sectors are collaborating on technology and practice applications. Industry and product benchmarking and metrics are being used at Oregon facilities using national level data to provide more efficacy, and broader data sets. Industries are setting energy and GhG goals to compete nationally and internationally. The state and other third parties are providing recognition and promotion of industries in the upper twentieth percentile performance on GHG emissions and energy use per unit of production. Additional capital inside and outside industry is pursuing investment in cost effective energy savings and GhG emissions reductions. Industry is realizing lower cost of production from efforts and gaining competitive advantage. The education and training available to industry is providing them with a world-class workforce fully prepared to implement continuous improvements in GhG emissions reductions, lean manufacturing, energy savings and renewable resource use. Higher education, industry associations and utility efficiency advocacy organizations provide a coordinated and complimentary array of efficiency training opportunities. Successful models of business co-location for energy systems operations, energy savings performance contracts, thermal energy sharing and combined heat an power operations exist and are details of that success are available for industry consideration.

III. KEY ACTIONS FOR 2020

To accomplish GhG reductions of 10% by 2020 requires a 27% reduction from 2005 emissions levels. To accomplish this the following actions must be taken to accelerate industry use of efficient technology and practices, align and motivate industry leadership around greenhouse gas emissions reduction goals, improvement needs to be made in streamlining and providing additional access to financing and incentives. Attention must be paid to development of the industrial workforce are required to assure the capacity to lead substantive industry process change.

The following actions need to be implemented immediately to even meet the 2020 goal. It is believed these actions provide the supportive framework necessary for industry to accomplish GhG emissions reductions through voluntary participation. These actions will provide additional employment, reduce industry waste, improve their productivity and improve their competitiveness. Achieving GhG reductions to 10% below 1990 levels by 2020 will require eliminating some 5.3 million metric tons of GhG emissions from Oregon industry per year. That is a 27% reduction in industrial emissions from 2005 levels!

Note: *More details for each of the actions below are discussed in more detail in Appendix B.*

1. Accelerate use of energy efficient technology and practice

Energy efficiency in boilers, thermal systems, motors and drives, refrigeration, air compression, lighting, materials handling and best design, operations and maintenance practices are not in widespread use in industry. The Northwest Power and Conservation Council identified in their Sixth Power Plan some 700 average megawatts of cost-effective known electric energy savings potential in Oregon. An estimated 200 average megawatts of that potential is in industry. The Energy Trust of Oregon is on track to accomplish nearly half or 300 average megawatts of that potential over the next decade, but from all market sectors including residential, commercial, industrial and new construction. Additional services and resources and approaches are called for to directly target Oregon's large industrial facilities. Natural gas energy savings technologies in boiler systems and many direct use thermal improvements are known and proven. The Energy Trust of Oregon has accomplished 21 million therms per year of natural gas savings through their efficiency programs to date. However, most of those savings can be attributed to commercial uses. Oregon's industrial energy efficiency service programs for natural gas focus on utility purchasers of natural gas while a larger proportion of industrial natural gas is purchased through pipeline contracts and not subject to public purpose charge incentives or organized services. This larger source of GhG emissions needs to be addressed through development of GhG metrics by industry, services and expertise from higher education, and focusing incentives, resources and financing options on these large GhG emissions. A comprehensive combined heat and power initiative has not been delivered in Oregon and evaluation, planning and implementation of one will result in significant reductions of GhG in Oregon's largest industries.

- Implement an aggressive boiler and direct natural gas efficiency initiative targeting industry.
- Provide additional cross-cutting industry efficiency training, analysis and implementation technical assistance.
- Provide support for distributed generation; Assess and initiate industry wide combined heat and power evaluations and support investment, assess and initiate industry wide distributed renewable generation scoping studies and investment.

2. Establish GhG leadership recognition program

Focused and deliberate planning and implementation of GhG reduction strategies needs to be understood as value-added by industry leadership. Recognition and "branding' of early commitment to effective GhG reduction needs to support that understanding, commitment and progress. Oregon has not historically engaged, nor fully supported, industry sectors to share best practices, identify benchmarks or determine the needed services to accomplish meaningful and valuable GhG reductions though energy efficiency and other measures. The Northwest Food Processors Association has begun to provide the planning, services and recognition to their members who have formally adopted energy intensity reduction goals. That effort is proving results and the lessons learned will benefit other industry sectors. Implementation of an industry "Leaders" program (detailed in Appendix C) will be essential to the success of these actions. The committee believes an industry "leaders" approach will be critical to the success of any regulatory accomplishment of Oregon industry GhG reductions as well, should they be considered. Recognition for industries that are successful and on track with GhG intensity or overall reductions will be essential as well. National and international expert assistance with the planning, initiation and implementation of industry sector (pulp and paper, wood products, steel, microelectronics, chemicals, metals casting) goals, plans, benchmarks (metrics) and practices needs to be coordinated and facilitated with industry leader participation.

- Create a Recognition, branding and marketing "Oregon Top Twentieth" or "Leaders" program that includes primary industry and the services. Integrate into Oregon marketing programs (see Appendix C).
- Assign state government to focus goals and action implementation on the top nine emissions and top ten industry sectors.

3. Improve access to financing and incentives

Oregon financing and incentives have not directly targeted GhG emissions reductions. Energy efficiency and renewable resource incentives and finance have resulted in GhG reductions. Oregon's largest industrial natural gas uses are not eligible for public purpose charge incentives or services. Access to GhG specific incentives and financing will help industry to set goals for reductions while providing ready, assured, fixed rate and terms finance. Coupled with focused cross-cutting technology knowledge, service and implementation assistance, bond backed financing of industrial GhG reduction efforts will improve industry profitability, provide employment and sustain accomplishment of industry GhG emissions reductions.

- Maintain and expand state incentives and financing that target industry GHG.
- Review, evaluate and adopt the most effective emerging or innovative funding mechanisms, particularly those that leverage private dollars
- Increase Energy Trust of Oregon (ETO) initiatives for industry.
- Encourage congressional delegation to expedite energy legislation with expansion of investment tax credit to GHG.

4. Build human capacity to innovate and execute industry process improvements

Perhaps the most significant opportunity to reduce Oregon industry GhG emissions and improve their global competitiveness is through significant changes in industry processes. Facilitated by USDOE, the pulp and paper, steel, wood, products, biotechnology and microelectronics industries have partnered to identify fundamental changes in materials transformation (see Appendix B. for examples) and production resulting in substantial energy savings and GhG reduction. These changes are essential for industry to begin to address the challenges of meeting the 2050 goal of 75% GhG reduction from 1990 levels.

Engaging higher education in providing technical assistance to Oregon's industries will both provide needed services now and prepare the future workforce for the daunting task(s) of implementing these fundamental changes. Drawing upon national "Roadmaps" for specific industries, engaging the national laboratories and using all possible federal resources (Commerce, Energy and Environmental Protection) will require planning, concerted human resources, curriculum emphasis and further technology research and application. Developing the science to where industry is confident of outcomes and supported technically in applications will be critical.

To accomplish these actions, a planned partnership of industry, state government, industry associations and utility efficiency advocacy groups must be developed and effectively managed. Energy efficiency technologies and practices are believed to be capable of providing cost effective approaches to accomplishing the 2020 reduction goals. Substantive industrial process changes or new CO_2 free energy sources will be required for savings past that threshold to meet the 2050 objective of having all industrial GhG emissions at 4 MMTCO2e.

- Develop Oregon industry specific plans and roadmaps for 2020 and 2050.
- Partner with industry to direct multi-discipline teams from agencies and higher education to develop a center of excellence to help industry sectors.
- Build lean manufacturing practices into standard engineering programs at state universities and community colleges.

Impacts to Oregon's Industry

The following table estimates the possible range of investment and cost savings should Oregon GhG reduction goals be accomplished by 2020. Emissions are shown in millions of metric tons of $C0_2$ emission equivalents per year. Energy savings in the natural gas direct use and industrial process category are shown in millions of therms per year and average megawatt hours for electricity consumption. Costs are in millions of dollars by 2020 for investments. Energy cost savings is shown in millions of dollars per year for energy cost savings in 2020 at 2005 cost for energy.

Table 1.

GhG Emissions Categories	$MMTCO_2e$			Annual Energy Saved	Investment		Net Energy Savings (annual)
	1990	2005	2020 Reduction		Low Cost	High Cost	
Direct Gas Use	5.308	6.711	1.934	387 Mthm	$388	$1,163	$155
Electricity Use	6.022	6.517	1.097	265 aMW	$397	$530	$100
Processes	1.380	1.343	0.101	20 Mthm	$20	$60	$ 8

Methane	2.776	3.081	0.583	-			
Nitrous Oxides	0.132	0.172	0.053	-			
CFC,HFC SF4	0.612	2.145	1.594	-			
Sums	**16.23**	**19.97**	**5.364**	**-**	**$805**	**$1,753**	**$263**

Capital cost for implementing GhG reduction projects and practices in Oregon industry that accomplish the 2020 goal of 10% below 1990 levels will be between $800 million and $1.7 billion dollars. The measure cost estimates and any simple payback based on those costs does not take into account any federal, state local or utility incentives. Conservative energy cost savings from that reduction is expected to be at least $265 million. The range of simple rate of return on these investments is from 3 to 6.6 years. Incentives will lower this simple payback range and improve the attractiveness of industrial efficiency investments. The natural gas savings is a third of all industrial natural gas use and some 18 times the annual natural gas savings implemented by the Energy Trust of Oregon (21 million therms per year) in over a half dozen years work with all market sectors. The electric energy savings is just over all of the potential cost-effective electric energy savings identified in the NW Power and Conservation Council 6th plan for Oregon industry.

Note that energy savings and costs are not shown for Methane, Nitrous Oxides and greenhouse gas depleting gasses and their substitutes (CFC, HFC, SF4). Less is known about the costs and reduction strategies for those emissions. In the case of Nitrous Oxide emissions it is expected that addressing industry direct gas use and industrial processes will result in some reduction. Even though, it is expected that the aforementioned actions will address those emissions sources through establishment of industry specific goals, sharing of best practices and development of Oregon specific action plans by industry segment.

Some assumptions for consideration of these estimates include:

- 2,205 pounds per metric ton of emissions
- 11 lbs CO_2 per therm of natural gas
- .96 pounds of CO_2 per kilowatt hour
- Natural gas efficiency cost range is $1 and $3 per therm saved
- Electric efficiency cost is between $1.5 million and $2 million per average megawatt hour (8,760,000 kilowatt hours)
- Natural gas cost savings assume $0.40 per therm
- Electric energy cost savings assume $44 dollars a megawatt hour

There are numerous, economic, environmental and future potential benefits to Oregon industry from accomplishment of 2020 industry GhG reduction goals. Up $1.7 billion dollars in new capital projects will create more jobs. Over $200 million in projects will have to be undertaken each year to meet these reduction goals at the estimated high cost. Given that approximately one third of industrial capital investments are for labor, we can estimate that more than $70 million per year would be spent on a technical workforce earning more than family wage jobs. At an average of $70,000 per person with all indirect costs included, employment could exceed 1,000 per year. Granted, some of those jobs will be currently employed construction and technical workers that are retained. However, this investment represents a more than threefold increase per year in industry capital investment in efficiency and GhG reductions. Energy cost savings to industry is very conservatively estimated at just over a quarter of a billion dollars per year in 2020. The simple return on investment to industry is 6.6 years without accounting for depreciation, incentives that buy down their cost or the likely escalation of energy costs over the next nine years. A simple internal return on investment of 15% or greater can be expected from the energy efficiency related investments in GhG reduction which accounts for nearly 60 percent of GhG reductions called for by industry, should we accomplish 2020 goals. The air quality improvements from reduced direct natural gas use, reductions in other GhG's and the indirect reduction in emissions from electric generation will result. No estimate for the resulting positive health impacts is determined at this time. Oregon industry reductions in GhG will position them to be more globally competitive in future energy supply and carbon constrained markets.

Conclusions

We call upon stakeholders, including government and elected officials, business leaders, environmental advocates and others to work together to make our energy use as productive and efficient as possible. We recommend that our community embrace and implement the actions that we discuss and use this approach to meet emission reduction goals from the industrial sector. This suite of actions provides a broader array of services and resources specifically targeting expressed business needs. These strategies build on recent voluntary initiatives that are making gains (e.g. NW Food Processors).

APPENDIX A

Industrial Technical Committee

Committee Members:

Lisa Adatto, Climate Solutions, Co-Chair
Dale Gehring, ESCO, Co-Chair
Pam Barrow, Northwest Food Processors
Sergio Dias, Sergio Dias Consulting, LLC
Al Dorgan, USW
Angus Duncan, Oregon Global Warming Commission
John Ledger, Association of Oregon Industries
Brendan McCarthy, Portland General Electric
Ruben Plantico, Portland General Electric
Elaine Prause, Energy Trust of Oregon
Marty Sedler, Intel
Victor Shestakov, Climate Solutions
John Wallner, Northwest Energy Efficiency Alliance

Staff:

Mark Kendall, Kendall Energy Consulting, LLC
Justin Klure, Pacific Energy Ventures, LLC
Bill Drumheller, ODOE

APPENDIX B

Industrial Inventory of Actions

ACTIONS/RECOMMENDATIONS	DESCRIPTION			METRIC				COMMENTS
CATEGORIES **I. Accelerate use of Energy Efficient Technology and Practice** **II. Establish GhG Leadership Recognition Program** **III. Improve access to Financing and Incentives** **IV. Build Human Capacity to Innovate and Execute Industry Process Improvements**	**Lead** Gov, (G) Agency (A) , Private (P), etc.?	**Type of Action** Incentive (Int), Tax/Fee,(T/F) Regulation (Reg), Standard (Stnd), Information (Info) , Technical Research (TR), etc.	**Timing of Impact** (Short = 1-5 yrs) Medium = 5-10 yrs. Long = > 10 yrs	**GHG Savings?** (Y/N, Quantity)	**Fossil Fuel Savings?** (Y/N, Quantity)	**Cost (High, Medium, Low)?**	**C/E** (Y/N)	Co-benefits? Risks/Tradeoffs? Unintended Consequences? Politics? Adaptation Value? (*use concise narrative*)
	The information above will continue to be collected and analyzed as it becomes available.							

I. Accelerate use of Energy Efficient Technology and Practice

1	**Implement an aggressive boiler and direct natural gas direct efficiency initiative targeting industry.**								Natural gas boilers account for over a third of industrial GhG emissions in Oregon. Annual maintenance standards, boiler efficiency upgrades and replacement standards should be readily available to all Oregon industry use efficiency forums, case studies, promotions and technical assistance
2	**Provide cross-cutting industry efficiency training, analysis and implementation technical assistance.**								Routine in-plant training with specific assessment examples industry is not available. Dedicated service with implementer performance goals will accelerate adoption
3	Double the capacity of the Oregon State University (OSU) Energy Efficiency Center.								OSU industrial Assessment Center work has proved

									valuable and motivating for industry. It develops the next generation industrial workforce while providing direct service.
4	**Provide support for distributed generation; Assess and initiate industry wide combined heat and power evaluations and support investment, assess and initiate industry wide distributed renewable generation scoping studies and investment.**								Combined heat and power directly addresses the largest direct industry emission of natural gas combustion. Utilization of available renewable resources for power generation provides multiple benefits, crossing into the utility sector plan.
II. Establish GhG Leadership Recognition Program									
5	**Create a Recognition, branding and marketing "Oregon Top Twentieth" or "Leaders" program that includes primary industry and the services. Integrate into Oregon marketing programs (see Appendix C).**								Industry leadership, with planned and directed government, utility, higher education, USDOE and national laboratory support will provide self-determined goals and objectives

6	**Assign state government to focus goals and action implementation on the top nine emissions and top ten industry sectors.**								The top ten industry sectors and top nine emissions represent over 95% of industrial emissions. Focus on the largest industries that are most prepared to reduce GhG first.
7	Industries, State, ETO and NEEA collaborate to develop voluntary GHG Benchmarks by industry sector.								Use national and international standards of practice and benchmarking to establish GHG baselines and metrics by industry type and for specific technologies
8	Recognize and help brand Oregon industry accomplishing GhG objectives.								Recognition, branding and marketing "Oregon Top Twentieth" or "Leaders" products and services to include primary industry and the services sectors (i.e. technical contractors, architectural design, engineering, other

									service providers)
III. Improve access to Financing and Incentives									
9	**Maintain and expand state incentives and financing that target industry GHG.**								Retain BETC with priority on GHG outcomes. Make state bonding authority available for qualifying/participatin g facilities. Develop terms and conditions for State co-signing or otherwise securing part or all of needed debt financing.
10	**Review, evaluate and adopt the most effective emerging or innovative funding mechanisms.**								National and international organizations and governments are innovating efficiency and GhG reduction financing.
11	**Increase Energy Trust of Oregon (ETO) initiatives for industry.**								Promote, educate, conduct analysis, and increase the Public Purpose Charges to the allowable 5% with dedicated to industry
12	Help Oregon industry get USDOE co-funding for plant wide assessments and support								Co funding up to $50k is available and

	implementation with direct link to available incentives and required follow-up component.								underutilized in Oregon
13	**Encourage congressional delegation to expedite energy legislation with expansion of invest tax credit to GHG.**								Process efficiency as well as energy efficiency and renewable resource investments should earn federal incentives
14	Provide property tax exemption for capital investments in projects that reduce GhG emissions.								Significant process improvements and technology platform transitions need to be recognized as sustainable investments
15	Local Government provides a freeze on incremental property tax for qualifying facilities.								Investment in efficiency and systems changes that reduce GhG emissions are exempt from future property tax for participating industry
16	Review and consolidate industry permitting and reporting for various emissions.								Multiple requirements and inventories and reporting on criteria pollutants, water, emerging MACT and GHG, can be more efficient and easier to manage if

									consolidated
17	Provide property tax exemption for capital investments in projects that reduce GHG emissions.								Significant process improvements and technology platform transitions need to be recognized as sustainable investments
IV. Build Human Capacity to Innovate and Execute Industry Process Improvements									
18	Engage USDOE and National Laboratories to actively participate in industry services in Oregon.								Develop Oregon specific science based technologies and applications for the specific needs of our industry. Develop local industry support that attracts national attention and research interest. Deliver proven technology to industry.
19	**Partner with industry to direct multi-discipline teams from agencies and higher education to develop a center of excellence to help industry sectors.**								Develop policy, incentives and outreach service to collaboratively respond to industry needs. An industry efficiency and manufacturing "*Center*

										of Excellence" is essential to building leadership confidence in moving forward.
20	Expand NEEA, ETO and NWFPA work to other industry sectors.									Duplicate the NWFPA market transformation intervention (training, expertise, services, and research) in other Industry segments.
21	**Develop Oregon industry specific plans and roadmaps for 2020 and 2050.**									Assemble industry opinion leader workgroups to review regulations, policies and national roadmaps to advise state government.
22	**Build lean manufacturing practices into standard engineering programs at state universities and community colleges.**									Require environmental and energy policy curriculum to prepare manufacturing managers of the future.

APPENDIX C

Example Industry Process Related GhG Reduction Technologies

Pulp and Paper Roadmap Technologies and Processes

APPENDIX A. NATIONAL ENERGY SAVINGS AND CARBON DIOXIDE EMISSIONS REDUCTIONS RESULTS

Table A-1 National Energy Savings And Carbon Dioxide Emissions Reductions

	CASE A (Excluding increased use of recycled paper)			CASE B (Including incrased use of recyled paper)		
	Throughput	Primary Energy Savings	Carbon Savings	Throughput	Primary Energy Savings	Carbon Savings
	Mt	PJ	MtC	Mt	PJ	Mtc
Raw Materials Preparation						
Ring style debarker	241.5	1.1	0.02	205.2	0.9	0.01
Cradle Debarker	241.5	1.8	0.03	205.2	1.5	0.02
Enzyme-assisted debarker	241.5	1.5	0.02	205.2	1.3	0.02
Bar-type chip screens	49.5	4.9	0.03	42.0	4.2	0.03
Chip conditioners	49.5	4.4	0.03	42.0	3.8	0.02
Screen out thick chips	49.5	4.9	0.03	42.0	4.2	0.03
Belt conveyors	239.4	2.0	0.03	203.5	1.7	0.03
Fine-slotted wedge wire baskets	5.3	0.7	0.01	4.5	0.6	0.01
Pulping Mechanical						
Refiner Improvements	3.2	1.1	0.02	2.8	0.9	0.01
Biopulping	5.3	3.6	0.06	4.5	3.1	0.05
Pulping Thermomechanical						
RTS	3.0	2.0	0.03	2.5	1.7	0.03
LCR	3.0	0.2	0.00	2.5	0.1	0.00
Thermopulp	3.0	1.0	0.02	2.5	0.8	0.01
Pressurized groundwood	3.0	1.6	0.02	2.5	1.4	0.02
Heat recovery in TMP	3.0	4.4	0.02	2.5	3.8	0.02
Improvements in CTMP	3.0	1.3	0.02	2.5	1.1	0.02
Pulping Chemical						
Continuous digesters	49.5	103.9	0.59	42.0	88.3	0.51
Continuous digester modifications	49.5	34.3	0.22	42.0	29.1	0.18
Batch digester modifications	49.5	33.8	0.21	42.0	28.7	0.18
Chemical Recovery						
Falling film black liquor evaporation	53.2	18.2	0.16	45.2	15.5	0.14
Tampella recovery system	53.2	3.0	0.02	45.2	2.5	0.01
Lime kiln modifications	53.2	4.9	0.08	45.2	4.2	0.07
Bleaching						
Ozone bleaching	29.6	0.2	0.00	25.1	0.1	0.00
Brownstock washing	29.6	0.5	0.01	25.1	0.4	0.01
Washing presses	29.6	2.4	0.02	25.1	2.1	0.01
Papermaking						
Gap forming	82.5	8.6	0.13	82.5	8.6	0.13
High consistency forming	70.6	34.3	0.26	70.6	34.3	0.26
Extended nip press (shoe press)	82.5	75.1	0.48	82.5	75.1	0.48
Hot Pressing	82.5	7.2	0.05	82.5	7.2	0.05
Direct drying cylinder firing	82.5	6.2	0.04	82.5	6.2	0.04
Reduced air requirements (closing hoods and optimizing ventilation)	82.5	37.0	0.25	82.5	37.0	0.25
Waste heat recovery	82.5	17.6	0.11	82.5	17.6	0.11
Condebelt drying	82.5	100.0	0.69	82.5	100.0	0.69
Infrared profiling	82.5	10.4	0.05	82.5	10.4	0.05
Dry sheet forming	82.5	69.2	0.26	82.5	69.2	0.26
General Measures						
Pinch Analysis	82.5	41.9	0.27	82.5	41.9	0.27
Optimization of regular equipment	82.5	5.4	0.08	82.5	5.4	0.08
Energy-efficient lighting	82.5	1.7	0.03	82.5	1.7	0.03
Efficient motors	82.5	103.0	1.61	82.5	103.0	1.61
Steam Production and Efficiency						
Boiler maintenance	82.5	29.4	0.19	82.5	29.4	0.19
Improved Process Control	82.5	31.4	0.20	82.5	31.4	0.20
Flue Gas Heat Recovery	82.5	14.7	0.09	82.5	14.7	0.09
Blowdown Steam Recovery	82.5	11.2	0.07	82.5	11.2	0.07
Steam trap maintenance	82.5	104.7	0.66	82.5	104.7	0.66
Automatic Steam Trap Monitoring	82.5	52.4	0.33	82.5	52.4	0.33
Leak Repair	82.5	7.5	0.05	82.5	7.5	0.05
Condensate Return	82.5	6.3	0.04	82.5	6.3	0.04
Fiber Substitution						
Increased use of recycled paper	60.0	202.0	1.67	60.0	202.0	1.67

Steel and Iron Roadmap Technology and Processes

Process	Production(Mtonne)	Fuel Saving (GJ/tonne crude steel)	Electricity Savings (GJ/tonne crude steel)	Primary Energy Saving (GJ/tonne crude steel)	Annual operating Costs(US$/tonne crude steel)	Retrofit Capitol Costs(US$/tonne crude steel)	Carbon Dioxide Emission Reduction (kgC/t)
Iron Ore Preparation (Sintering)	12.1	0.19	0	0.19	0	0.75	5.58
Coke Making	16.6	0.51	0	0.51	0.15	35.84	3.12
Iron Making - Blast Furnace	49.4	2.82	0.1	3.12	-4.45	35.29	51.1
Steelmaking – Basic Oxygen Furnace	55.4	0.92	0	0.93	0	22.2	12.69
Integrated Casting	49.5	3.39	0.65	5.38	-36.68	146.25	213.93
Integrated Hot Rolling	48.3	1.85	0.01	1.88	-1.09	25.92	25.86
Integrated Cold Rolling and Finishing	31.7	0.28	0.13	0.68	0	3.79	9.79
Primary Steel General	55.4	0.57	0.4	1.79	0.02	15.98	35.13
Steelmaking Electric Arc Furnace	35.9	-0.7	1.59	4.22	-18.3	45.2	61.51
Secondary Casting	32.1	2.88	0.57	4.64	-31.33	134.34	64.95
Secondary Hot Rolling	31.3	1.33	0.01	1.36	0.06	12.83	18.69
Secondary Steel General	35.9	0.11	0.06	0.3	0.02	0.16	5.11

APPENDIX D

"Leaders Program" of Industry Support and Recognition "Leaders" program

This program would seek a long term commitment and goal from industry CEO's and would coordinate the long term strategy and support that will help each company reach its goal. This program would be high profile and would include elements of public relations, marketing and executive-to-executive forums to create a network of business leaders.

Resources from organizations like Oregon Department of Energy, Energy Trust of Oregon, Northwest Energy Efficiency Alliance, the Climate Trust, Climate Solutions, Northwest Food Processors Association, Oregon Business Council, Associated Oregon Industries, Northwest Natural Gas, US Department of Energy and others would be coordinated to develop, fund and manage the program. A minimum of 5 years of intense assistance would be committed to participating facilities, tied to a multi-year plan created for each facility upon joining. Long-term commitment by federal, state, local and utilities to providing industry assistance is critical to assuring industry's active participation and progress towards GhG emissions reductions.

Projected launch date would be June 2011 and would target high gas consumption facilities but would be open to any industrial company. Characteristics of the GHG Leadership program includes:

1. Would be completely voluntary but would require CEO (or equivalent) signature to participate
2. High profile and include PR, news releases, Oregon Governor, etc.
3. Targeted at large Carbon emitters (directly or indirectly)
4. Requires participating companies to sign an agreement to target either:
    a. Reduction of carbon emissions by 10-25% over 10 years or
    b. Reach the top x percentile in their industry within x years
    c. Go beyond what is required
5. Initial 10 companies would sign an MOU with:
    a. The Governor
    b. CEO's from US DOE, ETO, NEEA, BPA, etc
6. Support would be coordinated beforehand by all signing organizations so that a clear and concise package was offered to those signing

7. A resource would be assigned to each company to develop the strategy for the company as well as coordinate resources and paperwork from all supporting organizations
8. Progress would be tracked by individual companies and would be shared through secure data collection.
9. There would be a six month check-in with the Governor and signing CEO's
10. There would be a one year dinner and award with all participants
11. Goals would be to get 10 companies within 3 months, 35% of targeted companies within 2 years and 80% within 10 years
12. Support would include management, technical, business, renewable energy, waste recover and emission reduction
13. Initial efforts would include CEO to CEO roundtables and discussions, development of the MOUs and development of the "support" package

APPENDIX E

Barriers to Accomplishing Industrial GhG reduction Goals

The state, industry, industry associations, higher education, local government and industry service providers are collaboratively addressing a number of barriers to the successful reduction of industry GHG emissions. Those include:

- Value in GhG reduction actions is diffuse
- Access to capital for longer return investment is limited
- Risk management in unproven or questionably reliable emerging technologies
- Human resources training education and technical resources
- Access to reliable, industry vetted information is not consistent
- Access to technology and quality standards for application vary
- Lack of confidence in technology
- Value added is not always clear or consistent
- Other business priorities distract from energy and GhG reduction investment
- Time available for implementation is limited and competed for by other process changes or maintenance
- Industry experience with the technology or application may be limited or
- Motivation around GhG reduction alone may not compete with other priorities
- Leadership and championship for energy and GHG reductions from outside and inside industry varies

APPENDIX F

Industry Characteristics in 2020 and 2050

More than 90% of the carbon emissions from the Oregon industrial sector are associated with the conversion and use of energy. The future portends a gradual restructuring of industry toward knowledge-intensive rather than materials/energy-intensive products, because of improved computer controls, gains in process efficiency, just-in-time manufacturing methods, more efficient conversion and use of energy supplies, application of advanced technologies, and resource recovery and optimized resource use.

2020

All boilers over 1 million British Thermal Units per hour capacity are maintained and tuned annually, stack heat recovery is installed, steam trap and pressure reduction are continuously maintained and use the best available technology. Other gas thermal systems use efficient radiant or fluidized bed drying technologies with the highest efficiency available. A coordinated, multi agency boiler efficiency program serves all industry throughout the state. This program coordinates resources (human and financial), marketing, information, technical support and measurement techniques in order to very quickly help industry reduce carbon emissions and develop research ideas in the technical area that has the highest carbon reduction potential, boilers. The largest boiler systems are targeted and marketed to for participation. Participants get over 100% rate of return on their investment in annual boiler tuning. Heat recovery and steam distribution energy savings are targeted, identified, quantified and internal business cases made for capital improvements to boilers made.

Industry associations, the ETO, NEEA and utilities regularly share best available practices through onsite education, project implementation workshops, industry staff training and case studies. Industry groups and higher education collaboratively develop areas of research to solve technical problems and to develop applied solutions to industry process management and GHG reduction.

Industries across Oregon all have energy managers who have benchmarked production energy, cost and emissions by facility and commodity. Targets are set for GHG emissions reductions in each industry and at each facility and specific technology applications are identified by process or system.

State and local government continue to provide access to low cost capital, incentives and property tax abatement that incent industry investment in GHG and energy reductions. Those include publically bonded financing, income and property tax credits, regulatory streamlining for air, water and structural permitting.

2050

Various and complimentary industry are co-located throughout the state, optimizing use of all feedstock's, energy and water supply. All production residues (materials, water, chemicals, thermal…) become feedstock for other complimentary industry. Nano-technology conversion systems are used in all industries to create unique products with superior qualities at low or no GHG emissions. Advanced separation systems use ambient temperature fractionation and cellulose fiber membranes to improve segregation, purity and use of chemicals and organics alike. Renewable energy supplies are either extracted from feedstock materials or scheduled for use based on real-time renewable energy supply forecasts and production schedules for just-in-time, on-time delivery at programmed costs.

Oregon institutions of higher education, and state, federal and local government provide industry advancement support by routinely sponsoring and convening industry market segment and cross-cutting technology, pre-competitive research, education, marketing and application implementation. Education institutes directly provide applied research for continuous improvement, rapidly, toughly and solution specific to each of Oregon's major industry sectors. State government provides policies that promote the use of best available practice (BAP) and technology (BAT) through workforce readiness, research of best available practice and technology, promotion of benefits, standards setting with achievable reach goals and education. State agencies have specific targets, and technical and policy staff to help industry accomplish GHG intensity targets through value-added field, policy and regulatory services. Local government provides land use and transportation infrastructure support that grows industry co-location, resource sharing and integration to continually improve local industry efficiency.

Quality. Oregon's, paper, wood products, metals, foods, microelectronics, chemicals, membranes, non-metallic minerals, machinery, transportation equipment, plastics and fabricated metals and wood products set global standards for production performance, specification tolerances, safety and durability. Oregon commodities are known for their low or net-zero carbon content, lean resource and manufacturing processes, metrics for accountability and performance reliability. The methods for accounting are transparent and published and available for adaptation by others in pre-competitive formats.

Energy. All natural gas, petroleum, electrical energy and renewable energy use per unit of production is 75% of 1990 levels. Thermal energy processes in industry require half the energy they did in 1990 and are twice as thermally efficient. Thermal energy reductions result from use of ambient temperature organic chemical catalysts, ceramic thermal management, and low vacuum forming. All remaining thermal processes use advanced gasification, pyrolysis and Fisher-Tropsh methods recovering all syn-gasses as higher added-value commodities or energy supplies. All feedstock materials are efficiently mined for all energy, fiber, mineral and chemical properties and the predominant volume of feedstock comes from renewable resources. Advanced energy and resource management telemetry enables industry to source the lowest GhG emission materials and energy supplies in real-time.

Technology. Full enterprise management systems optimize the use of all industry resources from raw material to product delivery (materials, resources, human resource, energy, services, technology, processes). Learning controls systems rewrite algorithms for systems optimization in reliable, replicable and accountable ways. All BAT and BAP are implemented in all industry. Advanced combustion, thermal, refrigeration, materials conversion and refining, conveyance, lean packaging, and multimodal transportation systems are in use industry wide. Cooling towers are all but eliminated as businesses co-locate with industry to optimize use of any of the remaining waste heat.

Principal Emissions. Natural gas, petroleum and coal combustion emissions in 2050 are less than 20% of the 6.711 $MMTCO_2e$ it was in 2005, when it was 40% of all industrial emissions. That reduction is due to the adoption of ambient temperature processing, unique chemicals and catalysts, enzyme use, vacuum environment production, application of nano-technology and improved thermal management (ceramic insulators) systems. Little or no direct combustion is used and is replaced by gasification, pyrolysis and Fisher-Tropsh processes where products are more efficiently fractionated, all gasses recovered and each element used at its highest and best value. Rankine cycle low temperature heat recovery is used throughout industry to generate electricity.

Emissions from electric energy consumption are likewise reduced to 20% of 2005 levels through transformation of conveyance, controls, refrigeration, adhesion and product processing technologies and systems. Pumping, fans and motors are re-designed through bio-mimicry efficiency replication (e.g. vortical versus centifugal). Refrigeration has been transformed by using non-condensing CO_2 or inert gas refrigerant cycles with higher heat transfer rates, better dimpled heat exchange with nano-engineered surfaces Overall refrigeration demand is less through more use of aseptic vacuum packaging. Organic light emitting diodes have reduced illumination and light sterilization processes energy use to less than 5% of their 2005 energy intensity levels. It provides improved color rendition, nanometer management, tuneable illumination levels, ten times longer equipment life and lower overall GhG life cycle footprint. Space conditioning and air filtering loads dramatically reduced through low fan speed air exchange, better filtration and reduced particulate production in plant processes. Rare gasses used in microelectronics production (solvents, catalysts, cleaning agents) are replaced with organic and naturally occurring solutions, methods and materials, further reducing high global warming potential gasses.

All ozone depleting substance substitutes are now replaced by no or low GHG producing gasses and solutions to include CO_2 refrigeration, organic thermo-chemicals, or no-refrigeration or rankine cycle production requirements. Refrigeration of Oregon industrially produced commodities is entirely replaced by all aseptic vacuum packaging, increasing product qualities, shelf life and percent raw materials to product ratios.

Practice. Industry associations, higher education and government collaborate on best practices and production management by industry sector with regard to cross-cutting technologies and approaches as well as industry specific and unique processes.

The Market Transformation approach taken by Northwest Food Processors to reduce energy intensity by 25% by 2020 is widespread across all industry sectors and includes: 1)

Operational Improvements, 2) Operational Management Improvements, 3) Business and Quality Process Improvements, and 4) Waste and Natural Resource Utilization [optimization]. Best available management and production processes are detailed and practiced for each industrial facility in Oregon and metrics are managed on a per product basis. Staff are trained, monitoring systems use common platforms and open sourced software and input output controls and sensors to assure uniform data quality throughout industry. Protocols are shared, and trained into place with industry associations sponsoring training in conjunction with higher education and government. International and national benchmarking by industry, product and industrial process are available, reliable and updated in real-time so that industry can compete in the global marketplace without revealing competitive details specific to their firm or commodities.

Multiple businesses operate at each single facility. Businesses that just manage energy, feedstock's, packaging, marketing or process control have emerged, are successful and enhance the transfer of best available practice and lowest cost of production considering all product attributes. Five nines, Six Sigma and Lean Manufacturing, international Standards Organization (ISO) standards have evolved into a digital information statistical process control realm where they fully integrate all industry actions into the entire industrial enterprise in such a way that each element is not distinctly distinguishable from standard practice.

Policy. Government's statutory and administrative role and relationship with industry is as a partner. Goals and targets are set by industry on a site and product specific basis. Governments' role is adopting law, policy and services necessary to accomplish those goals. A regulatory stance is only adopted for determining minimum expected standards of practice and realizable reach goals. Government's role is in helping industry to organize, plan, research, train, adapt, afford and acquire changes in practice and technology that advance their competitive position and accomplishment of GhG reduction goals. Permitting and evaluating next generation or new applications is collaborative, affordable and uses the best available information to identify consensus or compromise plans, practices or designs.

Market(s). International and global markets recognize the value of low GhG products and they are priced to prefer those with the lowest environmental cost with the highest qualities. Oregon's industrial products are sought after locally, nationally and to the extent they have low GhG contributions. Local demand for local products, with the lowest GHG impact, makes Oregon industry more competitive with higher margins through lower cost of delivery. A fully integrated multi-modal transportation system serves Oregon industry with maximally designed back-hauling, lowest carbon routes, timing, just-in-time logistics and co-shipment allowing them more affordability of the best available technologies and practices. State government and industry associations have a globally recognized and deemed highly credible branding campaign with third party verified performance.

Energy Conversion and Utilization. Energy efficiency could be improved through incorporating the best technologies in a systems approach. Technologies include solid oxide fuel cells, higher combustion efficiencies, and using thermal energy in a systems approach to mill/plant design. In the longer term, non-combustion technologies are likely to have a significant impact, such as fuel cells and gasification of biomass and in-plant residues (e.g., black liquor in the forest products industry).

Increased on-site power generation using materials currently sent for disposal and non-combustion technologies, such as fuel cells and gasification, will also play a crucial role in reaching energy reduction targets in the industrial sector. Within manufacturing, materials and process industries account for about 80% of the hazardous and toxic wastes and about 95% of nonhazardous wastes. These wastes often impose high cleanup and disposal costs but offer the potential for recovering the "embedded" energy and materials value. Steam and thermal system efficiencies can be improved by more than 20% using cross-cutting and proved technologies including better boiler technology, improved burners and controls, better insulation, steam trap repair sizing and replacement, condensate return and more efficient, lower chemical use water treatment.

Electric energy conversion technologies in lighting, pumping, fans, conveyance, power voltage transformation and process systems can likewise be improved using cross-cutting available technologies. Fewer than 20 % of electric motors in Oregon industry are rated as premium efficiency motors. Most motors under 50 horsepower in Oregon, with variable loads, have no variable speed or frequency drives or controls. Latest generation, electronic ballast fluorescent lighting provides higher lumens per watt that most industrial high intensity discharge lighting, allows for more switching control and is underrepresented in industry applications. Electronic or organic light emitting diode fixtures will soon provide even more energy efficiency, longer life and equivalent illumination qualities to fluorescent systems.

Industrial Process Efficiency. The industrial sector is extraordinarily complex and heterogeneous. The needs are diverse: hundreds of different processes are used to produce millions of different products. Improving process efficiency will be done through implementation of site-specific processes and protocols with management directive to manage process and procedure controls to meet GHG reduction targets and goals specific to products and facilities.

Some of the more broadly applicable industry process changes include: selective catalysts, advanced separations, improved measurement and control systems, improved materials, and improved electric motor systems, such as large motors with superconductivity wires, low temperature processing, forming and . A particularly attractive longer-term opportunity is the use of biotechnology and bioderived materials.

The need exists to identify various industries collective high-risk, high-payoff technology needs. This analysis allows higher education, U.S. Department of Energy (USDOE) and other federal research and development (R&D) organizations to align their resources to best meet those needs. Industry segments and local government need to align these interests and attract the participation of the national laboratories, Department of Commerce–National

Institute of Standards and Technology Advanced Technology Program to focus resources specifically on GHG reduction strategies.

Emerging Technologies. Increased understanding in the fundamentals of chemistry, metallurgy, and biotechnology will allow the development of innovative manufacturing processes. This knowledge, along with advanced modeling and simulation, improved industrial materials, and measurements (sensors) and intelligent control systems, will result in major incremental improvements and lead to fundamental break-throughs.

Resource Recovery and Utilization. This is a technological pathway is built on industrial ecology, wherein a community of producers and consumers perform in a closed system. Fossil energy is conserved and/or energy is obtained from non-GhG sources; materials are reused or recycled. Through technological advances, the raw materials and resources needed for manufacturing can be obtained by designing products for ease of disassembly and reuse.

Strategic Partnership. Strategic public–private R&D alliances for achieving GHG reduction goals in energy- intensive industries is needed. These alliances need to be extended to embrace climate change mitigation goals. Different types of public–private R&D partnerships are needed to reduce GhG emissions in the light-manufacturing sector. Finally, utility restructuring may challenge industrial self-generation and power sales using advanced industrial turbines integrated with combined-cycle generation or with non-combustion generation techniques such as fuel cells.

Cross-cutting energy efficiency solutions exist to cost effectively get GhG 10% below 1990 levels by 2020 in all Oregon industry sectors.

Cross-Cutting Technologies. Technologies, applicable across all industry sectors, are ready for deployment, proved and have demonstrated cost effectiveness. Manufacturing process controls include all systems and software that exert control over production processes. Control systems include process sensors, data processing equipment, actuators, networks to connect equipment, and algorithms to relate process variables to product attributes. These controls enable more comprehensive analysis of process systems so that systems can be prioritized for cross-cutting technology evaluation and applications. Cross-cutting applications include: Process Integration (pinch analysis), Combined heat and power, Condensing package boilers (Super Boiler), Lower fan speed air filtration and facilities HVAC, Advanced lighting technologies, Advanced lighting design, Advance adjustable speed drive (ASD) designs, Advanced compressor controls, Compressed air system management, Motor diagnostics, Motor system optimization, Pump efficiency improvement, Switched reluctance motors, Advanced lubricants, Anearobic waste water treatment, High efficiency/low NOx boiler burners, Membrane technology for wastewater treatment, Advanced Sensors and controls, Advanced cooling tower controls, Advanced CHP turbine systems, Advanced reciprocating engines, Fuel cells Microturbines,

Industry Specific Approaches. National industry directed technology “roadmaps” exist in the pulp and paper, wood products, steel and iron, aluminum, chemicals, microelectronics, and food processing sectors that address the technology needs both near and long-term to reduce Oregon industrial energy use and GhG emissions. Indexing the cost and emissions reductions attributable to these process shifts, technology leaps and game changing applications is not done comprehensively at this time.

Food Processing. Northwest Food Processors Association (NWFPA) has adopted an industry-wide goal to reduce product energy intensity by 25% by 2020. NWFPA has developed a Roadmap to assist the food processing industry in achieving this goal. The most definitive selection of food processing technologies that reduce energy and GHG is the emerging technologies database developed by Lawrence Berkeley National Laboratory and the NWFPA. In addition to the cross-cutting industry technologies, it identifies the leading edge and emerging technologies specific to most all food manufacturing processes. In addition, the following, next generation technologies, will take the food processing industry a long way towards 2050 GhG Reduction goals. Those technologies include: Low temperature processing and aseptic packaging, Electron Beam Sterilization, biotechnology processing, Heat recovery - low temperature, Membrane technology – food, Cooling and storage management, ultrasonic drying, and Closed-cycle air refrigeration (CCAR).

Pulp and Paper. A 2006 report sponsored by the U.S. Department of Energy (DOE) concluded that the U.S. pulp and paper industry could cost-effectively reduce energy consumption from 2.36 quads to 1.75 quads, a 25 percent reduction from 2002 levels, by broadly implementing the best available industry cross cutting technologies. Those savings could be greater by black liquor gasification, condebelt drying, direct electrolytic causticizing, dry sheet forming, heat recovery – paper, high consistency forming and impulse drying.

Chemicals. The chemical Industries Vision2020 Technology Partnership (Vision 2020) is an industry-led collaboration in the chemical and allied industries to leverage financial resources and technical expertise. The goal is to accelerate innovation and technology development resulting in superior materials, lower energy intensity and lower greenhouse gas emissions. Clean fractionation - celluose pulp, gas membrane technologies- chemicals, heat recovery technologies – chemicals, levulinic acid from biomass (biofine), liquid membrane technologies – chemistry, new catalysts, and autothermal reforming-ammonia. Advancements are being applied in Nanotechnology and Nanomaterials, Environmental, Safety, and Health Issues for Nanotechnology, R&D for Nanotechnology and Nanomaterials, Alternative Feedstocks, Corrosion Reduction, Advanced Separations, Distillation, Ionic Liquids, Process Intensification, Process Equipment Materials (Materials of Construction), and Computational Fluid Dynamics.

Steel and Iron. BOF gas and sensible heat recovery, Near-net shape casting/strip casting, New EAF furnace processes, Oxy-fuel combustion in reheat furnace, and Smelting reduction processes.

Ozone Depleting Substance Substitutes. The U.S Environmental Protection Agency (USEPA) is leading national efforts to implement replacement of ozone depleting substance substitutes (ODSS). In 2007 ODSS contribute nearly 20% to Oregon industrial direct emissions. Those include: Hydro Fluro Carbons (HFC) including some 16 compounds, Per Fluro Carbons (PFC) including some seven compounds, Sulfur hexaflouride (SF6), and to a lesser extent NF3 and HFE 7100 and 7200. The USEPA goal is to phase out all ODSS by 2050. Substitutes exist for most of these refrigerants and cleaning agents but applications are underdeveloped. Acceptance of water, air and CO_2 as refrigerants gasses is emerging. Lower energy Stirling cycles and evaporative/desiccant or straight evaporative cooling exist and can be commercialized for industrial application. Water lithium bromide absorption, or ammonia water absorption are replacements for many CFC's and HCFC's, known ozone depleting substances, that still exist in legacy systems. Direct nitrogen expansion, propane, propylene, CO_2 or butane is all applied as refrigerants. Non-mechanical heat transfer and electronics cleaning can be accomplished with methyl siloxanes and/or water to replace aerosol solvents. Powder coat deposition, ultraviolet and electron beam curing replace or eliminate the need for solvent processes in coatings and finishes. Mechanical cleaning and thermal vacuum de-oiling processes currently replace solvents in metals and electronics cleaning.