

**“Let's make it, don't waste it”: Direct Energy Savings in Industry**

Let's turn from simple material intensity reduction to energy processes once materials use has been reduced to a minimum.

Process heat and industrial boilers consume the vast majority of manufacturing energy<sup>169</sup>. We may save most of this.

	<b>% Savings</b>	<b>% Net Saving</b>	<b>% Consumption Remaining</b>
Refractories <sup>170,171,172</sup> 15% insulation, additional percent from smaller, lightweight refractories that hold less heat	20.0%	20.00%	80.00%
System Operation, Maintenance and Distribution <sup>173</sup>	35.0% of 80%	28.00%	52.00%
Boilers <sup>174,175,176</sup>	6.5% of 52%	3.38%	48.62%
<b>Total</b>		<b>51.38%</b>	<b>48.62%</b>

So we can conservatively save more than 51% of industrial process heat compared to current per capita consumption - if we include all means available at a market price around that of oil. So when we eventually replace industrial boilers (as we must at some time) increasing process heat efficiency will pay for itself not just in energy savings but in smaller boilers, and lowered replacement capital cost. Beyond this, when reduced maintenance costs are considered it may pay even at market prices to replace inefficient boilers process heat systems before their useful life ends.

Electric motor systems account for 23 percent of all electricity consumed in the United States, around 70 percent of manufacturing sector electricity consumption<sup>177</sup>; motor systems account for slightly below 14% of total U.S. industrial energy<sup>169</sup>.

According to Lovins & Hawkins<sup>178</sup>: "...At least a fifth of their total output, is pumping...In industrial pumping, most of the motor's energy is actually spent in fighting against friction. But friction can be ... nearly eliminated at a profit by looking beyond the individual pump to the whole pumping system of which it is a part."

Big pipes and small pumps use a great deal less energy than large pumps and small pipes. A fifty percent fatter pipe reduces friction by 86%. In addition, extra bends put into most piping systems multiply friction by three to five times<sup>178</sup>. Designers normally ignore this because the cost of additional piping would exceed the value of energy savings. But the savings in energy, plus the capital savings through buying smaller pumps do in fact lower costs as a whole.

The savings from fatter, better arranged pipes and smaller pumps should reduce pumping energy use by over 80% of pumping energy used<sup>179</sup>. One example is a factory carpet maker *Interface* built in Shanghai. A top western specialist specified 95 horsepower pumps; fatter, better laid out pipes reduced this to 7 horsepower - a 92% savings.<sup>178</sup>

After material savings, and after various types of throughput savings, half of motor energy could be saved in the motors themselves. In electric motors this can be achieved by more efficient variable speed motors sized right for the job, with the right mechanical and electrical interfaces to what is driven<sup>180</sup>. Because these new motors not only cut energy, but maintenance costs, they will pay for themselves quickly. (The more efficient motors run cooler and slower. Heat and motor speed both contribute to shorter motor life.) (Note: similar savings are possible with stationary heat driven motors as well - with similar paybacks.)

Between cutting energy use for motors in half, and cutting energy use for pumping by 80% or better, it seem we can end up with a 55% savings or better in total motor usage.

Facility heating, ventilation, lighting, air conditions and other facility support represents about 8.7% of industrial energy<sup>169</sup>. These are the same processes we will consider in commercial buildings; we will document 70% average savings in commercial buildings; because of that, we estimate comparable potential in industrial facilities.

Uses classified as “other” and “unreported” represent about 3.4% of industrial consumption<sup>169</sup>. It will not be unreasonable to assume this reflects industrial energy use as a whole, and that similar savings may be found.

On-site electricity generation represents 2.3% of industrial energy use, which will be discussed under co-generation, not here.

Electrochemical processes represent about 2.1% of industrial energy<sup>169</sup>. Since these are already pretty efficient, most of the savings here will come from savings in material use – which we have already counted.

Process cooling, and refrigeration represents less than 2% of industrial energy<sup>169</sup>. Refrigeration and cooling is mostly done by heat pumps; inefficiencies call attention to themselves. Most process cooling uses at least some insulation - though probably not to optimum levels. Because it takes place in confined spaces, there is probably less avoidable loss due to friction, though there may be some. On other hand, no great attempt has been made to substitute the most efficient motors; so there is the same opportunity here as with any other motor driven process of cutting energy use in half. Thus reducing process cooling use by a bit more than half is a reasonable estimate.

On site transportation represents about 0.6%<sup>169</sup>. We don't bother to model any saving here.

So, adding up all direct industrial savings:

	Btu	% before savings	% After savings
Indirect End Use (Boiler Fuel)	3,635	31.81%	15.59%
Process Heating	4,055	35.48%	17.39%
Process Cooling and Refrigeration	210	1.84%	0.92%
Machine Drive	1,691	14.80%	8.14%
Electrochemical Processes	298	2.61%	2.61%
Other Process Uses	69	0.60%	0.29%
Facility Heating, Ventilation, and Air Conditioning	692	6.05%	1.82%
Facility Lighting	211	1.85%	0.56%
Other Facility Support	96	0.84%	0.25%
Onsite Transportation	69	0.60%	0.60%
Conventional Electricity Generation	243	2.13%	2.13%
Other Non-Process Use	3	0.03%	0.01%
End Use Not Reported	157	1.37%	0.66%
<b>Total</b>	<b>11,429</b>	<b>100%</b>	<b>~51%</b>

After first having saved a bit more than half industrial energy use via reductions in material intensity, we can save nearly another half via conventional energy savings – reducing total industrial energy use by ~75% per capita.

This also means that half the savings is essentially free, paid for by material savings and pollution reduction. The other half still is done with very short payback periods – so that we are saving energy at about 25% to 30% of the cost buying fossil fuels. So if you include the 25% of fuel we have to continue to buy, plus the saving of the other 75% at a 30% of the cost of buying it, we come down to being able to buy renewable energy for industrial use at a 110% premium (2.1 times current costs) and still break even.

As a sanity check, we will note the European Union lists a potential 40% overall savings in industrial energy from a very small selection of older technologies<sup>181</sup> - not including significant reductions in material intensity. Given that the EU tends to use energy much more efficiently than the U.S. already<sup>182</sup>, this easily translates into a 50%+ savings for the U.S.

This section so far has focused on a very top down approach. That is, it has looked at very general categories, and very broad studies. So let us examine some specific examples – many of them funded by the U.S. DOE. Most are around 50%, some a bit less others a great deal more.

Example	% Saving
TurboFlo blancher by Key development uses steam convection, better insulation and better recovery valves to cut energy use in half, and water use by bit more <sup>183</sup> .	50%+
Henningsen Cold Storage Company's refrigeration facility in Gresham, Oregon more than doubled the insulation used in normal facilities, used a thermal siphon oil cooling system, installed oversized evaporators and condensers driven by high efficiency motors with variable frequency drives. It installed quick closing doors, and dimmable lights to minimize heat gain, and sophisticated controls <sup>184</sup> .	58%
American Water Heater Company cut the number of compressors it needed to run simultaneously by about half in its air compressor plant, and reduced cooling energy demand as well. It fixed leaks, stored air so as not to have produce it at wildly fluctuating pressures, locating compressors and end user of compressed air closer to one another, located the compressors in a single room, cleaning and dehumidifying the air to be compressed adequately, and adding a closed loop cooling system. <sup>185</sup> (12% increase in production, 22% drop in complaints)	~50%
The DOE developed weld computer resistance welder <sup>186</sup> which reduces energy used for resistance welding by precise measurement and control of electric current. This reduces the number of rejected welds and eliminates the need for destructive weld testing, saving money, materials, and energy.  It performs real-time diagnostics during each weld, precisely regulates voltage to ensure a high-quality process, and documents weld integrity.90%-200% gains in productivity due to decreased welding time, 55% reduction in scrap due to increased accuracy	50%+
Normally paint booths have to be ventilated with frequent air changes, with 100% of the input from outside air in order to avoid poisoning the workers applying the paint. This requires a great deal of filtering and treatment to prevent contamination of outside air, and a great deal of heating or cooling to maintain comfort inside the painting booth. And the workers still have to wear uncomfortable protective equipment to avoid poisoning. All the ventilation is simply to reduce contamination to the point where protective equipment is effective.  Instead this program developed a Mobile Zone Spray Booth Technology, a small mobile cab workers can paint from inside; it is this cab that is ventilated with outside air. So now the worker is exposed to no VOCs or pollutants, and her health is less threatened without uncomfortable masks and equipment than it was before with it. Only the air inside the small cab needs to be heated or cooled. And the air outside the cab, instead of having to be ventilated constantly, can be recirculated, reducing both costs, and emissions to outside air. <sup>187</sup> (This also cut capital costs and improved productivity)	85%
Irrigation sprinklers normally constantly draw AC power to operate valves and controllers – even though the systems may only run for minutes per day. Batteries avoid this drain, but only last between one and two years, cannot survive complete submersion, and make automated control difficult.  Alex-Tronix Controls <sup>188</sup> combines a DC Solenoid that saves 60% of energy compared to an AC system with a battery control technology that extends battery life to ten years, and a sealed protection that allows the system to operated under water and be remotely controlled without opening the box. So now such controllers can be battery operated, saving energy during the short operation period, and 100% otherwise (most of the time). Copper wiring for landscape and irrigation systems tends to be a significant enough expense that reducing this saves money and energy as well.	99%
ENS development of a fan that reduces evaporator and compressor energy consumption in medium temperature walk-in refrigerators <sup>189</sup> . Sensor detects when refrigerant not flowing through evaporator and drops voltage, saving energy need to run evaporator fans, and reducing waste heat from un-need running of evaporator fans, which would otherwise need added cooling.	30%-50%
Merrill Air Engineers has developed a new superheated steam process that saves much of the energy used for drying of molded pulp products, and allows recovery of waste heat from the process <sup>190</sup> .	50% saved, + up to 40% recovered
Bonal Technologies developed a harmonic resonance method of using vibrations to treat metal against temperature drop stress instead of high temperature heat <sup>191</sup> . Superior or equal results to heat treatment in 80% to 90% of applications.	98%
Jay Harmon's use of the principle of the logarithmic spiral to make propellers, impellers and fans more efficient <sup>192</sup> . Cumulative with other technology. Not yet commercially available.	40%

So we can show a variety of specific examples of efficiency improvements. We included some significantly below the 50% minimum we wish to achieve, and a number that greatly exceed it.

## End Notes

<sup>169</sup>Energy Information Administration Office of Energy Markets and End Use - U.S. Department of Energy, *Annual Energy Review 2001*, DOE/EIA-0384(2001). Nov 2002, Energy Information Administration Office of Energy Markets and End Use - U.S. Department of Energy, 25/Sep/2005  
<<http://tonto.eia.doe.gov/FTP/ROOT/multifuel/038401.pdf>>.p51.

Table 2.4 Manufacturing Inputs for Heat, Power, and Electricity Generation by End Use, 1998

<sup>170</sup>Arvind C. Thekdi, "Guest Column: Energy Savings in Industry Through Use of Insulation and Refractories,". *Energy Matters* May/June 2000: Best Practices, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Industrial Technologies Program, 25/Sep/2005  
<[http://www.eere.energy.gov/industry/bestpractices/may2000\\_guest.htm](http://www.eere.energy.gov/industry/bestpractices/may2000_guest.htm)>.

<sup>171</sup>U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Industrial Technologies Program, *Energy-Saving Lightweight Refractory: New Refractory Material Allows For Thinner, Lighter, And More Cost-Effective Manufacturing Of Kiln Furniture. Inventions and Innovation Project Fact Sheet*, DOE/GO-102001-1037. Feb 2001, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Industrial Technologies Program, 5/Sep/2004  
<<http://www.eere.energy.gov/inventions/pdfs/silicar.pdf>>.

<sup>172</sup>h Christine L. Grahl, "Saving Energy with Raw Materials,". *Ceramic Industry* 1/Jul 2002, BNP Media, 25/Sep/2005  
<<http://www.ceramicindustry.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,2708,80846,00.html>>.

<sup>173</sup>Tourism and Resources Australia Department of Industry, "Steam Leaks,". *Australian Energy News*, no. 16 June 2000, Australia Department of Industry, Tourism and Resources, 25/Sep/2005  
<<http://www1.industry.gov.au/archive/pubs/aen/aen16/34steam.html> (Same info as old ASE site page <http://www.ase.org/programs/industrial/steam.htm#Table%201> which has disappeared)>.

<sup>174</sup>

Weil-McLain, *Straight Talk About Boiler Efficiency*. 21/Jan 2005, Weil-McLain, 25/Sep/2005  
<<http://www.weil-mclain.com/netdocs/straighttalk.htm>>.

Weil-McLain calculates that single (non-adjustable) boilers tend to run at around 65% average efficiency, whereas multiple (or adjustable) boilers tend to run at around 80% average efficiency. This translates into slightly less than a 20% savings from the more efficient to the less efficient boiler.

Note that this is talking commercial boilers – used for space and hot water heating. But the same principals apply to industrial boilers; a boiler operates much less efficiently when used at less than capacity. So multiple boilers turned on as needed, so that all running boiler operate near maximum efficiency are more efficient than one big boiler running at less than maximum efficiency most of the time. Note there are two major limits to this. One is cost: many small boilers cost more than a few big ones. The second is that warming up and cooling down a boiler also costs energy. If you have too many boilers and spend a lot of time turning them on and off, you will waste more energy than you save. But the optimum is fairly easy to calculate on a plant by plant basis, and we are nowhere near it.

<sup>175</sup>Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Minimize Boiler Short Cycling Losses. Tip Sheets*, Tip Sheet 16. Dec 2000. *Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy*, 8/Oct/2005  
<[http://www.eere.energy.gov/industry/bestpractices/pdfs/boil\\_cycl.pdf](http://www.eere.energy.gov/industry/bestpractices/pdfs/boil_cycl.pdf)>.

Pacific Gas & Electric Company, *Energy Efficient Operations and Maintenance Strategies for Industrial Gas Burners. PG&E Energy Efficiency Information*© "Industrial Gas Boiler O&M Strategies". 25/Apr

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1997, Pacific Gas & Electric Company, 8/Oct/2005

<[http://www.pge.com/003\\_save\\_energy/003c\\_edu\\_train/pec/info\\_resource/pdf/GASBOILR.PDF](http://www.pge.com/003_save_energy/003c_edu_train/pec/info_resource/pdf/GASBOILR.PDF)>.

CANMET Energy Technology Centre, Natural Resources Canada, "Chapter 2: Getting the Most For Your Fuel Bill," *An Energy Efficiency and Environment Primer for Boiler and Heaters*. 22/Jan 2003, CANMET Energy Technology Centre, Natural Resources Canada, 8/Oct/2005

<[http://www.energysolutionscenter.org/BoilerBurner/Resources/Primer/Primer\\_Chap2.pdf](http://www.energysolutionscenter.org/BoilerBurner/Resources/Primer/Primer_Chap2.pdf)>.

<sup>176</sup>The Delta Institute, *Sector-Based Pollution Prevention: Toxic Reductions Through Energy Efficiency and Conservation Among Industrial Boilers: A Report to the United States EPA Great Lakes National Program Office*, GL97514402. July 2002. *The Delta Institute*, 25/Sep/2005 <<http://delta-institute.org/publications/boilers/SectorBasedP2.pdf>>.p16. (8.5X11 Pages)

Table 3-3

(Note: recommendation 3 in table 3-3 appears to have a multi-century payback because a period was substituted for a comma. The same number appears in table 3-2 in the document <http://www.delta-institute.org/publications/boilers/Table3-2.pdf> with comma in the proper place.)

<sup>177</sup>Consortium for Energy Efficiency, Inc, *Motor Decisions Matter Energy Efficiency/Usage Fact Sheet*. ~2002, Consortium for Energy Efficiency, Inc (Consortium of Motor Industry Manufacturers and Service Centers, Trade Associations, Electric Utilities and Government Agencies), 25/Sep/2005 <[http://www.motorsmatter.org/press/press\\_kit/energy\\_facts.html](http://www.motorsmatter.org/press/press_kit/energy_facts.html)>.

<sup>178</sup> **Ibid Error! Bookmark not defined.** p115.

Chapter 6, Tunneling through the Cost Barrier | Integrating Design to Capture multiple Benefits

<sup>179</sup> U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Industrial Technologies Program, *Energy Tips: Reduce Pumping Costs Through Optimum Pipe Sizing: Motor Tip Sheet # 1*, DOE/GO-10099-879. Dec 1999. *U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Industrial Technologies Program*, 16/Aug/2004 <<http://www.energystar.gov/ia/business/industry/motor1.pdf>>.

<sup>180</sup>Paul Hawken, Amory Lovins, and L.Hunter Lovins, "Additional Book Material -Appendix 5-D," *Natural Capitalism*, Additional Material for Hawken, Lovins&Lovins "Natural Capitalism" - On-Line Only, 1999, Rocky Mountain Institute, 25/Sep/2005 <[http://www.natcap.org/sitepages/art58.php?pageName=Additional%20Book%20Material&article\\_refresh=%2Fsitepages%2Fpid27.php%3FpageId%3D27](http://www.natcap.org/sitepages/art58.php?pageName=Additional%20Book%20Material&article_refresh=%2Fsitepages%2Fpid27.php%3FpageId%3D27)>.

<sup>181</sup>The Atlas Project of the European Commission, *Estimated Long Term Technical Energy Savings Potential*. 7/Mar 2002, The Atlas Project of the European Commission, 17/Aug/2004 <[http://europa.eu.int/comm/energy\\_transport/atlas/htmlu/ioeneffa.html](http://europa.eu.int/comm/energy_transport/atlas/htmlu/ioeneffa.html)>.

<sup>182</sup>U.S. Department of Energy - Energy Information Administration, *E.Ig World Energy Intensity (Total Primary Energy Consumption Per Dollar of Gross Domestic Product),1980-2002 (Btu Per 1995 U.S. Dollars Using Market Exchange Rates)*. 25/Jun 2004, U.S. Department of Energy - Energy Information Administration, 18/Aug/2004 <<http://www.eia.doe.gov/pub/international/iealf/tablee1c.xls>>.

<sup>183</sup>Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Energy-Efficient Food-Blanching System: New Blanching System Increases Productivity While Saving Energy. NICE 3 - National Industrial Competitiveness Through Energy, Environment, and Economics*. Mar 2002, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy <<http://www.oit.doe.gov/nice3/factsheets/key.pdf> (Note:removed from web along with a lot of other federal energy information. I kept a copy; substitute URL on book site.)>.

<sup>184</sup> Joseph J. Romm, *Cool Companies: Proven Results - Cool Buildings*. 2005, Romm,Joseph J., 22/Aug/2005 <<http://www.cool-companies.com/proven/buildings.cfm>>.

<sup>185</sup> Industrial Technologies Program - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *American Water Heater Company: Compressed Air System Optimization Project Saves Energy and Improves Production at Water Heater Plant. BestPractices Case Study*, DOE/GO-102003-1716. Nov 2003, Industrial Technologies Program - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 26/Sep/2005 <<http://www.nrel.gov/docs/fy04osti/33648.pdf>>.

<sup>186</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Weldcomputer® Resistance Welder Adaptive Control: Sophisticated Welding Control System Saves Energy, Improves Quality, and is Affordable for General Industrial Use. Inventions and Innovation Success Story*, I-OT-588. Jan 2002, Fice of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 4/Sep/2005 <<http://www.eere.energy.gov/inventions/pdfs/weldcomp.pdf>>.

<sup>187</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Mobile Zone Spray Booth Technology For Ultra-Efficient Surface Coating Operations: New Technology Saves Energy And Reduces Pollution During Surface Coating Operations. Inventions & Innovation*, I-OT-489. Dec 2001, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 5/Sep/2004 <<http://www.eere.energy.gov/inventions/pdfs/clydesmith.pdf>>.

<sup>188</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Irrigation Valve Solenoid Energy Saver • New Battery-Powered Controllers Save Energy in Irrigation Applications. Agriculture Success Story*, I-OT-698. Sep 2001, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 5/Sep/2004 <<http://www.eere.energy.gov/inventions/pdfs/alextronix.pdf>>.

<sup>189</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *ENS Fan Saver For Medium-Temperature Walk-In Refrigerators • New Fan Saver Reduces Energy Consumption up to 50%. Inventions & Innovation*, I-OT-670. Oct 2001, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 6/Sep/2004 <<http://www.eere.energy.gov/inventions/pdfs/ensfansaver.pdf>>.

<sup>190</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Thermodyne™ Evaporator - A Molded Pulp Products Dryer • New Technology Revolutionizes Pulp Product Drying. Forest Products Success Story*, I-FP-529. Apr 2002, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 6/Sep/2004 <<http://www.eere.energy.gov/inventions/pdfs/merrillaireng.pdf>>.

<sup>191</sup> Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, *Meta-Lax® Stress Relief Process - Greatly Reduces Energy Consumption and Eliminates Pollution. Metal Success Story*, I-MC-412. Aug 2002, Office of Industrial Technologies - Energy Efficiency and Renewable Energy • U.S. Department of Energy, 6/Sep/2004 <<http://www.eere.energy.gov/inventions/pdfs/bonaltech.pdf>>.

<sup>192</sup> Ross A. Leventhal, "Sustainable in Seattle." *Architecture Week*, no. 101 5/Jun 2002: Environment, Artifice Inc., 6/Sep/2004 <[http://www.architectureweek.com/2002/0605/environment\\_2-2.html](http://www.architectureweek.com/2002/0605/environment_2-2.html)>. pE2.2.