Clean Sweep: Reducing Material Intensity by Lowering Pollution

We have covered enough types of consumer goods to know we can spot ways to reduce material intensity by close to factor four just through analysis by end use classification. In some areas we can reduce by much more than factor four, in some a great deal less. It is close enough that we cannot be sure they balance out. But there is one other step; so far we have examined reduced pollution just as we examined reduced industrial energy use – as a side effect of overall reductions in material intensity.

Pollution reduction, though, is desirable for its own sake. Particulate emissions from power plants kill 30,000 people in the U.S. every year[163]. Non-particulate emissions from power plants and other sources, toxic wastes, water pollution and other pollution sources may kill a great many more than this. And as with other material intensity reductions, pollution reduction reduces energy consumption as a by-product. Not every pollution reduction technique does this of course. Some means of filtering air and water emissions decrease energy efficiency – as do lower temperature combustion processes to reduce NOx production. But overall a broad program of pollution reduction reduces energy use.

For example, a great deal of toxic waste is generated simply by leaks and spills of expensive useful chemicals. Reducing such leaks, and reducing or recovering the spills saves those same substances for input into processes and finished goods; this usually saves money over older more wasteful industrial processes, and saves the energy that would have been used to manufacture replace chemicals for what was spilled. Similarly, recovering used chemicals for reuse accomplishes the same thing. Reducing water pollution often involves decreasing total use of water, lowers the amount of energy required to heat and pump that water. Reducing air pollution often involves burning waste gas, and using the heat generated for industrial processes. A small net energy saving is pretty clear. (By some measures it provides a large one; but that is because increasing energy efficiency is one way to lower pollution. Since the bulk of this study is devoted to detailing means of increasing energy efficiency, to include this would be double counting with a vengeance. Leaving direct energy savings aside, considering pollution reduction to provide a small net energy savings is more reasonable.)

There are a great many low tech, low cost methods that produce savings. One of the first is bureaucracy - horrible old fashioned red tape. Yes, excessive un-needed bureaucracy has a well-earned reputation for preventing work; but bureaucracy, in the right place, is also a way of getting things done. Think of the flight list pilots have to go over before takeoff. A paper checklist increases the odds they will perform the proper procedure each time – without failures of human or electronic memory causing them to skip a step. There a lot of points in industrial operation where the same principles apply. A far from exhaustive list:

- Documenting startup and shutdown procedures; doing either improperly may lead to anything from a major accident to a minor wastage of material
- Documenting operational procedures; most industries have turnover; it is fairly common in industries that don't document procedures properly to run into things like failing to turn off the water when a rinsing procedure is complete.

- Documenting emergency procedures; it may seem silly to keep a manual of what to do in an emergency; but if the person who knows what to do is not immediately available you may find the manual faster than you find the person. And if the person who knows leaves, having procedures documented increases the odds that the next person to do the job will be trained properly.
- Documenting inventory on hand someplace outside the physical location; helpful to firefighters and emergency crews in the event of an accident.
- Documenting all spills and accidents – helpful in managing sites post-shutdown.

Red tape, every bit of that list; but which item would want an oil refinery or chemical factory in your neighborhood to omit? And while the emergency documentation is usually required by law, the operational documentation, lack of which is most likely to lead to accidents, is often omitted.

Returning to the “pilot’s list” analogy for the moment, this entire section on pollution prevention is an example of that principle. Most individual paragraphs in it are something common sense might suggest; but as you go through paragraph after paragraph think – if you were doing pollution prevention for a particular plant, would you remember or think of **every single one of these** that are applicable? And this is by no means a pollution prevention manual or text book. Serious reference works, which I will cite at the end, generally run hundreds of pages.

Depending on circumstances there are other bureaucratic processes that can help prevent problems and lead to improvements:

- Regular reviews with major customers and suppliers of the way your processes and theirs interact. You never know when a change can lead to a product supplied to you becoming less suitable, or a product you supply being less suitable for a customer. Reworks, regardless of who pays, are a major cause of wasted material. And even if someone else pays for a problem, it is likely to come back to bite you in a future transactions. This does not just help head off problems; it can help spot opportunities too. Sometimes win-win changes can be made lowering costs or increasing quality for both parties.
- Regular reviews of standard literature to spot new processes and technologies that might lead to improvements. Most companies have informal networks - company geeks or proactive managers that keep an eye out. But – especially in larger organizations- you need a formal process or easy opportunities get missed. That is one of things bureaucracy was invented for – to allow large organizations to overcome the inertia that would otherwise stop them from doing some of the same things small groups do naturally. Why not just have small groups? Because there is stuff only large groups can do. No, turning large organizations into networks of small ones does not solve that particular problem; whether a large group is structured like a pyramid or like a web you still have cracks important things can fall into; no matter how irritating it is you need formal procedures to minimize this.

- Extending the last two a bit, regular reviews of policy from the ground up – rather than just looking at incremental changes, and taking all existing procedures for granted, occasional examination of everything from top to bottom to see if some of the routine has become obsolete, or was never the optimum approach in the first place.
- Formal training; default job training in the U.S. is often "throw her in the water, and see if she swims". Or the previous job holder's can spend her last day showing the new woman the ropes. This can lead to routine operating information not being conveyed properly. Almost never does it teach exception handling, shutdowns and startups, or dealing with emergency situations. You also need a clear chain of responsibility set up.
- During design phases – either of new plants or major modifications, relative risk assessment can help minimize pollution and wastages both. For a given pollutant – say sulfur or dioxin – assess what source in your plant is the greatest contributor, which is the second and so on; rank them. Now you can prioritize, find where you will get the greatest reduction for a given investment. Even if you are completely eliminating a pollutant, identifying this lets you get rid of it faster.

Similarly routine maintenance can reduce waste tremendously. For example, simply inspecting pipes and ducts regularly for leaks, and fixing them quickly can save a great deal. Inspecting and (in the case of chemicals) occasionally testing raw materials and other inputs before they come in the door can save wasted material and wasted time.

Housekeeping is even more interesting, because – though the term is used metaphorically – much of what it covers is literal. For example, dusting more frequently can prevent filters from plugging so quickly, and save both material and filters - nothing metaphorical about that use of the term "housekeeping". Or the point that in automated cleaning processes, you can start with dry processes (essentially wiping with a cloth) before moving on to wet cleaning. This can not only save on water; the chemicals absorbed by the cloth (being more concentrated) may be recovered from the cloth if of sufficient value to do so. [Note again that these are automated processes, not somebody manually wiping a vat with rags.] Further, the cleaning step can go more quickly, allowing the next stage to start sooner, and increasing labor productivity as well. There is also the point that supplies for dealing with spills should be stored where they are likely to occur, comparable to keeping cleaning supplies in the kitchen and bathroom.

There are other related points which, while a metaphorical use of the term, still obviously would have been instituted when processes were first designed if the designers had thought like someone who did housework. For example, an important principle of design is to build vessels for liquids bigger than the minimum required to hold them - making them less likely to overflow. Anyone who cooks regularly knows a too small pot is more likely to make a mess. Similarly there is the principle of "bunds" storing dangerous or valuable material in containers held in other containers – so that if there is a leak or spill, you can catch the overflow; the same principle you use when place a coffee or tea cup on a saucer, a bowl of cereal on a plate, or use a coaster for a beer can.

Someone knowledgeable in feminist theory could do some very interesting analysis of all this. Part of it is that probably most of those who helped design industrial processes have never done significant amounts of housework. However it is unlikely that every single designer was without experience in basic household chores. Just as important may be the fact that housework has mostly been gendered, designated as women's work and disrespected. So even if an industrial designer knew housekeeping principles, most likely until recently she would not have thought of applying them in designing chemical plants, steel mills, oil refineries and such. [In the past ten years, paying proper attention to housekeeping has become conventional wisdom – though audits of actual practice usually turn up major opportunities for improvement. It is known in principle, but just barely beginning to be implemented.]

Beyond maintenance and housekeeping, come other fairly simple universal things.

Gas emergency pressure relief valves should consist of multiple valves to deal with different levels of emergency releases with treatment equipment just like routine operating valves. In some plants half of air and water pollution is from "emergencies".
Alarm systems to detect spills and leaks, warn of changes in pressure or chemical composition well short of emergencies. Regular inspection to detect ground contamination – since this is almost impossible to detect via automatic systems.
Sequence to minimize startups & shutdowns. Also, similar processes should follow one another.
Pipes should be ground level for easy maintenance & inspection.
Short in-campus, roads, conveyer belts, pipes and corridors and transport. Continuous transport such as conveyer belts and pipes than road, or steam shovel or crane or pallet. Similarly, covered transport is generally better than open transport (as covered storage is better than open storage).
Integrating processes is preferable to separating them. For example a pulp mill and the paper mills it feeds will operate more efficiently together than apart – more opportunity to reuse waste products, including waste heat. In general there are very few diseconomies of scale in pollution prevention. When it comes to minimizing emissions per output produced, big is beautiful.
Circumstances alter cases; these are all general rules, with plenty of exceptions where particulars make them the worst rather than best choice. To avoid repetition, please assume this entry appears on every list, and at the end of every paragraph on pollution prevention.

Water pollution:

Dry methods to replace water, or as "pre-cleaner" to reduce water use.
Pigging (pipelines). Solid object driven through a pipe, like a bullet passing through the barrel of a gun. (In some cases a gel rather than a solid is used.) This greatly reduces water use and pollution in many cases; it can also provide superior results to wet methods, sometimes save labor costs, and save on cleaning solutions too. The latter three benefits usually provide a much higher economic payback than the first.
Picking the optimal choice between baths and sprays where wet methods are unavoidable. Water sprays can often replace all or some bath steps, and save chemicals as well as water.
Cool via heat exchangers rather than pumps or sprays.
Shape vessels so as to have as little waste space as possible – while still leaving extra room at the top to minimize spills and overflows. (Since the point of oversizing is not to fill them all the way up, this will not waste water.)
Automatic overflow detection and shutoff valves.
high concentrations of chemicals in less water, rather than higher volumes of water with lower concentrations. Water management is easier; if chemicals are worth recovering, recovery is more likely to be economically feasible.
The more precise control over chemical dosing the better.
shorten drying times -- wringers, air jets and squeezing, etc.
Segregation of types of waste water – rain water runoff, biological treatable streams, heavy metals and other toxic or recalcitrant steams.
Near-site storage to hold results of accidents, and firefighting waters; and act as a buffer – so that irregularly produced waste can be treated steadily – without requiring treatment capabilities matching peak emissions.
Countercurrrent washing, where water from the cleanest process is used in the next cleanest.
To generalize the above, reusing, recirculating and recycling water – where costs (such as reverse osmosis filters) don't exceed benefits.
In larger scale plants, water should be treated on site; this allows specialized treatment directed towards the particular pollutants generated, and avoids forcing a general purpose plant to deal with them.
Biological treatment as one step can usually reduce emissions a great deal. (Heavy metals, and any type of pollutant that would reduce biological activity has to be dealt with prior to the biological step of course – one reason for segregation of waste streams.)
Catalytic hydrogenation can often replace catalytic reduction in industrial processes. This avoids water emissions from reduction agents.

Note that while there are energy consuming aspects to water pollution prevention techniques, they overwhelming lean towards aspects with energy saving side effects. With air pollution prevention, the energy consumption and savings aspects are much more evenly balanced – again because we are excluding techniques such as combined heat and power which aim primarily at saving energy.

Air pollution control techniques:

Double sealing where practical to minimize leaks
Flammable gas concentration below LEL (Lowest Explosive Level)
Filter out dust and large particles first, and then treat gaseous contaminants, followed by any further steps needed. Gas emissions usually need to be treated in multiple steps.
Material recovery is preferable, if practical; if not, in many cases, both waste gas and dust may be burned - providing energy, and also producing a less toxic emission that is cheaper to treat.
In many cases water based processes can be the most effective means of treating waste gas; this has to be weighed against additional water consumption and water pollution.
Even when the waste gases themselves are not sufficient fuel to support combustion, incineration of waste gases and dusk particles can be the most effective means of disposal. In this case incineration is obviously energy consuming, not energy saving.
When non-auto-thermal (i.e. energy consuming) incineration is needed, catalytic incineration rather than thermal incineration may often be used. This saves energy and the lower temperatures produce less NOx as well.
Flaring should only be used to dispose of emergency releases; and even this can minimized as noted above by having multiple pressure release valves, with normal treatments applied in smaller emergencies.
Select fuel and raw material to minimize emissions - low sulfur fuel or low voc raw materials, for example
When dealing with highly toxic or highly corrosive material follow the KISS (Keep It Simple Stupid) principle. More complexity means more to go wrong.
Prereactors and preheating of input can often shorten total process time, energy use, and air emissions.
In some cases dampening small particle material will not affect its usefulness, but will reduce dust.
Optimize pressures, temperatures and ingredient ratios. In some cases it is amazing how far from optimal a process can drift and still work; fixing or at least improving this is usually very cheap with a very short payback.
Often polluted water is a source of fume emissions; water recovery and recirculation can sometimes reduce air as well as water pollution.
Gas phase balancing between vessels containing compatible substances, so that if one empties the other fills.
Where practical, storing gases at slightly below atmospheric pressure to minimize leaks,
Leak minimization - examples: where practical, replacement of flanges by welds, the use of seal-less pumps and bellow pumps; effective gaskets or flanges, valves and pumps with high integrity packaging.
Dust from dust producing processes should be minimized by enclosures(covering conveyor belts etc.).

For more specifics on such techniques, one of the world's best resources has been put together by the EU's International Pollution Prevention and Control department. This is an attempt to put together a compilation of best available techniques for pollution control for every major industrial pollution source in Europe. Environmental representatives of every government in the EU were involved in putting these together as were representatives from every industry. Just as when using CIA documents, or UN documents or U.S. State department documents, one should be aware of biases – but that does not prevent them from being useful.

In spite of the fact that it is probably contrary to the intentions of the technical people working on them – these reference works are likely to be used to reduce environmental protection in Europe. Since each document states that it is simply a technical reference, without legal force, this is not obvious in reading them. But the legal structure of the EU makes this likely for the following reasons:

1) Each document tries to determine which techniques are cost effective. In some cases, standards that have been enforced successfully in the most environmentally aware nations are considered not to be cost effective – either by consensus or by a split decision. In the latter case, the advocates for the more stringent position are usually in a minority.
2) In the case of court cases alleging trade barriers, the EU judges tend to be more concerned with trade than environmental protection; in addition they have very few restrictions on what evidence they can use to judge by. So they are very likely to turn to these reference documents, and consider any standards beyond the majority opinion in them unfair or discriminatory trade barriers if applied to foreigners doing business in these nations.
3) If an EU constitution ever passes, and a European parliament starts passing enforceable environmental laws, these documents are likely to serve as the technical basis either for the laws themselves or for regulation created within these laws.

Likely future misuse of these documents does not prevent them from being superb technical references. While you may or may not agree with their decisions as to what constitutes Best Available Techniques, the detailed sections preceding them – consisting of techniques to consider in choosing Best Available Techniques – usually will tell you everything you are likely to wish to know about available options. Brief sections on emerging technology following the BAT sections are sometimes excellent as well. A list of the most helpful BAT sources is included in the endnotes[164].

One point not emphasized in the EU documents is "green" production of plastics by making them from biological rather than petroleum sources. It is fairly well known we can produce plastic from recent biological sources (soybeans, cotton waste and such) rather than fossil biological ones. How much environmental impact can we save by doing this? In some cases we can obtain a factor four or five reduction - in many as little as a 20% savings. And, we must be careful, because in some contexts biological sourced plastics have a higher environmental impact than petroleum based ones. An excellent over view may be found in the LCA chapter of Volume 10 of the Encyclopedia of Biopolymers[165].

We already looked at substituting waste straw, hemp and kenaf for wood as a fiber source, with an increase in agricultural land use of 11 million acres (though saving a great deal more than this is forest use). To produce today's consumption of plastics from agriculture sources as well would add another 17 million acres to this[166]. Given longer lasting consumer goods, more thrifty use of materials in manufacturing and increased recycling, it is reasonable to assume a factor four reduction in the use of plastics. So that would result in the use of four and quarter million acres. But we have to allow for population growth. That makes a total of about 6.4 million acres through 2050.

An economy that reduced material throughput per unit of economic growth by four times from the present, we could produce all our fiber and plastic needs on 17.4 million additional acres – out of 57 million acres that have been presently taken out of production by set-aside programs. Given no till farming for row crops, and intensely managed rotational grazing for meat production we ought to be able to achieve up to a 20% increase in total food production we will need with the use of no additional land – possibly needing to reduce meat production by a very small percent. This also returns to a point I made towards the beginning of this chapter. We do not face a crisis in agricultural production or even in land available for agricultural production – provided we stop paving over farmland and putting farmers out of work. We need to produce our food and fiber via more sustainable techniques. Such techniques are available, and sufficient for the land currently in production, plus a very tiny portion of the set asides. But such techniques will not be sufficient if we continue to lose land to urbanization, erosion, and farmers being put out of business by unstable and absurdly low crop prices. Every bit as urgent as other sustainability issues is the preservation of farmland, and the preservation of small farmers to keep them operating on land large agribusiness won't touch.

End Notes

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164 Note the following are the document versions I downloaded. Point your ftp enabled browser to ftp://ftp.jrc.es/pub/eippcb/doc/ for the latest versions – since these documents are revised often, and the particular FTP documents will probably have been replaced by more recent versions.

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