Adding Energy Savings in the Supply Chain

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ABSTRACT

Over 85% of manufacturing energy use occurs before the factory making the final product receives the supplies it uses in its own processes. Working with suppliers to increase their efficiency and procuring supplies requiring less energy can reduce industrial energy use.

Substantial energy savings through the supply chain can occur through three mechanisms. First, an organization can work with its suppliers to encourage them to implement more energy efficiency in their own operations. Second, businesses can realize savings by selecting vendors whose operations are already more efficient than their competitors, or by specifying different components that are less energy intensive than the alternatives. Third, a whole-system approach can allow an organization to make changes in infrastructure that is shared among many different organizations and would be beyond the ability of any one of them to change independently.

Additional savings in industrial sector energy can be made based on methods that consider the upstream consequences of consumer end uses. Four such examples are explored: personal transportation, electronics, the supply chain for data, and the sharing economy.

This paper explores how a perspective on energy use that accounts for supply chain energy can enhance efficiency, and how this view can be implemented in practice by industrial plants.

I. Introduction

Industrial energy efficiency policy has focused on how plant managers can improve the operations of their own plant. While the U.S. and other countries have made considerable progress in improving efficiency over the years—a result of both independent decisions by plant owners and of energy policy efforts by governments, nonprofits, and utilities—there remain formidable barriers to implementing efficiency in this sector.

This paper looks at a relatively new method to increase savings from the industrial sector: focusing on energy used in the entire supply chain for a manufacturing facility or end use rather than exclusively on energy used within each individual facility.

Over 85% of manufacturing energy use occurs before a final assembly factory receives the component parts or supplies that it uses in its own processes (Smith and Hutson 2013). By considering quantitatively the energy use of suppliers we can increase our ability, as a global economy, to broaden the scope and depth of realized energy efficiency opportunities.

This paper suggests three different ways to do this:

1. An organization can work with its suppliers to encourage them to implement more energy efficiency in their own operations.
2. An organization can select supplies or vendors based (in part) on the energy content of their products or services.
3. An organization can take a whole-system approach that allows it to make changes in infrastructure that is shared among many different organizations and would be beyond the ability of any one of them to change independently of the others.

This paper explores how these three concepts could be applied, and in some cases how they are already being applied, in guidance documents and in the field.

It also poses a broader structure for looking at supply chain energy use and savings as the embodiment of consumer choices. The overwhelming bulk of industrial energy use is part of production processes that provide end-use services to household consumers—services such as homes and their furnishings and appliances, food and its preparation, cars and other transportation products and services, water supply and disposal, community services such as shopping, schools, community and religious centers, sports venues, Internet and telephone services, etc. The only major exception to this generalization is government activities such as military defense.

If industrial energy use is conceptualized as serving consumer demands, however indirectly, it allows policies to enable consumer and business choices concerning how to satisfy those demands with less impact on global energy consumption. For example, if it were the case that the supply chain impact of a house varied faster than proportionally with size, it might encourage consumers of luxury housing to focus on more ornate architecture and craftsmanship rather than size, especially among the subset of home buyers who want to be "green."

The approach of looking at supply chains as they affect consumer end uses is illustrated with four examples— personal transportation, consumer electronics, the use of data supplied by Internet use, and the sharing economy.

Note that not all supply chain energy[1] is recorded in the industrial sector. The supply chain includes service providers as well as product suppliers, so some of the embodied energy in services shows up in the buildings sector. Also transportation energy is a part of the supply chain. This includes both freight transportation to bring supplies to a facility and personal transportation energy for employees of a facility anywhere in the supply chain.

Consideration of energy use in the supply chain is beginning to be recognized worldwide. The International Organization for Standardization's new standards ISO 50001, 50004, and 50006 are all consistent with the consideration of supply chain energy as part of ISO methods for continual improvement in energy performance. Although they do not discuss supply chain energy explicitly, ISO 50004 does suggest the involvement of supply chain managers in an energy management system (ISO 2014). Some complying organizations may consider supply chain energy (also called embodied energy) as a "significant energy use," defining the scope and boundaries of the Energy Management System, as all three standards require, to include it, and try to improve energy performance of this use just as it would for in-plant energy.

II. Supply Chain Energy

The industrial sector uses energy to transform raw materials into final products. The energy use of a facility can be considered to be embodied in the products that it produces. This observation applies to every level of the supply chain down to the final producer.

Supply chain energy is measured by considering the energy inputs from all suppliers to the facility in question. This may go back only one link in the supply chain, but it is hard to think of a good example of this: consider an oil refinery that purchases oil from a supplier. Their energy use (for drilling and transportation) will not be the only input: the driller will see supply chain energy in the manufacture of the drilling rigs, who in turn will see a supply chain from the

[1] Note also that the words energy "supply chain" can also be used to refer to the supply chain of energy itself, such as the electricity system from the mine or well to the consumer. This is not the meaning employed in this paper.

steel manufacturer, etc. In many cases, the supply chain will be quite long. Supply chain effects may have to be traced back several levels.

Suppliers may be providing either goods or services.

Supply chain energy is a form of Life Cycle Assessment and uses the same types of analysis. However, Life Cycle Assessments, particularly those dating from the 1970s, tend to be based on broad economic methods such as input-output matrices rather than specific and defined supply chains. These broader analytic methods do not require explicitly tracing the supply chains but rather rely on aggregate economic data concerning the exchanges between different sectors of the economy.

Several guidance documents have been produced to show how to perform the supply chain energy calculations. (BSI 2011, WRI et al. 2013 and 2014). These standards offer a methodology for calculating total energy use (or greenhouse gas emissions). They follow consistent protocols both in their subjecting draft documents to extensive public comments from worldwide stakeholders and in trying to harmonize practices across national borders. The latter endeavor is particularly important in a globalizing economy.

The methods described in these standards are mutually consistent.

The protocols distinguish between three types of energy use or emissions. “Scope 1” refers to direct energy use within a facility. “Scope 2” refers to indirect emissions or usage, counting the coal or gas used to produce electricity or the fuel(s) used to produce delivered steam, etc. “Scope 3” refers to supply chain energy (upstream) and customer use (downstream).

This paper considers supply chain energy calculations to be essentially indistinguishable from supply chain greenhouse gas emissions calculations, since the latter are in most cases obtained from the former by multiplying the impacts for each fuel times a specific emissions factor for each fuel. (Of course, impacts from non- CO2 greenhouse gases must also be included in supply chain emissions analysis.) Some method of adding the impacts of different fuels would have to be used to achieve Scope 2 compliance in any event.

The calculations of interest for this paper are known as “cradle-to-gate,” and are to be distinguished from “cradle-to-grave” calculations that take into account downstream behaviors. This issue is discussed in Section IV below.

A. Helping Suppliers Realize Efficiency Opportunities

The first approach—helping suppliers to realize efficiency opportunities—is already being used by leading companies to realize more efficiency from their suppliers.

There are powerful barriers to the functioning of markets in industrial energy efficiency, so encouragement and technical/managerial advice from customers can help companies raise the priority of considering money-saving efficiency opportunities.

In addition, many industrial energy management decisions involve the choice of whether to produce a part or assembly on-site or to outsource it. For example, a refrigerator plant might have the choice between producing its compressors in a corner of the facility or buying them from an internal or third-party vendor.

Suppose an organization is tracking its energy use as part of a Strategic Energy Management effort, for example using ISO 50001. The organization will be tracking Energy Performance Indicators (EnPIs) and typically measuring its energy use per product. Failure to include supply chain energy may result in serious sub-optimization that undercuts the purpose of an Energy Management System: one way to improve a management level EnPI such as energy used per product produced is to outsource some of the production: the indicator looks better (lower) even though no change has been made in total energy use.

Supply chain energy may be the dominant energy use for an organization. For example, in a life cycle analysis of energy consumption for several different alternate ways of constructing highways in Finland, supply chain energy embodied in construction materials was always the dominant energy use, usually with double the impact of transport energy (the energy used to transport construction materials and staff to the highway construction site) and an order of magnitude more impact than construction energy. (Markku 1999)

B. Procurement Based on Supply chain Energy

When supply-chain energy is known, businesses can make informed choices to save energy by using different supplies or vendors. For example, many building designers have a choice of construction materials, such as reinforced concrete framing versus wood or steel. All of these choices involve considerable supply chain energy, but for a given choice of options, one may be substantially lower than another.

Selecting products based (in part) on supply chain energy impacts involves taking into account the energy consumption embodied in a particular product or part as supplied by a particular vendor. Buyers can select vendors whose operations are already more efficient than their competitors, or they can specify different components that are less energy intensive than the alternatives. It could be applied to purchasing or procurement by businesses or by end use consumers.

This approach is a part of the Athena Sustainable Materials Institute’s calculators. (Athena Sustainable Materials Institute 2015). The calculators allow a builder to compare different types of construction at a detailed level, and to choose options with relatively lower supply chain energy. Athena’s work is based on generic estimates of the supply chain energy of different construction sections. The next step would be to refine the analysis to compare the same materials delivered by different vendors.

The consideration of energy use to construct buildings is large: for California, the 50-year energy use for utilities of a typical home that meets energy code is about the same as the energy use from the construction supply chain (Goldstein and Bacchus 2012); while for China 21% of its entire industrial energy use is in the building construction supply chain (Chang et al. 2014).

Russia’s construction sector relied mainly on the use of heavy, 30-cm–thick external load-bearing walls of reinforced concrete. When regions began enforcing an energy code that was based on a three-layer wall—structural concrete on the inside, insulation in the middle, and weather-protection concrete on the outside—the stringency of the code encouraged the substitution of polystyrene or mineral wool insulation for some of the concrete. The exterior dimensions of the walls stayed the same to avoid the need for capital costs for new molds for the wall assemblies (Matrosov 2002 and 2004), resulting in substantial savings in supply chain energy, as concrete is one of the most energy-intensive construction materials per cm^3.

Thus the net effect of the energy code was to substitute insulation for concrete on a volumetric basis. The outcome from a direct energy use perspective was that the new type of walls greatly reduced heat loss, and that the net cost of efficiency was negative because insulation costs less per cm^3 than concrete.

But the second benefit of the supply chain energy savings was left uncalculated.

Another, albeit anecdotal, example is the use of concrete in the former Soviet Union. The Soviet Union was one of the most energy-intensive large economies on earth, and a visitor could easily see one of the reasons why: concrete was used in quantities and applications that were not seen other places in the world. Public parks, roads, etc., were built as if concrete was perceived as a free good.

An additional anecdotal example of how this method can be used is in light construction in non-OECD countries. One of the authors has observed widespread use of nonstructural brick for the construction of wall assemblies for buildings whose load-bearing structure is reinforced concrete framing. Identical-appearing products were seen in Argentina, Turkey, Morocco, and China. These assemblies are intended only to provide weather protection. They appear to have poor heat transfer characteristics as well as relatively high embodied energy. (In China, at least, they also appear to have land conservation impacts through the supply chain: the mud used to manufacture them depletes the soil because so many of them are used.)

A serious study of supply chain energy and policies to reduce it could reinforce efforts to construct new building that save energy both in their construction and in their operation. The reduced supply chain energy would show up as reduced industrial sector energy consumption, although without supply chain analysis, one would see it as an unexplained reduction in the trends for demand of certain energy-intensive products.

C. Generating System-Wide Savings That Transcend One Energy User

An important reason to evaluate supply chain energy is that an organization that wants to reduce its overall impact can find additional degrees of freedom to do so. Rather than being limited to the savings it can achieve in its own facilities, it can encourage its suppliers to implement common efficiency upgrades that they would not be able to implement on their own.

For example, Walmart decided to reduce its energy use from selling milk by asking suppliers to package the milk in plastic containers that are airtight and thus do not require refrigeration until the customer opens them. This saved the company money from being able to sell the milk on non-refrigerated shelves. But it also allowed the supplier to ship the product in non-refrigerated trucks, and the shippers and dairies to use non-refrigerated warehouses. Neither the dairies nor the warehouse owners nor the trucking companies would have been able to implement this measure on their own: without knowing in advance that the milk would be compatible with the other parts of the supply chain, the elimination of refrigeration would not have been possible.

Xerox recognized that one of the largest energy impacts of its copiers was not in the construction or operation of the machine itself but in the supply chain manufacturing the paper that the machines used. The company developed two-sided copying machines and worked with paper manufacturers to allow the use of thinner, less energy-intensive paper in its copiers. The paper companies would not have been able to implement this measure on their own, because they would not be able to count on compatibility with the customers' copying machines.

III. Looking at Industrial Energy Use as Supplying Consumer End Use Demands

A. Personal Transportation

Personal transportation energy is fully half that of industrial energy in North America. Its impacts are strongly associated with local zoning and with transportation infrastructure, in particular, the availability of mass transit (Holtzclaw 2002). More compact neighborhoods with good transit service and walkable streets produce severalfold lower demand for cars.

This reduction in the need to drive cars is increasingly being seen by urban planners and transportation planners as an approach that can reduce traffic congestion and save energy in the form of gasoline. Many such officials are required to allow for more compact cities and to provide greater emphasis on transit, and bicycle and pedestrian infrastructure.

But while the main purpose of these policies has been to reduce driving, this set of choices also reduces the length of roads, the number of parking spaces that need to be built, and allows narrower streets, all of which require less supply chain energy use.

Compact development also minimizes the need for water, sewer, storm water, gas pipes, and electric distribution lines. This is a consequence of several factors: First, for compact development, distances are smaller for a given population so the length of infrastructure decreases. Second, runoff falls off in a relatively exponential fashion with density.

None of these savings, which would show up in conventional analyses as reductions in the demand for steel, copper, asphalt, and concrete, can be assigned to individual company decisions, so they are lost from analyses of energy efficiency potential in industry.

Consideration of supply chain energy can lead to better decisions. In this case, the organizations using the information would be regional, state, and municipal transportation planning agencies and local land use regulatory agencies as well as their regional affiliates.

This analysis is beginning to be performed at the academic research level. But a 2010 paper (Chester, Horvath and Madanat 2010a) claimed that the type of analysis suggested here (and performed in the paper) had never before been performed before in the published literature. Several other prominent examples of this sort of work followed (Chester et al. 2013, Nahlik and Chester 2014). However, the number of analyses is small.

The scope of the analysis appears to be expanding over time as it expands from just the transportation system, and even within this system newer work adds detail to analysis of marginal (or long-term) supply chain impacts for parking and roadway capacity, distinguishing between overall reductions in vehicle kilometers traveled and peak hour capacity needs, and by analyzing transit and related transportation networks. However, the supply chain impacts on utility pipes and wires seems to still await inclusion.

This area of inquiry is developing. The WRI protocol for calculating community-scale emissions (WRI 2014) does not yet account for infrastructure costs in a well-elaborated way. In part, this is because the calculation is framed in the context of energy management from year to year, and therefore does not track one-time long-lived investments such as those in highways, subways, parking, utility pipes and wires, etc. Yet the underlying methodology for doing such a calculation is presented in WRI 2013.

This is an area deserving of considerable additional research. The number of kilometers traveled by cars in America peaked in 2007, and projections for areas with smart growth objectives call for essentially no future growth. This is a considerable and growing departure from conventional forecasts and has large effects on likely future demand for road and auto infrastructure supplies and products from the industrial sector.

B. Electronics

The consumer electronics (CE) and Information Technology (IT) sectors provide a good example of the opportunity for substantial energy savings through supply chain energy efficiency. The CE and IT industries are already investing a considerable amount of effort into making electronics more efficient because of market incentives such as battery life in mobile electronics or data center energy availability and costs for servers and other data center equipment. Electronics now represent 15 percent of global residential electricity consumption, and a significant share in commercial buildings, especially when including data centers (IEA 2015, EIA 2013).

But little known is the fact that more energy is embodied in electronic products than is consumed operating them over their lifetime, and not as much is being done about this aspect of the problem. There were 1.8 billion mobile phone sold worldwide in 2013 (Gartner 2014). Embodied energy represents 85 percent of lifecycle greenhouse gas emissions for an iPhone 5S, six times the emissions associated with its use phase (Apple 2014a). Other types of electronic products such as tablets, laptops, desktop computers and displays also have embodied emissions ranging from 66 to 86 percent of lifecycle emissions (Apple 2015).

Fortunately, there is a large hotspot in the production emissions of smart phones, and likely of other electronic products: the lifecycle analysis of a sample smart phone shows that integrated circuits (IC) represent roughly 60 percent of the device's production emissions (Ercan 2013). This makes ICs a key opportunity and focus area for energy efficiency. Integrated circuits are manufactured in semiconductor fabrication plants (also known as "fabs" or foundries). Fabs are very energy intensive, using as much power annually as 50,000 homes. McKinsey found that energy efficiency best-practices could cut energy use by 20 to 30 percent, through a combination of plant management process improvements and modest infrastructure investments (McKinsey 2013).

Energy savings in semiconductor fabs would reduce the energy intensity in integrated circuits used in all electronic products, as well in electronic components used in appliances, automotive and other applications. These efficiency opportunities can be achieved through both the supplier capability building approach and the competitive procurement approach. In the former, leading companies can help develop operating best-practices, train their suppliers, demand progress reports, and include fab efficiency in the key performance indicators used in their regular supplier reviews. This is consistent with the way such organizations would operate if they followed an Energy Management System Standard (ISO 2011). From a competitive procurement perspective, CE and IT manufacturers can include fab efficiency in their supplier evaluation criteria and harness competitive pressure for IC suppliers to implement energy efficiency programs in their fabrication plants.

C. The Internet: The Data Supply Chain

For Internet-connected electronic devices such as smart phones, computers, set-top boxes, and emerging "Internet of Things" devices, the concept of supply chain efficiency adds a new dimension: that of the energy use in the supply chain of data used by these devices.

Applications on smart phones, tablets, computers and other devices rely on the Internet to access and process data: the single click of a button on the screen of these devices such as launching a Google Search or pressing Play on a video, can trigger transactions in multiple cloud data centers, and make the Internet and the wireless 4G and 3G data networks spend energy to transmit the data from the device to the data centers and back.

Watching a pay-TV show from a cable or satellite provider also requires the provider's data centers and network infrastructure to expand energy to store, compress, and transmit the data that makes up the program.

There are high uncertainties about how much energy can be associated with the data use of a particular device: this is dependent on usage patterns, and very sensitive to modeling assumptions, such as how much of a wireless phone network tower's energy to attribute to each bytes of data transmitted, whether to use the average or the marginal energy cost, etc.

Most lifecycle analyses of electronic products focus on cradle-to-grave, including production, transport, customer use, and end-of-life. For example Apple's Product Environmental Report for the iPhone 6 estimates that these four areas amount to 95 kg CO2-equivalent lifetime greenhouse gas emissions, of which 11 percent is customer use and 85 percent production (Apple 2014b).

However, this does not include the emissions associated with the operation of cloud computing services that store, process and transmit the data for the applications running on the phone, such as email, iTunes, photo and video storage, maps, and many others. These applications run on servers and data storage equipment in data centers around the country and potentially the world. The transmission of data over the internet uses networking equipment in telecommunications data centers. Based on information published by Google, a rough estimate of the annual energy use of key Google services (Google Search, Gmail, YouTube) is 7 kWh (Delforge 2011). Multiplying this by eight (author's assumption for the sake of this exercise, not based on data) to account for other cloud services used on the phone, and applying the average U.S. carbon emissions factor, yields approximately 82 kg CO2e over the two-year lifetime of a phone.

Finally, smart phones use cellular networks (3G and 4G) to receive and transmit data when not connected to Wi-Fi. A rough estimate of the energy consumption of cellular networks per smart phone is 11 kWh per year, which translates into 15 kg CO2e over the two-year lifetime of a phone (Koomey 2013).

Adding it all up suggests that the data carbon footprint of a smart phone may be comparable with its cradle-to-grave footprint, and the customer use of a phone may represent just 6 percent of its total supply chain emissions, or put another way, the entire supply chain footprint of the phone may be of the order of 18 times that of its customer use.

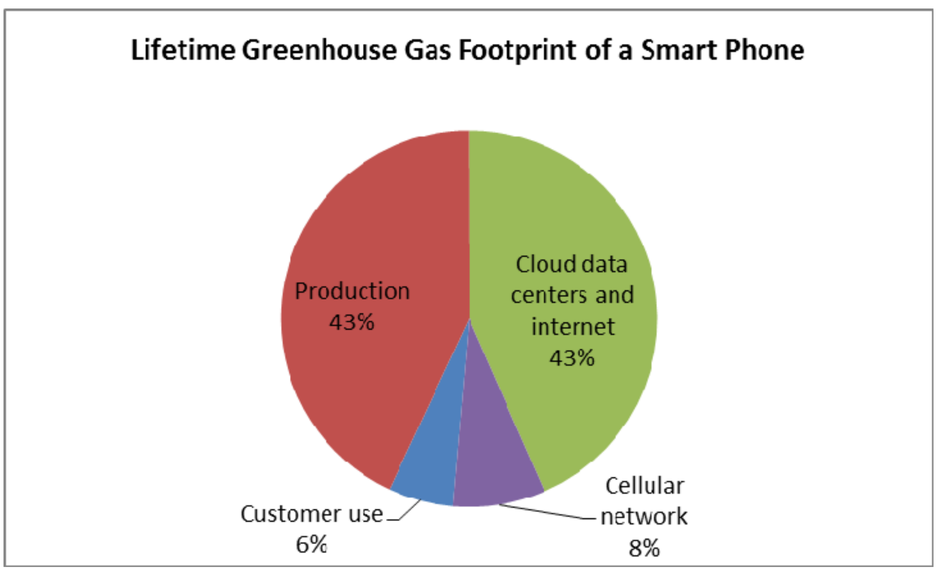

Figure 1. Lifetime Greenhouse Gas Footprint of a Smart Phone

D. The Sharing Economy

One of the major developments of the last several years is the emergence of Internet-based services that facilitate the sharing of major capital goods, such as houses or automobiles. Construction of houses and commercial buildings uses about as much energy as operating them, as already noted, so if fewer homes (such as second homes, especially) or hotels are needed because of house sharing on a short-term basis, this trend could yield noticeable savings in supply chain energy.

Similarly, personal automobiles are used only 5 percent of the time (Barter 2013), generally to transport only one person. Recently emerging car sharing sites allow higher capacity factors for cars, both in the sense of percentage of clock time in which they are used and in terms of transportation services provided per kilometer driven. Both have the potential to reduce supply chain energy in the industrial sector.

In the former case, it is likely that a car that is more intensely used will have to be replaced in fewer years than one with lighter use, which would not change the supply chain energy requirements much. However, it is reasonable to expect that a more heavily used car will travel more distance before it is finally junked than one that is more lightly used. And in the case of shared rides, facilitated by the Internet, total driving will be less and the supply chain savings will be large.

Either sort of shared mobility saves infrastructure costs. For example, there are estimated to be 3.4 parking places for each car in America, and the supply chain energy for providing parking is roughly 770 petajoules (0.75 quads) annually (Chester, Horvath and Madanat 2010b). This is roughly 4% of the energy consumed by automobiles in the form of gasoline! Shared mobility reduces the need for parking, and Internet-based parking sharing methods that are beginning to emerge also allow reductions in the amount of parking needed and thus reductions in supply chain energy.

It seems likely that there are other ways of sharing expensive and energy-intensive capital goods that can also develop based on these models.

IV. How Can Supply Chain Energy Be Estimated?

Supply chains tend to be global, so common procedures are necessary. These have been developing rapidly over the past decade.

Four methods are listed in the references, and they are generally mutually supportive but with varying scopes of application. It appears that the main use of these methods has been in developing energy or emissions footprints for companies or for communities. This would encourage suppliers to improve their own energy efficiency, the first purpose of these calculations discussed above.

But it is generally insufficient to the second purpose or procurement based on supply chain energy use. To accomplish this purpose, it would be useful to have a global labeling system for major products, both to serve as a default data source if a supplier has not done its own supply chain analysis or to allow both household and business purchasers to make an informed choice between products.

For example, suppose a consumer wants to minimize impact of buying vegetables. The consumer might be a household or it might be a frozen vegetable manufacturer. One choice would be to buy local products and avoid transportation costs, while the other might be to buy products produced in Europe using low-impact agriculture. Which is the better choice? At present we have no way of knowing.

To do so would appear to require the creation of a voluntary product energy footprint labeling scheme. At first, this would need to be done as Athena has done it: using generic industry-wide averages for particular categories of products, starting with the ones with the greatest energy impact and the fewest steps in the supply chain. Later, more company-specific data could be developed, especially if the defaults were constructed to be conservatively high such that a given company that was efficient would have an incentive to replace the generic numbers with specific ones.

Eventually, one would hope that enough upstream company-specific data would be available to allow an organization to trace its supply chain energy back to the initial producers. This would require compounding all of the upstream impacts. It would have to rely on cradle-to-gate data to avoid getting into circular reasoning.

Cradle-to-Gate Method

The WRI protocol seems to favor the calculation of cradle-to-grave impacts. Thus a widget producer would account for the energy it used itself to make the widgets, the energy its suppliers used to make the raw materials to produce the widgets and the machine tools it requires to craft them, etc.

The calculation would also include the energy used by the widget customers and the energy involved in disposing of the widgets responsibly or of recycling them.

But the last two impacts would make it difficult and self-referential to do supply chain energy analysis over several levels. Each widget buyer might use the widgets for a specific purpose, and this purpose may be different than what the widget producer assumed. To correct for that, the user (the widget buyer) would need to know not only the overall cradle-to-grave impact, but how much of that was due to estimates of his own usage, which he is already tracking. It would also have to subtract out the disposal energy for the same reasons.

It would be much easier to just use cradle-to-gate impacts: the impacts of the first level of the supply chain could simply be added to those of the second, the third, etc.

For example, if the facility in question manufactures automobiles, its total energy impact consists of the energy it uses plus the energy use by its suppliers, included among which is the producer of the auto air conditioner. To derive its own supply chain energy, the auto plant wants to know the energy embodied in making the air conditioner, but it does not need to know the energy that the customer will use in operating the air conditioner: the latter would double-count customer energy (if the auto plant is keeping track of it) and would be less accurate than what the auto plant itself would do if the energy use depends in part on the car as well as the air conditioner. The problem is compounded if the customer is a fleet owner, since that customer would do its energy impact analysis based on the embodied energy of the car, and use its own data on using patterns—in fact, reducing usage might be part of the fleet owner's energy management system plan.

As another example, consider the study discussed above concerning the life cycle energy consumption of highway construction. A cradle-to-grave analysis would have considered the use phase energy of the highway—the energy used by the cars and trucks that drive on it—and this number would have swamped all of the other energy inputs. Knowing the total life cycle energy might lead policy makers to ask whether the road should have been constructed at all, but that question is not useful: the decision to build had already been made. The only remaining relevant question was which type of construction method to use. Cradle-to-gate provides this useful input.

Next Steps

At this point, we do not have a means to know the supply chain energy for most individual products. But if enough organizations start to calculate their own impact, a governmental organization or an NGO can set up and maintain a database on particular products, with default values based on industry averages. Such a proposal passed the U.S. House of Representatives in 2009 as section 247 of H.R. 2454 (https://www.congress.gov/bill/111th-congress/house-bill/2454?q=%7B%22search%22%3A%5B%22HR+2454%22%5D%7D).

Summary and Conclusions

Consideration of supply chain energy opens the door to much broader and more effective implementation of industrial sector energy efficiency, some of the effects of which extend even beyond this sector.

We have already seen how organizations that consider supply chain energy are helping upstream suppliers be more efficient. We have seen how private sector organizations and government agencies both are taking advantage of system-wide analyses to encourage or facilitate changes in the supply chain that substitute less energy-intensive processes and infrastructure than would otherwise have occurred.

And we are seeing the beginnings of a systematic consideration of how product selection can reduce supply chain energy.

All of these processes can generate greater energy savings than current efficiency scenarios, both by allowing the prediction of higher market penetration rates of efficiency technologies and practices and by opening the door to product substitution, either on a system-wide level or on a product-by-product level, which reduces overall energy use.

All of these factors indicate that a greater efficiency potential may be found in the industrial sector than is suggested by the existing literature.

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